Understanding the potential exposure of coastal marae and urupā in Aotearoa New Zealand to sea level rise

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Dedication

One month before my thesis was due to be submitted, on the 7th of May 2021, my great-grandmother Margaret Kohine Noho Waaka passed away at the enduring age of 89 (four months short of her 90th birthday). She was a wife, mother, grandmother, great-grandmother and great-great-grandmother, but to all of us she was affectionately known as our Kui. She was the matriarch of our whānau being the strength and stay throughout the death of her husband, two children and several mokopuna. Her absence in our whānau and to myself is going to take some time to adjust. I was her first moko to attend university and graduate, now I am completing a master's degree and will pursue a PhD. She was always so proud of my accomplishments and if it wasn't for her, I wouldn't be alive today. I dedicate this thesis in memory of you Kui. May you have endless housie games up there with Koro Honey and Nanny Anzio.

All my love and adoration.

Akuhata.

Margaret Kohine Noho Waaka

02/09/1931 – 07/05/2021

"Tōka toa, he toa Rangatira"

"My bravery is inherited from the chiefs who were my forebears"

Abstract

In Aotearoa New Zealand, Māori are Indigenous and have inhabited these islands for the past 700 years. They have an intricate physical and spiritual connection to places and the environment. This is reflected in the Māori creation story, where Ranginui (sky father) and Papatūānuku (Earth mother) are the ancestral parents of Māori. Between these two gods is the marae, the Māori meeting house. Marae are where the domestic life of Māori traditionally ran its course, with marae being an overarching term to illustrate multiple buildings which each have a specific role to play within the community. Often, marae have an associated urupā (burial ground). Historically, marae and their associated urupā are positioned along the low-lying coast, providing easy access to kaimoana (sea food), transport and trade. However, coastal marae and urupā are at an increasing threat of inundation and erosion from sea level rise, and will also be impacted by other effects of climate change such as drought and other changes to weather patterns such as storms.

Many coastal marae and urupā are already experiencing the impacts of coastal flooding and erosion, however, little is known about the exposure of coastal marae and urupā to sea level rise nationally. Therefore, the main aim of this thesis is to explore the potential exposure of coastal marae nationally, with a particular focus on the Bay of Plenty coastal marae including coastal urupā. This aim was achieved by addressing three objectives. The first of which was to investigate the potential national exposure of coastal marae to a 100 year annual recurrence interval extreme sea level event, with the addition of sea level rise. Second, I conducted a nationally-focused assessment of the local coastal geomorphology surrounding coastal marae to determine the potential response of the coast to sea level rise. I also undertook a case study on the BOP which included a more detailed assessment of the geomorphology around the coastal marae and urupā in this region. Third, findings from these two objectives are brought together to consider the next steps to determine how to move forward with planning to manage coastal marae and urupā with sea level rise.

A spatial mapping approach using Arc GIS and existing datasets was used to address these aims, combining the Coastlines and Islands polygon, marae and urupā locational data and the Aotearoa New Zealand coastal hydrosystem classification system proposed by Hume in 2016. This showed that 191 marae around Aotearoa New Zealand are within 1 km of the coast and in the Bay of Plenty 41 urupā are within 1 km. I then used the bathtub modelling approach to get a national first-pass assessment of the potential exposure of these marae and urupā to a 100 year extreme sea level event at current mean sea level, with 10 cm increments of sea level rise up to 3 m. Six coastal marae were potentially exposed to a 100 year extreme sea level event at current mean sea level, with 41 coastal marae are potentially exposed to a 100 year extreme sea level event with a 3 m rise in mean sea level. The most common type of coastal geomorphology nationally and in the Bay of Plenty was shallow drowned valleys, with 72 coastal marae in this category. The response of these systems to sea level rise manifests as changes in the tidal regime and sediment transport dynamics which will affect inundation and erosion of low-lying areas, where many coastal marae and urupā are positioned.

Thus, it is clear that marae and urupā are nationally at risk to sea level rise, and their responses will be highly variable with geomorphology. But what are the next steps? There are many legislative documents such as the coastal climate change and hazards report by the Ministry for the Environment which suggests that the Dynamic Adaptive Policy Pathways strategy to address the uncertainty surrounding climate change, recommended as a method for future planning. Another is the pending reform of the Resource Management Act which will introduce a climate change adaptation act where support for managed retreat will be made available. However, any management strategies for marae, hapū and iwi will need to be cognisant of the tapū and mana that these places hold, and there will be no one size fits all approach.

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To my best friends and whānau Elisabeth, Kayne and Kathy thank you for opening your whānau to Reynar and I, and being an escape from life in Tauranga. To my Hodge whānau, Di, Rod and Sam, thank you for being my second parents and sister, love to you all.

Finally, I would like to give a huge mihi to my whānau, my mum Margaret and dad Stephen, without your support, guidance and $$ I wouldn't be who I am and where I am without you, so heaps of love to you two. My sisters Stephanie and Manaia-Rei thank you for your support and love. To my Koro Pat, your love, guidance, wisdom and advice will see me throughout my life journey, my eternal love and gratitude goes to you Koro.

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To everyone I have mentioned and those who I have missed, all my aroha goes to you all. All the best – Aku.

"Aroha mai, aroha atu – Love received, love returned"

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Kuputaka - Glossary of Māori words

Aotearoa	North Island, now often used to refer to the country of New Zealand
Atua	Gods or ancestors
Hapū	sub-tribe
Hāpua-type lagoon	pool of water, lagoon.
Haumietiketike	atua of uncultivated food
Hui	meeting / gathering
Io	supreme being
Ira atua	supernatural/non-living realm
Ira tangata	human genes, human element
Iwi	extended kinship group, tribe or nation
Kaimoana	seafood
Kaitiakitanga	guardianship, stewardship or trustee
Kaupapa Māori	Māori approach, Māori research
Kohanga reo	Māori language preschool
Koiwi	human bone or corpse
Kōrero	to tell or speak
Mana	prestige, authority or control
Manaakitanga	hospitality, kindness and generosity
Māori	Indigenous person of Aotearoa New Zealand
Marae	“marae atea” area in front of wharenui and complex of structures
Mātauranga	knowledge, wisdom or understanding
Mauri	life principle / life essence
Mihi	to greet / pay tribute

Moana	sea or ocean
Papatūānuku	earth, earth mother or wife of Ranginui
Pepeha	to say or a tribal saying
Pou	post or support beam
Ranginui	god of the sky or husband of Papatūānuku
Rohe	boundary or district
Rongomātāne	god of kūmara and cultivated food
Taiao	world or environment
Tāne Mahuta	god of forests and birds
Tangaroa	god of the sea
Tangata whenua	local people, hosts or indigenous peoples
Tangi	to cry, to mourn as well as the funeral procession
Taniwha	water spirit / powerful creature
Taonga	treasure or holds value spiritually, physically or culturally
Tapu	be sacred, prohibited, restricted or set apart for the Gods
Tāwhirimātea	god of weather
Te Ao Māori	Māori world view
Te Ao Marama	world of light
Te Ika a Māui	North island
Te Kore	the void
Te Reo Māori	Māori language
Te Waipounamu	South island
Tikanga	correct procedure, custom or habit
Tūmatauenga	god of war
Tuna	eel

Tūpuna	ancestors or grandparent
Tūrangawaewae	right to stand, place of belonging
Urupā	burial ground, cemetery or graveyard
Waka	canoe or vehicle
Wānanga	to meet and discuss
Whakamarumaru	to shade, shelter or protect
Whakapapa	genealogy
Whakataukī	significant proverb or significant saying
Whānau	family group
Whare-karakia	church
Wharekai	dining hall
Wharenui	Māori meeting house
Wharepaku	toilet
Whenua	land, country or placenta

Chapter 1 Introduction

“Mahia i runga i te rangimārie, me te ngākau māhaki.”

“With a peaceful mind and a respectful heart, we will always get the best results.”

1.1 The importance of marae and urupā

Marae are the ancestral meeting houses of Māori, the Indigenous people of Aotearoa New Zealand. Marae are not just a building. They are a physical embodiment of the connection between Māori and the atua (deity) Papatūānuku, Earth mother. In the Māori creation story, Io is the supreme spiritual being and source of life, and as in many Polynesian cultures, created Ranginui (the sky father) and Papatūānuku. They were husband and wife locked in a permanent embrace (Higgins & Moorfield, 2004). They had six sons who were also atua, that were locked between their embrace **(Figure 1.1a)**. They were Tūmatauenga (God of people and war), Tāwhirimātea (God of wind and weather), Tāne mahuta (God of forests and birds), Tangaroa (God of the sea and fish), Rongomātāne (God of cultivated food and peace) and Haumietiketike (God of uncultivated food) (Marsden, 1992a).

Eventually, the children of Ranginui and Papatūānuku wanted to bring life and light to the world, known as Te Ao Mārama (the world of light). So Tāne mahuta separated them by stretching his legs upward analogous to a tree. Once the parents were separated, each atua occupied their respective domains. Māori people are part of this ancestral lineage or whakapapa, connecting Māori people to the flora, fauna and to the natural environment **(Figure 1.1b)**. Papatūānuku is the mother of Māori people, as throughout the life journey she provides everything needed to survive and eventually in death, Māori are returned to her when buried in urupā (Māori cemeteries) (Roberts et al., 1995). Marae are used for tangi (funeral ritual), celebrations and hui (meeting), and urupā are a place of remembrance of those who have passed on. The marae historically was divided, with the marae ātea directly in front of the wharenui (meeting house) which was the domain of Tūmatauenga God of war, as historically the marae ātea was the area of battle from opposing hapū (smaller tribal group) or iwi (larger tribal group). Once you have been welcomed onto the marae and your intentions have been identified as peaceful, you enter the wharenui which is the domain of

Rongomātāne God of peace (Mulholland & Bargh, 2015). Some marae are ornate buildings with symbolic artistry depicting ancestors of a whānau (family group), hapū and/or iwi. Originally the marae was home to the hapū, where domestic life ran its course, comprising of many structures all with a certain purpose to fulfil for the community (Mulholland & Bargh, 2015). A common layout of marae consists of the wharenui (ancestral meeting house), wharekai (dining hall) and wharepaku (lavatory) (Mulholland & Bargh, 2015).

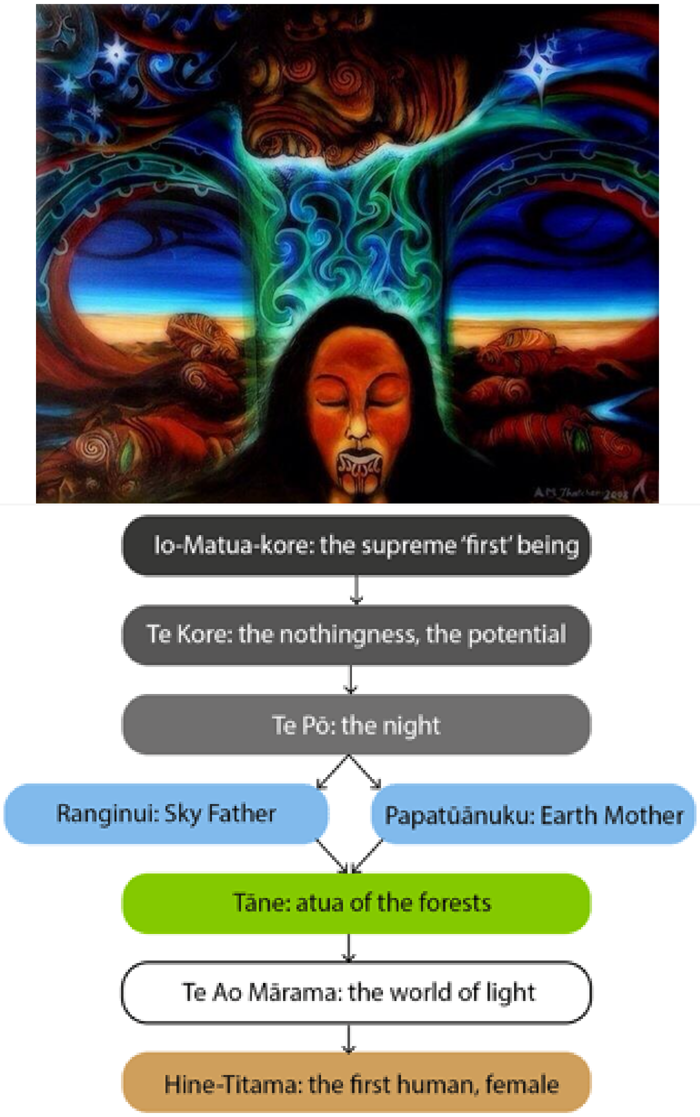


Figure 1-1: a) Ranginui and Papatūānuku separated by their children as part of the Māori creation story (Thatcher, 2008) and b) whakapapa of Māori through the Māori world view connecting Māori to the natural world

1.2 Marae and urupā and the risk of sea level rise

Many Māori communities positioned their marae in locations where it was easy to access kaimoana (seafood) and to engage in transport and trade with other hapū and iwi (Paulin, 2007). Thus, many marae and urupā are positioned on low lying coastal land, many of which are not obvious, such as in the case of urupā in sand dunes (King et al., 2012a; Jones, 2021). Therefore, their proximity to the ocean makes marae and urupā susceptible to coastal flooding and coastal erosion, which will be exacerbated with climate change such as due to sea level rise (SLR), increased storm frequency and intensity in some areas (Walsh et al., 2016). This is combined with other climate-related pressures such as marine heat waves (Frölicher et al., 2018), ocean acidification (Hoegh-Guldberg et al., 2007; Doney et al., 2009) and prolonged drought (Prospero & Lamb, 2003). The rates and impacts of SLR have been well documented both internationally such as by the IPCC (Intergovernmental Panel on Climate Change) and nationally such as the predictions by Hannah and Bell (2012), with other work looking at exposure of infrastructure to SLR (Paulik et al., 2019; Paulik et al., 2020) and coastal hazard guidance (Bell et al., 2017). The susceptibility of marae and urupā to climate change is a contemporary issue in Aotearoa New Zealand, and it is a topic of importance to many whānau, hapū and iwi. However, there is a lack of nationwide data and studies investigating the impacts of marae and urupā to the impacts of climate change, although there are a range of private investigations into certain marae and urupā.

1.3 Thesis Objectives

The aim of this thesis is to assess potential exposure of coastal marae and urupa to SLR in Aotearoa New Zealand. To achieve this goal, there were three objectives, to:

1. Determine which marae and urupā are potentially exposed to a 100 year annual recurrence interval extreme sea level event through understanding their elevation, distance, topographical profiles and potential exposure to 100 year extreme sea level (ESL) event; and
2. Conduct a geomorphological analysis of marae and urupā to determine the susceptibility and potential response to SLR; and
3. Outline the potential legislation relevant to climate change adaptation for coastal marae and urupā

To address these objectives, I analyse marae nationally and urupā within the Bay of Plenty (BOP) to those within 1 kilometre of the coastline, defined as "coastal marae and urupā". Investigating coastal urupā in the BOP was a case study to get a better understanding of the exposure of urupā which has not been well documented in the literature only through media and newspaper events, however, this thesis is predominantly concerned with coastal marae. In understanding the potential exposure of coastal marae and urupā, I analyse how many may be exposed to a 100 year ESL. As well as defining their elevation, distance to the coast and the topographical profile showing the variation in topography to the coast. The potential response to SLR can also depend on the type of coastal geomorphology, whether the coastal marae is on the open coast or within an estuary can change the response and impacts felt due to SLR. Thus I also classify the coastal geomorphology of coastal marae and urupā.

1.4 Thesis Outline

Following this chapter, the thesis will be arranged into six subsequent chapters:

Chapter 2: Significance of marae and urupā and the impact of sea level rise

Chapter two is an overview of the significance of coastal marae and urupā in the context of Te Ao Māori (the Māori world view), discussing how marae and urupā are sites of connection to the past, present and future. I discuss key cultural values which underpin the significance of marae and urupā, including tikanga, kaitiakitanga, whenua and tūrangawaewae. This chapter ends with discussing the impact that climate change has on coastal marae and urupā in terms of sea level rise, giving scientific context and understanding to the processes involved with climate change.

Chapter 3: Methodology

Chapter three outlines the methodology and origins of the research topic. This chapter describes my position as a Māori scientist and the internal and external conflict between the demands placed upon a Māori scientist in a western world. I highlight my positioning on a spectrum of research systems ranging from kaupapa Māori research to western science and how this influences my research approach. This chapter also describes the origin and creator of the datasets used and the steps taken to manipulate these datasets to produce the desired outputs. Alongside the spatial analysis, the awareness of data sovereignty and data masking techniques/principles were described in order to keep marae and urupā that have been identified by this analysis private and anonymous.

Chapter 4: Potential exposure of coastal marae and urupā to sea level rise

Chapter four discusses the exposure of coastal marae nationally by categorizing coastal marae into rohe and includes coastal urupā within the BOP region. I present my analysis of the elevation, distance to coast and topographical profile of these coastal marae and urupā. I analyse the exposure of coastal marae and urupā to a 100 year ESL event with increments of sea level ranging from 0 – 3 m.

Chapter 5: Coastal geomorphological response to sea level rise

Chapter five categorizes coastal marae and urupā based on their coastal geomorphology using the Hume et al. (2016) hydrosystem classification system, consisting of damp sand plain lake, waituna-type lagoon, hapua-type lagoon, beach stream, freshwater river mouth, tidal river mouth, tidal lagoon, shallow drowned valley, deep drowned valley, fjord, coastal embayment and open coast. This chapter gives an overview of the methodology of the Hume et al. (2016) classification and identifies the coastal geomorphology of coastal marae by rohe and highlights the common and interesting variation/trends.

Chapter 6: Discussion and conclusion

Chapter six brings together the results of **Chapter 4 and 5** to understand the potential exposure of coastal marae to a 100 year ESL event with increments SLR, and how the coastal geomorphology affects the response to SLR which highlighted the need for topographical profiles of coastal marae and urupā to understand how they can influence the response to a rise in sea level. I then highlight the limitations of this research and address the direction and future solutions for climate change adaptation for coastal marae outlining relevant legislation to this issue.

Chapter 2 Significance of marae and urupā and the impact of sea level rise

“Ko Papatūānuku to tatou whaea, ko ia te matua atawhai, he oranga mo tatou, i roto i te moengaroa, ka hoki tatou ki te kopu o te whenua.” - Roberts et al. (1995)

“The land is our mother, she is the loving parent, she nourishes us and sustains us, when we die she enfolds us in her arms”.

2.1 Introduction

The coast is of great importance to Māori, as are all facets of the natural world. In Te Ao Māori (Māori world), the natural world is holistic and cyclical, and humans are not exempt from the hierarchy or whakapapa (genealogy) of the natural world, tying Māori people to the earth and to the flora and fauna (Higgins & Moorfield, 2004). This tie between Māori people and the land is the driving force of tangata whenua (Māori people of the land) to actively protect and preserve taonga (sacred possessions) for future generations of whānau (family), hapū (sub-tribe) and iwi (tribe) through kaitiakitanga (guardianship) Selby et al. (2010) and according to protocols of tikanga (customs/traditional protocols) (Roberts et al., 1995; Mead, 2006). Marae and urupā are taonga, as they are a place of connection in the Māori world view, rather than just physical structures. Marae are a place where members of the associated iwi/ hapū or whānau can go and feel a spiritual connection to the Earth and to their tūpuna (ancestors) through whakapapa, a connection known as tūrangawaewae (right to stand, place of belonging) (Kawharu, 2010). This chapter describes the significance of marae and urupā through understanding Te Ao Māori and through tikanga, whenua (land or placenta), tūrangawaewae and kaitiakitanga and how these taonga are preserved for generations to come. This will be followed by a discussion of coastal impacts on marae and urupā around Aotearoa New Zealand and a review of relevant SLR research globally and regionally.

2.2 Te Ao Māori

Globally, there is a significant difference in the world view of, and between, Indigenous and non-Indigenous peoples, including when it comes to the environment (Cheung, 2008). This is no exception in Aotearoa New Zealand, where the Māori creation story illustrates the inextricable interrelated connection to the natural and supernatural worlds from which we draw life, sustenance and longevity from, a world which no one person solely owns (Roberts et al., 1995; Mead, 2006; Morgan & Manuel, 2020). This ideology is termed a Māori world view and stems from the Māori creation story which is believed to be the foundation of everything that is visible and invisible in the universe (Pio et al., 2014; Hikuroa, 2017).

Te Ao Māori is deemed holistic and reciprocal in nature, where everything in the natural world is grounded by whakapapa. Whakapapa relates Māori to flora, fauna, rivers, mountains, oceans and lakes as they are part of Papatūānuku our earth mother (Forster, 2019). A pertinent whakataukī (proverb) that illustrates this is discussed by Roberts et al. (1995): pg. 10 "The land is our mother, she is the loving parent, she nourishes us and sustains us, when we die she enfolds us in her arms". This whakapapa as mentioned in **Section 1.1** shows the connection from the supreme being through to Papatūānuku and Ranginui through to the flora and fauna and finally to Hine-Titama which was the beginning of the human realm (Wilkinson et al., 2020).

The connection of Māori to the land and its natural landmarks is strengthened through the process of reciting pepeha, which is a formal Māori introduction where you pay homage to the surrounding environment from where you are from. These typically include your mountain, river, lake, ocean, forest, waka (canoe), iwi/hapū, marae as well as your parents and tupuna. The reciting of your pepeha is a spiritual method of connecting to the environment that gave birth to you and sustained you through your life journey (Harmsworth & Awatere, 2013; Forster, 2019). This spiritual connection transcends to other concepts relevant for Māori to the land and in terms of this thesis which focuses on coastal marae and urupā, these concepts are critically important in the fundamental approach of this thesis, in particular, tikanga, kaitiakitanga, whenua and tūrangawaewae,, which are summarised below.

2.2.1 Tikanga (Māori ways of knowing)

Tikanga has many definitions and variations from hapū to iwi with most describing it as a set of customs, ethics, way of life and means of social control. These stem from the word "tika" which in Māori means 'to be right', hence tikanga can be thought of as the correct way of doing something (Mead, 2006). The basis of Tikanga has come from hundreds of years of knowledge accumulation which has been passed down from generation to generation, with some key variations of tikanga:

tapu (sacred, set apart and/or under atua (God) protection) , mana (power, authority), whakapapa and tūrangawaewae (Moorfield, 2003).

2.2.2 Kaitiakitanga (guardianship)

Kaitiakitanga is a central pillar of Te Ao Māori. Kaitiakitanga or to be a kaitiaki means to actively protect, preserve and maintain resources or the environment for future generations. The environment illustrated with kaitiakitanga spans both physical and non-physical aspects, such as the preservation of waterbodies, forests or resources in order to maintain the mauri (life force) of a hapū or iwi (Cheung, 2008; Walker et al., 2019). Kaitiakitanga can also be the management of marae and urupā to protect and preserve against the impacts of climate change for future generations as well as resource management, as it takes into account customary mātauranga (knowledge) and processes which ensure the longevity and sustainability of resources for future generations (Kawharu, 2000). Kaitiakitanga is important to this research as information will be available for kaitiaki of coastal marae and urupā allowing them to make informed and relevant decisions to preserve and protect their coastal marae and urupā to a rise in sea level where applicable.

2.2.3 Whenua (land and placenta)

Whenua has dual meanings being the land as well as placenta or afterbirth. Tikanga requires that the placenta is returned to the land, often buried at places of significance to the hapū or whānau such as marae, urupā and family land, initiating a lifelong connection of the child to the land. However, the connection does not only extend to birth but also death, with tikanga requiring the kōiwi (human remains) to be returned to the whenua, as to complete the life cycle, from the whenua in areas called urupā (Marsden, 1992b; Selby et al., 2010). This makes urupā significant in that they play host to the remains of Māori people in their connection back to Papatūānuku. With the impacts of climate change on urupā such as erosion and inundation, this connection could be severed. Whenua is important to this research in that it is the intersection between land and oceans, where effects of SLR will occur. Hence understanding the perspective of Māori to the land provides a deeper understanding and illustrates the significance that land has to Māori highlighting the contribution this research will have to protect these marae and urupā.

2.2.4 Tūrangawaewae (place to stand and belong)

Tūrangawaewae has whakapapa at the heart of this concept, with tūrangawaewae being and having a place to stand, a place where one feels connected to the whenua and to their ancestors, and ultimately where one feels a sense of belonging (Groot et al., 2010; Brown, 2014). Tūrangawaewae can be a significant physical place in the environment, buildings such as marae and urupā, or even the family home. It is an important component of Māori identity (Mead, 2006; Brown, 2014). Marae and urupā are often considered tūrangawaewae as they are a space where people can feel the spirit of their ancestors. For instance at a marae, your ancestors would have stood in the same place as you are standing, so it is the spiritual connection that these places foster provides ones tūrangawaewae.

2.3 Marae

This thesis focuses primarily on the potential sea level exposure of coastal marae. Marae are crucial in Te Ao Māori and the spiritual connection to the land as discussed above as they are central to Māori structure, community and institutions. Marae is an overacrching term used to describe the larger marae area complex which generally consist of a ceremonial courtyard with a wharenui – the centre of the hapū or iwi's focus, and often named after a prominent ancestor (Tapsell, 2002). There is often a seperate wharekai (dining quarters), wharepaku (toilets) (Moorfield, 2003; Higgins & Moorfield, 2004). Some marae also have other buildings such as whare karakia (church) and kohunga reo (Māori language preschool) **(Figure 2.1)**.

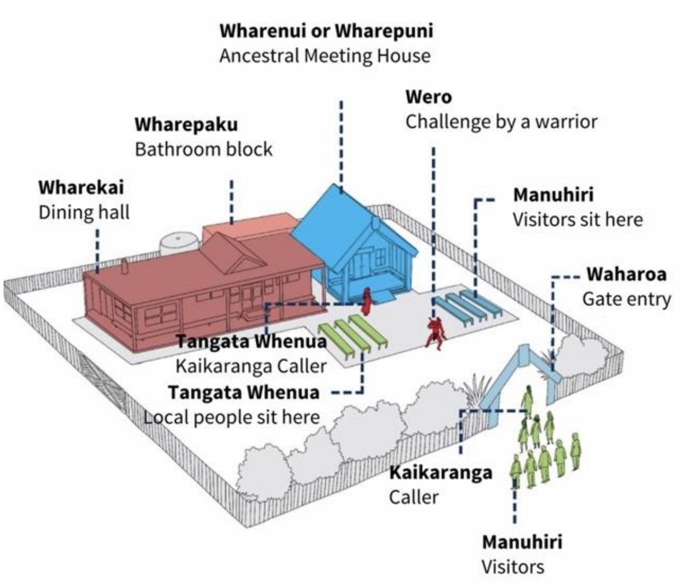


Figure 2-1: Diagram of marae ceremonial courtyard with the wharenui (meeting house), wharekai (dining quarters) etc.(Kiwa Digital, 2019)

Marae are significant to Māori identity and culture not only bound as a physical place to hui (meet) but as a spiritual place with a lasting connection to ancestors and the divine creation, creating a physical connection between Ranginui and Papatūānuku (Tapsell, 2002). The spiritual connection is illustrated by Kawharu (2010) **(Figure 2.2)**. **Ira atua** is the realm where the ancestors reside and **ira tangata** is the present human race and spans between **Ranginui** and **Papatūānuku**. This is significant in two ways, first, the house contains the pou which in a western view are the support beams, these separate the roof and the floor acting as a metaphor for the separation of Ranginui and Papatūānuku from Tane (god of forests) giving rise to ira tangata (Henare, 2001; Kawharu, 2010). Second, it is a physical and spiritual connection to those who have gone before us, connecting Ira Atua with Ira Tangata through whakapapa, with a whakataukī by Sir James Henare in Kawharu (2010) pg 9 "When I look at this area I see my ancestors walking back to me".

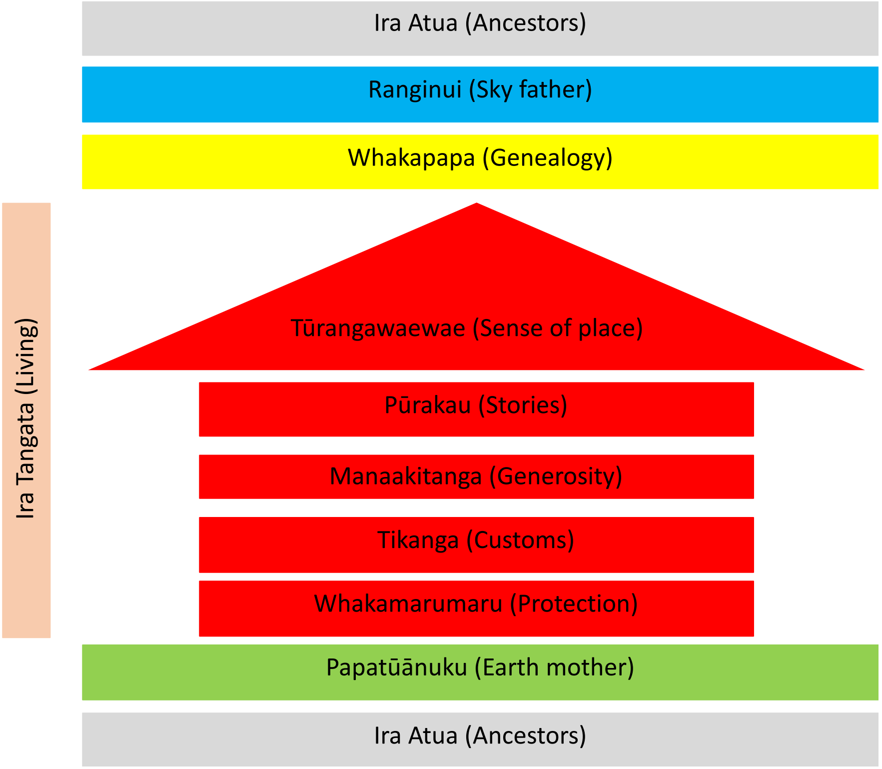


Figure 2-2: Dissection of marae illustrating the connection they create between the living and the non-living realms, adapted from Kawharu (2000)

Marae play an essential role in the execution of traditions and **tikanga** of a hapū or iwi such as during times of crisis, including tangihanga (funerals). It is this tikanga as well as **whakapapa** which centralises what it means to be Māori and maintains the connection between the present and the ancestors that have gone before in a place which is intricately woven from the past (Tapsell, 2002; Kawharu, 2010). **Pūrākau** are the traditional form of Māori narrative which contains philsophical and ideological views of the world, cultural norms and are fundamental to Mātauranga Māori, the pursuit of and application of knowledge essential to the Māori world view (Lee, 2009; Hikuroa, 2017). **Manaakitanga** and **whakamarumaru** can be seen in times of disasters as marae show geneoristy and kindness as they become places of refuge for people in need. For example, many marae are used as civil defence evacuation zones for flood and tsunamis, and during the COVID-19 pandemic some marae housed homeless people to provide shelter during that unprecendented event (Hudson & Hughes, 2007; Kenney & Phibbs, 2015).

2.4 Urupā

Generally, marae have a nearby associated urupā (Mulholland & Bargh, 2015). Urupā are the traditional burial grounds of Māori, where members of the hapū, iwi and/or whānau can go to commerate their loved ones, while one day expecting that they may be buried there amongst their whānau. Urupā are places of significant spiritual, historical and cultural importance to Māori. This is because urupā are an important part of the death process as koiwi (human remains) have the highest amount of tapū in that no eating, drinking or smoking is permitted. Surroundng this there are certain tikanga practices that are required in urupā to protect everyone throughout the funeral and visiting after the funeral (Shirres, 1982). For example, after leaving an urupā tikanga practice is to wash your hands with water on departure to lift the tapū (Heritage New Zealand Pouhere Taonga, 2014; Milroy, 2014; Barlow, 2015). In this thesis I explore potential exposure of urupā in the BOP, but also include cemeteries run by city / district councils, private cemeteries as well as marae, hapū and iwi urupā. Many marae and their associated urupā are situated along the coastline due to the historical purpose the ocean bestowed, however, at present and in the future the impact climate change in particular SLR will have on marae and urupā will intensify.

2.5 Sea level rise and coastal marae and urupā

The coast is intrinsic to Māori identity due to the social, cultural, educational and historical significance embodied. Therefore, a multitude of coastal marae and subsequently urupā are situated on low lying coastal land as the moana (ocean) was used as a source of kaimoana (seafood), a mode of transport, enabled a trading economy and provided a space where intergenerational knowledge was passed down (King et al., 2012a; Iorns, 2019). However, with the projected impacts of climate change, in particular SLR, it is important to consider how to take care of marae and their urupā (King et al., 2010; King et al., 2013). SLR is estimated to rise between 0.46 m under RCP 2.6 and 1.05 m under RCP 8.5 H^+ around Aotearoa New Zealand by 2100 (Bell et al., 2017). This will likely expose some low-lying coastal marae and urupā to more intense and frequent storm surge events, coastal flooding and coastal erosion, making them vulnerable to degradation and harm. Around the country there are already several documented cases of coastal marae, urupā and Māori communities who are already believed to be facing issues of climate change including coastal adaptation to climate variability of coastal Māori communities (King et al., 2012a; King et al., 2013) and understanding the use of Māori knowledge to manage climate variability and the impact on Māori (King et al., 2008; King et al., 2010). In newspaper articles and other news stories hapū and iwi are describing coastal inundation and coastal erosion events impacting marae and urupā such as "Four-peg plea for urupā before guardian 'keels over" (Angeloni, 2018), "Historical Māori kōiwi bones unearthed by erosion in Nūhaka" (Angeloni, 2021), "Climate change exposes Māori bones" (Davis, 2018), and "A hapū's quest to save their marae" (Day, 2018), just to name a few.

2.6 Anthropogenic climate change

The climate has changed many times over the history of the Earth. Changes can manifest as alterations in temperature, precipitation, storm intensity and frequency for example (Withgott & Laposata, 2015). These changes can be divided into natural change, which is the variation which would occur naturally, and anthropogenic change induced by human influence, largely due to emissions of greenhouse gases such as carbon dioxide, methane, nitrous oxide and ozone (Withgott & Laposata, 2015) including due to burning of fossil fuels and land-use changes such as deforestation, urban development and intense agriculture (Wong et al., 2014).

The radiative warming which occurs due to anthropogenic emissions produces a range of interacting effects. For example, in addition to SLR, other impacts of climate change include physical effects such as potential changes in storm frequency and intensity in some areas (Walsh et al., 2016), ocean acidification (Hoegh-Guldberg et al., 2007; Doney et al., 2009), marine heat waves (Frölicher et al., 2018), altered rainfall patterns and extreme weather events such as droughts (Prospero & Lamb, 2003) and storms (Michener et al., 1997; Wong et al., 2014). Planning for the impacts of climate change requires robust predictions of the future climate setting, which is currently done using representative concentration pathways (RCPs).

RCPs were developed in 2007 for climate change research by the IPCC (Intergovernmental Panel on Climate Change) to provide plausible descriptions for the evolution of the earth, with respect to important variations in technology, social economies, energy consumption, land use and future emissions of greenhouse gases and pollutants (van Vuuren et al., 2011). RCPs are commonly used as inputs for climate models to account for natural and anthropogenic change and are used as a base for future impacts which may arise such as SLR as well as the cost associated with reduced emissions (van Vuuren et al., 2011).

The RCP scenarios produced by the IPCC include RCP 2.6, 4.5, 6.0 and 8.5 **(Figure 2.3)**. RCP 2.6 is a stringent representation of net negative global emissions and robust mitigation scenarios with temperature rises below 2°C (Pachauri & Meyer, 2014). RCP 4.5 and RCP 6.0 are representative of intermediate scenarios with a combination of mitigation strategies as well as some fossil fuel and carbon emissions (Thomson et al., 2011; van Vuuren et al., 2011). RCP 8.5 reflects high global emissions with zero mitigation scenarios, causing a likely rise of 4.0 – 6.1°C by 2100 (Moss et al., 2010; Rogelj et al., 2012). These are global scenarios and they do not reflect regional settings such as that of Aotearoa New Zealand.

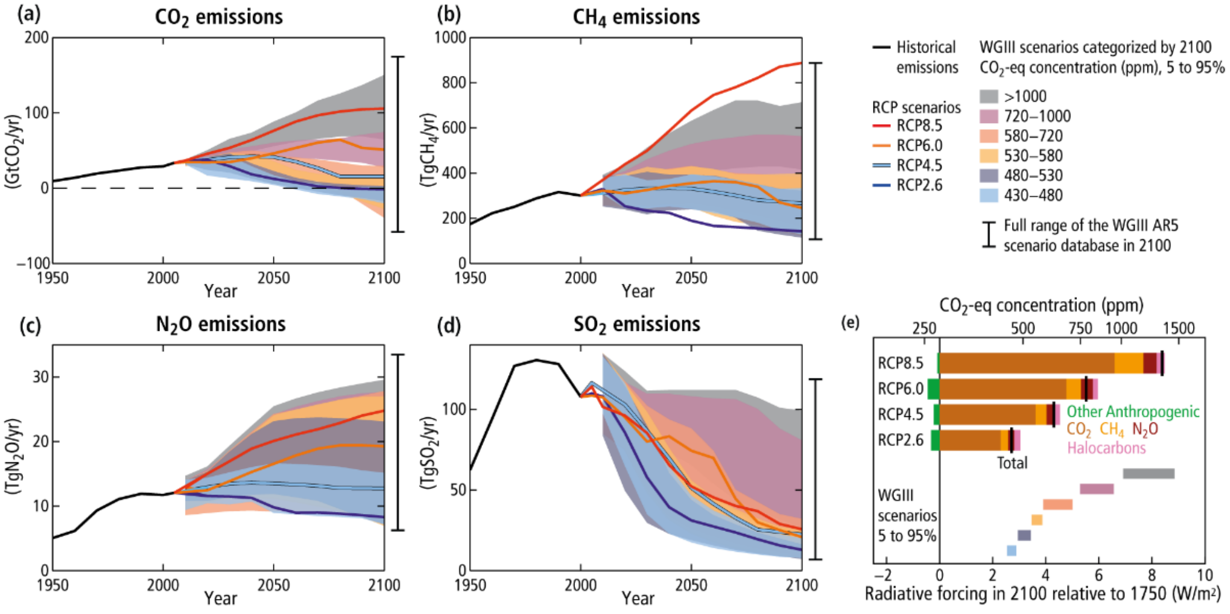


Figure 2-3: RCP scenarios and the associated radiative forcing (y-axis) and time in years (x-axis) represented through different greenhouse gas emissions scenarios (Pachauri & Meyer, 2014)

In the case of Aotearoa New Zealand, there is a north-south warming gradient with the highest temperatures occurring in the north of the country, with temperatures projected to increase between

0.7°C (RCP 2.6) and 1.0°C (RCP 8.5) by 2040 and up to 3.0°C (RCP 8.5) by 2090 (Carey-Smith et al., 2018). The national impacts currently being observed include the loss of 3.8 cubic kilometres of glacier ice in the southern alps following an ocean-atmospheric heatwave in 2017 – 2018, being the largest amount lost since at least 1962 (Salinger et al., 2019; Vargo et al., 2020). Glacial melt contributes to SLR around Aotearoa New Zealand with an average 1.81 (+/- 0.05) millimetres per year, with the rate doubling from 1960 onwards, with oceans warming by 0.2°C on average per decade between 1981 – 2018, which also contributes to SLR (Chiswell & Grant, 2018; Ministry for the Environment & Stats NZ, 2020).

2.7 Mechanisms and predictions of sea level rise

SLR is a principal consequence of climate change, defined as the change in mean sea level (MSL) due to the effects of climate change, with respect to a local datum (Gregory & Church, 2002). The key causes of climate change driven SLR are radiative absorption of the ocean and increased input from land reservoirs. When water increases in temperature, the volume of water increases, raising the MSL (Gregory & Church, 2002). Moreover, when there is an increased input to the ocean from land water reservoirs such as glaciers and ice caps, it further raises MSL (Bindoff et al., 2007). This process is accompanied with radiative induced melting of the polar ice sheets and temperate glaciers adding to the rising sea .

SLR can be split into two types, absolute SLR and relative SLR **(Figure 2.4)**. Absolute SLR is measured relative to the centre of the Earth using satellites and is often expressed as a global MSL (Rovere et al., 2016). Changes in absolute sea level occur as ocean volumes change, such as through radiative absorption of the ocean, where the temperature of the ocean increases causing water to expand and increase in volume, resulting in the absolute SLR (Gregory & Church, 2002). Absolute sea level can change due to inputs from terrestrial water reservoirs such as melting glaciers and ice caps, with melting enhanced through radiative processes accelerated by climate change (Bindoff et al., 2007). Relative SLR is the sea level relative to a point on land taking into account absolute changes (Kopp et al., 2014) as well as vertical land movements such as from groundwater extraction (Galloway & Burbey, 2011), oil and gas extraction (Syvitski et al., 2009) or areas of high dynamic tectonism (Beavan & Litchfield, 2012; King et al., 2020). As the land subsides it allows the MSL to rise and as the land uplifts, this causes the MSL to fall. This makes it difficult to predict SLR at the global scale as well as at a regional scale.

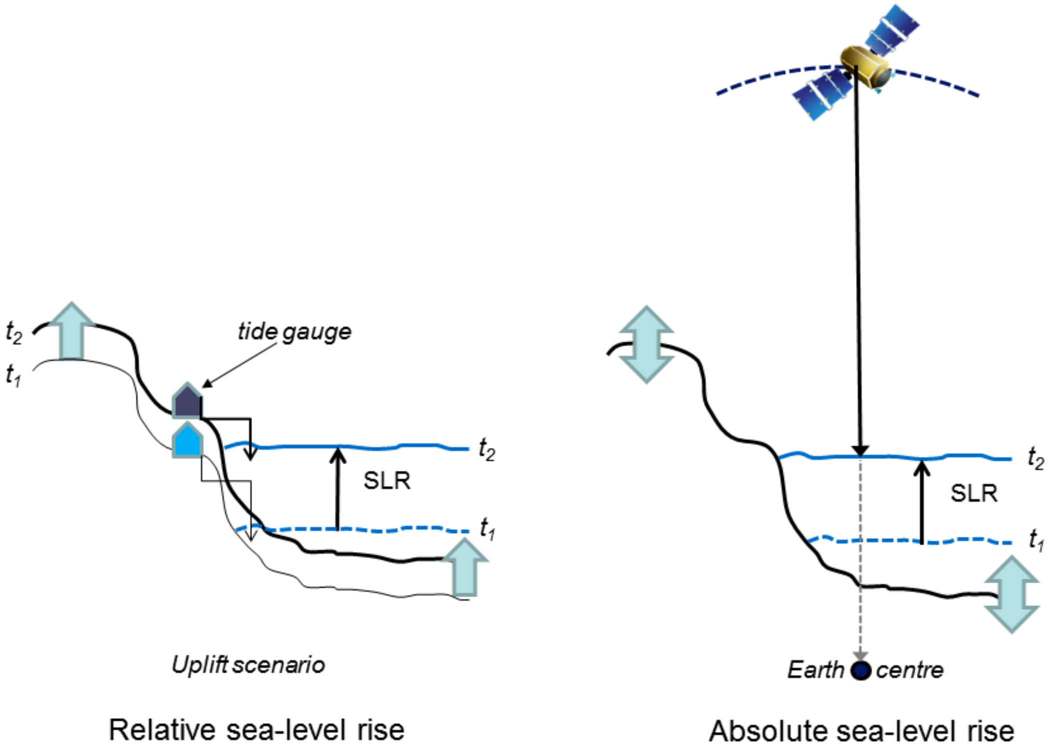


Figure 2-4: Difference between relative sea level rise and absolute sea level rise, showing relative sea level rise through an uplifting scenario (NIWA, 2021)

There is a large degree of uncertainty of future SLR, due to both political/social factors combined with scientific factors such as melting rates of ice sheets and vertical land movements. Therefore, the current general consensus is that rather than trying to make exact SLR predictions, it is better to produce a range of SLR estimates to get a better understanding of how SLR may occur based on key assumptions and possibilities (Moss et al., 2010). Based on this, current estimates of SLR coincide with the RCP scenarios outlined in **Section 2.6**. Under each of these RCPs, the IPCC (Wong et al., 2014) have produced a range of potential corresponding SLR pathways, based on various levels of emissions and factoring in contributions of climate-driven SLR. Under RCP 2.6, global mean sea level (GMSL) is predicted to rise by an average of 0.24 m between 2046 – 2065 with an average rise of 0.44 m by 2100. At RCP 4.5 GMSL is predicted to rise by an average of 0.26 m between 2046 – 2065 with an average rise of 0.53 m by 2100. At RCP 6.0 GMSL is predicted to rise by an average of 0.25 m between 2046 – 2065 with an average rise of 0.55 m by 2100. At RCP 8.5, GMSL will rise by an average of 0.29 m between 2046 – 2065 with an average rise of 0.74 m by 2100 **(Figure 2.5).** However, for regional adaptation planning for SLR particularly in Aotearoa New Zealand, it is more appropriate to use relative sea level due to the dynamic tectonism that occurs on this landmass (Kopp et al., 2014; Oppenheimer et al., 2019).

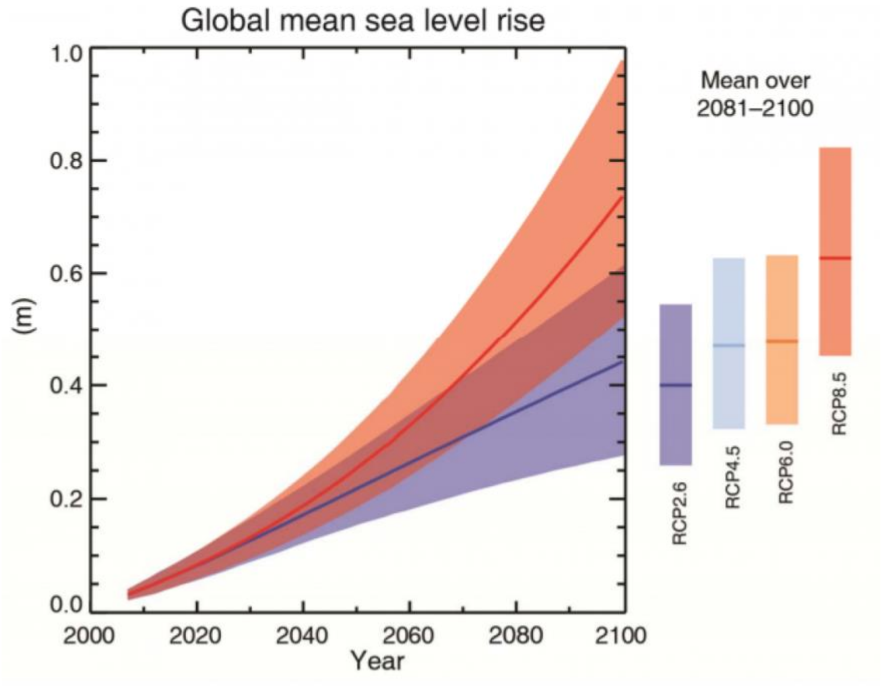


Figure 2-5: GMSL rise showing the rise in sea level through to 2100 under the RCP scenarios (IPCC, 2013)

2.8 Sea level rise in Aotearoa New Zealand

Aotearoa New Zealand has sparse sea level records, with the longest tide gauge data sets dating back to the start of the 20th century and located at four main ports of Auckland, Wellington, Lyttleton (Christchurch) and Dunedin. In the early nineties, Hannah (1990) began analyzing sea level data from the four ports around Aotearoa New Zealand to gain an idea of the sea level trends that had occurred since the turn of the century (Hannah, 1990). The project begun by digitizing the historical tidal records of the four ports considering factors such as linear sea level trends, response of sea level to temperature and pressure changes and lunar tides, with the aim of understanding the type of long-term changes in sea level but as well as assessing the vertical land movement of Aotearoa New Zealand. They found that while rates varied around Aotearoa New Zealand, particularly on the east coast of Aotearoa New Zealand there was on average a SLR of 1.7 ± 0.1 mm yr^{-1} with no significant vertical land movement (Hannah, 1990) (**Figure 2.6**).

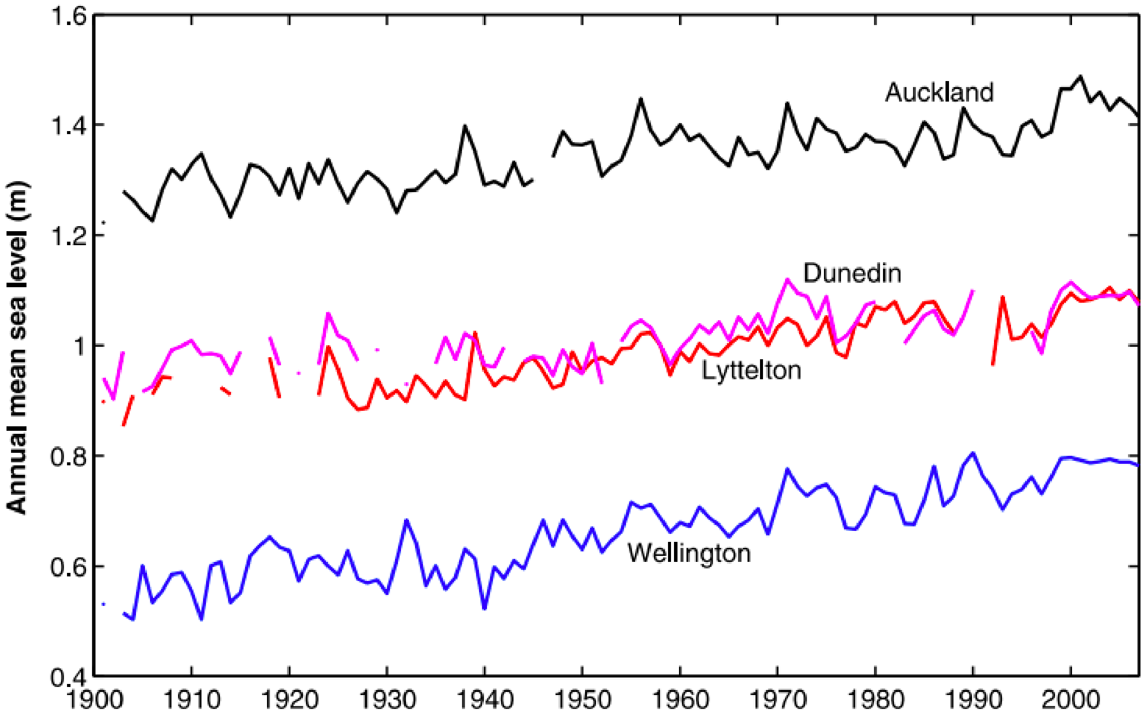
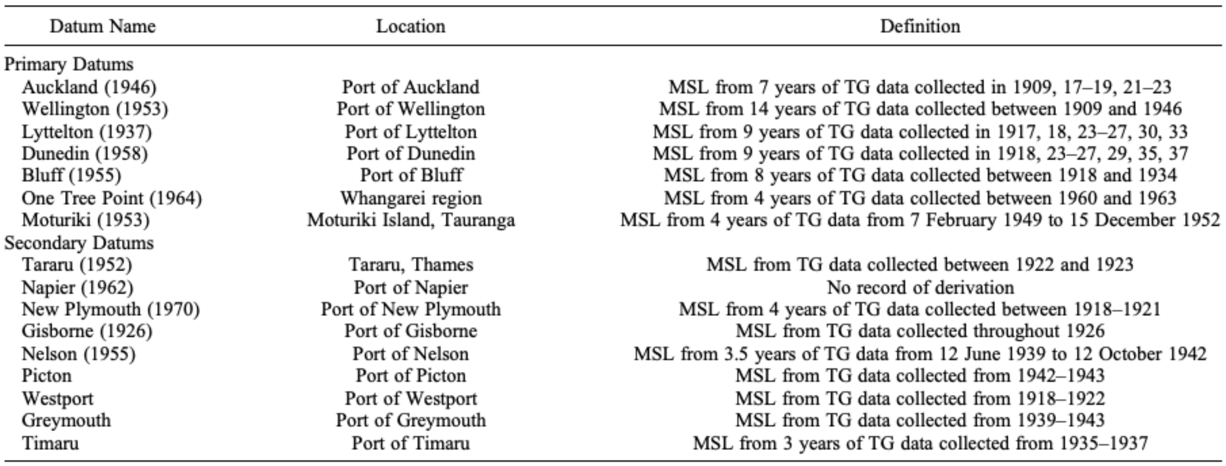


Figure 2-6: Change in sea level at the four main tidal gauges in Aotearoa New Zealand from 1900 to 2000+ (Hannah & Bell, 2012)

Further studies such as Gehrels et al. (2008), Hannah (2004) and Hannah et al. (2010) confirmed the SLR estimate from Hannah (1990). Moreover, a report by Hannah and Bell (2012) used historical data from the 4 tidal gauges around Aotearoa New Zealand to provide a larger spatial coverage for other areas of the country, given that in the past three decades tide gauges have been established at Nelson, New Plymouth, Timaru, Bluff, Whangarei and Tauranga (Moturiki Island). They compared old MSL datums with new datums and tried several approaches to reduce the bias caused by the El Nino Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO), which are dominant drivers of change in sea level around the coast of Aotearoa New Zealand over time scales of 1 – 2 years for ENSO and decades for IPO. An average SLR trend of 1.7 ± 0.1 mm yr^{-1} from the six new sites was identified which again agreed with previous studies mentioned earlier **(Table 2.1)**.

Table 2.1: Tidal gauges around Aotearoa New Zealand with the time periods of data collection (Hannah & Bell, 2012)

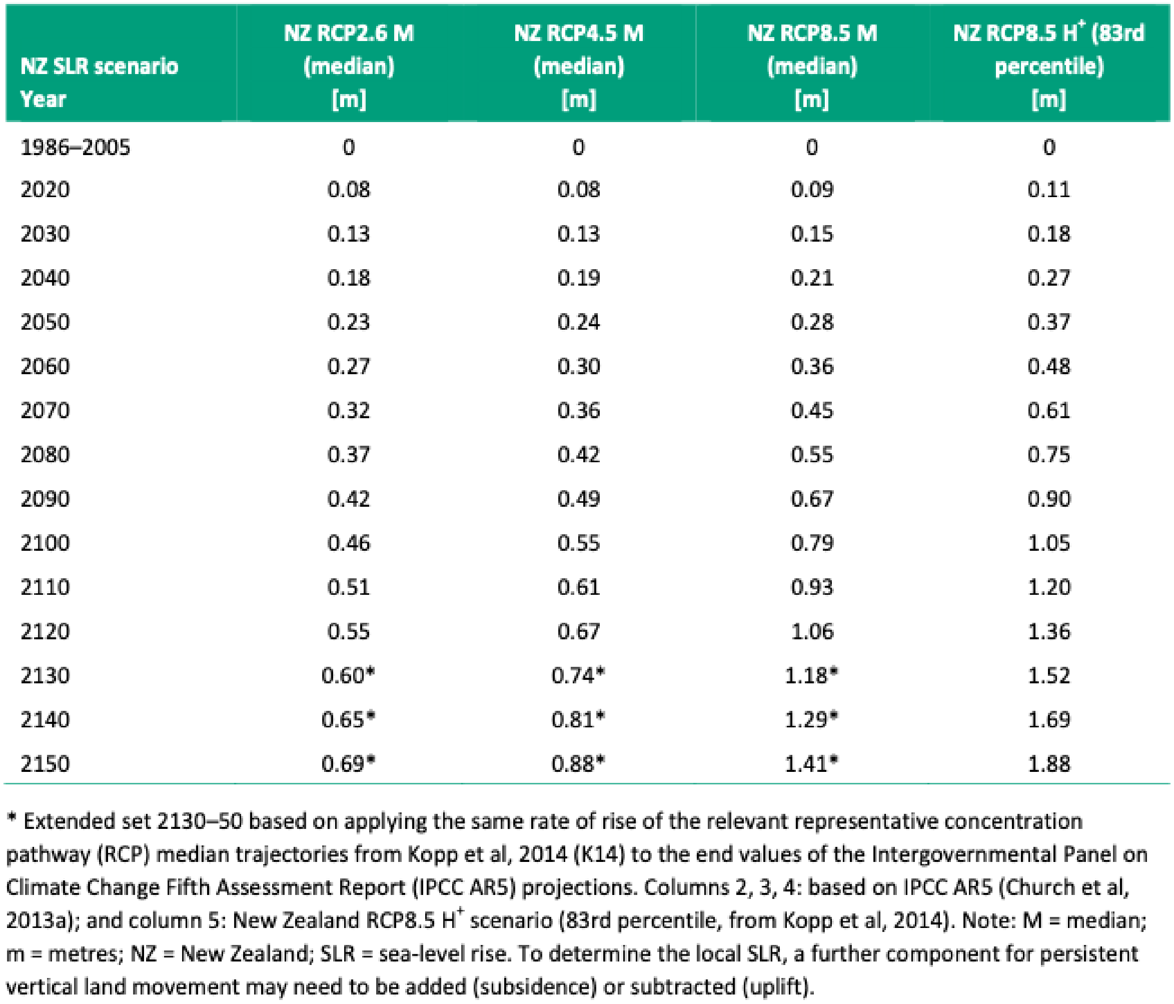


Datum Name	Location	Definition
Primary Datums		
Auckland (1946)	Port of Auckland	MSL from 7 years of TG data collected in 1909, 17–19, 21–23
Wellington (1953)	Port of Wellington	MSL from 14 years of TG data collected between 1909 and 1946
Lyttelton (1937)	Port of Lyttelton	MSL from 9 years of TG data collected in 1917, 18, 23–27, 30, 33
Dunedin (1958)	Port of Dunedin	MSL from 9 years of TG data collected in 1918, 23–27, 29, 35, 37
Bluff (1955)	Port of Bluff	MSL from 8 years of TG data collected between 1918 and 1934
One Tree Point (1964)	Whangarei region	MSL from 4 years of TG data collected between 1960 and 1963
Moturiki (1953)	Moturiki Island, Tauranga	MSL from 4 years of TG data from 7 February 1949 to 15 December 1952
Secondary Datums		
Tararu (1952)	Tararu, Thames	MSL from TG data collected between 1922 and 1923
Napier (1962)	Port of Napier	No record of derivation
New Plymouth (1970)	Port of New Plymouth	MSL from 4 years of TG data collected between 1918–1921
Gisborne (1926)	Port of Gisborne	MSL from TG data collected throughout 1926
Nelson (1955)	Port of Nelson	MSL from 3.5 years of TG data from 12 June 1939 to 12 October 1942
Picton	Port of Picton	MSL from TG data collected from 1942–1943
Westport	Port of Westport	MSL from TG data collected from 1918–1922
Greymouth	Port of Greymouth	MSL from TG data collected from 1939–1943
Timaru	Port of Timaru	MSL from 3 years of TG data collected from 1935–1937

Projections of SLR were also modeled in a Ministry for the Environment report conducted by (Bell et al., 2017), which was commissioned to provide guidance on how Aotearoa New Zealand can adapt to coastal hazard risk due to climate change, particularly that associated with SLR, as well as the vulnerability of certain elements such as communities, culture and infrastructure (Bell et al., 2017). This report associated projections of SLR with scenarios of RCP as mentioned in **Section 2.6**, however the extra RCP scenario of RCP 8.5 H^+ is included to represent instabilities in polar ice sheets based on RCP 8.5 (Kopp et al., 2014). SLR estimates around Aotearoa New Zealand have baseline data from 1986 – 2005 and the four future RCP scenarios, illustrating the gradual increase in sea level at each scenario as the decades progress **(Table 2.2)**. These SLR scenarios were also used by Paulik et al. (2020), whom investigated the national exposure of the built environment to a 100 year ESL event with 10 cm increments of SLR up to 3 m. This study defines exposure as the location of built land and assets which overlap within the coastal flood zones, they used an analytical risk framework “Riskscape” to understand the exposure of the built environment to coastal inundation due to SLR (Paulik et al., 2020). The key output from this study, and also what was used in this thesis research, were the 100 year ESL coastal flood maps as discussed in **Chapter 3.** These flood maps were used in conjunction with risk scape by Paulik et al. (2020) and a key finding was that the national exposure to a 100 year ESL doubles with less than 1 m rise in sea level, and in regions with high concentration of built infrastructure within the coastal zone the exposure increases with SLR. Sea level rise research in Aotearoa New Zealand is constantly evolving, especially with much of the population and the country’s infrastructure inhabiting the coastal margin, rendering many communities at risk to the effects of climate change such as SLR

(Stephenson et al., 2018). Bell et al. (2015) concluded that nationally, where LiDAR was available, 133, 265 (3.1% of the Aotearoa New Zealand total population) occupy areas at 0 – 1 m elevation and 281,902 (6.6% of Aotearoa New Zealand total population) occupy areas at 0 – 3 m elevation according to the 2013 census (Bell et al., 2015). This illustrates the sheer number of people in coastal areas, and an increase of 1 m in sea level will see 3.1% of the population homes being inundated (Bell et al., 2015). As well as the population of Aotearoa New Zealand being at risk, the fragility of the nation's economy is also at risk to increasing sea levels. The dependence on agriculture, tourism, forestry and fisheries puts Aotearoa New Zealand in a precarious position in the future as inundation due to SLR can result in the destruction of these key industries as well as related infrastructure such as ports, roading and train networks (Hopkins et al., 2015).

Table 2.2: SLR estimates under varying RCP scenarios from 2020 – 2150 (Bell et al., 2017)



NZ SLR scenario Year	NZ RCP2.6 M (median) [m]	NZ RCP4.5 M (median) [m]	NZ RCP8.5 M (median) [m]	NZ RCP8.5 H^+ (83rd percentile) [m]
1986–2005	0	0	0	0
2020	0.08	0.08	0.09	0.11
2030	0.13	0.13	0.15	0.18
2040	0.18	0.19	0.21	0.27
2050	0.23	0.24	0.28	0.37
2060	0.27	0.30	0.36	0.48
2070	0.32	0.36	0.45	0.61
2080	0.37	0.42	0.55	0.75
2090	0.42	0.49	0.67	0.90
2100	0.46	0.55	0.79	1.05
2110	0.51	0.61	0.93	1.20
2120	0.55	0.67	1.06	1.36
2130	0.60*	0.74*	1.18*	1.52
2140	0.65*	0.81*	1.29*	1.69
2150	0.69*	0.88*	1.41*	1.88

* Extended set 2130–50 based on applying the same rate of rise of the relevant representative concentration pathway (RCP) median trajectories from Kopp et al, 2014 (K14) to the end values of the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) projections. Columns 2, 3, 4: based on IPCC AR5 (Church et al, 2013a); and column 5: New Zealand RCP8.5 H^+ scenario (83rd percentile, from Kopp et al, 2014). Note: M = median; m = metres; NZ = New Zealand; SLR = sea-level rise. To determine the local SLR, a further component for persistent vertical land movement may need to be added (subsidence) or subtracted (uplift).

2.9 Summary

Te Ao Māori is the cyclical and holistic Māori world view that is connects Māori people to everything that is tangible and intangible in the world, linking them to the flora, fauna and the Earth through whakapapa. Whakapapa is also the means whereby Māori connect to marae and urupā in that their family members either once lived at the marae or are buried in urupā. Marae and urupā represent the physical embodiment of the connection between Papatūānuku and Ranginui, as part of the Māori creation story which saw them separated to bring life to the world, they embody this connection and are significant for Māori culture and identity. Many marae and urupā are potentially exposed to coastal inundation due to SLR induced by climate change, as traditionally marae and subsequently urupā were positioned along the coast for proximity to resources. Sea level rise in Aotearoa New Zealand under different RCP scenarios varies, but under the most stringent scenario of RCP 2.6 a rise of 0.46 m by 2100 is expected and under the unchanging scenario of RCP 8.5 H^+ a rise of 1.05 m by 2100, resulting in 133,265 people in Aotearoa New Zealand exposed to coastal flooding of a rise of 1m. Exposure of coastal marae and urupā is crucial as there has been no national assessment into this field and the events of coastal marae and urupā being flooded is continuing to rise. Robust mapping with sound methodology is required to understand their exposure.

Chapter 3 Methodology

“Titiro whakamuri, kōkiri whakamua.”

“Look backwards to move forwards”

3.1 Introduction

This chapter describes the methodology used to achieve the aim and objectives of this thesis, as outlined in **Section 1.2**. The flowchart in **Figure 3.1** illustrates the components of the methodology, that are introduced in that order in this chapter. First I outline the origins of the research topic and my positioning as a Māori scientist. I explain the preliminary changes which were required to utilise the information these datasets hold as well as the analysis techniques and steps taken to produce the outputs required to understand the potential exposure of coastal marae and urupā to SLR.

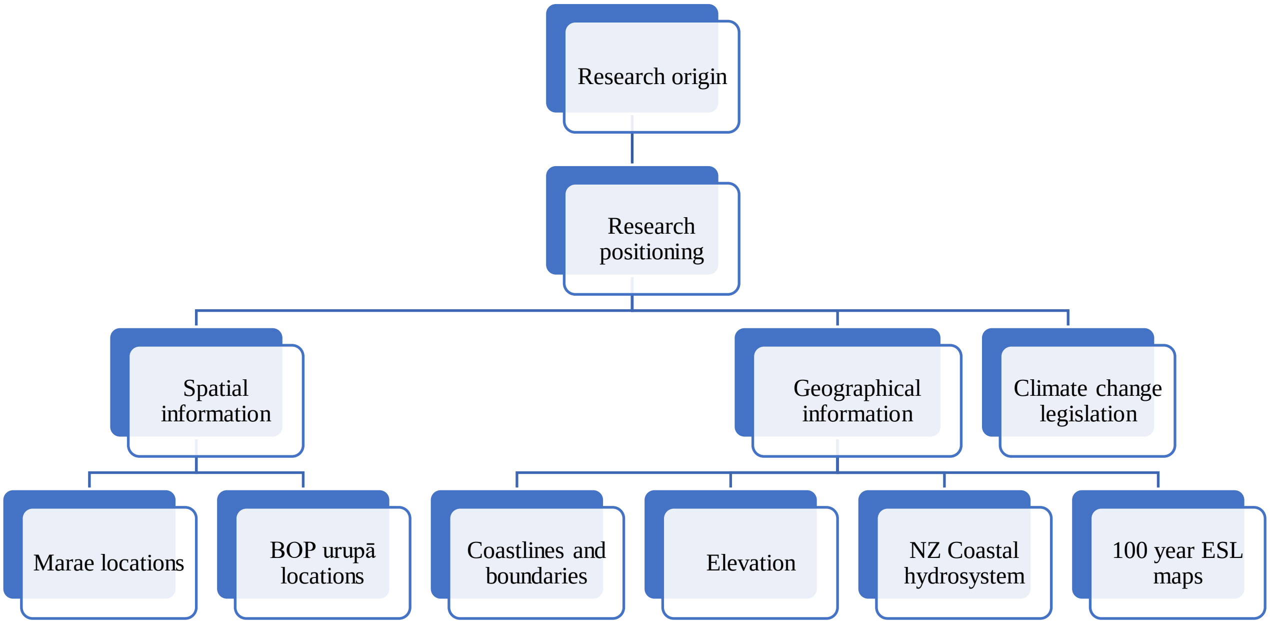


Figure 3-1: Flowchart showing progression of thesis methodology

3.2 Research origin

The origins and approach of this thesis is dominated by western science principles and research, but I am in receipt of precious and valuable Māori data and information. Therefore, the origins of this research and the way I went about it needs to be explained to ensure that my positioning is clear and that my approach is culturally sensitive (Smith, 2012). The origins of this thesis was as a University of Waikato Summer Student Scholarship in 2019 – 2020, where the groundwork was laid of gathering spatial information of marae locations around Aotearoa New Zealand. I began extracting preliminary information using a geographic information system using a national marae dataset and coastline and river data to understand the distance between the coast and to rivers of marae, as well as their elevation using the national 8 m digital elevation model and the slope to the nearest waterbody. This preliminary data gathering was integrated into the beginnings of this Master's thesis. The preliminary mapping from my summer project showed that 93% of marae are found within the North Island of Aotearoa New Zealand with 6.3% in the South Island. It also demonstrated clustering of marae at the coast, with 45% of marae being within 200 metres of the coast and 40% of marae being with 200 metres of a river. It also highlighted the need for further research to understand potential exposure to SLR. Therefore, the overall aim and the research objectives of this thesis **Section 1.2** were developed to build on this beginning.

3.3 Positioning as a Māori scientist for this thesis

Through conversations with friends and lecturers at the commencement of my master's programme, they highlighted the reflective and revealing process that accompanies postgraduate study and research. However, I didn't realise when embarking on this journey that my whole perception of who I was and where I fit in the world would be turned upside down. I was born and bred in Rotorua, Aotearoa New Zealand, where Māoridom is strong and prevalent. You would think that a Māori kid in Rotorua would be immersed in Te Reo Māori (Māori language) and Tikanga (protocols). However, my parents were of the generation where learning "too much of Māori" wasn't going to set you up for a successful life in this world. This perpetuates from their parents and grandparents upbringing where they were punished for speaking Te Reo (Durie, 1998) as a form of assimilation of Māori into the commonwealth and stigmatized for being Māori or in my mother's case as a "half-caste" (Paterson, 2010). With this experience of my parents and whānau, my siblings and I went to a mainstream pākehā school which was where my science journey began. As I progressed through the stages of university education, I neglected to take notice of the privilege I have of being Māori and a scientist. It was not until I started this masters thesis that I was made to think of what it means to be a Māori researcher in science, and how to navigate this. This resulted in the dilemma of what Smith (1999) describes as the insider/outsider researcher dilemma, where you are both part of the "researched community" and are the "researcher". This can result in conflict of one’s positionality on issues related to their communities in that they want the best outcomes for them, but they have the pressures from their organisations to deliver outcomes. However, speaking from my experience so far and learning from other Māori scientists, if you are a Māori you are pigeon-holed into being the token Māori, including engagement with Māori communities, to conduct karakia or waiata at the beginning and end of a meeting or being able to navigate the intersection of western science and mātauranga Māori (Māori knowledge) knowledge systems (Reid, 2011; Haar & Martin, 2021). I am not at the point yet where I am able to fulfil these sacred processes and hence it was crucial to make my positioning known on where I stand as a Māori scientist / researcher.

I outline my position as a Māori scientist / researcher, which is uncommon in western science as our general training is to remain objective, be absent from commitments and value freedom and absence of personal bias (Reiss & Sprenger, 2014). However, as a Māori scientist, in line with Moyle (2014) and Tiakiwai (2015), explicitly outlining your positionality identifies where you sit on matters and the extent that your capabilities are to consult on or are included in research that will have an impact on yourself and your community. Through this positionality journey, a subsequent dilemma arose for me that many other Indigenous researchers have experienced, where our education in the western academy has moulded our brains and ways of thinking to be from a western perspective (Smith, 2012). However, “being Māori” isn’t something you learn or earn, it is something that is deep within us and it comes out in emotive and spiritual ways which western science and knowledge is not used to.

A colleague of mine enlightened me on this and said that we as Māori researchers are on a spectrum (**Figure 3.2).** Where you place yourself on this spectrum defines what you can consult on, and what you cannot. You are able to move and learn about both sides and to position yourself where you see fit. The western science end is science dominant with little to no engagement of Māori communities or Te Ao Māori. On the other hand, the kaupapa Māori end of the spectrum involves using mātauranga Māori to conduct research, by Māori for Māori. You can be in between the two extremes, where the merging and utilisation of both knowledge systems occurs to various degrees. Where I am in terms of this research and where I am at as I write this, as a scientist / researcher in this thesis, is represented by the red star. This position is based on my training as a western scientist, but as Māori. To move further into the purple arrow would involve further learning on kaupapa Māori research, which can incorporate mātauranga Māori into research which I am working towards. However, people have also said that my positioning is unique in that I can see the coin from both sides. This spectrum does not form my opinion or passion for things, my passion lies with my science and getting it out there to help my people. This thesis is just one step in my journey, but important to make known.

Figure 3-2: Māori research spectrum with western science and kaupapa Māori at the extremes with the red star representing my current positioning as a researcher for this thesis

My positioning as a Māori researcher **(Figure 3.2)** enables me to understand the impact that this predominantly western science-based research can have for Māori, especially as I am working on such significant sites as marae and urupā. Aligned with this, Harmsworth (2020) summarised types of research in Aotearoa New Zealand in a guide to the Vision Mātauranga policy, which is the national public policy introduced to incorporate Māori knowledge and communities in scientific research (Ministry of Research Science and Technology, 2005). They outlined five different types of research, depending on levels of Māori inclusion and engagement in the research being undertaken **(Figure 3.3).** A brief summary of each is provided below, based on Harmsworth (2020), and I show where my research fits on this spectrum.

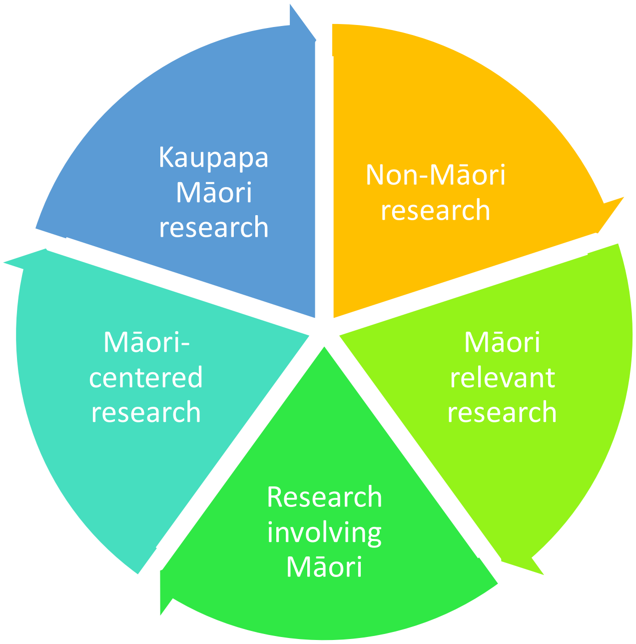


Figure 3-3: Different types of Māori research ranging from non-Māori research with zero Māori engagement and collaboration with projects which may be relevant to Māori to Kaupapa Māori research, which is Māori led, for Māori by Māori with collaboration and engagement. (adapted from Harmsworth (2020))

1) ***Non-Māori research*** is science-led not involving Māori but may be of interest to Māori.
2) ***Māori relevant research*** is a science project relevant to Māori but does not involve Māori at any stage of the development, with outputs being broad but which may be relevant to Māori.
3) ***Research involving Māori*** is dominantly science based with some minor contribution of Māori such as for work or as participants. This research is often relevant to Māori and addresses aspirations and critical issues facing Māori.
4) ***Māori-centered research*** addresses Māori issues, they are key players in co-design, co-development and is often Māori-led increasing Māori capacity. This approach uses mātauranga Māori alongside science, with Māori being the key end users of this research.
5) ***Kaupapa Māori research*** is Māori led, for Māori by Māori with key principles used throughout, with the inclusion of mātauranga Māori throughout, building on Māori capacity, awareness and contributing to aspirations of hapū and iwi.

I would classify this masters research as Māori relevant research, as it is a science based project, but Māori communities, iwi, hapū and marae have not been part of this research, although it is relevant to Māori. Although I have had many kōrero (discussions) with various members of the wider Māori community, where reception of this research has been highly positive, I have not explicitly worked with or engaged with iwi/hapū. I have ensured that this research was approached in a culturally sensitive and respectful discourse, such as I have masked the names and physical location of coastal marae and urupā in this analysis, assigning them code names in the form of roman numerals to allow for anonymity and protection as discussed in Raghunathan (2013), as I have not asked permission to utilise their locational data and have only accessed publicly available datasets. I did this in accordance with Indigenous data sovereignty principles which set out regulations to enable the inherent rights and interests that Indigenous people have in relation to the governing principles they have over their data from the point of collection to the outputs produced (Smith, 2015; Lovett et al., 2019; West et al., 2020).

3.4 Spatial information data

3.4.1 Marae locations

The dataset of marae locations that I used in this thesis was created by Te Potiki National Trust Limited through www.māorimaps.com. It is a point layer file which provides the name, location and iwi representative with contact details for each marae around Aotearoa New Zealand (Te Potiki National Trust, 2011). There are 774 marae in this dataset **(Figure 3.4)**. For this research I focussed on SLR impacts on marae and urupā, hence I confined the marae in this dataset to those that are within 1 km of the coastline, producing 191 coastal marae (LINZ, 2012). An issue which arose with this dataset is that the points used to represent marae were sometimes located at the road entrance rather than on any structures such as the wharenui (meeting house). I manually edited these data points so that marae locations were centred on the wharenui.

3.4.2 Bay of Plenty coastal urupā

Urupā are very sacred places to communities and society, in particular Māori. This means that any research about these sacred sites needs to be done with the upmost respect, aroha (love) and kindness. Many urupā in Aotearoa New Zealand are not mapped for a range of reasons, including due to (1) urupā are a sensitive topic in the community, (2) whānau, hapū and iwi may not want their urupā to be mapped and location widely known and (3) urupā are numerous and many are unmarked with the locations of some unknown. However, there have been numerous accounts in the national media of urupā being impacted from erosional and inundation processes (Angeloni, 2018, 2021). Therefore, as a case study I focused on urupā in the BOP region whose locations are publicly-available, to start to understand how they may be affected by SLR and what the next steps may be. This analysis begun by researching online the available cemeteries on websites such as findagrave.com and general searches. I collated the data into a Google Earth file to those within 1 km from the coast. This includes public cemeteries (council-operated) and private cemeteries which I defined as urupā which did not have associated information online or were family only cemeteries, and urupā associated with marae or hapū. From here I converted the file to be used in ArcGIS Pro using "KML to Layer" tool.

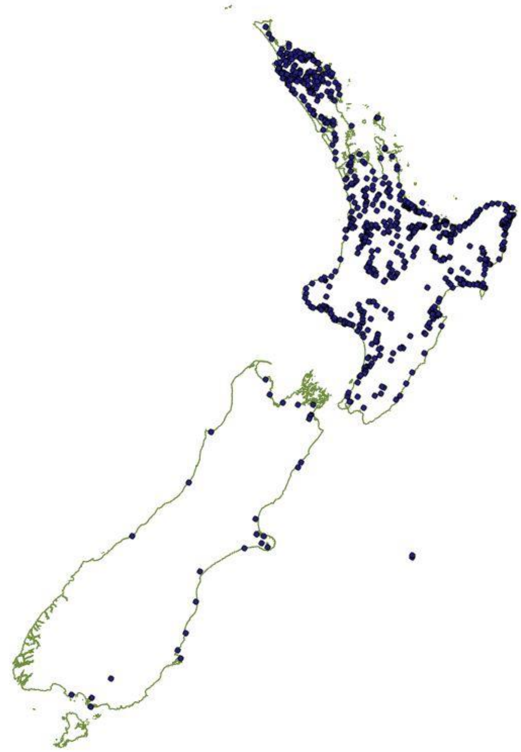


Figure 3-4: Marae located around Aotearoa New Zealand as part of the Te Potiki National Trust, 2011 database (Te Potiki National Trust, 2011)

3.5 Geographical and regional data

3.5.1 Coastline and boundaries

I used the Aotearoa New Zealand Coastline and Islands Polygons (1:500k), which is a GIS layer of the boundary between the land and sea, defined by the mean high water level **(Figure 3.5)**. It is a vector polygon layer which provides the name of the coastline and islands (LINZ, 2012). This layer was used as a reference to obtain proximity data between marae and urupā to the coast. To delineate regional boundaries, I used the Regional Council 2020 (generalised) Polygon layer, which is the definitive version of Aotearoa New Zealand Regional Council boundaries for 2020, as defined by Regional Councils and local government, and is maintained by Statistics NZ (2020). This dataset exists as a polygon layer with 16 Regional Councils identified and was used to assign coastal marae to a region.

Figure 3-5: Outline of the Aotearoa New Zealand coastline as part of the coastline and islands polygon (LINZ, 2012)

I also used the Iwi areas of Interest layer identified in the Māori Fisheries Act 2004, as well as those who have begun the treaty settlement process provided by Te Puni Kokiri (2017) accessed through hub.arcgis.com. This dataset was used to assign coastal marae to a rohe or larger tribal grouping which was an important accompaniment to the Regional Council boundaries as it puts it into a format which is targeted to Māori and is in a more cultural and practical format.

3.5.2 National 8 m digital elevation model (2012)

The 8 m digital elevation model (2012) is a depiction of the elevation of natural landforms for cartographic visualisations, from interpolating 20 m contours with 90% of points within ±22 m horizontally and ±10 m vertically (LINZ, 2016). This dataset was used to get elevations of marae and urupā nationally **(Figure 3.6)**.

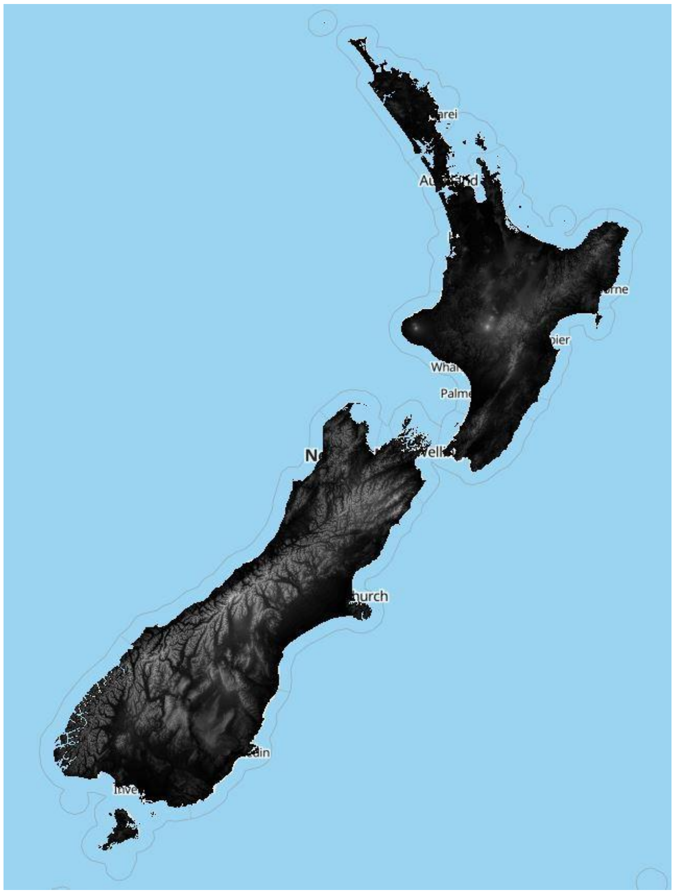


Figure 3-6: Digital elevation model with 8 m horizontal resolution covering the entire landmass of Aotearoa New Zealand. Areas in white are higher elevation zones and areas in black are lower elevation zones (LINZ, 2016)

3.5.3 LiDAR in the Bay of Plenty

For the BOP I used two higher resolution LiDAR datasets including BOP LiDAR 2018 and Tauranga and Coasts LiDAR 2015. The BOP LiDAR 2018 dataset was funded by BOPLASS, limited between December 2018 – April 2019, and is distributed by LINZ. The survey area covers

Tauranga, Rotorua, Whakatāne and surrounding areas with a vertical accuracy of ± 0.2 m and a horizontal accuracy of ±1.0 m (BOPLASS & LINZ, 2018). This dataset was used to get more accurate elevations than compared to the DEM for BOP coastal marae and urupā. The Tauranga and Coasts 2015 dataset is 1m LiDAR captured in the BOP region, funded by BOPLASS limited, captured from January 2015 to April 2015 and is distributed through LINZ. The survey area covers Tauranga and Whakatane as well as the coastline in between (BOPLASS & LINZ, 2015). This dataset was used in conjunction with LINZ (2017) and BOPLASS and LINZ (2018) as it did not cover all coastal marae and urupā in the region. The purpose of using LiDAR was to gather elevation information for coastal marae and urupā in the BOP region, due to the accuracy of LiDAR compared to the national DEM. However, LiDAR was only utilised for the BOP region as LiDAR can be computationally intensive and is not readily available for the entire coast of Aotearoa New Zealand.

To download these datasets, opentopography.org is a distributor of LiDAR data and is where BOPLASS and LINZ (2015, 2018) were downloaded. Due to the size of the files, LiDAR portions for each BOP coastal marae and urupā were downloaded and analysed separately. Each section was downloaded as a LAS point cloud file which reduced the processing time and the TIN selected to calculate the surface morphology. The LAS file was represented as a group of points varying in colour **(Figure 3.7a)**, with the colour representing the elevation. Green represents higher elevations and purple represents lower elevations.

A DEM was produced using LAS tools (LAS Dataset to Raster) in using ArcGIS Pro. This produced a DEM layer which shows the spatial variation in elevation **(Figure 3.7b)** by taking the LAS points and converting them to a raster DEM**.** Assigning LiDAR elevations to coastal marae and urupā was done manually by adding a new field in the attributes table and then by clicking on each pixel the coastal marae or urupā is situated on, recording that value in the attributes table. When using the National 8m DEM for coastal marae nationally, instead of manually assigning elevation values, I assigned elevations using the add surface information tool and selecting z value (elevation). This assigns every point in the input layer a z value and was used in this step as the DEM was downloaded in larger sections which meant that you have more features in each section than you would LiDAR and hence you can assign elevations automatically.

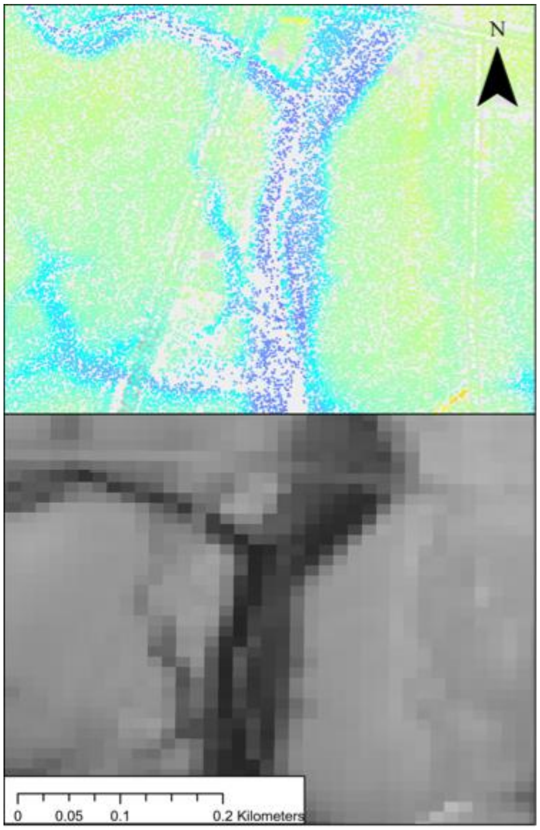


Figure 3-7: a) LAS file to derive the LiDAR for specific BOP coastal marae and urupā. Green means higher elevation and purple means lower elevation and b) Raster produced from LAS file to derive elevation data for BOP coastal marae and urupā. White represents higher elevation whereas black represents lower elevations

3.5.4 New Zealand coastal hydrosystem

The classification of Aotearoa New Zealand's coastal hydrosystems developed by Hume et al. (2016) was available as a GIS layer (LINZ, 2017), and describes the coastal environment around Aotearoa New Zealand ranging from coastal wetlands, riverine, estuarine and marine environments. This dataset exists as a point layer **(Figure 3.8a),** with supporting polygon layers which were used in this analysis, with the blue shading representing the polygon layer **(Figure 3.8b)**. This dataset was used as it provided a classification of the coastal systems of coastal marae and urupā, in particular, it provided a classification of coastal geomorphology around Aotearoa New Zealand which was needed to conduct the second research objective. This geomorphic classification will be described in detail in **Chapter 5** of this thesis.

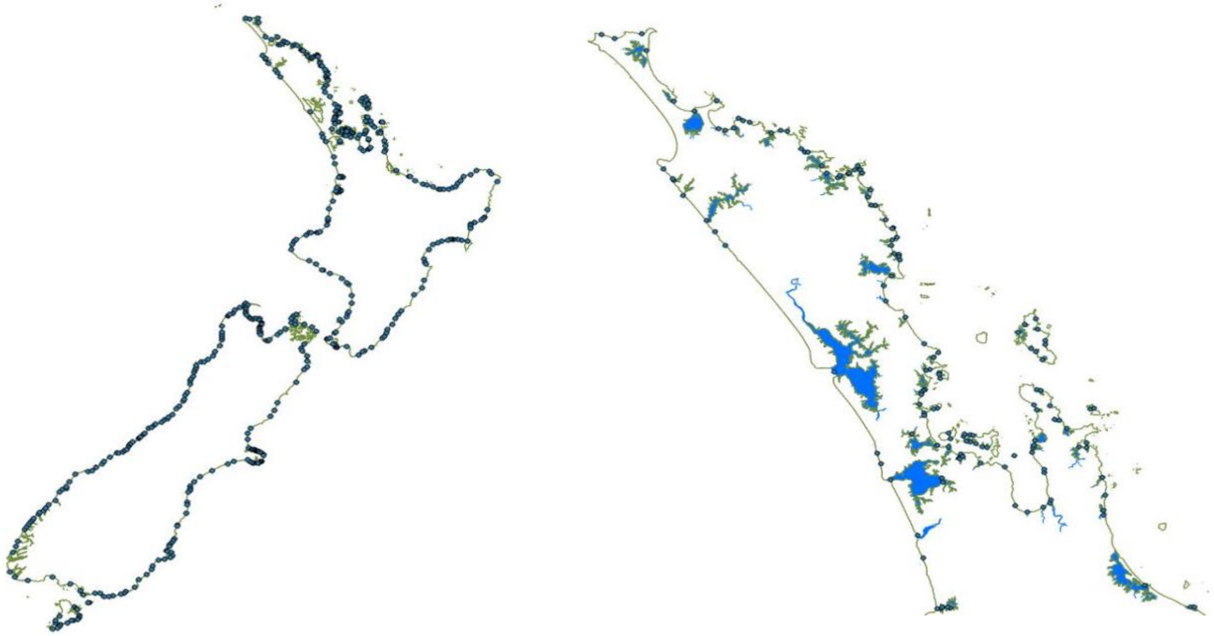


Figure 3-8: Aotearoa New Zealand coastal hydrosystem classification represented as panel (a) points representing coastal geomorphology and panel (b) polygons representing coastal geomorphology Hume et al. (2016) and LINZ (2017)

3.5.5 Extreme sea level maps

To assess the potential exposure of coastal marae and urupā to SLR, I used data from Paulik et al. (2020) who employed a bathtub modelling approach as a first assessment of the exposure to the built environment of Aotearoa New Zealand to future coastal flooding at a national scale. The bathtub approach assumes that water level of a certain height is able to inundate land grids of elevations lower than this, and that all grid cells surrounding a flooded grid cell will also flood (Poulter & Halpin, 2008; Didier et al., 2019). This approach has well-known limitations, being that it can overpredict and underpredict zones which may be inundated as it doesn't account for hydraulic connectivity such as drainage systems and barriers, this can cause overestimation of engineering structures and management systems (Seenath et al., 2016; Teng et al., 2017). Nevertheless, bathtub modelling can provide baseline data which may be used for a first-pass assessment of potential exposure of coastal features to coastal flooding due to SLR (Kont et al., 2008; Shepard et al., 2012), and was applied in this thesis. For regional research, detailed hydrodynamic modelling would provide a more accurate estimation of the flooding exposure (McInnes et al., 2013).

The resulting dataset by Paulik et al. (2020) has a series of polygon layers which illustrate the potential coastal flooding due to a 100 year annual recurrence interval extreme sea level event (ESL). An ESL is a high sea level event that occurs through a combination of MSL, storm surge, tides and wave setup (Stephens, 2017; Paulik et al., 2019; Paulik et al., 2020) and can be exacerbated with SLR. ESL was calculated in Paulik et al. (2020) using **(Equation 3.1)**.

$$ESL = MSL + ST + WS + SLR \qquad \textbf{(3.1)}$$

Where **MSL** is mean sea level, **ST** is storm tide, **WS** is wave set up and **SLR** is sea level rise. ESL in Aotearoa New Zealand is affected by large climate variations such as ENSO (El Niño Southern Oscillation) and IPO (Interdecadal Pacific Oscillation), with ENSO being the dominant driver of sea level variation. In Aotearoa New Zealand during El Niño there is cooler sea temperatures and increased westerlies resulting in drier conditions to the east and wetter conditions in the west. However, during La Niña the sea temperatures are warmer, causing the mean sea level to rise, with more rainy conditions in the North island and drier conditions in the South island, with climate change intensifying this dynamic system (Stephens et al., 2016).

Storm tide is a combination of storm surge and the astronomical tide. Storm surge is when the sea level is temporarily elevated, and can be due to two mechanisms: (1) the inverse barometer effect where every 1 hPA decrease in atmospheric pressure results in a 1 cm increase in sea level (Bell & Stephens, 2015) and (2) strong wind pushing water onshore causing it to “pile up” (Bell et al., 2000). The astronomical tide is a key driver of water level at the coast and within estuaries due to the gravitational attraction which exists primarily between the Earth, the Earth’s moon and the sun. Tidal ranges vary both spatially and temporally over a range of scales, in that a surge maximum occurs more frequently on a rising tide than a falling tide (Rossiter, 1961; Prandle & Wolf, 1978; Haigh et al., 2010). It is important to consider local tidal effects as local processes at the coast affect the tidal range in four ways: 1) inertial effects due to acceleration and deceleration (these are often negligible if not in a shallow tidal zone), 2) shoaling, 3) bottom friction and 4) standing wave resonance (van Rijn, 2011a). Shoaling due to convergence of shorelines and resonance due to standing wave formation tends to amplify the tidal signal, whereas diverging shorelines and bottom friction tend to attenuate the tidal signal (van Rijn, 2011a). Tidal amplification is common within estuaries as the estuarine basin allows for standing wave resonance and convergent channels which tend to amplify the range (Haigh et al., 2020; Talke & Jay, 2020)

Wave set up is a rise in the water level at the coast which accompanies breaking waves, through an excess of momentum as the water mass moves shoreward through the surf-zone termed radiation stresses (Longuet-Higgins & Stewart, 1962). Radiation stresses are important in that they push the water shoreward and raise the total water level at the coast which is able to inundate coastal land and combined with storm-tide is important to coastal inundation (Gallop et al., 2020a). Wave set up is different to wave run up which is the maximum vertical extent of wave rush up, and is important to coastal erosion via wave action (Muis et al., 2016; Stephens et al., 2016). The extreme sea level calculated by Paulik et al. (2020) are categorised into regional groups and are imposed over LiDAR where available. Extreme sea level layers begin at present day MSL with a 100 year annual recurrence interval (ARI) event which includes wave set up but not run up and from here increments of 10 cm SLR until 3 m was recorded (Paulik et al., 2020). This dataset was used to assign increments of SLR to coastal marae and urupā to understand their exposure. The west coast region was the only one without LiDAR and used a DEM with 3m and 5m 100 year ESL layers available.

3.6 Data analysis

This section outlines the data analysis conducted on the datasets introduced above, to achieve the research objectives outlined in **Section 1.2**.

3.6.1 Coastal marae categorised into regional groups

The datasets used in this analysis include coastal marae locations **Section 3.4.1** and Regional Council boundaries. Coastal marae were categorised by region, using a spatial join between these two layers. This was chosen to identify coastal marae within each Regional Council group, with (**Figure 3.9)** showing coastal marae categorised into regions.

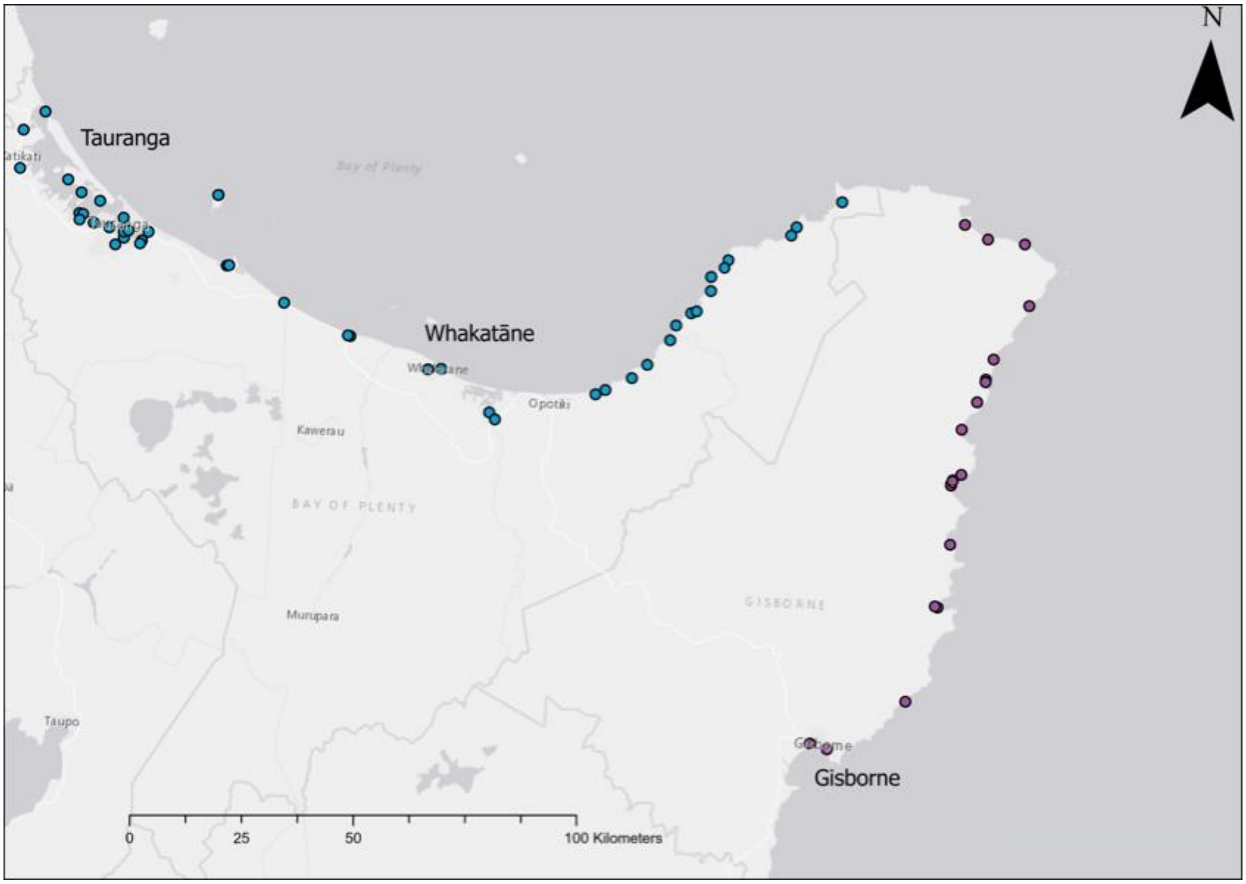


Figure 3-9: Coastal marae categorized into Regional Council groups showing example of the BOP (blue) and Gisborne (purple)

3.6.2 Coastal marae categorised into rohe

The datasets used in this analysis include coastal marae locations and Iwi areas of Interest. This was done to categorize coastal marae by rohe or boundaries of iwi by a similar process to that of **Section 3.6.1**. The only difference between the Regional Council layer and the iwi of interest layer was that the iwi areas of interest did not have clear geographic boundaries such that different hapū overlapped into others, due to historical delineation not being inducive to mapping or surveying and ownership was not individualised. Customary methods of delineation and ownership were that of collective ownership, where no one person owned the land, as Māori understand that they are born from Papatūānuku, and hence they belong to the land they do not own the land. As utilisation and demarcation of land was done through relationships and connections to neighbouring hapū and iwi, but no physical line was drawn until colonisation occurred (Kingi, 2008). In order to categorise coastal marae, I used the available larger grouping of rohe which meant I could categorise using this as an indicator. I followed the same method as **Section 3.6.1** and cross-referenced each coastal marae with the corresponding coastal marae available on the māorimaps.com website, to ensure that each coastal marae had the correct rohe attributed, such as the Tauranga example (**Figure 3.10)**.

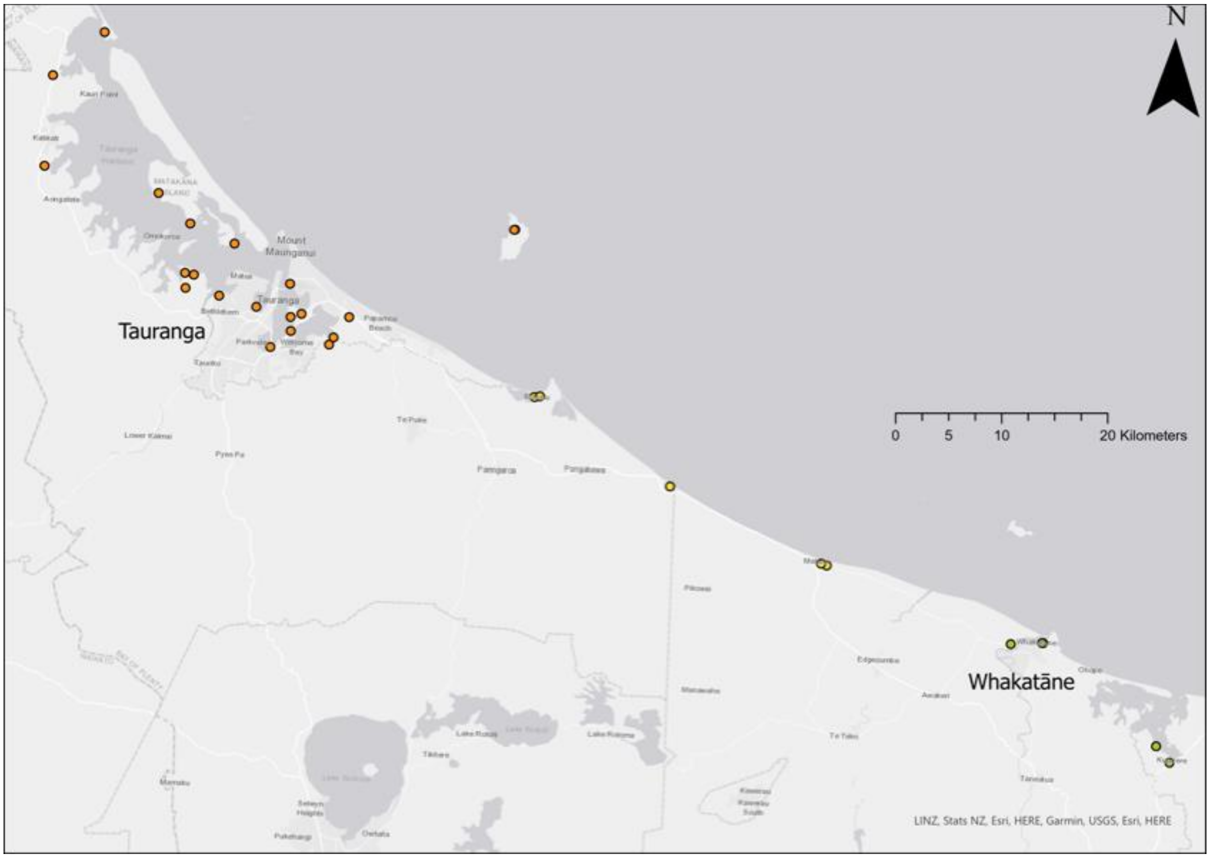


Figure 3-10: Coastal marae categorized into rohe, showing example of Tauranga Moana in orange, Te Arawa in yellow and Mātaatua in green

3.6.3 Coastal marae and urupā with extreme flood maps

The datasets used in this analysis include coastal marae and urupā locations and the NIWA 100 year ESL flood maps (Paulik et al., 2019). This was done to estimate which coastal marae and urupā may be inundated at a 100 year ESL with increments of SLR. The NIWA flood maps were categorised into Regional Councils and all utilised LiDAR except for the West Coast Council which was unavailable. From here they were organised into national increments of SLR and using the “intersect” tool, the coastal marae and urupā that intersect the coastal flood maps were attributed, this then grouped coastal marae and urupā into groups of inundation. This dataset was then used to illustrate the proportion of coastal marae and urupā that may be inundated with a rise in sea level.

3.6.4 Bay of Plenty marae and urupā topographical profiles

The datasets used in this analysis include marae and urupā locations, associated LiDAR layers and the Coastline and Islands layer. The coastline and island layer had a higher resolution agreeing with satellite imagery of the coastline, providing a better understanding of what the physical environment between the marae/ urupā and the coast was like. For instance, was there a large dune feature fronting a marae? Or was it so close with a less than 1 metre drop in elevation? To assess what the environment was like between the coastal marae/urupā I created a point along the coastline that was closest to the marae or urupā by using the "Near Tool". From here I used "Display XY Coordinates" to create a new point layer along the coast. A line was created to join the two points by "XY to Line" which requires inputting the coordinates of the marae or urupā as well as the coordinates of the nearest point just created. From here I used "Generate Points Along a Line" which generates points along this line with specific intervals of 10 metres (**Figure 3.11**). Then using the tool "Add Surface Information" selecting z values, I attributed the elevation of the DEM layer (per pixel) at each of those points along the line. I then exported this table as an excel spreadsheet using "Table to Excel" and created the profile using a line chart with distance along the x-axis and elevation along the y-axis. The profiles produced were highly variable, however some profiles did not end at the coast where elevation is assumed to be 0 m. There were 24 coastal marae profiles in the BOP that did not end at 0 m, and it is unsure what has caused this to occur.

Figure 3-11: Example of a topographical profile created between the marae and the coastline using points along a line to identify the elevation progression towards the coast

3.6.5 Geomorphic classification of marae and urupā

To categorise coastal marae and urupā by their coastal geomorphology, and hence understand their potential responses to SLR, coastal marae and urupā were categorised into types of coastal geomorphology using the New Zealand Coastal Hydrosystem classification (LINZ, 2017). As mentioned in **Section 3.5.4,** this New Zealand Coastal Hydrosystem dataset contains both point and polygon layer versions of the coastal hydrosystem. For example, in Tauranga Harbour which is a shallow drowned valley, there are point and polygon versions of this coastal hydrosystem which represents the entire harbour system. However, there was only one single point in the dataset representing the entire Tauranga Harbour, which was situated in the channel entrance near Mount Maunganui. This means that a coastal marae positioned further up in the Tauranga Harbour, that was in fact closer to a beach stream would be classified as a beach stream only not as a shallow drowned valley – Tauranga Harbour. Whereas the polygon version of the coastal hydrosystem, encompasses the full perimeter of the coastal hydrosystem such as the Tauranga Harbour perimeter and hence will identify that coastal marae further in the system as part of the shallow drowned valley – Tauranga Harbour. This meant that three steps of analysis were conducted. First, the Near Tool was used to see what marae and urupā were within 15 m of a coastal hydrosystem point. This distance was selected as the coastal hydrosystem points were represented as a single point for the system. If there was a significant distance to scope for marae or urupā, there was a chance that it would attribute the wrong coastal geomorphology. This was where the polygon variant was used to attribute marae or urupā that were within 15 m of a coastal hydrosystem polygon. This did not attribute every marae and urupā with a coastal hydrosystem, and manual analysis of each feature in relation to its geomorphic environment was conducted. This was accomplished using the decision tree diagram from Hume et al. (2016) which allowed the geomorphology to be determined using aerial analysis of each marae and urupā **(see Appendix)**. However, there were some cases where the geomorphology of a feature could not easily be delineated using the decision tree and a combination of two geomorphologies were utilised. There were 34 coastal marae and 3 coastal urupā on the open coast or a combination of two geomorphologies.

3.7 Summary

This research is the first national-scale investigation of potential coastal marae and urupā exposure to SLR in Aotearoa New Zealand. In this methods chapter it outlined my position as a Māori scientist / researcher to justify my research approach and the capability I possess as a Māori scientist. The methodology of this research sought to understand the exposure of coastal marae nationally and urupā in the BOP, defined as being within 1 km of the coast. Using the National Digital Elevation Model 8m and LiDAR in the BOP, I was able to ascertain the elevations of coastal marae and urupā above MSL and using the available LiDAR produce topographical profiles along the pathway to the coast. I also classified coastal marae into rohe and regional groups and using the extreme sea level maps produced by NIWA, I mapped which coastal marae and urupā would be potentially exposed to inundation from a 100 year ESL event with +10 cm increments of SLR up to 3 m. The number of coastal marae determined was 191 and coastal urupā totalled 41 in the BOP. I also classified the hydrosystem of each marae and urupa following the Hume et al. (2016) New Zealand Coastal Hydrosystem classification, as this will dictate the potential coastal response of these marae and urupā to a rise in sea level.

Chapter 4 Potential exposure of coastal marae and urupā to sea level rise

"I orea te tuatara ka patu ki waho"

"A problem solved by continuing to find solutions"

4.1 Introduction

Sea level rise will likely expose many coastal marae and urupā to increased frequency and severity of inundation, however a national-approach to determine potential impacts is lacking. Therefore, this chapter describes the potential exposure to SLR of coastal marae nationally with a focus on the BOP, where coastal urupā are included. I use spatial information to ascertain the elevation, distance and topographical profiles of marae and urupā. I then use NIWA extreme sea level maps at different increments of SLR described in **Section 3.5.5** to determine which marae and urupā may be inundated by a 100 year ESL.

4.2 Coastal marae by region

Aotearoa New Zealand has ~774 marae that are documented by the Te Potiki National Trust (2011) (a not-for-profit trust that has the marae of Aotearoa New Zealand as its beneficiaries), with 191 of these marae being within 1 km of the coastline, and thus deemed *coastal marae* in this thesis. A disproportionate number of these coastal marae are in Te Ika a Maui (the North Island), compared to Te Wai Pounamu (the South Island) **(Figure 4.1).** Northland has the largest number of coastal marae, with 58 in total, followed by the BOP region with 46 coastal marae. These regions with high numbers of coastal marae coincide with where predominantly Māori communities reside; according to the 2001–2006 census, 87% of Māori live in the North Island (Robson & Harris, 2007). The regions with the next highest number of coastal marae are Gisborne, which has 19 and Waikato with 18. Marlborough, Nelson, Tasman and the West Coast regions in the South Island have the lowest amount of coastal marae, with only 1 in each region.

4.3 Aotearoa New Zealand coastal marae by rohe

In line with the Māori-centric methodology (Smith, 2015) mentioned in **Section 3.3**, coastal marae were also categorized into rohe; the boundaries are similar to regions but have some differences. The analysis in this chapter is based largely on these rohe rather than regions. This was done to ensure the information in this thesis aligns with boundaries that are important to Māori. There are 13 rohe, extending from Te Tai Tokerau in the far north of Aotearoa New Zealand to Waipounamu in the far south **(Figure 4.2).** The rohe with the greatest number of coastal marae was Te Tai Tokerau with 61, followed by Tauranga Moana with 21, Mātaatua around the East Cape with 20 and Te Tai Rāwhiti around Gisborne with 19. The rohe with the least amount of coastal marae was Te Moana O Raukawa in the Wellington Region, with 1 coastal marae, which differs to the minimum amount of coastal marae by region, which were in the South Island. However, this is due to Waipounamu encompassing most of the South Island landmass whereas Te Moana O Raukawa encompasses only a small section of the lower North Island. Overall, the regional map in **(Figure 4.1)** is fairly similar to **(Figure 4.2)** providing another layer of classification.

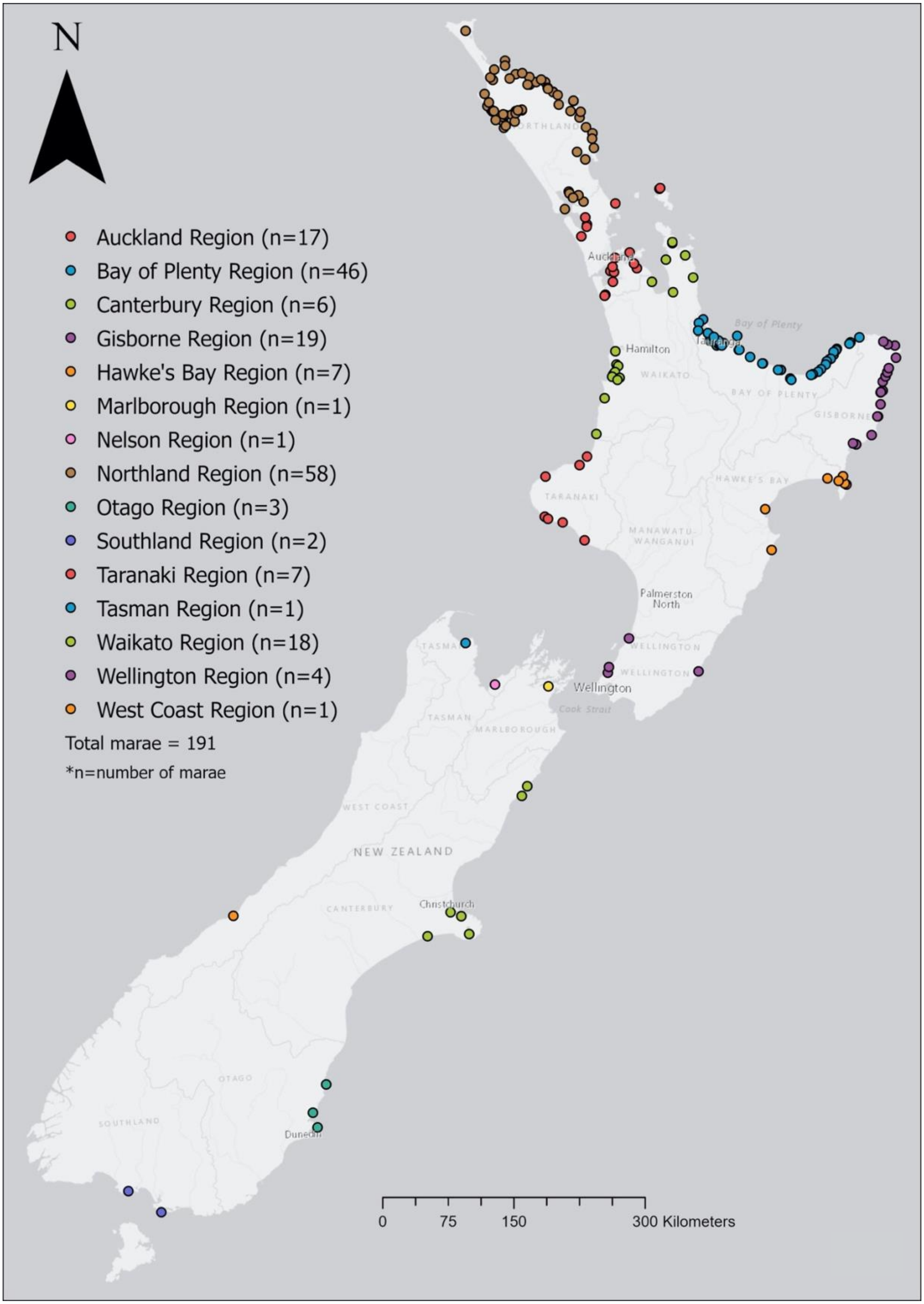


Figure 4-1: Map of coastal marae (< 1km to coast) around Aotearoa New Zealand, classified by regional council

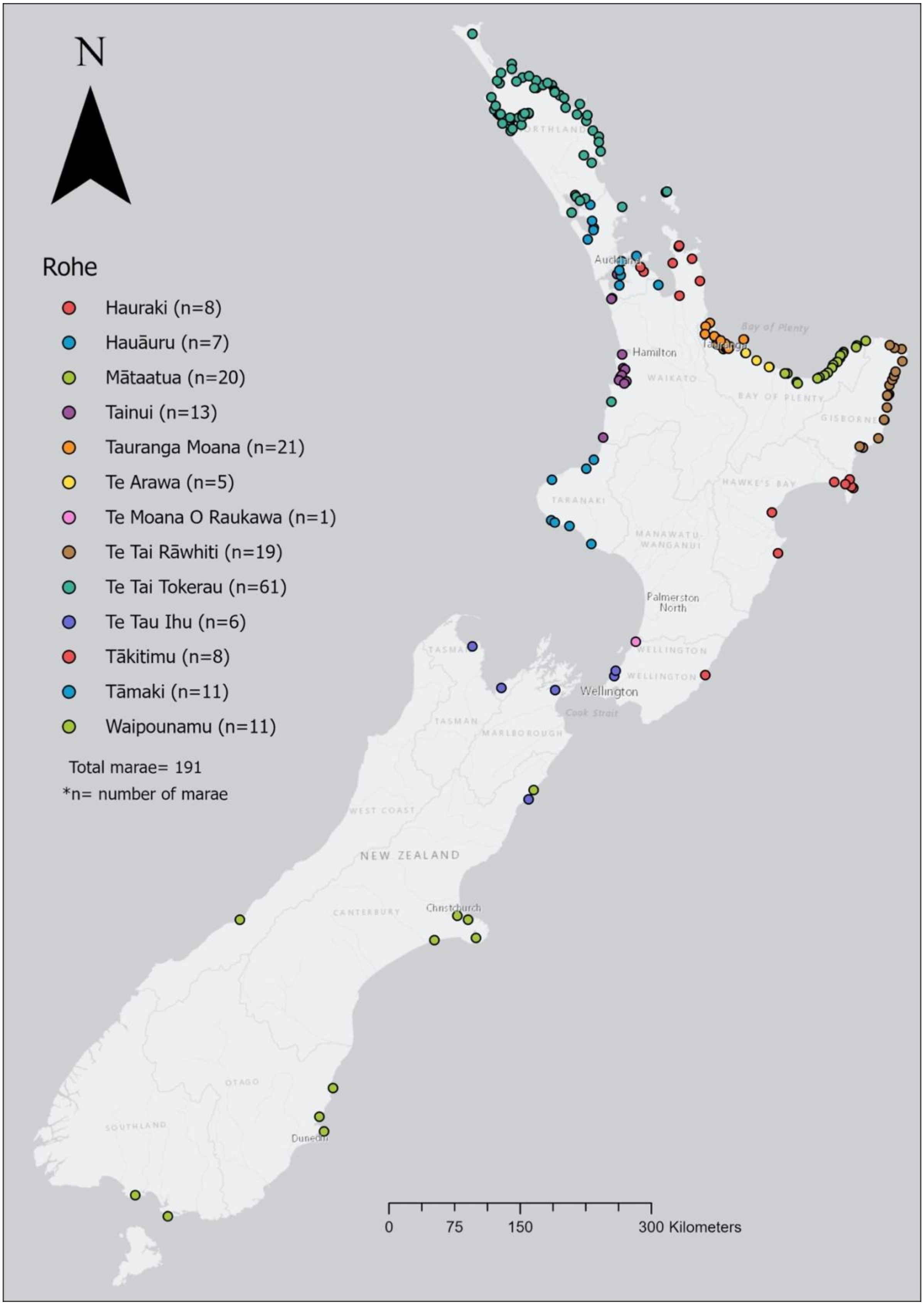


Figure 4-2: Map of coastal marae around Aotearoa New Zealand classified into rohe

4.4 Distance between coastal marae and the coast

In addition to marae and urupā elevation being a key determinant of if coastal inundation will occur, the horizontal distance to the coast is also important. This distance provides a visual parameter for people to easily understand the encroachment of SLR as well as being a buffer zone of sediment (van Rijn, 2011b). The distances of coastal marae and urupā were calculated in **Section 3.4.1** and are represented in **Figure 4.3**. There is large variation in distance to the coast for coastal marae; the distance to the coast with the largest number of coastal marae is between 0 – 150 m, with 39% (74) coastal marae, from here there is a steady trend of decreasing coastal marae further from the coastline down to the category of 900 – 1050 m level with 4% (8) coastal marae in this elevation band. The decrease in marae further from the coast is likely due to the coast historically being a source of food, transport and trade for the Māori people and hence being close to these meant increased chance of survival (King et al., 2012b; Iorns, 2019).

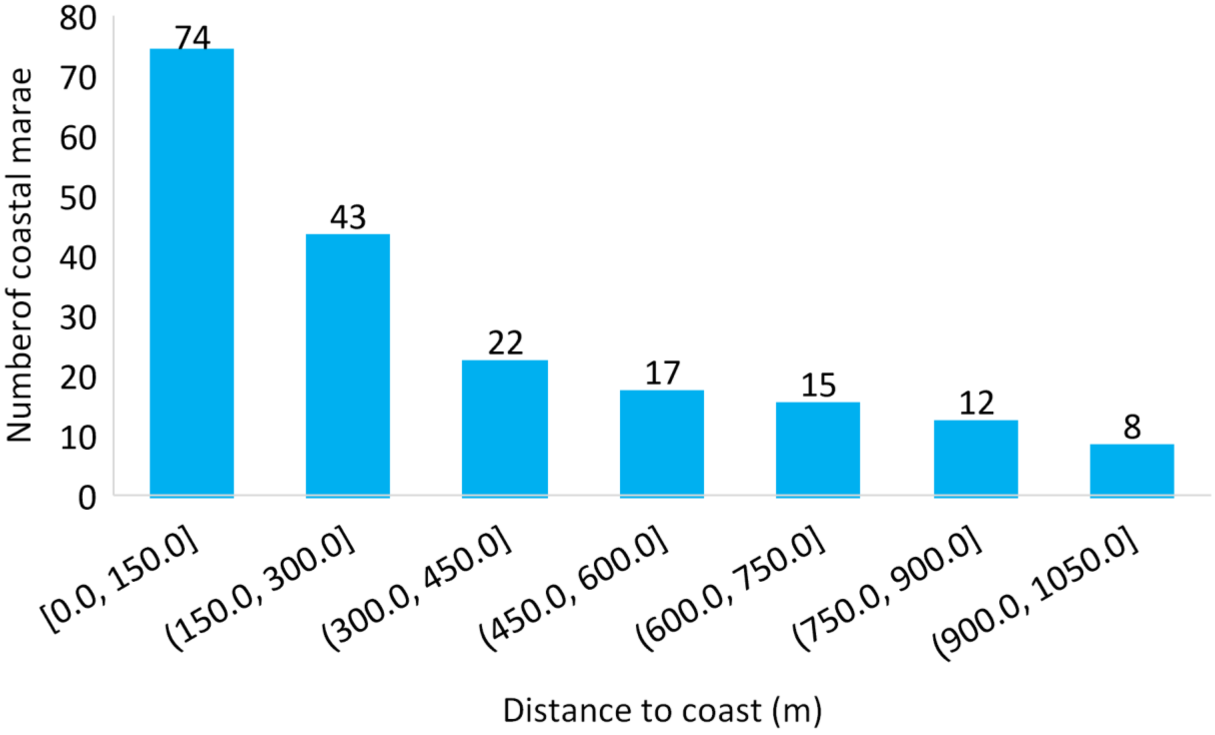


Figure 4-3: Bar graph illustrates the number of coastal marae at increasing distances to the coast of total n=191

4.5 Elevation of coastal marae

The elevation of coastal marae for each rohe was mapped and is represented in **Figure 4.4** with the size of the pie chart corresponding to the number of coastal marae. The elevation of coastal marae nationally is highly variable and ranges from 0 – 5 m to 100 – 200 m (**Figure 4.5a).**

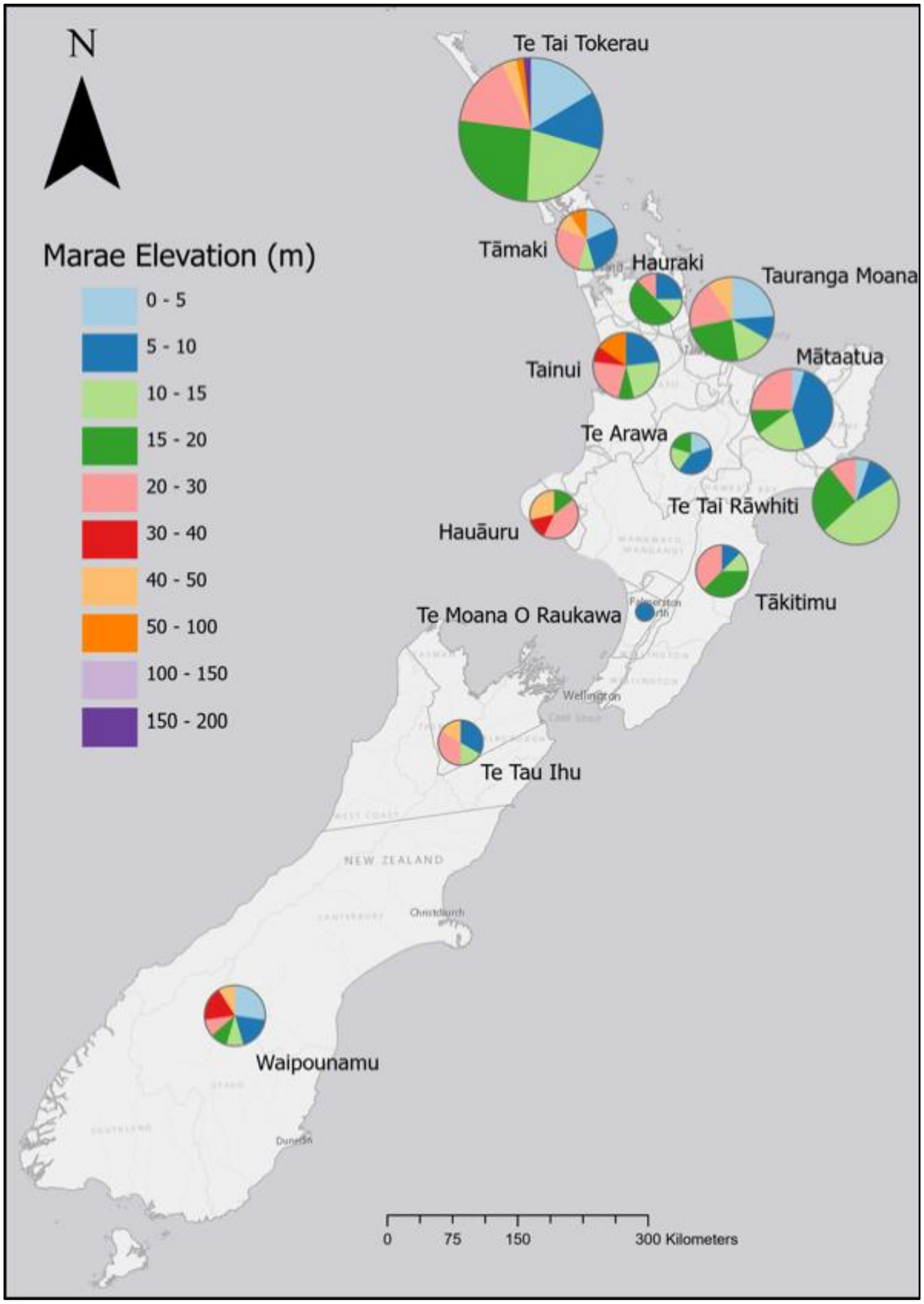


Figure 4-4: Map of elevations of coastal marae categorized by elevation in each rohe. The size of the pie graph corresponds to the number of coastal marae found in each rohe

Approximately 71% (136) of coastal marae nationally are situated below 20 m above MSL, with 31% (59) below 10 m. Comparing coastal marae at elevations less than 10 m above MSL and their distance to the coast **(Figure 4.5b)**, more than half of these marae are less than 300 m to the coastline. Of these coastal marae below 10 m elevation, 30% (18) are found within the Te Tai Tokerau rohe, 15.25% (9) are in the Mātaatua rohe and 11.86% (7) are in Tauranga Moana. This section here on in goes into detail for each pie graph of each rohe outlining key points to understand the potential exposure.

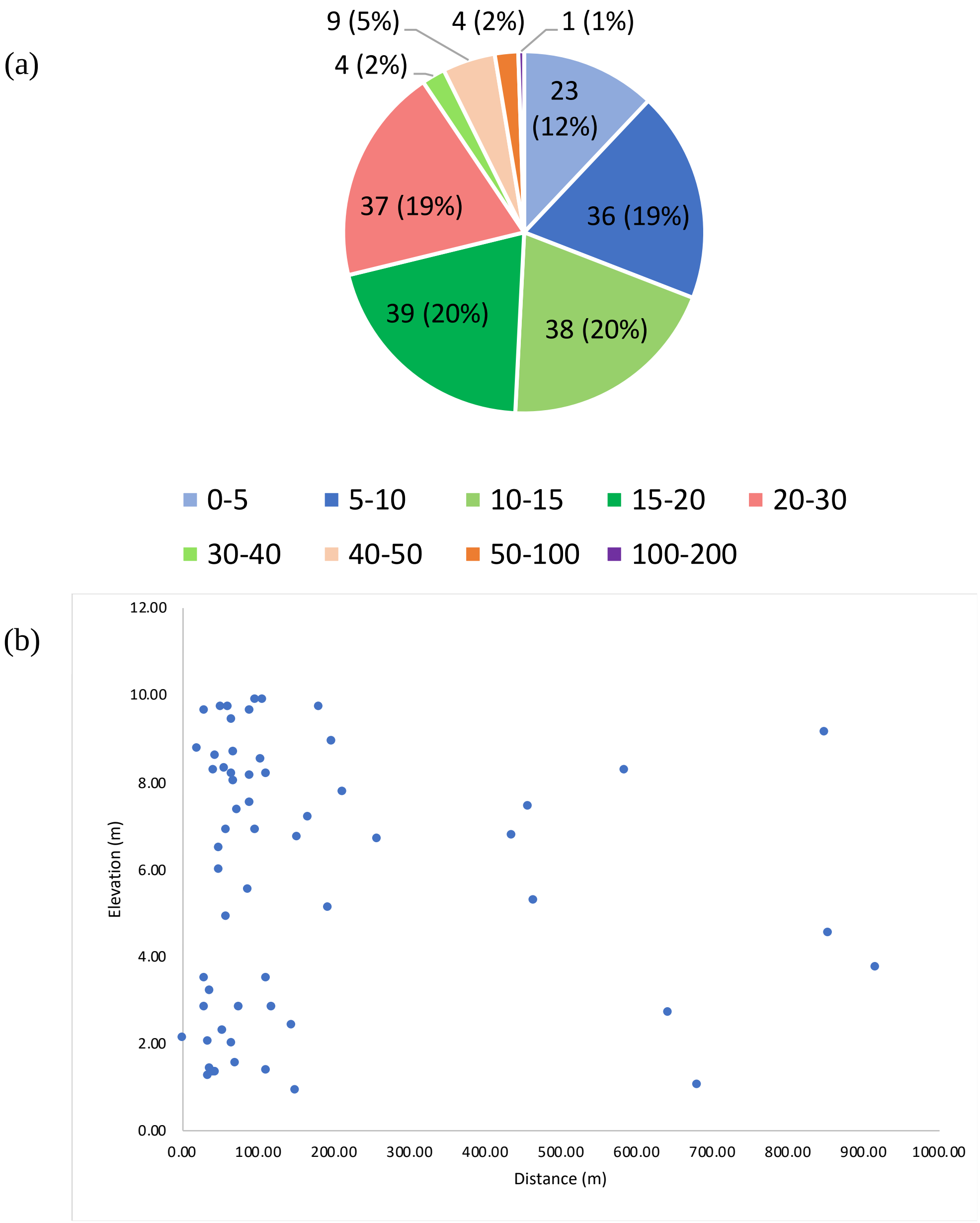


Figure 4-5: a) pie graph of national coastal marae elevations (m) and b) distance (x-axis) vs elevation (y-axis) of coastal marae with elevation less than 10m

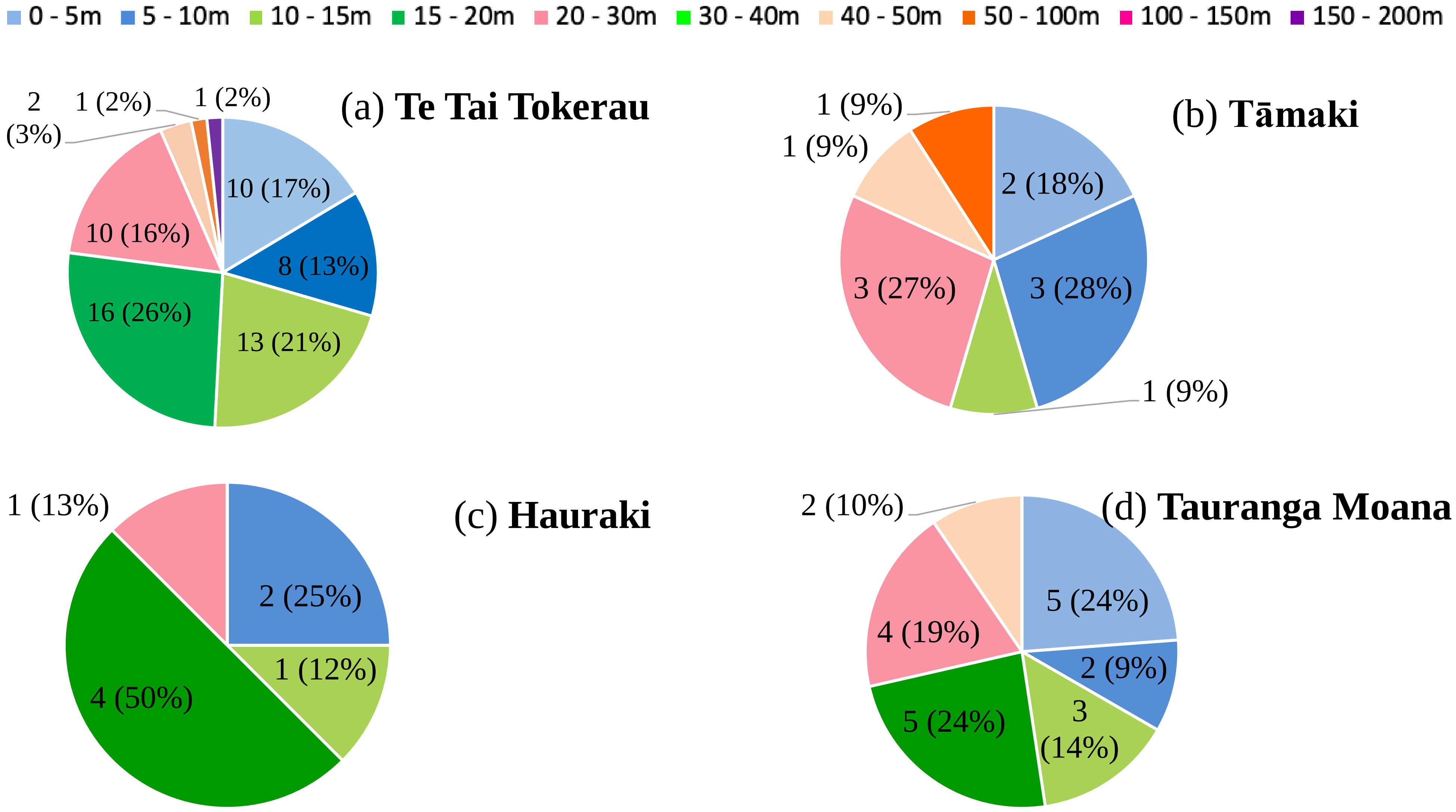


*Figure 4-6: Elevation pie graphs by rohe: a) elevation of Te Tai Tokerau coastal marae and b) elevation of Tāmaki coastal marae and c) elevation of Hauraki coastal marae and d) elevation of Tauranga Moana coastal marae. *Legend is at the top of Figure 4.6.*

Elevation of Te Tai Tokerau coastal marae

Te Tai Tokerau is the most northern rohe in Aotearoa New Zealand and has 61 coastal marae. The elevation of coastal marae is highly variable in this rohe **(Figure 4.6a)**, with 26% (16) coastal marae within 15 – 20 m elevation, 21% (13) between 10 – 15 m and 17% (10) being between 0 – 5m. However, at higher elevations such as at 150 – 200 m and 50 – 100 m there is far less coastal marae found at these elevations, with 77% of coastal marae located below 20 m elevation.

Elevation of Tāmaki coastal marae

The Tāmaki rohe extends south and north of Auckland. Tāmaki has 11 coastal marae with highly variable elevation **(Figure 4.6b)** In this rohe, 28% (3) of coastal marae are within 5 – 10 m elevation, followed by 27% (3) between 20 – 30 m and a further 18% (2) between 0 – 5 m. There are far less coastal marae at higher elevations such as 40 – 50 m and 50 – 100 m with only having 1 per band, resulting in 55% of coastal marae in the Tāmaki rohe being under 15m elevation.

Elevation of Hauraki coastal marae

The Hauraki rohe encompasses the Coromandel and Tīkapa Moana **(**Hauraki Gulf) regions and has 8 coastal marae. The elevations of the marae in this rohe are somewhat variable **(Figure 4.6c)**, spanning over 4 elevation categories. Within Hauraki, 50% (4) coastal marae are within 15 – 20 m elevation followed by 25% (2) at 5 – 10 m and the last 2 coastal marae being split into 10 – 15 m and 20 – 30 m.

Elevation of Tauranga Moana coastal marae

The Tauranga Moana rohe includes Tauranga Harbour and extends out to Motiti island. This rohe has 21 coastal marae with their elevations being highly variable (**Figure 4.6d)**. Within this rohe 24% (5) coastal marae are between 0 – 5 m and 24% between 15 – 20 m. A further 19% (4) coastal marae are between 20 – 30 m, 14% (3) at 10 – 15 m and 10% (2) at 40 –50

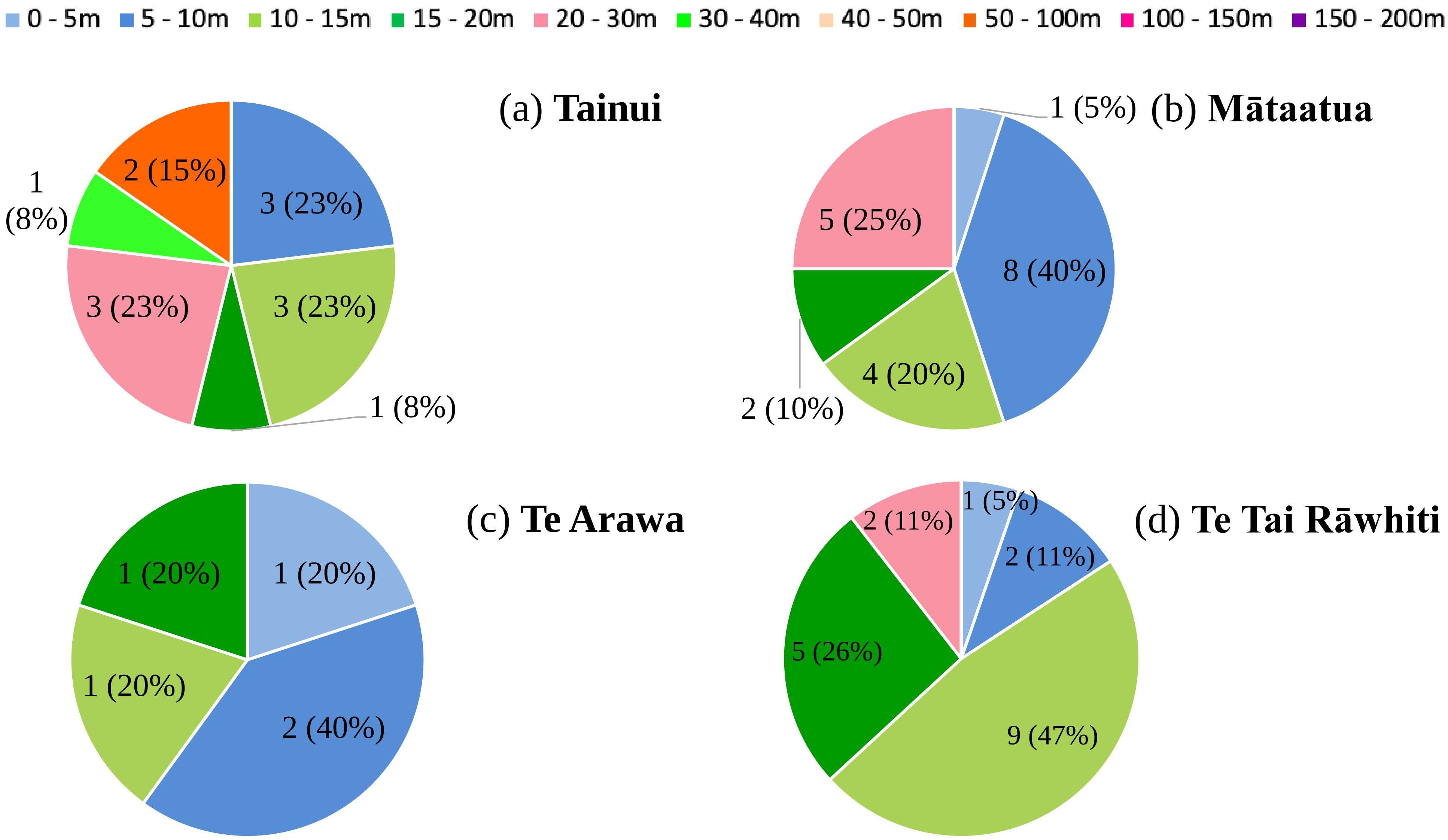


*Figure 4-7: Elevation pie graphs by rohe: a) elevation of Tainui coastal marae and b) elevation of Mātaatua coastal marae and c) elevation of Te Arawa coastal marae and d) elevation of Te Tai Rāwhiti coastal marae *Legend is at the top of Figure 4.7*

Elevation of Tainui coastal marae

The Tainui rohe encompasses the Waikato region and has 13 coastal marae. The coastal marae in this rohe are highly variable in terms of their elevation **(Figure 4.7a),** with 23% (8) coastal marae at 5 – 10 m, 10 – 15 m and 20 – 30 m elevation. The highest elevation category in this rohe is 50 – 100 m with 15% (2) coastal marae in this category.

Elevation of Mātaatua coastal marae

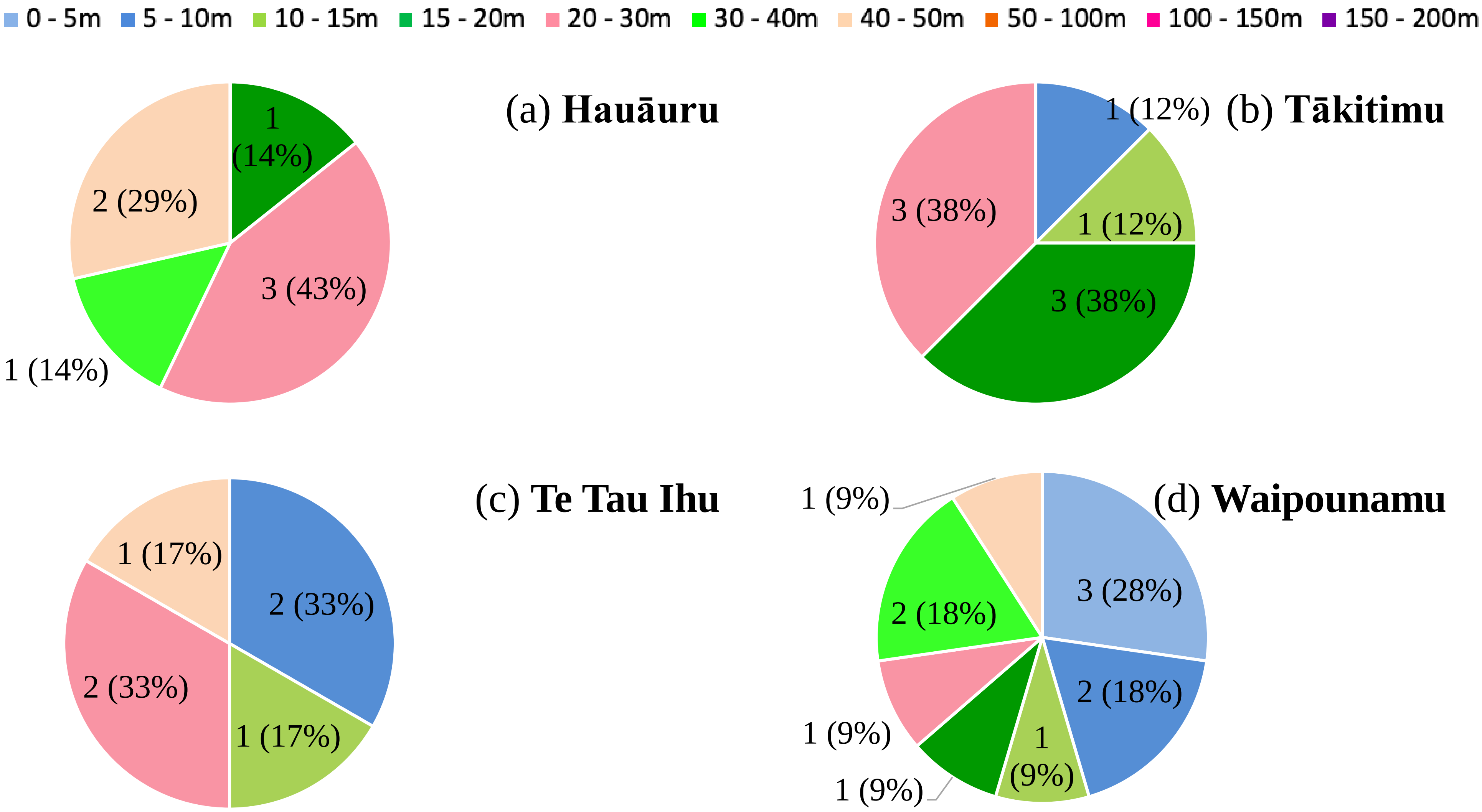
The Mātaatua rohe encompasses Whakatane through to the East Cape. This rohe has 20 coastal marae and the elevation of the coastal marae are highly variable (**Figure 4.7b)**, with 40% (8) of coastal marae between 5 – 10 m elevation, followed by 25% (5) between 20 – 30 m and 20% (4) between 10 – 15 m.

Elevation of Te Arawa coastal marae

The Te Arawa rohe encompasses the Rotorua region towards Maketū and through to Matatā. This rohe has 5 coastal marae with 40% (2) of these being between 5 – 10 m and 20% (1) between 0 – 5 m, 10 – 15 m and 15 – 20 m (**Figure 4.7c)**.

Elevation of Te Tai Rāwhiti coastal marae

Te Tai Rāwhiti rohe covers from the East Cape through to Gisborne. This rohe has 22 coastal marae, with 47% (9) between 10 – 15 m, 26% (5) between 15 – 20 m, 11% (2) between 5 – 10 m and 20 – 30 m **(Figure 4.7d).** However, only 1 coastal marae is within 0 – 5 m.



(a) **Hauāuru**

(b) **Tākitimu**

(c) **Te Tau Ihu**

(d) **Waipounamu**

*Figure 4-8: Elevation pie graphs by rohe: a) elevation of Hauāuru coastal marae and b) elevation of Tākitimu coastal marae and c) elevation of Te Tau Ihu coastal marae and d) elevation of Waipounamu coastal marae. *Legend is at the top of Figure 4.8*

Elevation of Hauāuru coastal marae

The Hauāuru rohe covers most of the Taranaki region and has 7 coastal marae. These coastal marae have elevations ranging from 15 m to 50 m (**Figure 4.8a)**. 43% (3) of coastal marae in this rohe are in the 20 – 30 m elevation range, followed by 29% in the 40 – 50 m range. There are 14% (1) each in the 30 – 40 m and 15 – 20 m ranges.

Elevation of Tākitimu coastal marae

The Tākitimu rohe covers the Hawkes Bay region and extends south towards Wellington, and has 8 coastal marae. This rohe is varied in terms of coastal marae elevations (**Figure 4.8b).** The elevations comprise of 38% (3) coastal marae at 20 – 30 m and 15 – 20 m respectively, with a further 12% (1) coastal marae at elevations of 10 – 15 m and 5 – 10 m.

Elevation of Te Tau Ihu coastal marae

The Te Tau Ihu rohe comprises the northern regions of the south island such as Nelson, Marlborough, Tasman and Wellington regions, and has 6 coastal marae. Coastal marae elevations range from 33% (2) in the 5 – 10 m and 20 – 30 m elevation ranges (**Figure 4.8c)**. Followed by 17% (1) in the 10 – 15 m and 40 – 50 m elevations.

Elevation of Waipounamu coastal marae

The Waipounamu rohe covers most of the rest of the south island, with 11 coastal marae. Marae Elevations range from 28% (3) between 0 – 5 m, followed by 18% (2) between 5 – 10 m and 30 – 40 m (**Figure 4.8d**). The other remaining categories (10 – 15 m, 15 – 20 m, 20 – 30 m, 20 – 30 m and 40 – 50 m) have 1 (9%) coastal marae in each.

Elevation of Te Moana o Raukawa coastal marae

Te Moana o Raukawa rohe covers most of the lower west coast of the north island and has 1 coastal marae. This coastal marae has an elevation of 5 – 10 m.

4.6 BOP case study

In this section I focus on the BOP as a more detailed case study, which encompasses the Tauranga Moana, Te Arawa and Mātaatua rohe. I chose to focus on this area to include a more detailed focus on the topographical profiles of the coastal marae in this region, and to investigate the potential exposure of urupā to SLR. For the coastal marae and urupā in this region, I utilised LiDAR as described in **Section 3.5.3** to derive higher resolution elevation data than that of the national-scale analysis.

4.6.1 Distance to coast

For coastal marae in this region, 58% (18) are between 0 – 250 m of the coast with decreasing number of coastal marae as you go further inland with 3 coastal marae between 750 – 1000 m **(Figure 4.9)**. Of the urupā in this region, 60% (26) are between 0 – 250 m of the coast, with a similar trend of decreasing number of coastal urupā heading inland, with 2 coastal urupā found between 750 – 1000 m (**Figure 4.10**).

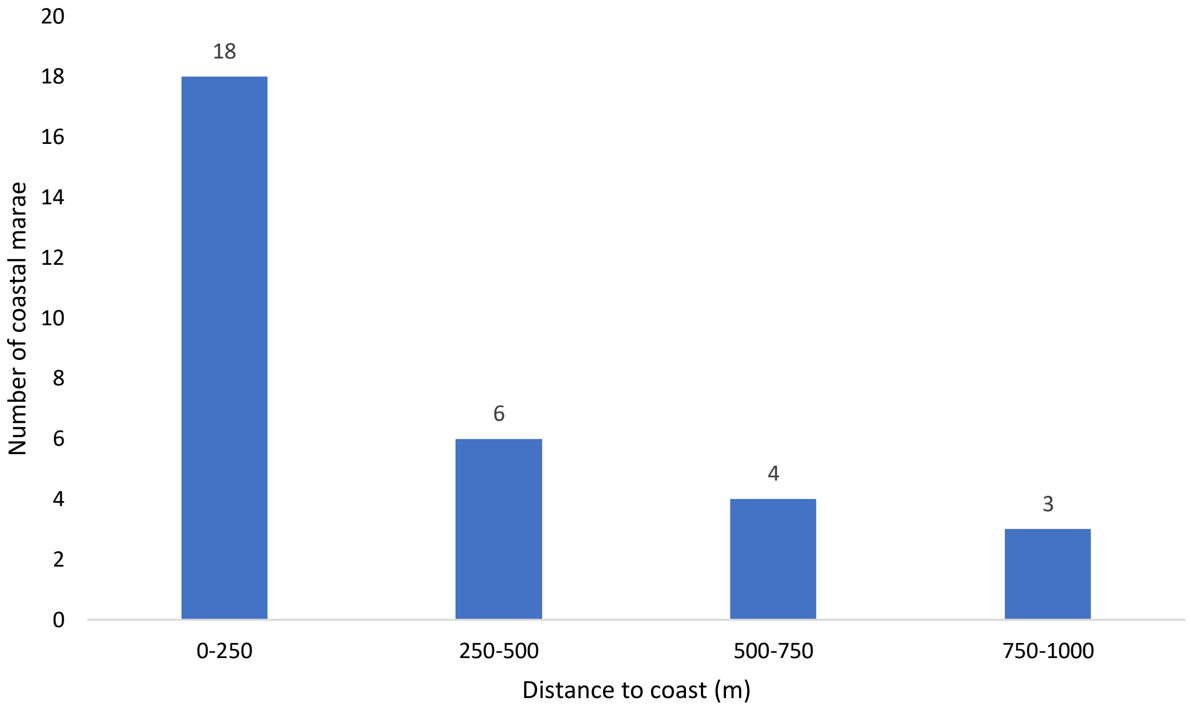


Figure 4-9: Distance to the coast of coastal marae in the BOP region ranging from 0 -1000 m

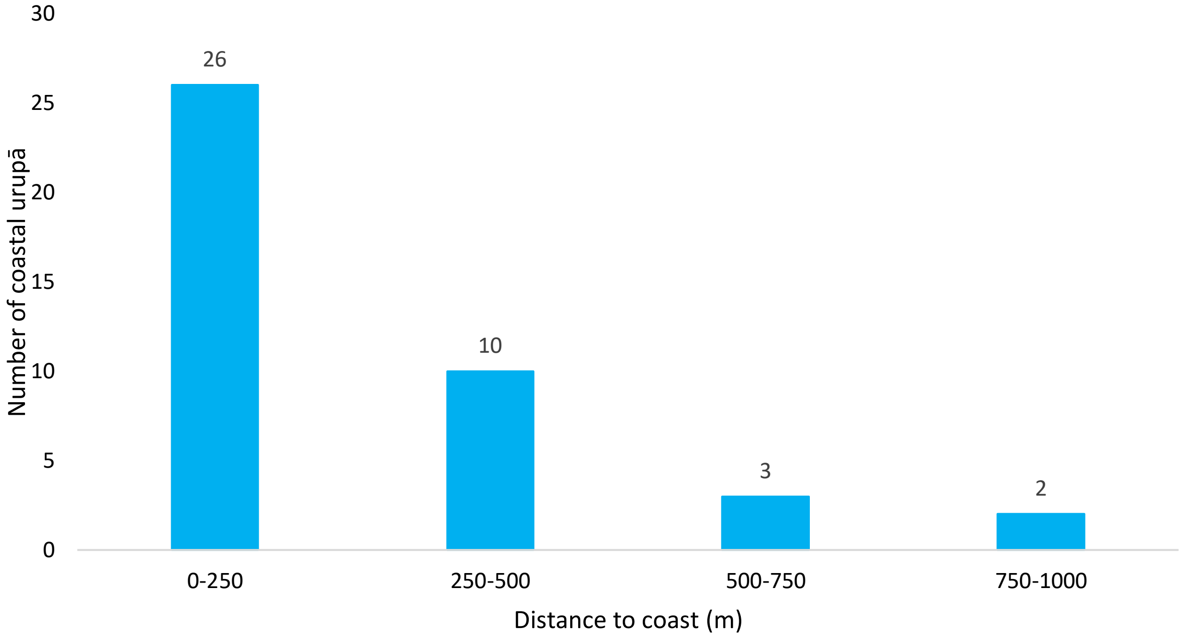


Figure 4-10: Distance to the coast of coastal urupā in the BOP region ranging from 0 – 1000 m

4.6.2 Elevation of Bay of Plenty coastal marae and urupā

The elevation of coastal marae and urupā in the BOP is highly variable **(Figure 4.11a & Figure 4.11b)**. Elevations for coastal marae range from 0 – 35 m above sea level, with 9 coastal marae between 0 – 5 m, 4 at 5 – 10 m, 3 at 10 – 15 m, 9 at 15 – 20 m, 2 at 20 – 25 m, 1 at 25 – 30 m and 3 at 30 – 35 m **(Figure 4.11a)**. Coastal urupā range from 0 to 50 m above sea level, with 4 coastal urupā between 0 – 5 m, 5 at 5 – 10 m, 7 at 10 – 15 m, 11 at 15 – 20, 11 at 20 – 30 m, 1 at 30 – 40 m and 2 at 40 – 50 m **(Figure 4.11b)**.

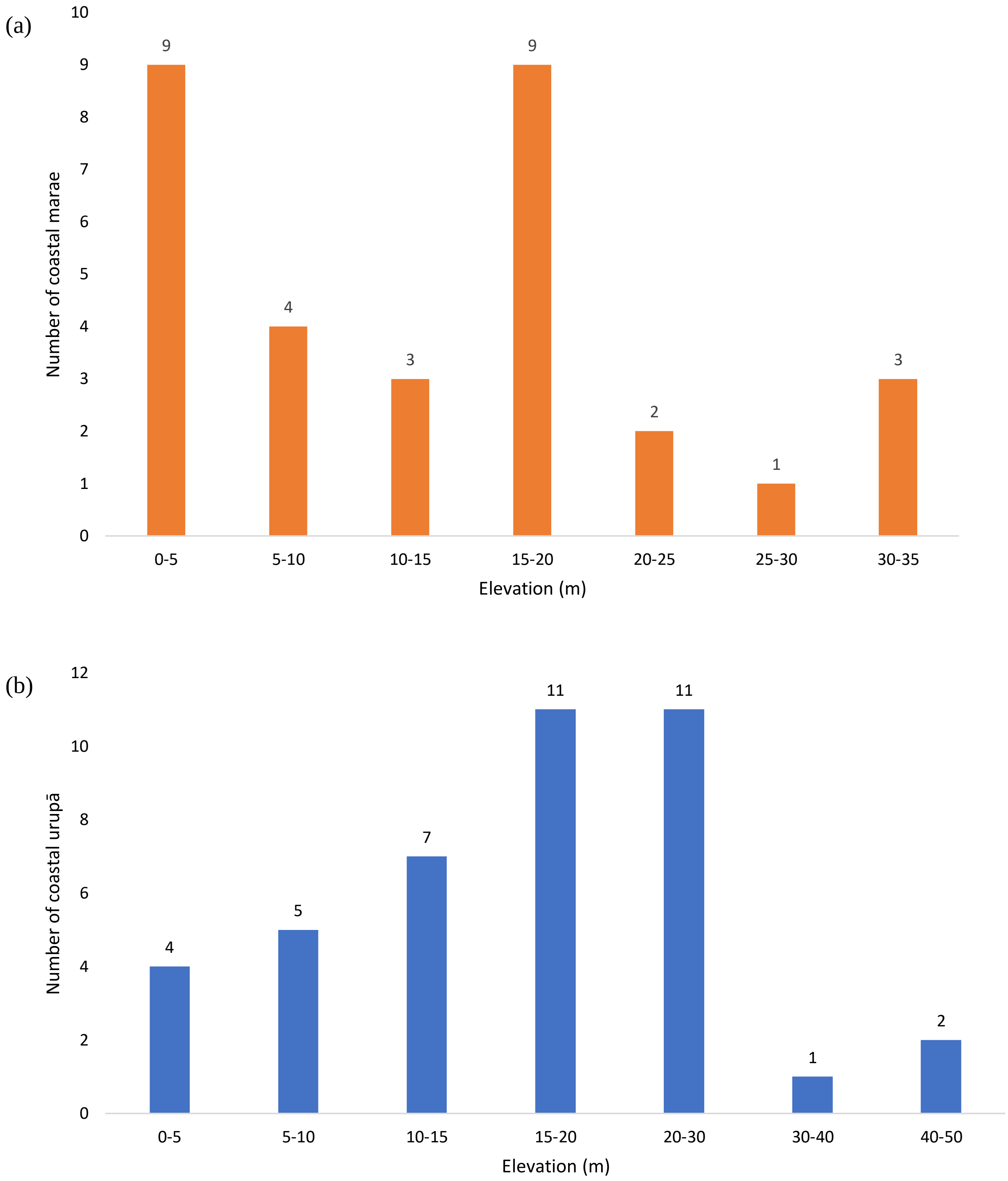


Figure 4-11: a) number of BOP coastal marae at each elevation group (orange) and b) number of BOP coastal urupā at each elevation group (blue)

4.6.3 LiDAR vs. DEM

This section used LiDAR to gather more accurate elevation data for BOP coastal marae and urupā only, due to its availability and how computationally intensive it can be. A comparison between elevation derived from LiDAR and elevation from the national DEM was done to understand the difference between them **(Figure 4.13 and Figure 4.14)**. I found that LiDAR tends to have greater estimates of elevation compared to the national DEM for both coastal marae and urupā. These differences are attributed to the difference in vertical accuracy and horizontal resolution. The national DEM has a vertical accuracy of ± 10 m whereas the vertical accuracy of LiDAR is ± 0.2 m, this means that the accuracy in the vertical direction is accurate to within ± 10 or 0.2 m respectively. Whereas the horizontal resolution of the DEM was 8m compared to LiDAR 1 m. The horizontal resolution means that LiDAR is able to detect a 1 m x 1 m square on the land surface, whereas the national DEM can detect an 8 m x 8 m square on land **(Figure 4.12)**. Within these squares are points of elevation called centroids which are averaged to get the elevation of that square (Anderson et al., 2006). Hence LiDAR averages over a smaller square compared to the DEM and hence its result will be more accurate than that of the DEM. However, using LiDAR for the whole country is beyond the scope of this research as LiDAR is not yet available along the entire coast, it can also be computationally intensive and time-consuming. The difference that occurs from using DEM compared to LIDAR means that the potential exposure determined from this analysis will have some uncertainty surrounding it, and hence this needs to either be addressed when using this information or addressed as best as possible to minimise this uncertainty in future research.

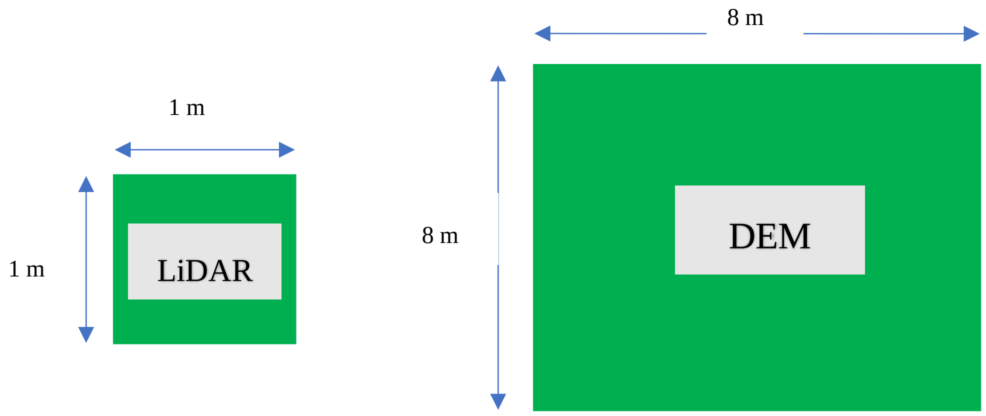


Figure 4-12: Illustrating the influence of horizontal resolution on the accuracy of LiDAR and DEM

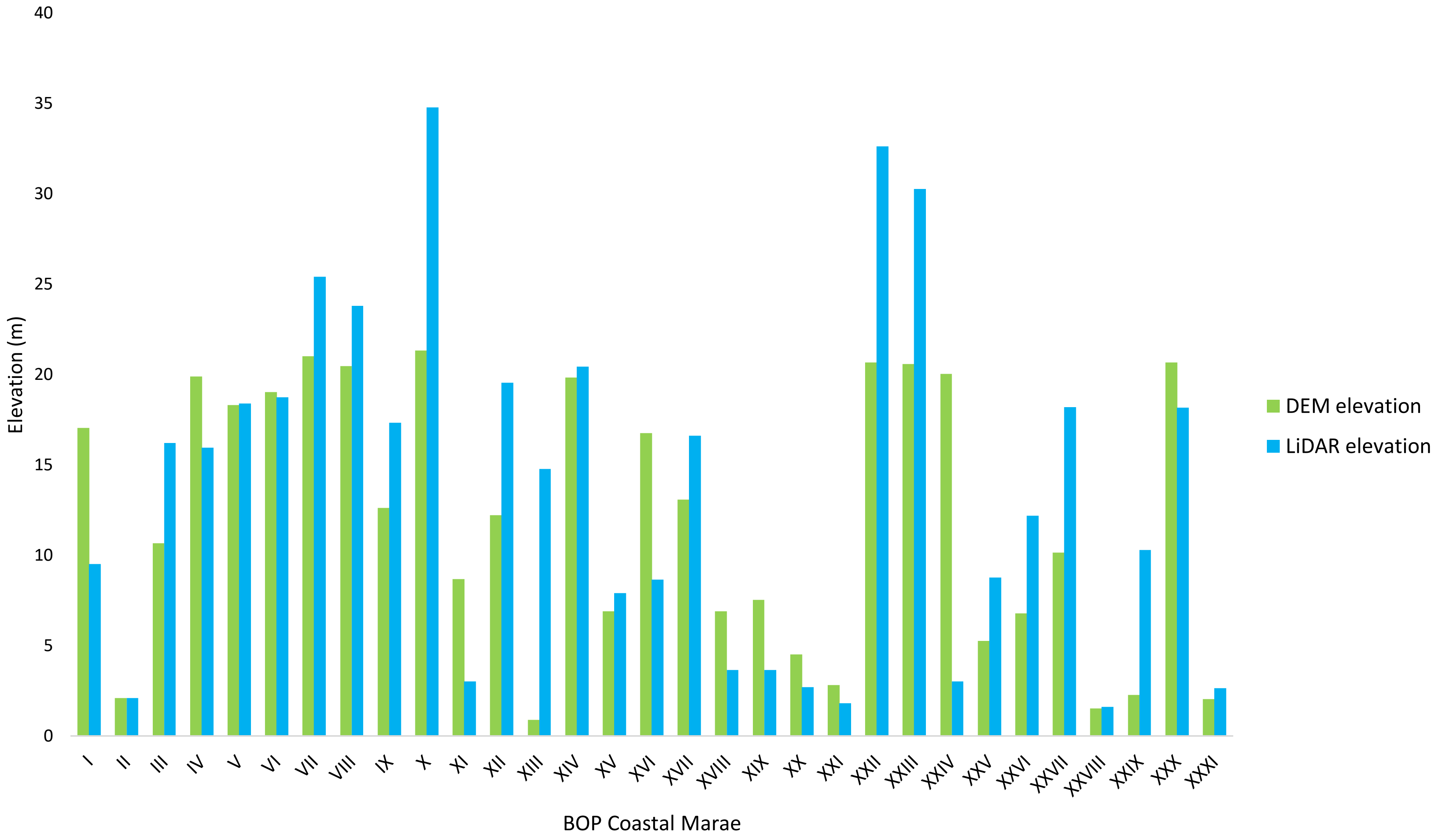


Figure 4-13: Comparison of the elevations derived from the national digital elevation model and BOP LiDAR surveys for BOP coastal marae

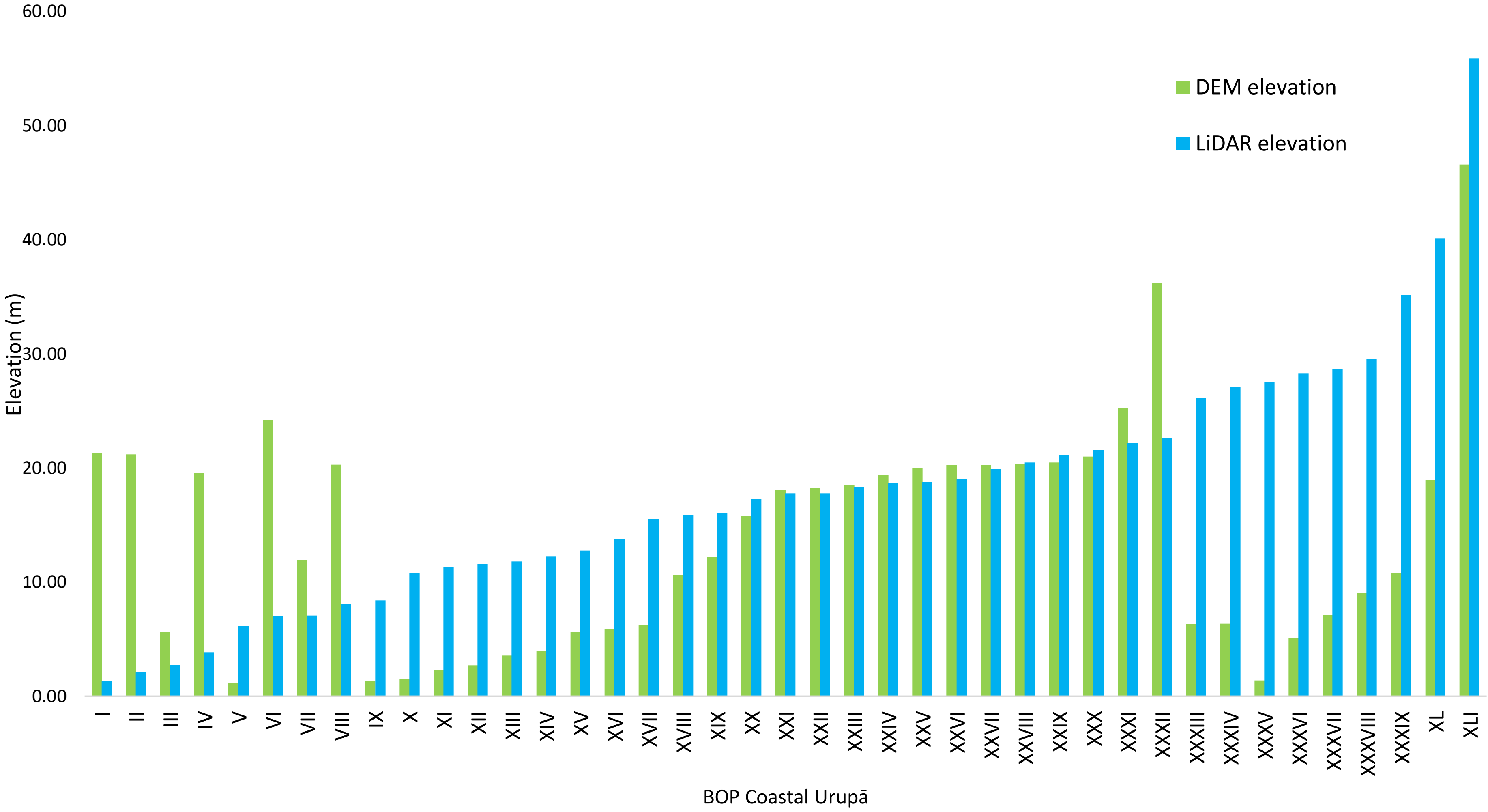


Figure 4-14: Comparison of the elevation derived from the national digital elevation model and BOP LiDAR surveys for BOP coastal urupā

4.7 Topographical coastal profiles for Bay of Plenty coastal marae and urupā

The topographical profile is a cross sectional cut of the terrain, which in this case follows the pathway between the marae and urupā to the coast. This provides a physical and visual idea of terrain between the marae and urupā, and the coast as well as the distance. These profiles can help identify the exposure of coastal marae and urupā to SLR, for example: to see if the coastal marae or urupā was situated on a cliff face delineated by a steep and sharp drop in elevation. If this is the case, SLR may not impact through inundation processes, however erosional processes due to a rise in sea level maybe more pertinent to explore for that marae or urupā. Conversely, if the coastal marae or urupā is situated on a very gentle sloping coastal margin with a short distance to the coast, then inundation due to SLR would be a key consideration. Moreover, it is also important to look at the smaller-scale variation in the coastal profile, such as the elevation of the coastal marae could be relatively low, but there could be a large dune or other feature in front, providing a buffer to both inundation and erosion caused by SLR. In this section I anonymise coastal marae in the BOP to adhere to data sovereignty principles (Raghunathan, 2013; West et al., 2020) as well as to be culturally sensitive and respectful of how this data is used and analysed as I have not specifically sought permission from these marae to conduct this research as mentioned in **Section 3.3**.

Bay of Plenty coastal marae

The topographical profiles of coastal marae were categorised by their distance to the coast. In **Figure 4.15**, the coastal marae are within 300 m of the coast, with 4 coastal marae within **0 – 10 m (Figure 4.15a)**, 3 coastal marae within **10 – 50 m (Figure 4.15b)**, 7 coastal marae within **50 – 100 m** (**Figure 4.15c)** and 4 coastal marae within **100 – 300 m (Figure 4.15d).** These profiles are highly variable, however, in **Figure 4.15a** the coastal marae are low-lying and very close to the coast. Whereas when you go further from the coast, the profiles become highly variable, with some profiles remaining low-lying but with an increased distance to the coast such as lines **XIII** and **XIV (Figure 4.15c)**. Or their elevation is higher, with a cliff dropping to the coastline such as lines **V** and **VI (Figure 4.15b)** and some which have gullies and terraces towards the coast such as lines **XI** and **XVII** in **Figures 4.15c and 4.15d** respectively.

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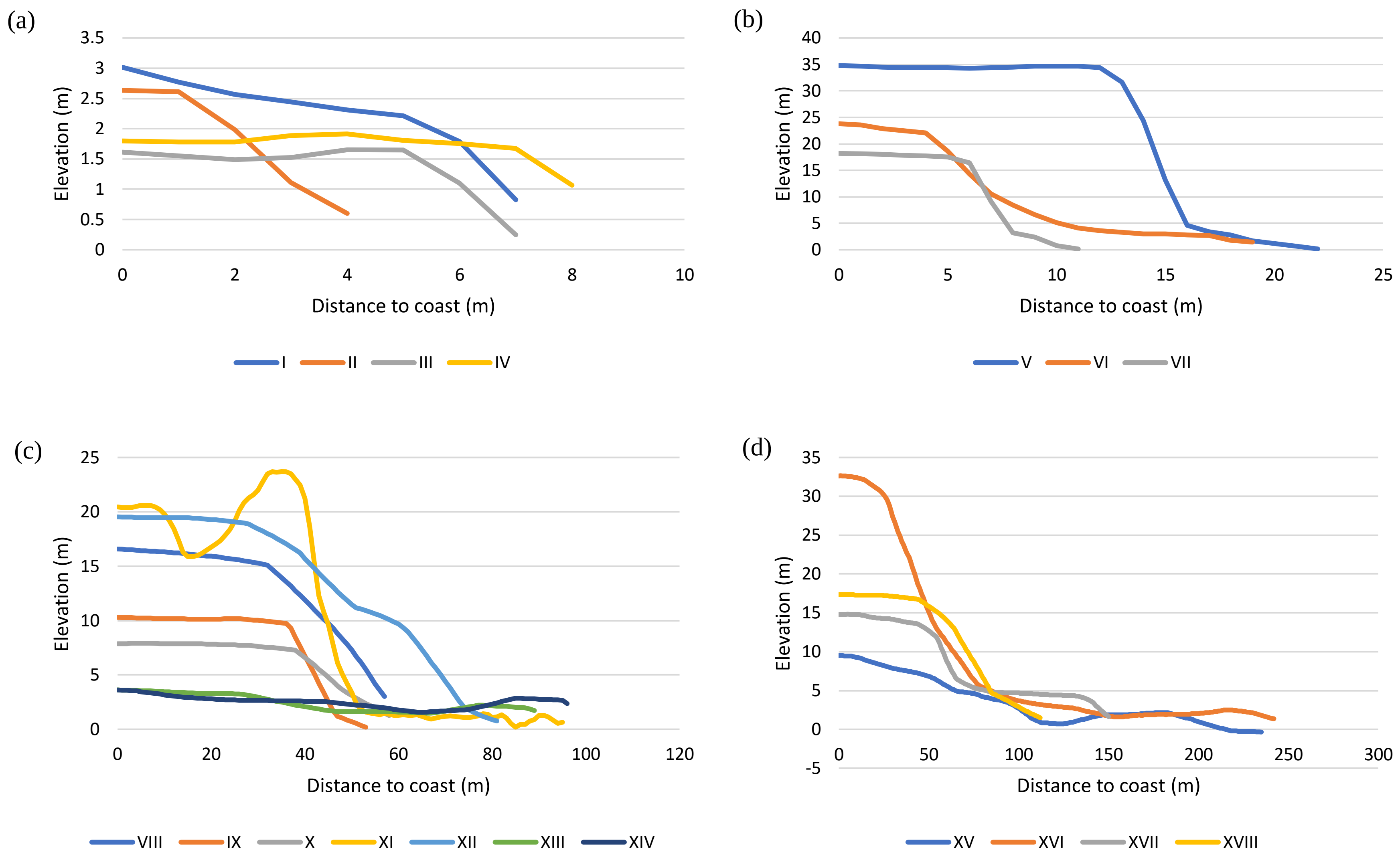


Figure 4-15: Anonymized topographical profiles of BOP coastal marae: (a) profile of coastal marae between 0 – 10 m and (b) profile of coastal marae between 10 – 50 m and (c)profile of coastal marae between 50 – 100 m and (d) profile of coastal marae between 100 – 300 m

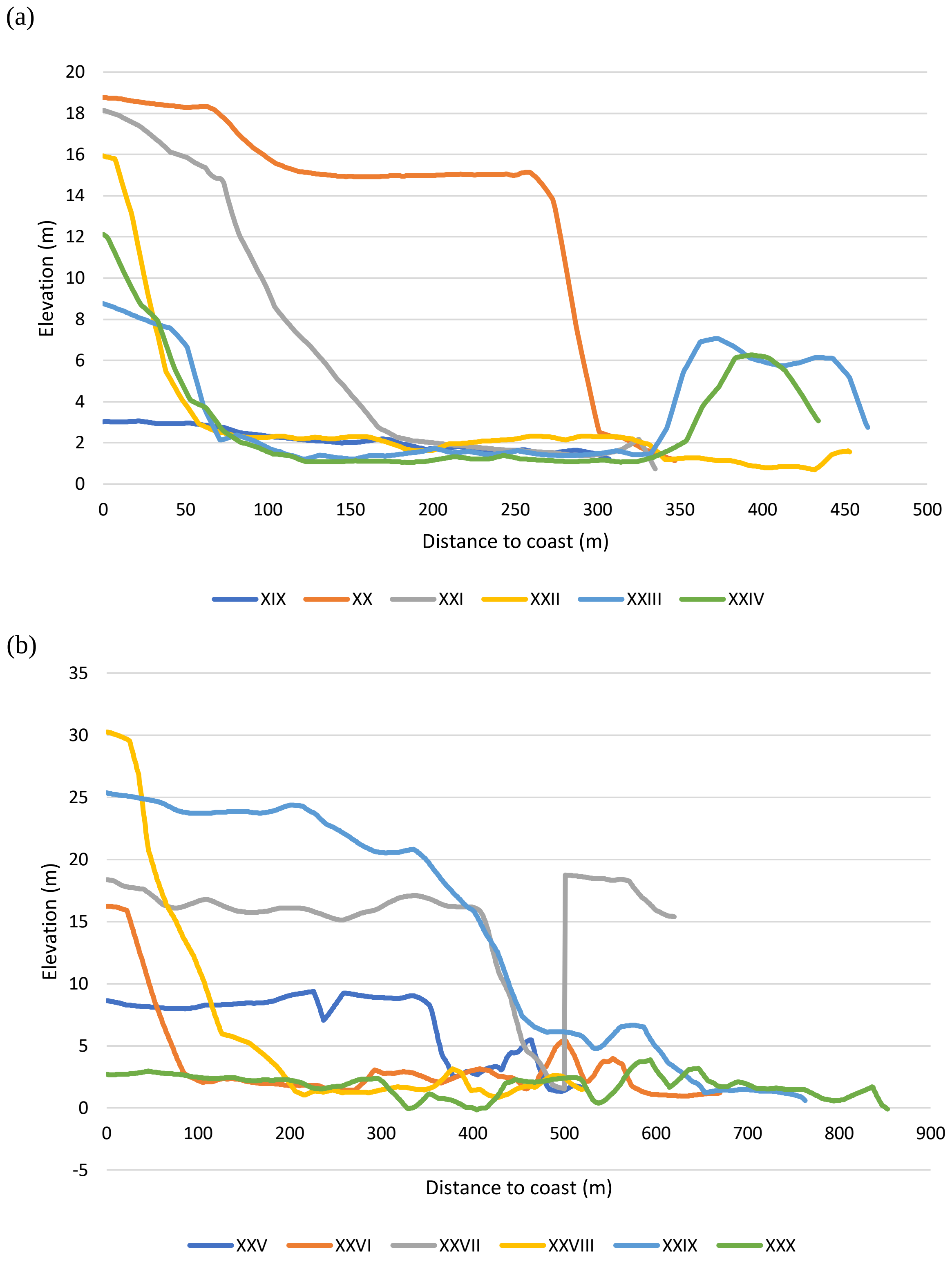


Figure 4-16: Anonymized topographical profiles of a) coastal marae between 300-500 m and b) coastal marae between 500-800 m

The topographical profiles presented in **Figure 4.16** are within 800 m of the coast, with 6 coastal marae within **300 – 500 m (Figure 4.16a)** and 6 coastal marae within **500 – 800 m (Figure 4.16b)**. The profiles of **Figure 4.16** are highly variable, with some being very low-lying and far from the coast such as line **XIX (Figure 4.16a)** and some that are low-lying with a dune at the coastal intersection such as lines **XXIII** and **XXIV (Figure 4.16a**) and line **XXX (Figure 4.16b)**. There are also some profiles where the coastal marae is elevated with a cliff towards the coast such as line **XX (Figure 4.16a)** and lines **XXVI** and **XXVIII (Figure 4.16b).** The XXVII profile has a significantly large dip in the topography close to the coastline, but it does not finish at 0 m which would be MSL, which could be an issue in terms of LiDAR scanning going to the edge of the terrestrial land not into the marine / coastal area.

Bay of Plenty coastal urupā

The profiles of BOP coastal urupā were categorised by distance to the coast. The categories include 8 coastal urupā within **0 – 5 m (Figure 4.17a),** 7 within **5 – 10 m (Figure 4.17b),** 10 within **10 – 30 m (Figure 4.17c)** and 8 within **30 – 50 m (Figure 4.17d)**. These profiles between coastal urupā and the coast are highly variable with some being low-lying such as lines **II (Figure 4.17a)** and **XVII (Figure 4.17c)**. There were some coastal urupā situated behind a cliff but very close to the coast such as lines **I** and **VII (Figure 4.17a)** or some that were behind a cliff but further away such as lines **XVIII** and **XIX** (**Figure 4.17c)** and line **XXXIII (Figure 4.17d)**. The II, III and IV profiles do not finish at 0 which would be MSL.

There are 8 coastal urupā in the BOP within **50 – 130 m** of the coastline (**Figure 4.18)**. Again these profiles are highly variable and with interesting profiles, some have very staggered and spikey terrain such as lines **II, IV** and **V**, or very flat and low sloping elevation such as lines **I** and VI. In terms of line **II** it is unknown what the cause of such dramatic peaks, however, it could be down to uneven topography along this pathway to the coast.

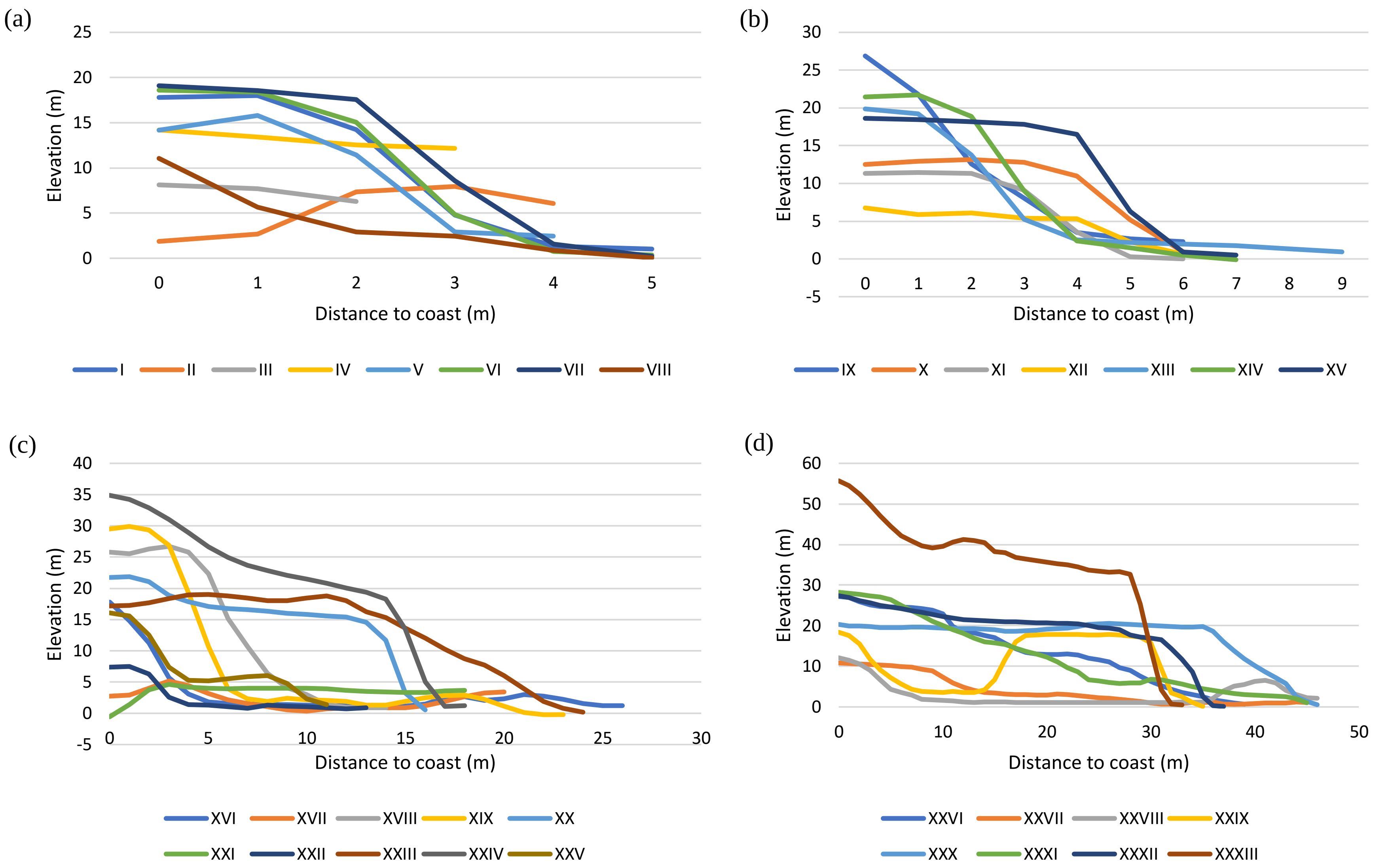


Figure 4-17: Anonymized topographical profiles of BOP coastal urupā: (a) profile of coastal urupā between 0 – 5 m and (b) profile of coastal urupā between 5 – 10 m and (c) profile of coastal urupā between 10 – 30 m and (d) profile of coastal urupā between 30 – 50 m

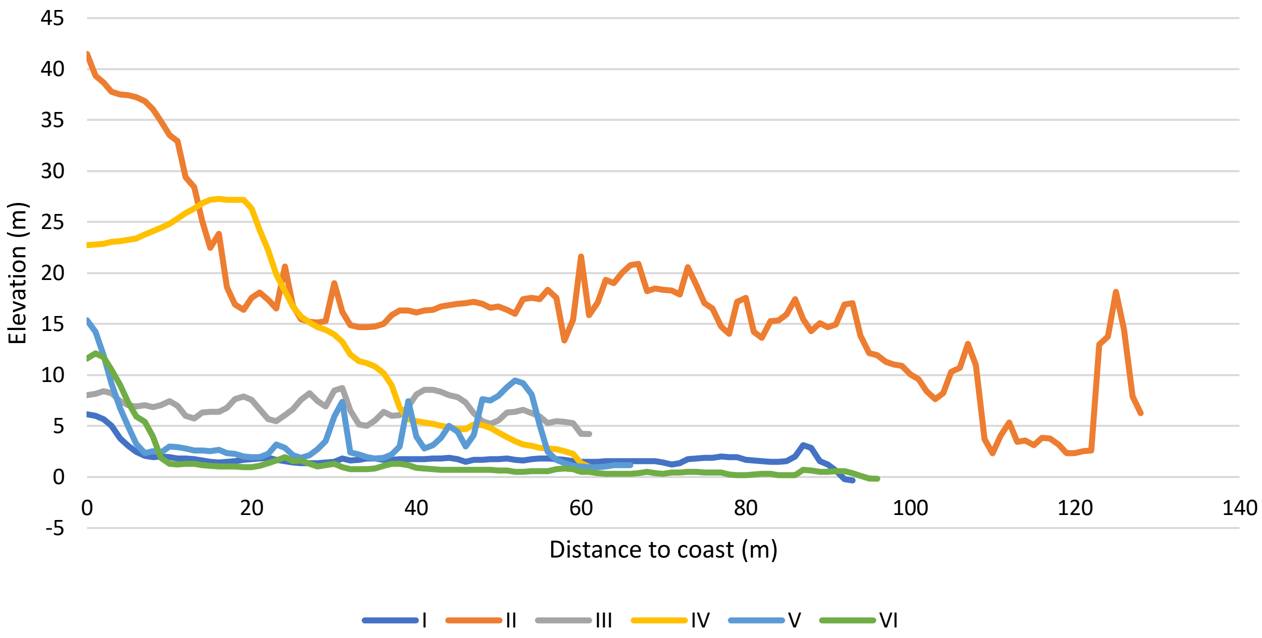


Figure 4-18: Anonymized topographic profiles of coastal urupā in the BOP region ranging from 50 – 130 m

4.8 Mapping inundation with sea level rise

NIWA extreme sea level maps (Paulik et al., 2020) described in **Section 3.5.5** were used to delineate which coastal marae and urupā are predicted to be inundated by a 100 year ESL with a rise in sea level. Inundation of coastal marae and coastal urupā were mapped **(Figure 4.19)** and **(Figure 4.20)**, under SLR estimates ranging from 100 year ESL with 0 m rise with increments of 10 cm until the greatest rise in sea level, the 100 year ESL with a 3 m rise. Some key observations from **Figure 4.20** is that 6 coastal marae around Aotearoa New Zealand are predicted to be inundated with a 100 year ESL, with 2 in the Tauranga Moana rohe and 1 in each of the Te Arawa, Te Tai Tokerau and Waipounamu rohe. A further 16 coastal marae are possibly inundated at a 100 year ESL with a 1 m rise in sea level, another 11 at 2 m and a further 8 with a 3 m rise in sea level, meaning 41 of the 191 coastal marae are detected from these maps (**Figure 4.20)**. The greatest number of marae detected by these maps were those that are potentially affected by a 100 year ESL at current MSL, meaning these coastal marae have a potentially greater exposure to a 100 year ESL event regardless of SLR, with the number of coastal marae increasing as SLR increments increase. However, there are several increments which have no coastal marae detected due to no marae being located at these elevations. In terms of coastal urupā, 4 urupā were detected by the coastal flood maps (**Figure 4.21)** which are potentially being affected by inundation processes under a 100 year

ESL. Of these, 2 are possibly inundated with a 100 year ESL with 0 m rise, 1 at 100 year ESL with 1 m rise and 1 at 100 year ESL 2 m rise.

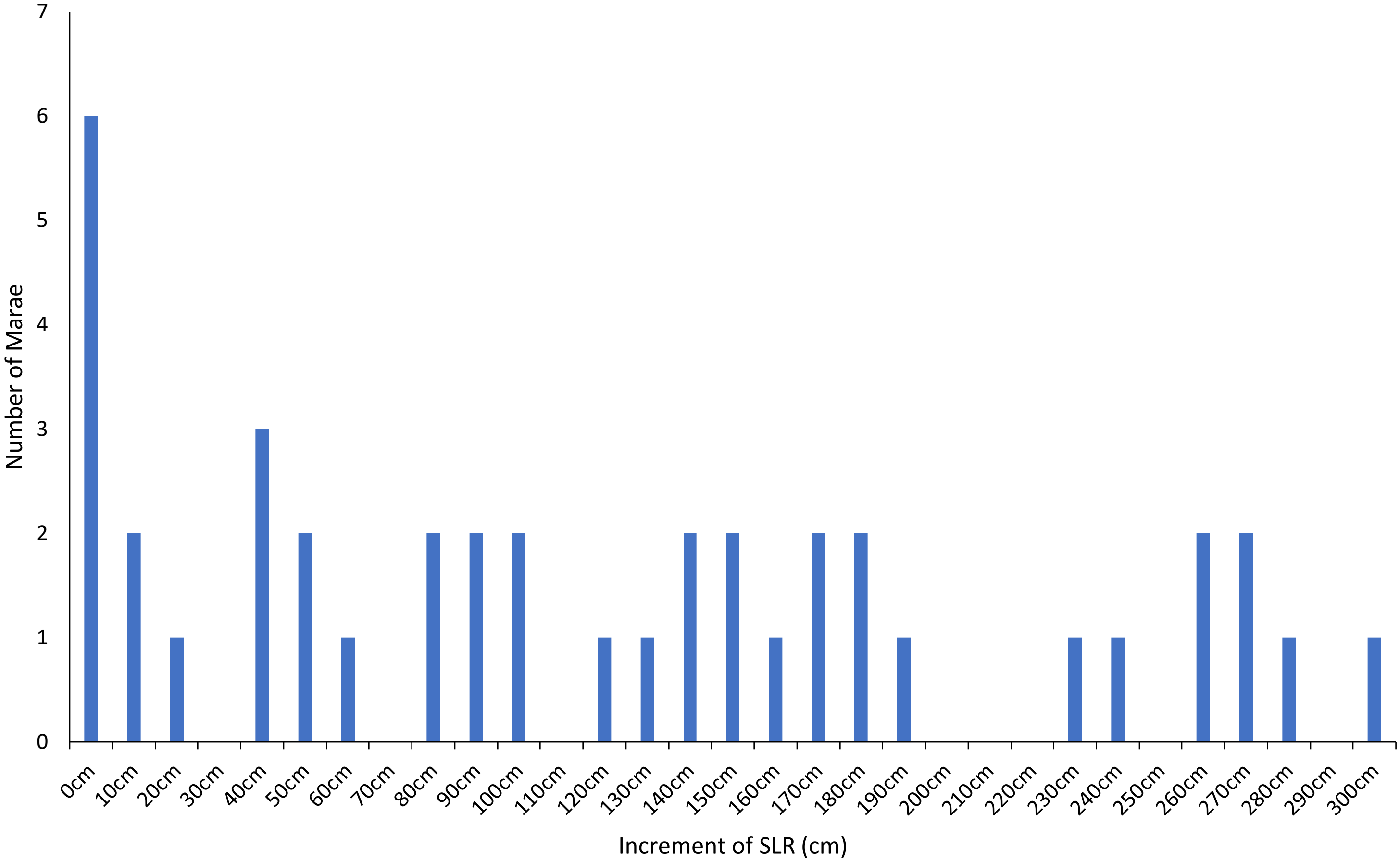


Figure 4-19: Bar graph showing the number of coastal marae nationally that are potentially inundated by a 100 year ESL event, with +10cm increments of sea level

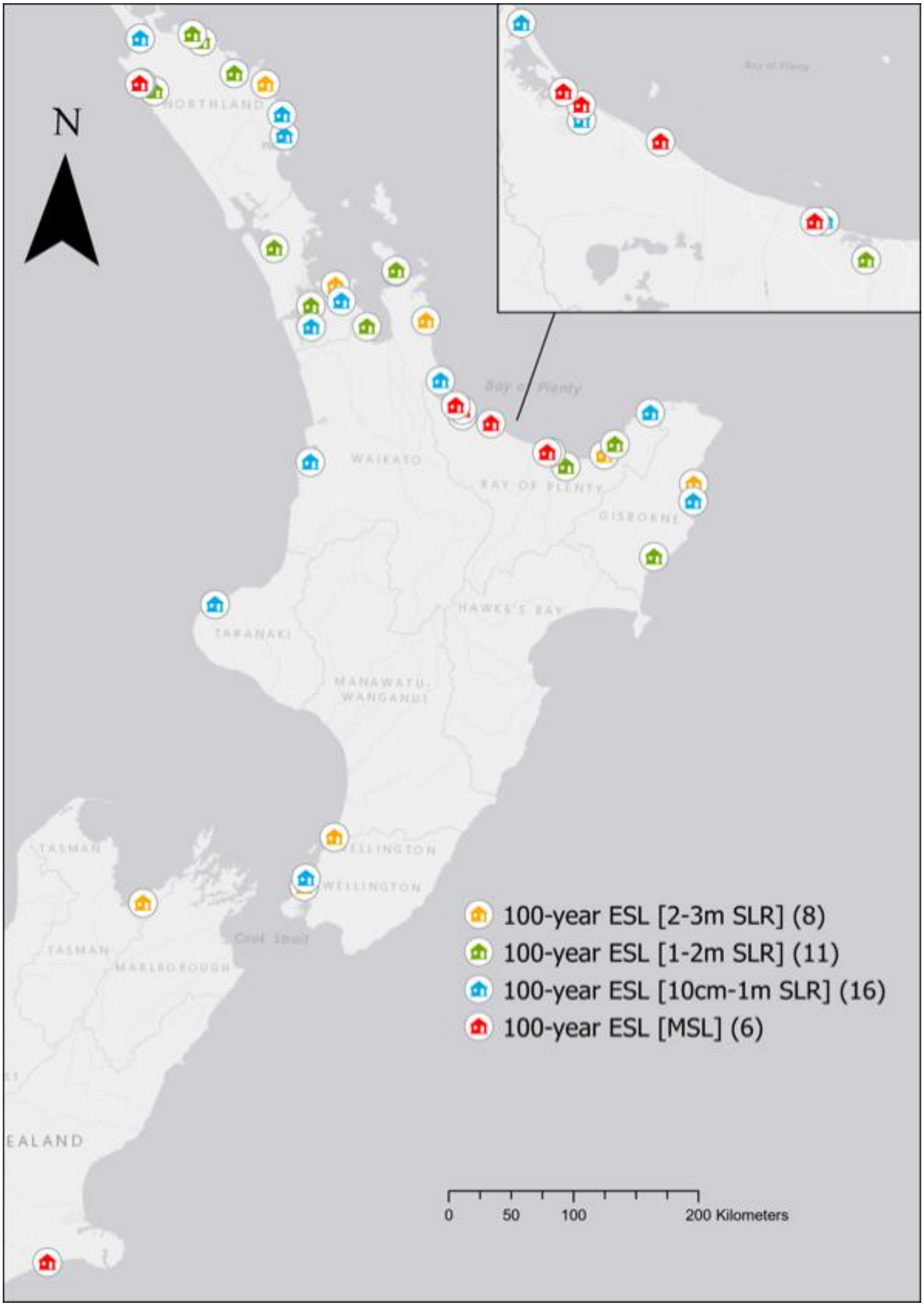


Figure 4-20: Map showing the number of coastal marae inundated by a 100 year extreme sea level event with an incremental rise of +1m in sea level

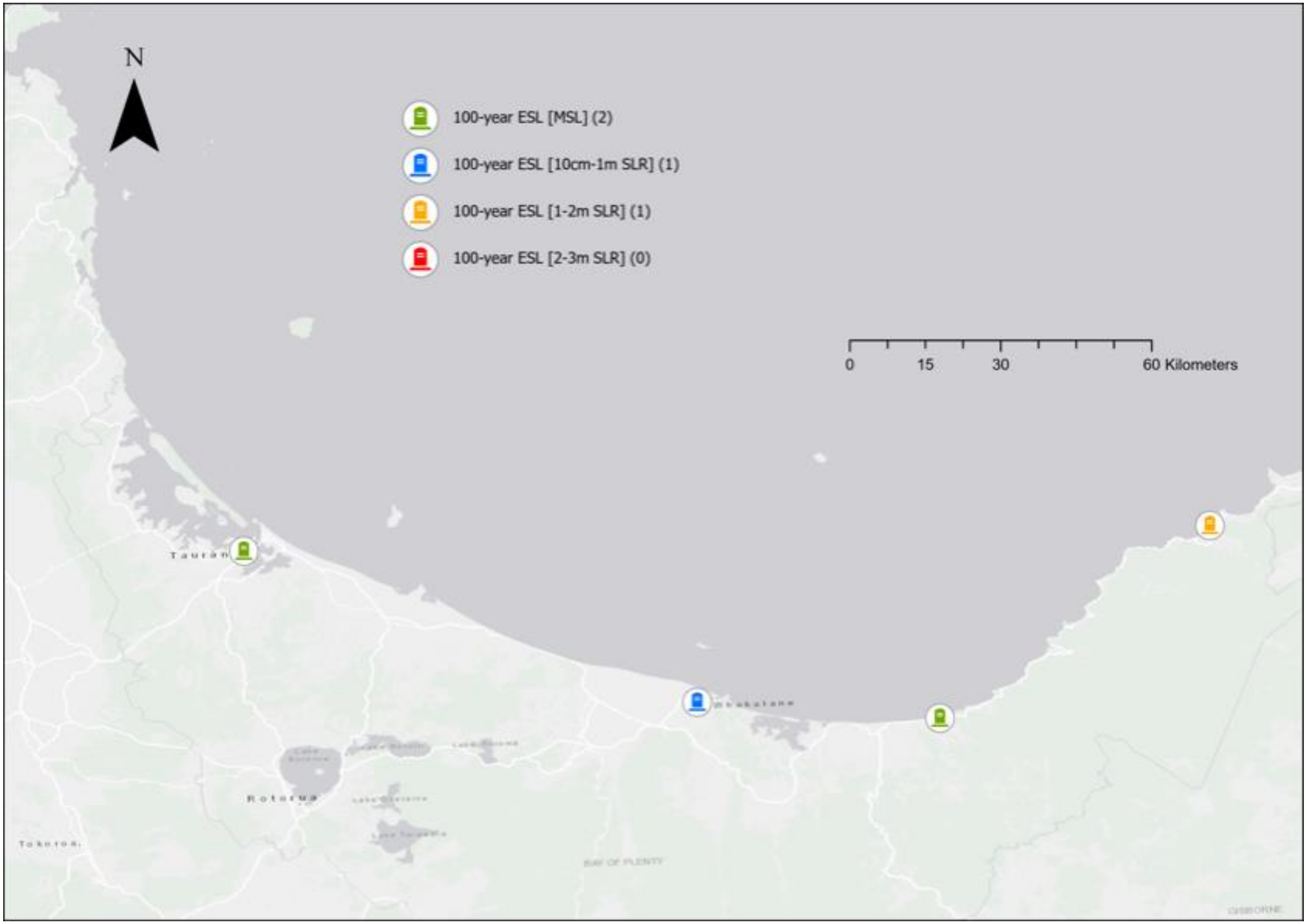


Figure 4-21: Map of BOP coastal urupā potentially inundated by a 100 year ESL event with +1 m increment of SLR

4.9 Summary

This chapter identified 191 coastal marae around Aotearoa New Zealand, located within 1 km of the coastline. Te Tai Tokerau rohe had 61 coastal marae followed by Te Tai Rawhiti with 22 and Tauranga Moana with 21. In terms of elevation of coastal marae, it is highly variable nationally, however, Te Tai Tokerau coastal marae were the most variable in terms of elevations with 10 coastal marae being with 0 – 5 m elevation, with the distance to the coast ranging up to 200 m. In terms of distance, the largest porportions of coastal marae and urupā were found in the smallest distance category, 39% of coastal marae were within 150 m of the coast and 60% of BOP coastal urupā were below 260 m of the coast. In the BOP region I identified 31 coastal marae and 41 coastal urupā. There were 18 coastal marae and 26 coastal urupā within 250 m of the coast in the BOP. There were also 9 coastal marae at elevations between 0-5m and 4 coastal urupā at elevations between 0 – 5 m in the BOP. The topographical profiles of BOP coastal marae and urupā are highly variable with some having sharp drops to the coast as a cliff formation, some have very low and short profiles to the coast and some have mounds or dunes at the intersection with the coast, boading well for them in terms of protection against SLR. The exposure to a 100 year ESL event at MSL saw 6 coastal marae nationally and 2 coastal urupā in the BOP potentially at risk. With a 1 m rise in MSL, saw 16 coastal marae and 1 coastal urupā potentially at risk, with 11 coastal marae and 0 coastal urupā potentially at risk with a 2 m rise in MSL and with 3 m rise in MSL saw 41 coastal marae and 4 coastal urupā in the BOP potentially exposed.

Chapter 5 Coastal geomorphological response to sea level rise

“Toitū te marae a Tane-Mahuta, Toitū te marae a Tangaroa, Toitū te tangata”

“If the land is well and the sea is well, the people will thrive”

5.1 Introduction

Coastal geomorphology focuses on how the ocean influences the morphology (physical attributes) of the land. Coastal geomorphology involves overlapping disciplines including geology, meteorology, and biology. Robust classification systems of coastal morphology is a key theme of this field (Masselink et al., 2011; Davidson-Arnott et al., 2019). In the context of SLR, the coastal geomorphology of an area is a crucial determinant of how vulnerable and susceptible this part of the coast and its communities are to the impacts of climate change, and what management strategies may be needed (Hume & Hart, 2020). This chapter introduces some of the common classifications of coastal geomorphologies used globally and detail the 1 used in this thesis to classify the coastal geomorphology around coastal marae and urupā.

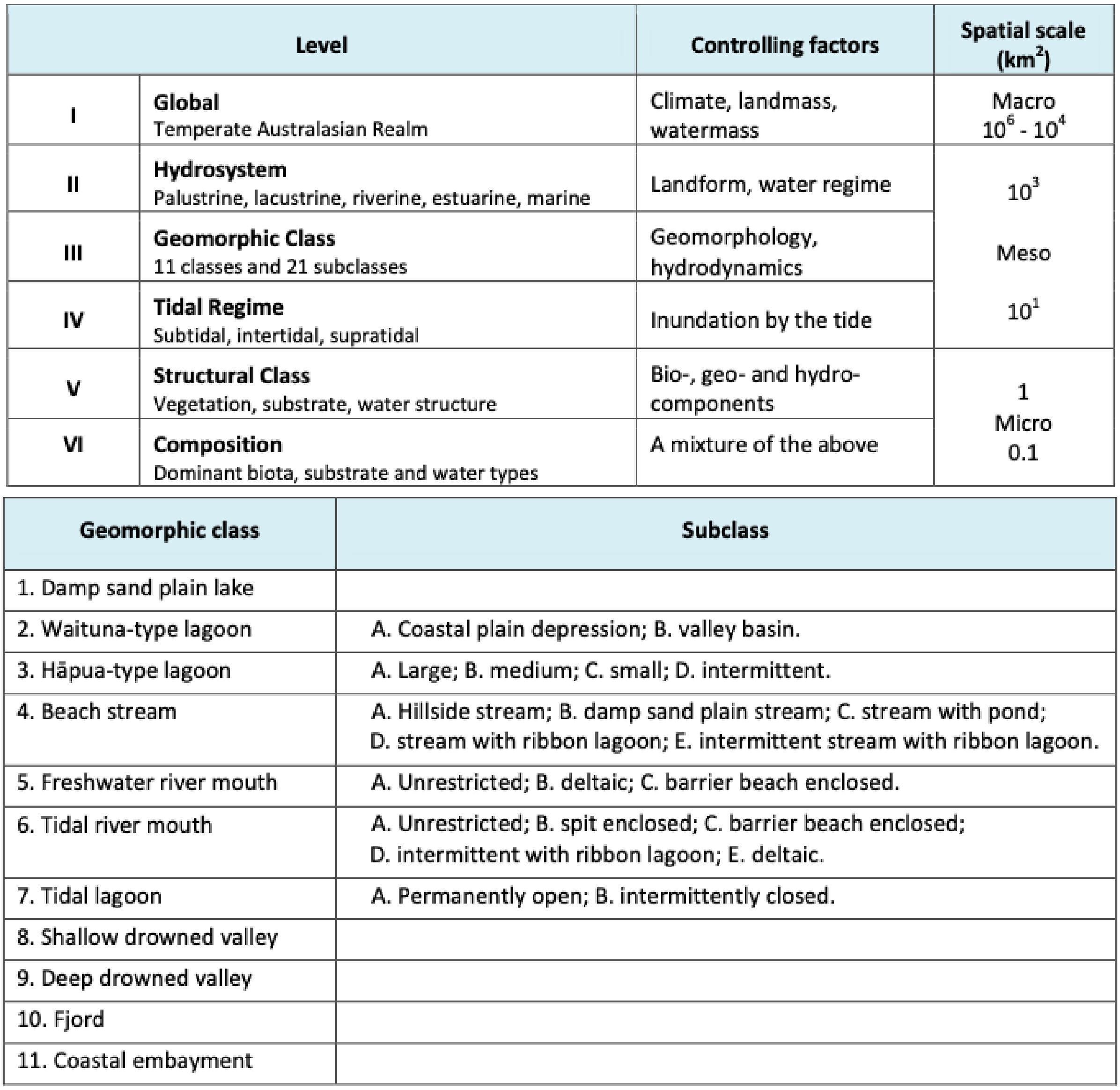
5.2 Coastal geomorphologic classifications

There is a large range of classification systems for coastal geomorphology, starting from the broad geological scale, accounting for the history of MSL changes, such as by Johnson (1919) who distinguished between emerged (coastal plains) and submerged coasts (drowned river valleys, fjords, etc.) (Johnson, 1919; Masselink et al., 2011). Coastal geomorphology can also be classified based on the tectonic environment, such as leading edge coasts located near a subduction zone, as in Aotearoa New Zealand, forming large mountainous zones leading to erosive and rocky coastlines (Inman & Nordstrom, 1971). On the other hand, trailing edge coasts are far from subduction zones so are oldest in geological time, such as the coasts of North and South America which have sediment-rich and deltaic coastlines (Dillenburg & Hesp, 2009; Masselink et al., 2011). At a smaller scale, there are various geomorphic classifications for different types of coasts on a local basis, such as for types of cliff and platform coasts (Sunamura, 1992). There is also a range of classifications for different types of sandy beaches, such as by Wright and Short (1984) and Short and Masselink (1999) for wave- and tide-dominated sandy beaches respectively. Classifications for barrier beaches include that by Carter and Orford (1984) and Cope (2004) and various others for geologically controlled beaches including: sandy geologically controlled beaches on the open coast such as Gallop et al. (2020c) and Jackson et al. (2005), embayed beaches such Fellowes et al. (2019), and low-energy beaches such as those protected by reefs such as Hegge et al. (1996). There are additional classifications for sandy beaches in estuaries and bays such as Vila-Concejo et al. (2020), and gravel barriers such as Bluck (1967), Carter and Orford (1993) and Jennings and Shulmeister (2002), amongst others.

5.3 Geomorphic classification in Aotearoa New Zealand

In this thesis I apply a classification of coastal geomorphology developed by Hume et al., (2016), deemed herein as a coastal hydrosystem. This system provides a hierarchal classification of coastal and marine zones such as coastal wetlands, rivers, estuaries and marine zones for Aotearoa New Zealand's highly variable and dynamic coastline. This classification builds on previous work including Heath (1976), Hume et al. (2007) and Hume and Herdendorf (1988), with the addition of key parameters noted in Stephenson et al. (2018), Ward and Lambie (1999) and Williams et al. (2007). The hierarchy consists of 6 classes (**Table 5.1a)**, ranging from Global (level 1) through levels of hydrosystem, geomorphic class, tidal regime and structural class, through to composition at (level 5). Geomorphic class (level 3), **(Table 5.1a)** is of particular importance for coastal processes as the coast is impacted by both land and sea, which are the main mechanisms for creating, maintaining, and destroying coastal morphologies. The geomorphic class has 11 geomorphic subclasses **(Table 5.1b)**, which are discriminated by their landscape and waterscape characteristics such as geology, morphology, hydrodynamics, basin morphometry and river and ocean forcing (Hume et al., 2016). The 11 geomorphic subclasses are applied to coastal marae and urupā in this thesis, and are summarized below largely from Hume et al. (2016), with associated diagrams and examples **(Table 5.2)**.

Table 5.1: a) New Zealand coastal hydrosystem classification showing the different levels, controlling factors and spatial scale and b) the kinds of geomorphic classes and subclasses (Hume et al., 2016)



Level		Controlling factors	Spatial scale (km^2)
I	**Global** Temperate Australasian Realm	Climate, landmass, watermass	Macro 10^6 - 10^4
II	**Hydrosystem** Palustrine, lacustrine, riverine, estuarine, marine	Landform, water regime	10^3 Meso 10^1
III	**Geomorphic Class** 11 classes and 21 subclasses	Geomorphology, hydrodynamics	
IV	**Tidal Regime** Subtidal, intertidal, supratidal	Inundation by the tide	
V	**Structural Class** Vegetation, substrate, water structure	Bio-, geo- and hydro-components	1 Micro 0.1
VI	**Composition** Dominant biota, substrate and water types	A mixture of the above	

Geomorphic class	Subclass
1. Damp sand plain lake	
2. Waituna-type lagoon	A. Coastal plain depression; B. valley basin.
3. Hāpua-type lagoon	A. Large; B. medium; C. small; D. intermittent.
4. Beach stream	A. Hillside stream; B. damp sand plain stream; C. stream with pond; D. stream with ribbon lagoon; E. intermittent stream with ribbon lagoon.
5. Freshwater river mouth	A. Unrestricted; B. deltaic; C. barrier beach enclosed.
6. Tidal river mouth	A. Unrestricted; B. spit enclosed; C. barrier beach enclosed; D. intermittent with ribbon lagoon; E. deltaic.
7. Tidal lagoon	A. Permanently open; B. intermittently closed.
8. Shallow drowned valley	
9. Deep drowned valley	
10. Fjord	
11. Coastal embayment	

5.3.1. Damp sand plain lake (dune lake, coastal lake)

Dune and coastal lakes form in coastal dunes and older sand deposits. They are very uncommon internationally, but in Aotearoa New Zealand they are the third most common lake type and the most common lake type in the North Island (Champion & deWinton, 2012). They are small, shallow bodies of water with no connection to the sea, occurring in the depressions formed between rows of dunes (**Figure 5.1a)**. They are ephemeral features, with the potential to dry out during drought conditions and are sustained by rainfall, groundwater and sea spray with an example being Okupe Lagoon on Kapiti Island (**Figure 5.1b)**.

5.3.2 Waituna-type lagoon (barrier or enclosed barrier lagoon)

Waituna-type lagoons are typically large, shallow lagoons that are closed to the sea **(Figure 5.2a)**. The lagoon is usually fresh, although can sometimes be brackish in parts. During storms, overtopping of the lagoon barrier can occur, from increased freshwater input and wave action, causing short periods of tidal inflow, however these inflows are not sustained (Kirk & Lauder, 2000). An example of a waituna-type lagoon is Lake Ellesmere South of Christchurch **(Figure 5.2b)**

5.3.3 Hāpua-type lagoon (barrier beach enclosed wave-dominated river)

Hāpua type lagoons often occur at the mouth of braided rivers and generally run parallel to the coast **(Figure 5.3a).** They enclose predominantly freshwater with a barrier spit, where the spit is produced by the deposition of sediment as part of a longshore transport system (Hart, 2009). Hāpua means a hollow, depression or pool / lagoon frequented by birds in Te Reo Māori (Best, 1977; Ulluwishewa et al., 2008). This type of lagoon typically has no tidal influence, however, during rough swell and flooding, breaches occur for short periods of time, before longshore transport restricts the tidal inflow (Kirk & Lauder, 2000). An example of a Hāpua-type lagoon is the Rakaia River South-West of Lake Ellesmere situated in the South Island of Aotearoa New Zealand (**Figure 5.3b).**

5.3.4 Beach stream (stream or coastal stream)

Beach streams are very shallow streams which flow over the beach to the sea. They can be ephemeral features as during drought conditions their flow is reduced as well as when sediment accumulates at the outlet point as a berm. There can be two variations of this type of coastal geomorphology: (1) beach stream with a pond at the intersection with the coast **(Figure 5.4a)**, with an example of a stream located at Mokihinui, on the West coast of the South Island of Aotearoa New Zealand **(Figure 5.4b)**; and (2) beach stream with a ribbon lagoon which runs parallel to the coast **(Figure 5.4c)**, with an example of a beach stream situated to the South of Mokihinui, South Island **(Figure 5.4d)**.

5.3.5 Freshwater River mouth (river mouth)

Freshwater river mouths occur where river discharge is strong and large enough to maintain a permanent channel **(Figure 5.5a)**, by which the river can flow into the sea, with the potential for deltas to form at the coastal intersection **(Figure 5.5c).** The gradient between the upper reaches of the river and the sea outlet is also large enough to prevent tidal intrusion further up the river. An example of a freshwater river mouth is the Haast river situated on the West coast of the South Island **(Figure 5.5b)** and an example of a deltaic freshwater river mouth is the Clarence River, South Island **(Figure 5.5d)**.

5.3.6 Tidal River mouth (tidal river or river mouth)

Tidal river mouths tend to be elongated, narrow and shallow basins which are permanently open to the coast due to the large and persistent river and tidal flows which are able to keep a permanent channel **(Figure 5.6a).** An example of an unrestricted tidal river mouth is the Whakatāne River, BOP **(Figure 5.6b)**. The outflow of freshwater is balanced with the inflow of salt water to form a salt wedge in the channel, with salt water sometimes intruding kilometers up the estuary. Tidal river mouths can also be intermittent with a ribbon lagoon which runs parallel with the coast **(Figure 5.6c)** such as the New River situated on the West coast of the South Island (**Figure 5.6d)**.

5.3.7 Tidal lagoon (lagoon, bay or inlet)

Tidal lagoons can be circular to elongated basins with extensive intertidal zones with a narrow entrance, with strong reversing ebb and flood currents forming corresponding deltas on both sides of the channel. Hydrodynamic processes are tidal-dominated due to the large tidal prism, and they are hence well mixed with no vertical stratification. They are mostly always open **(Figure 5.7a)**, such as Blue Skin Bay, Otago (**Figure 5.7b),** but can also close intermittently, (**Figure 5.7c)** such as occurs at Hoopers inlet in Otago (**Figure 5.7d & 5.7e)**. They vary in name by country, for example in Australia they are referred to as intermittently closed and open lagoons (ICOLLS) (Haines et al., 2006), and in the USA as intermittently closed/open lakes and lagoons or temporarily closed lagoons (McSweeney et al., 2017).

5.3.8 Shallow drowned valley (harbour or estuary)

Shallow drowned valleys are shallow systems with intense dendritic branching shorelines and extensive intertidal flats **(Figure 5.8a)**, ranging from small creeks to large harbors bounded by a rocky headland on one side (**Figure 5.8b)**. They are tidally dominated with a permanent connection to the coast with flood and ebb deltas present, such as Tauranga Harbour in the BOP (**Figure 5.8c)**.

5.3.9 Deep drowned valley (ria, sound, firth or harbour)

Deep drowned valleys are large subtidal systems formed by the submergence of an unglaciated river valley **(Figure 5.9a)**. They typically have a straight planform but inherited dendritic patterns may occur. River and tidal inputs are small compared to the total basin volume, however river forcing dominates higher up in this system, whereas tidal forcing dominates at the entrance with an example being the Firth of Thames, Coromandel (**Figure 5.9b)**

5.3.10 Fjord (drowned glacial valley or sound)

Fjords are long, deep and narrow glacial valleys flooded by the sea following the last glacial period. The basin is manly subtidal, with some intertidal zones far in the fjord and with dominant sill features at the mouth which were once glacial terminal moraines (**Figure 5.10a)**. An example of a fjord is the Queen Charlotte Sound, Marlborough (**Figure 5.10b)**.

5.3.11 Coastal embayment (pocket beach, cove, or bay)

Coastal embayment's are often thought of as an indentation in the shoreline, bound by rocky headlands and with wide open entrances to the coast (**Figure 5.11a),** allowing swell to enter and further in you can have subtidal and intertidal regions (Fellowes et al., 2019). An example of a coastal embayment is Maitai Bay, Northland **(Figure 5.11b).**

5.3.12 Open coast

Open coast geomorphology was not part of the Hume et.al. (2016) classification system. The open coast comprises various types of beaches depending on the geology, nature of the waves, tides and sediment (Short & Woodroffe, 2009). I found several coastal marae and urupā that were situated on the open coast, but not part of a coastal embayment, which is included in Hume et al. (2016). In this thesis, the open coast is distinguished from a coastal embayment in that there are no headlands creating the embayed nature leading to pocket beaches or coves (Fellowes et al., 2019). Open coast beaches therefore tend to be relatively long, without significant geological controls such as headlands. They may be backed by dunes and exist as barrier coasts from alongshore sediment accumulation (Woodroffe, 2002). For example, open coast beaches include the Matatā straights, Bay of Plenty, Aotearoa New Zealand **(Figure 5.12a)**, and Te Oneroa-A-Tohe (Ninety Mile Beach) is another well-known example **(Figure 5.12b).**

Table 5.2: Cross-sectional diagram and examples of each coastal geomorphology type in Hume et al. **(2016)**

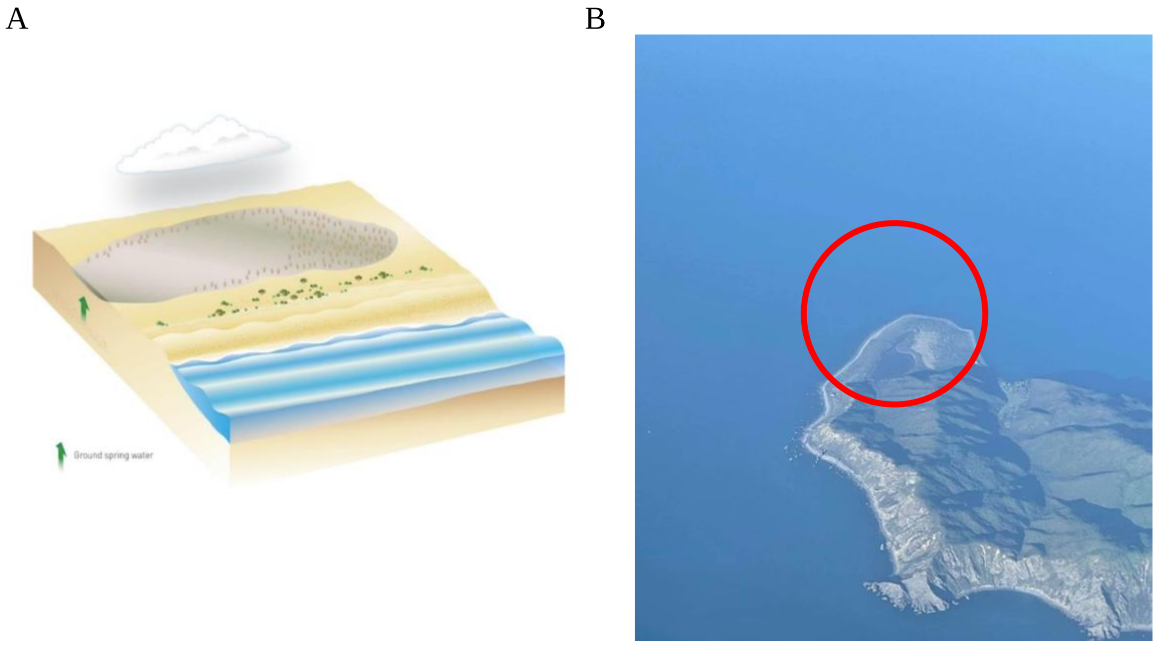


Figure 5-1: a) cross sectional diagram of a damp sand plain lake (Hume et al., 2016) and b) an example of this at Okupe Lagoon, Kapiti Island (Image taken by A.P.S Bailey-Winiata))

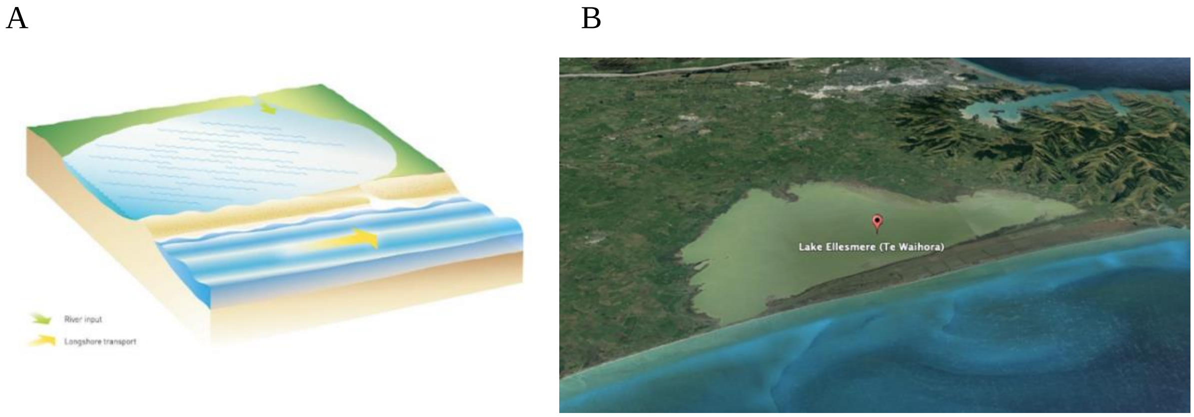


Figure 5-2: a) cross sectional diagram of a Waituna-type lagoon being parallel to the coast (Hume et al., 2016) and b) example of a Waituna-type lagoon at Lakes Elsmere, Canterbury, Aotearoa New Zealand (Google Earth)

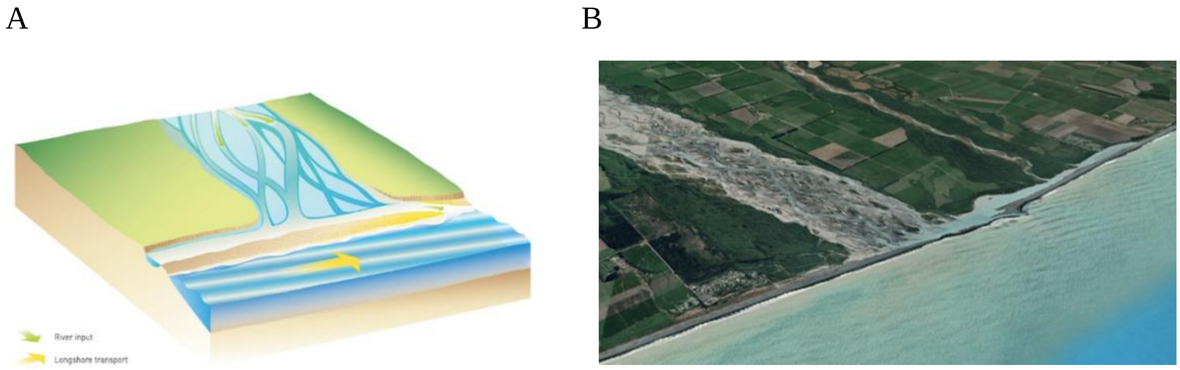


Figure 5-3: a) cross sectional diagram of a Hāpua-type lagoon running parallel to the coast (Hume et al., 2016) and b) example of a Hāpua-type lagoon at the Rakaia River, Canterbury, Aotearoa New Zealand (Google Earth)

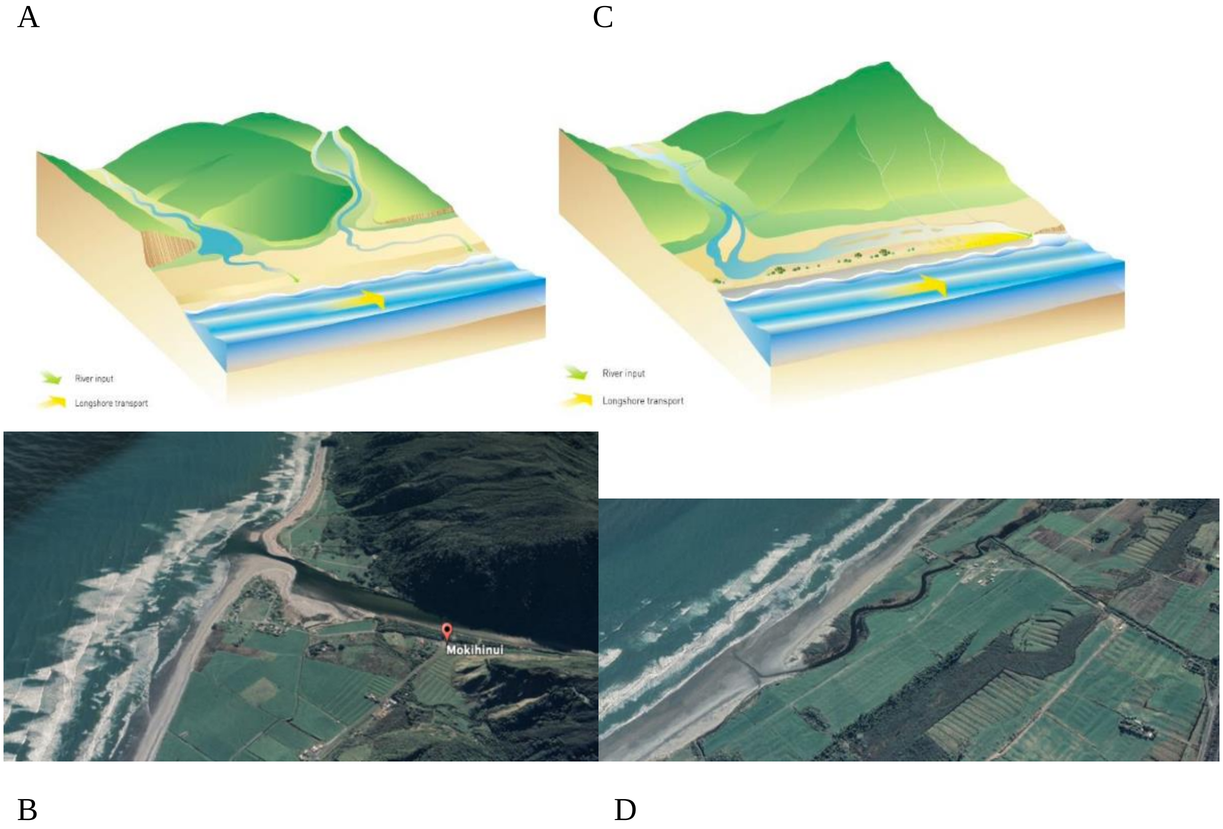


Figure 5-4: a) cross sectional diagram of a beach stream with a pond accumulating at the exit (Hume et al., 2016) and b) is an example of 5.4a at Mokihinui on the west coast of the South Island of Aotearoa New Zealand (Google Earth) and c) cross sectional diagram of a beach stream with a ribbon lagoon (Hume et al., 2016) and d) an example of 5.4c south of Mokihinui, South Island, Aotearoa New Zealand (Google Earth)

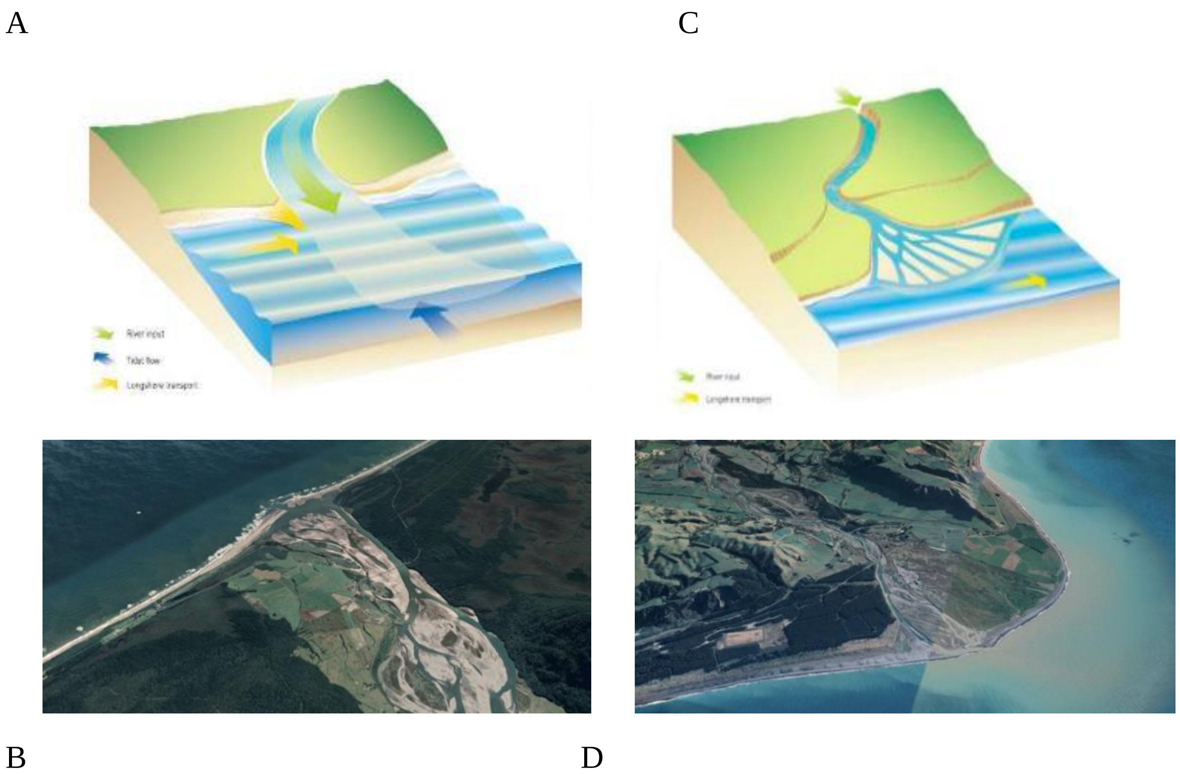


Figure 5-5:a) cross sectional diagram of an unrestricted river mouth (Hume et al., 2016) and b) example of 5.5a is the Haast river on the west coast of the South Island, Aotearoa New Zealand (Google Earth) and c) cross sectional diagram of a deltaic freshwater river mouth (Hume et al., 2016) and d) example of 5.5c is the Clarence River on the east coast of the South Island, Aotearoa, New Zealand (Google Earth)

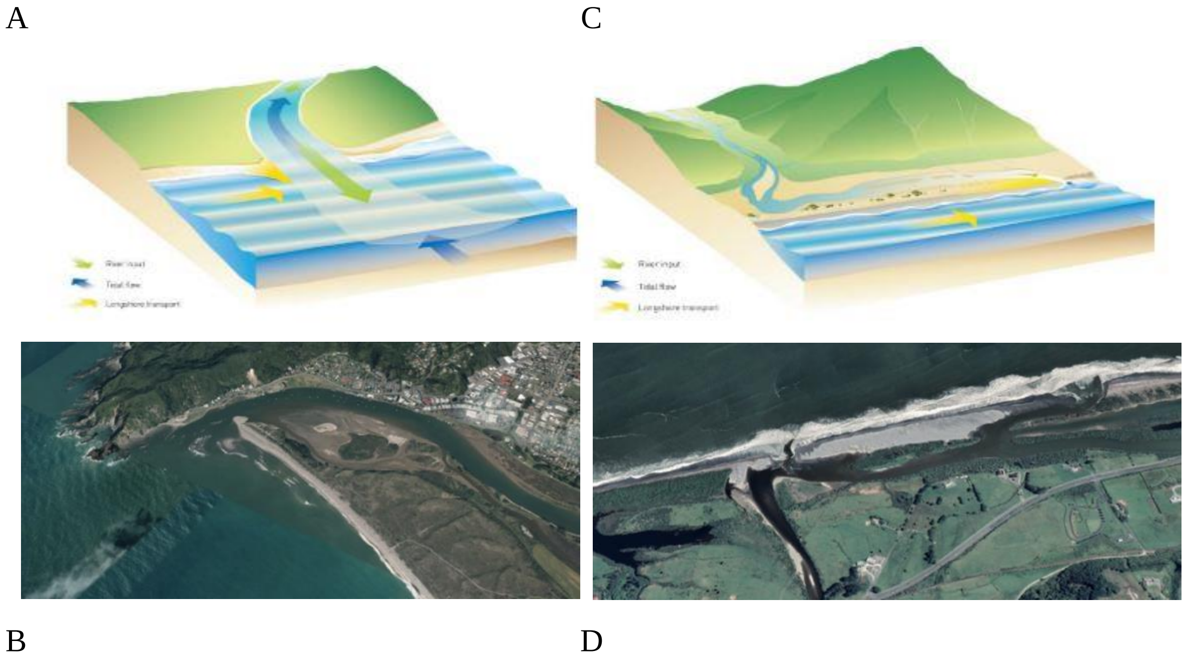


Figure 5-6: a) cross sectional diagram of an unrestricted tidal river mouth (Hume et al., 2016) and b) an example of an unrestricted tidal river mouth is the Whakatane river, BOP, Aotearoa New Zealand (Google Earth) and c) cross sectional diagram of an intermittent tidal river mouth with a ribbon lagoon (Hume et al., 2016) and d) an example of an intermittent tidal river mouth is the New river on the west coast of the South Island, Aotearoa, New Zealand (Google Earth)

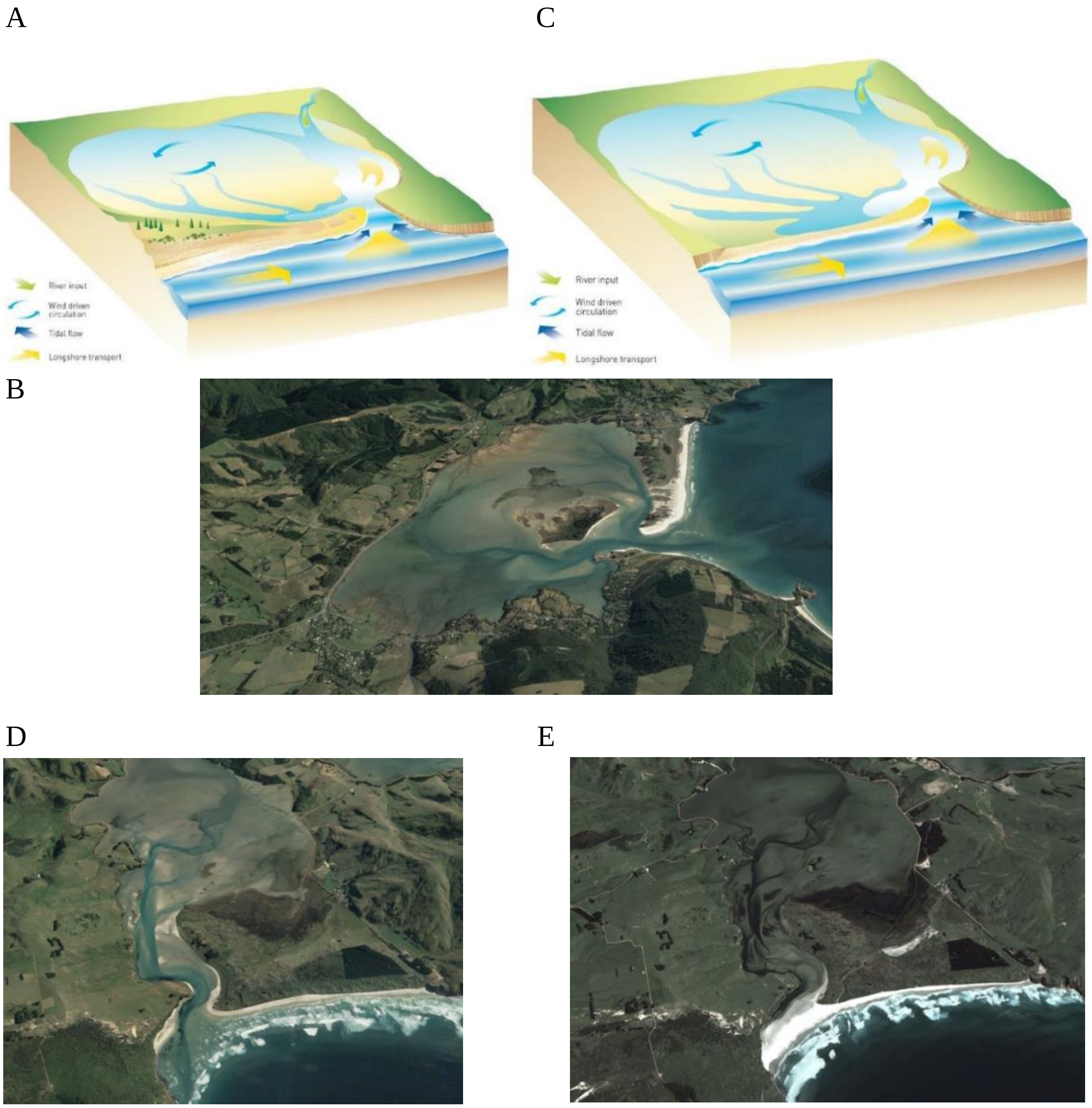


Figure 5-7: a) cross sectional diagram of a permanently open tidal lagoon (Hume et al., 2016) and b) example of a permanently open tidal lagoon at Blue skin bay, Otago, Aotearoa New Zealand (Google Earth) and c) cross sectional diagram of a barrier beach / spit tidal lagoon that can be intermittently open (Hume et al., 2016) and d) example of Hoopers inlet, Otago, Aotearoa New Zealand (Google Earth) when it is open and e) Hoopers inlet when it is closed

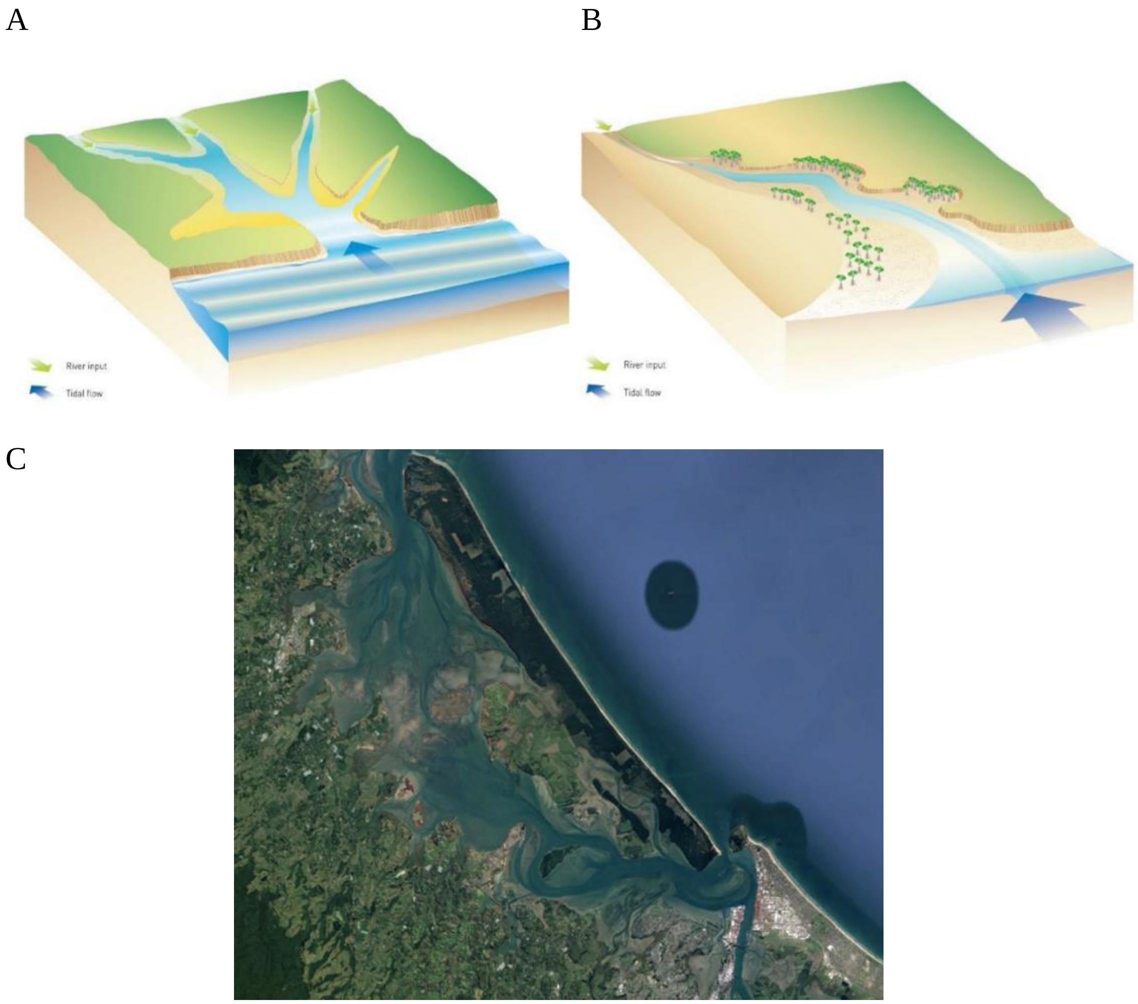


Figure 5-8: a) cross sectional diagram of a permanently open shallow drowned valley (Hume et al., 2016) and b) is the arm of a tidal creek further up the shallow drowned system (Hume et al., 2016) and c) example of a shallow drowned valley at Tauranga Harbour, BOP

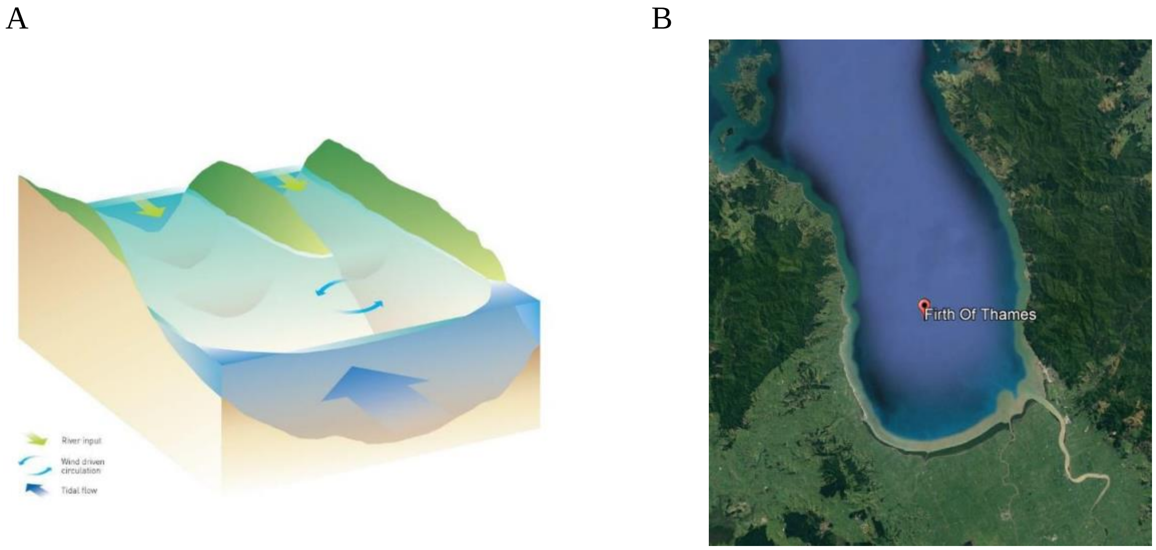


Figure 5-9: a) cross sectional diagram of a deep drowned valley (Hume et al., 2016) and b) is an example of a deep drowned valley at the Firth of Thames, Coromandel, Aotearoa New Zealand (Google Earth)

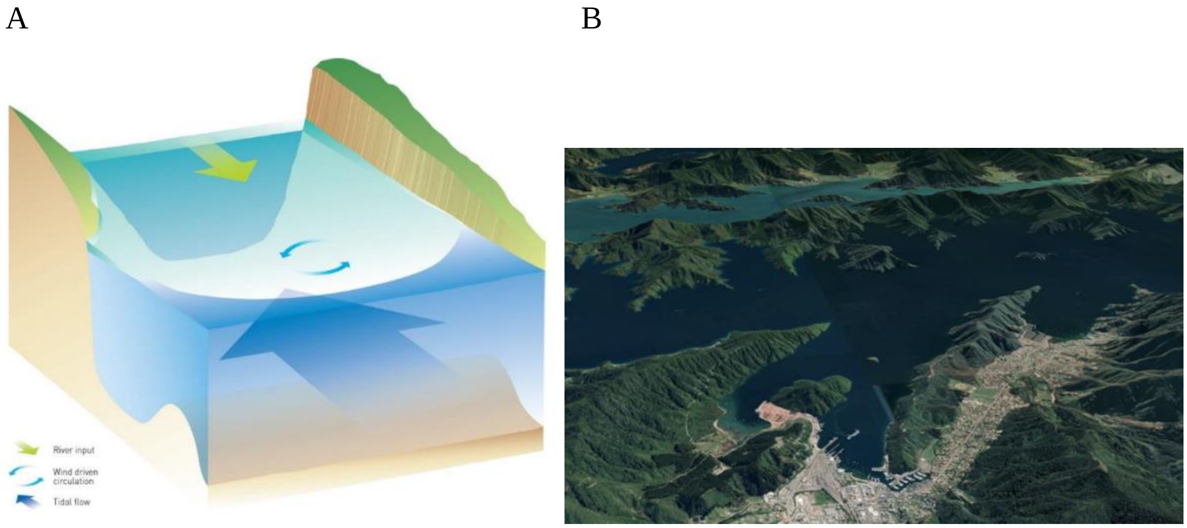


Figure 5-10: a) a cross sectional diagram of a fjord (Hume et al., 2016) and b) example of a fjord at Queen Charlotte Sound, Marlborough, South Island, Aotearoa New Zealand (Google Earth)

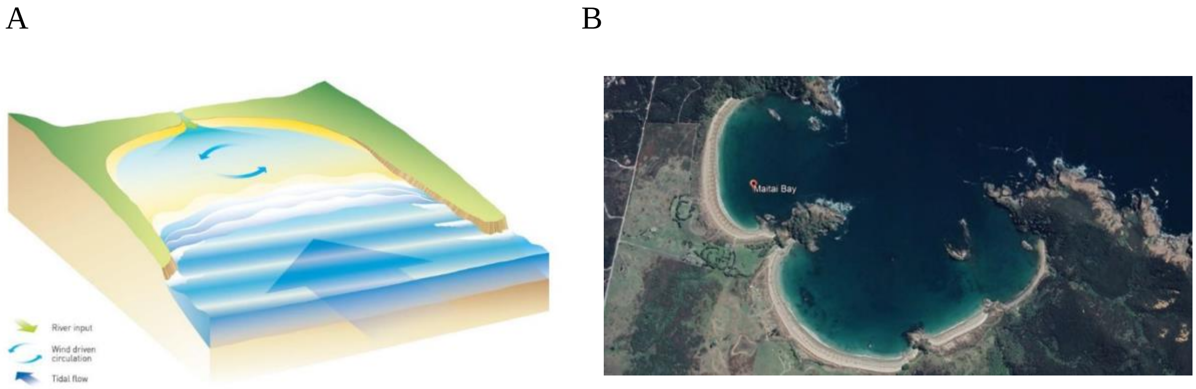


Figure 5.11: a) cross sectional diagram of a coastal embayment (Hume et al., 2016) and b) an example of a coastal embayment at Maitai bay, Northland, Aotearoa New Zealand (Google Earth)

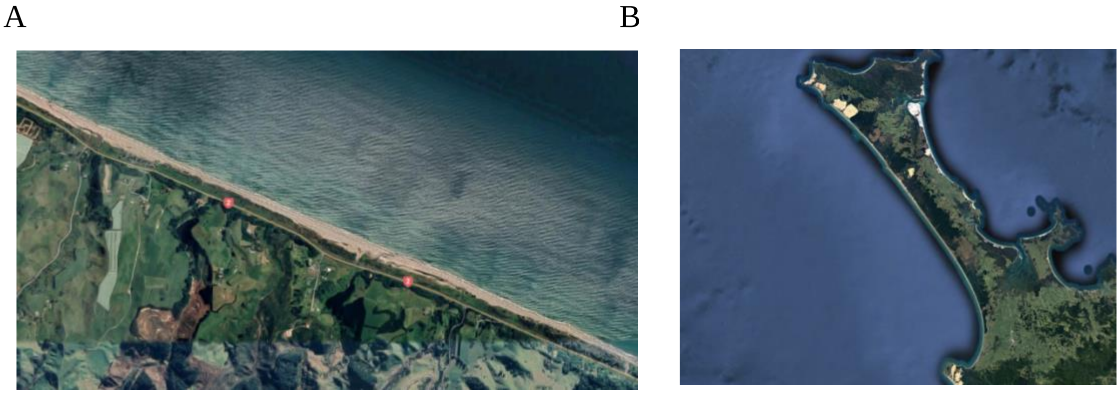


Figure 5.12: a) example of the open coast along the Matatā straights in the BOP, Aotearoa New Zealand (Google Earth) and b) Te Oneroa a Tohe (Ninety mile beach), Northland, Aotearoa New Zealand (Google Earth)

5.4 Geomorphology of coastal marae and urupā

The coastal geomorphology around coastal marae and urupā was classified using the Hume et al. (2016) classification. The methods of classifying coastal marae and urupā can be found in **Section 3.6.5**, and it is important to note that for some locations there were mixtures of 2 geomorphologies. For example, a coastal marae may be situated near a freshwater river mouth that exits into a coastal embayment, hence the coastal marae will be exposed to processes specific to those 2 types of coastal geomorphology, and that coastal marae was classified as both. The most common geomorphology for coastal marae was shallow drowned valley, with 72 coastal marae, followed by 41 coastal embayment, 14 deep drowned valley's and 13 tidal river mouths. The least common geomorphologies at coastal marae were tidal river mouth / coastal embayment, tidal river mouth / open coast and waituna type lagoon all with 1 coastal marae **(Figure 5.13)**. Damp sand plain lake, hāpua type lagoon and fjords had no marae in these categories. I organized coastal marae into rohe, following kaupapa Māori research principles and Indigenous land demarcation (Kingi, 2008; Smith, 2015) **(Figure 5.14)** and below I discuss the geomorphologies of each rohe.

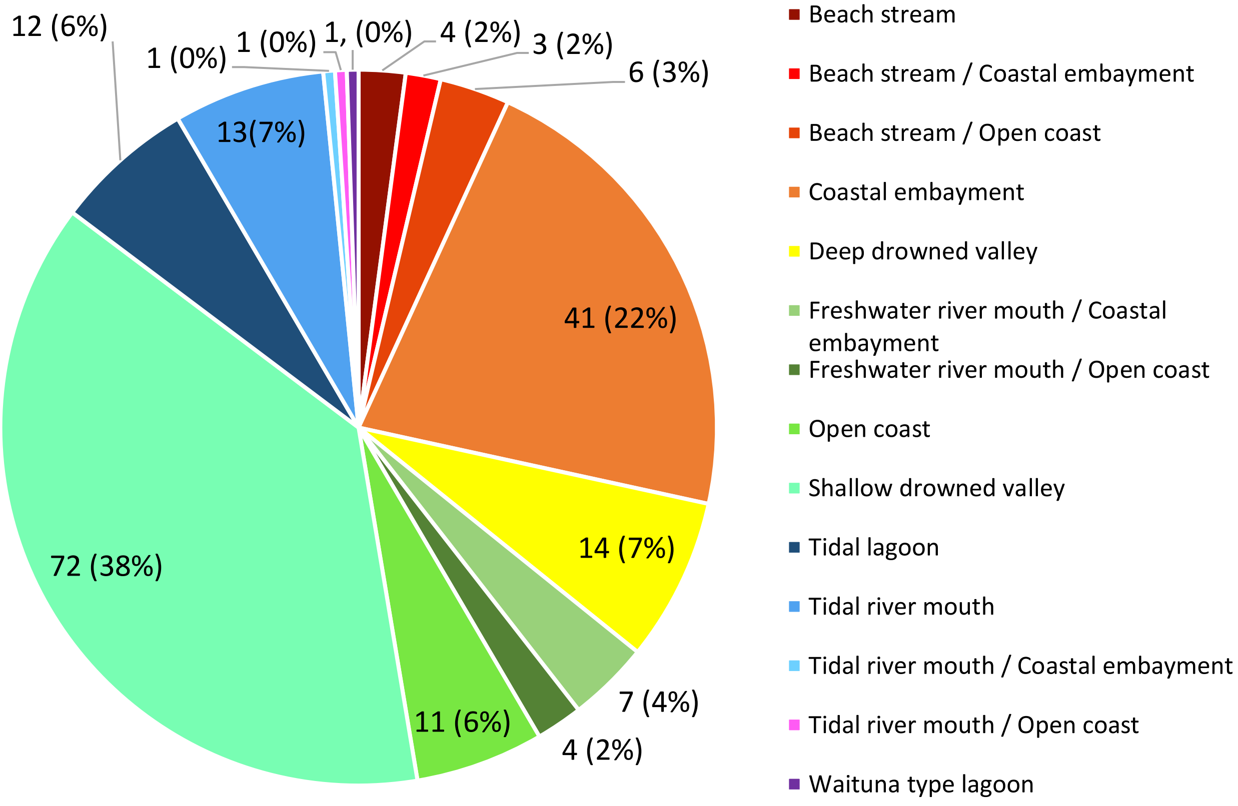


Figure 5.13: Pie graph of coastal geomorphology of national coastal marae including numbers and percentages in each category showing the variability of the types of coastal geomorphology

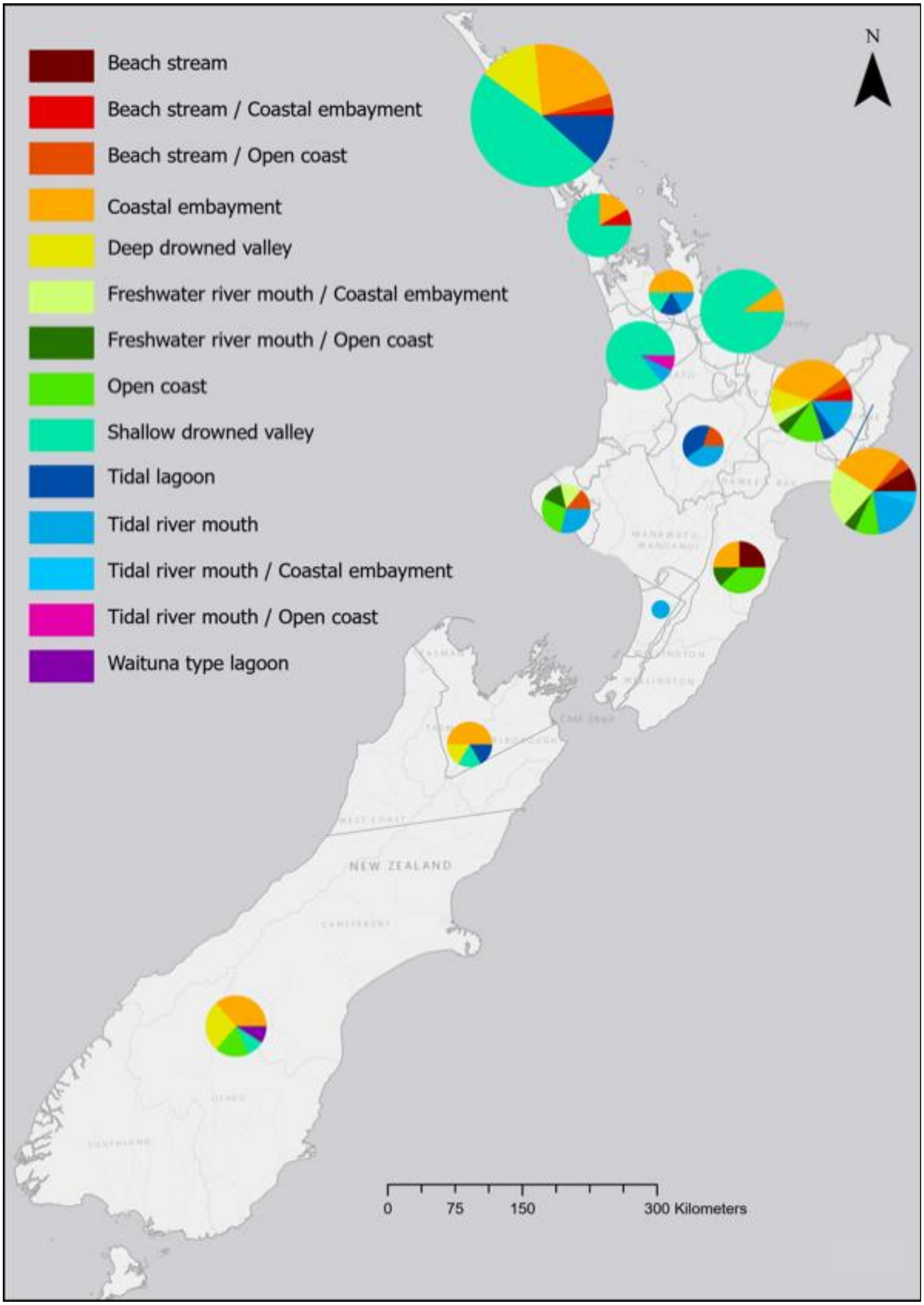
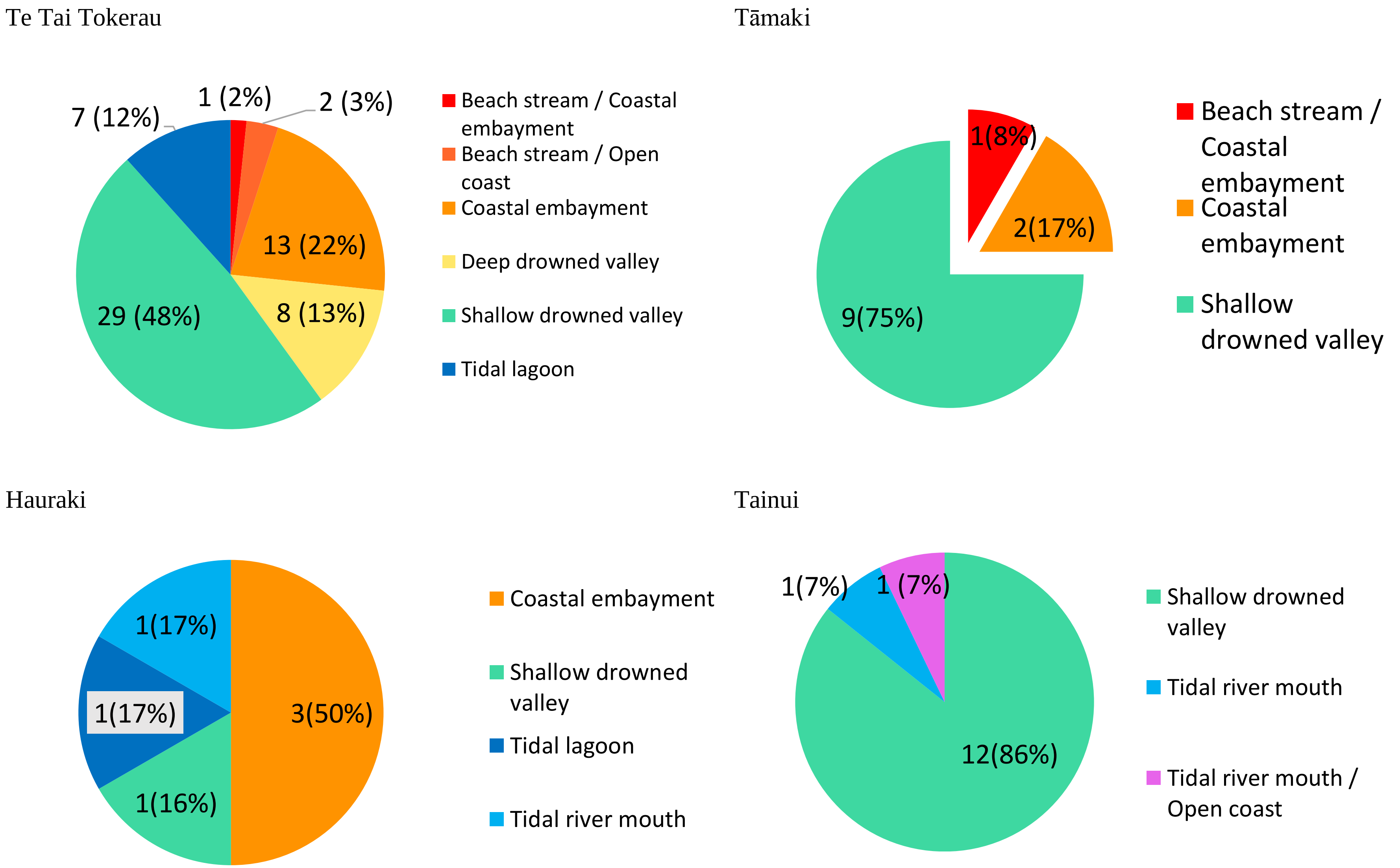


Figure 5.14: National map of coastal marae categorized into rohe showing the range of coastal geomorphology



Te Tai Tokerau

Tāmaki

Hauraki

Tainui

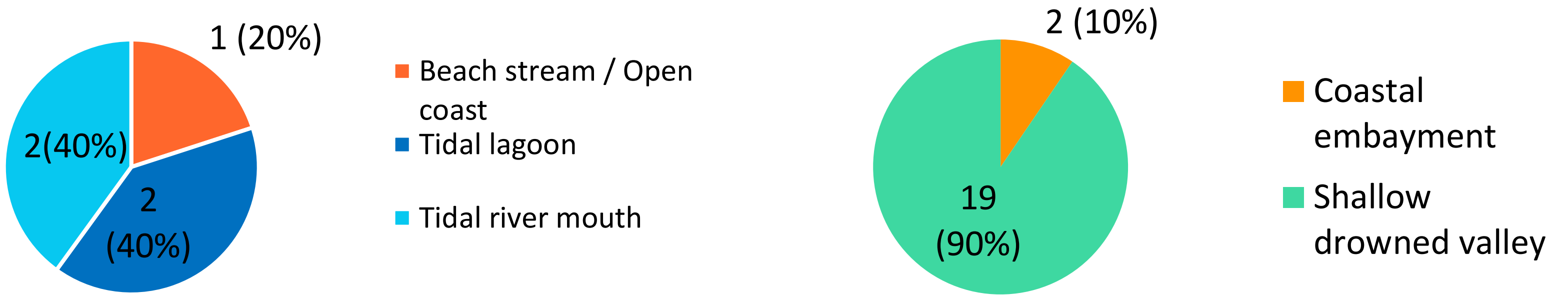
Figure 5-15: Pie graphs showing the coastal geomorphology of different coastal marae by rohe: a) Te Tai Tokerau, b) Tāmaki, c) Hauraki and d) Tainui

Starting in the north, **Te Tai Tokerau** has 61 coastal marae with 6 different coastal geomorphologies **(5.15a)**. The most common geomorphology in this rohe is shallow drowned valley, with 48% (29) coastal marae, followed by 22% (13) coastal embayment and 13% (8) in deep drowned valleys. The **Tāmaki** rohe has 12 coastal marae covering 3 geomorphologies (**Figure 5.15b)** including shallow drowned valley with 75% (9) coastal marae, followed by 17% (2) coastal embayment and 8% (1) beach stream. **Hauraki** has 6 coastal marae spanning 4 geomorphologies (**Figure 5.15c)**. The most common geomorphology in this rohe was a coastal embayment with 50% (3) coastal marae, followed by 1 coastal marae in each of shallow drowned valley, tidal lagoon and tidal river mouth classes. The **Tainui** rohe has 14 coastal marae covering 3 geomorphologies (**Figure 5.15d)**. The most common geomorphology in this rohe was shallow drowned valley having 86% (12) coastal marae, followed by 7% (1) in both tidal river mouth and tidal river mouth / open coast. **Te Arawa** has 5 coastal marae covering 3 geomorphologies (**Figure 5.16a)**. The most common geomorphology in this rohe are tidal lagoons and tidal river mouths, both with 40% (2) coastal marae, with beach stream / open coast with 1 coastal marae.

Tauranga Moana has 21 coastal marae covering 2 geomorphologies (**Figure 5.16b)**; 90% (19) of coastal marae in this rohe are in the shallow drowned valley of Tauranga Harbour with 10% (2) coastal marae having coastal embayment geomorphology. The **Mataatua** rohe has 20 coastal marae covering 9 geomorphologies, making it the most variable in terms of geomorphology (**Figure 5.16c)**. The most common geomorphology in this rohe is coastal embayment with 35% (7) coastal marae, followed by 15% (3) coastal marae each situated in tidal river mouths and along the open coast. The **Te Tai Rawhiti** rohe has 19 coastal marae covering 8 geomorphologies making it also highly variable (**Figure 5.17a)**. The most common geomorphology is coastal embayment and freshwater river mouths / coastal embayment both having ~27% (5) coastal marae. This is followed by 16% (3) coastal marae being on tidal river mouths and 11% (2) coastal marae being on a beach stream. The **Tākitimu** rohe has 8 coastal marae covering 4 geomorphologies (**Figure 5.17b)**. The most common geomorphology is the open coast with 38% (3) coastal marae found in these environments, followed by 25% (2) coastal marae in coastal embayment and beach streams with 12% (1) coastal marae found in a freshwater river mouth / open coast environment.

The **Hauāuru** rohe has 7 coastal marae covering 5 geomorphologies (**Figure 5.17c).** The most common geomorphologies are tidal river mouths and the open coast both having 29% (2) coastal marae each, followed by 14% (1) coastal marae in each of the beach stream / open coast, freshwater river mouth / coastal embayment and freshwater river mouth / open coast categories. **Te Moana o Raukawa** rohe has only 1 coastal marae with a geomorphology of tidal river mouth (hence a pie graph was not produced for this rohe). **Te Tau Ihu** rohe has 6 coastal marae covering 4 geomorphologies (**Figure 5.18)**. The most common geomorphology is a coastal embayment with 50% (3) coastal marae, followed by 17% (1) coastal marae being in each of a deep drowned valley, shallow drowned valley and tidal lagoon. The **Waipounamu** rohe has 13 coastal marae covering 5 geomorphologies (**Figure 5.19)**. The most common geomorphology is the coastal embayment with 37% (4) coastal marae followed by 27% (3) coastal marae found in deep drowned valleys, 18% (2) coastal marae found on the open coast and 9% (1) coastal marae in each of a shallow drowned valley and a waituna type lagoon.

Te Arawa   Tauranga Moana



Mātaatua

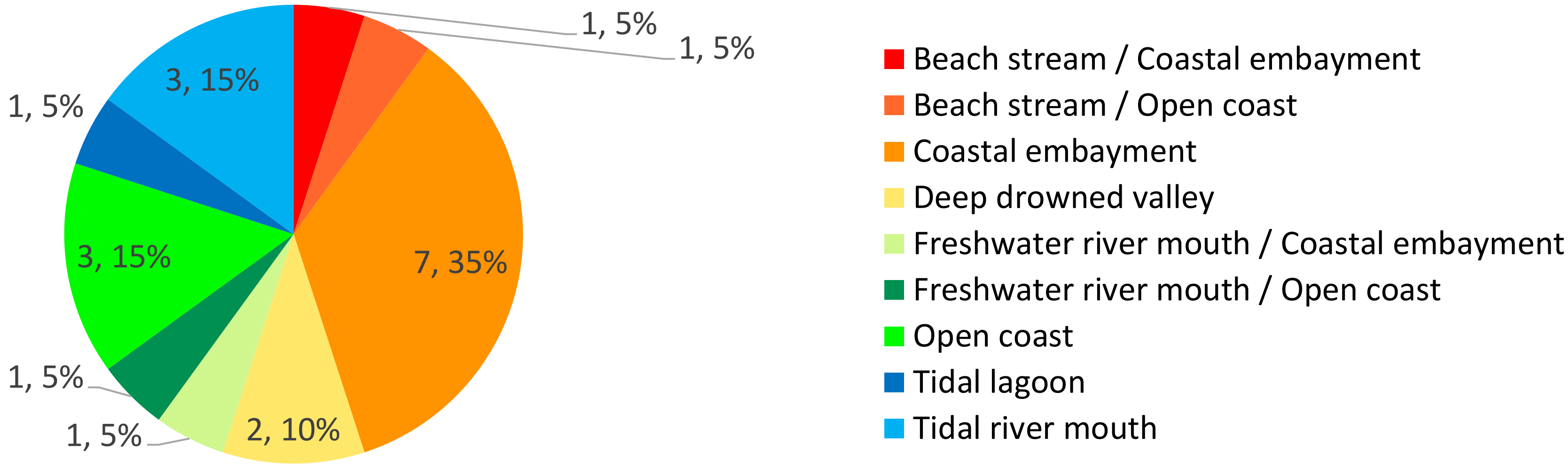


Figure 5-16: Pie graphs showing the coastal geomorphology of different coastal marae by rohe: a) Te Arawa, b) Tauranga Moana and c) Mātaatua

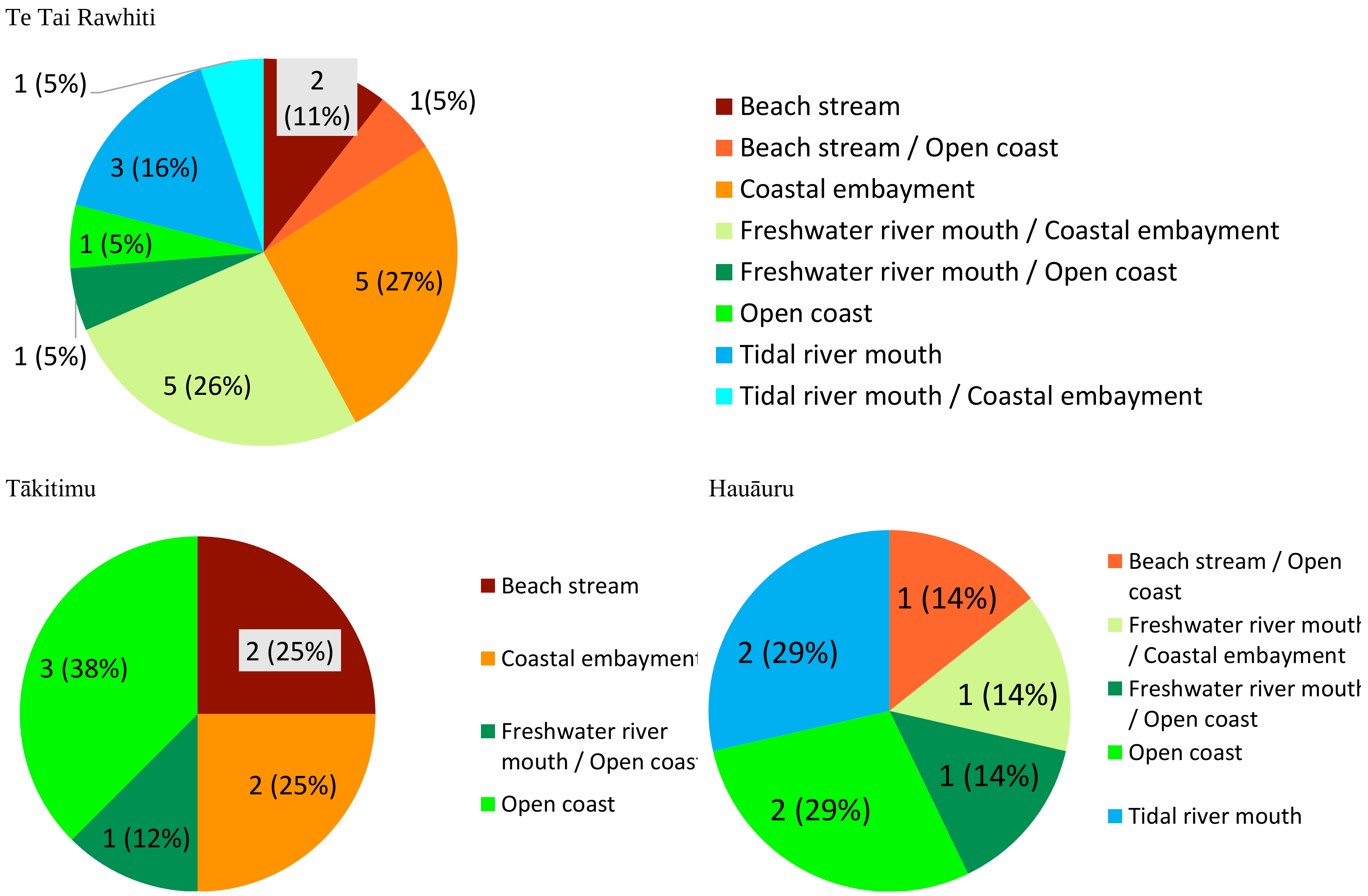


Figure 5-17: Pie graphs showing the coastal geomorphologies of coastal marae by rohe: a) Te Tai Rawhiti, b) Tākitimu and c) Hauāuru

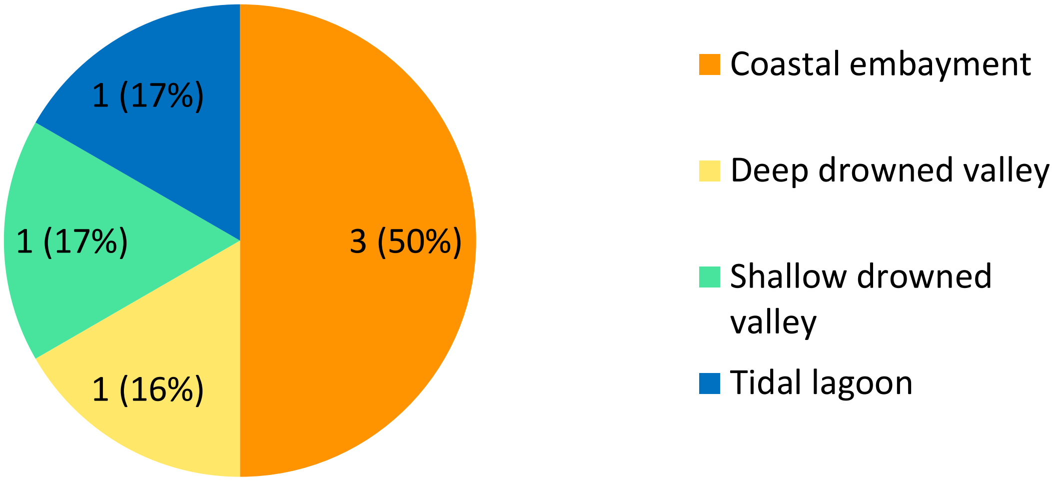


Figure 5-18: Pie graph showing the coastal geomorphology of coastal marae in the Te Tau Ihu rohe

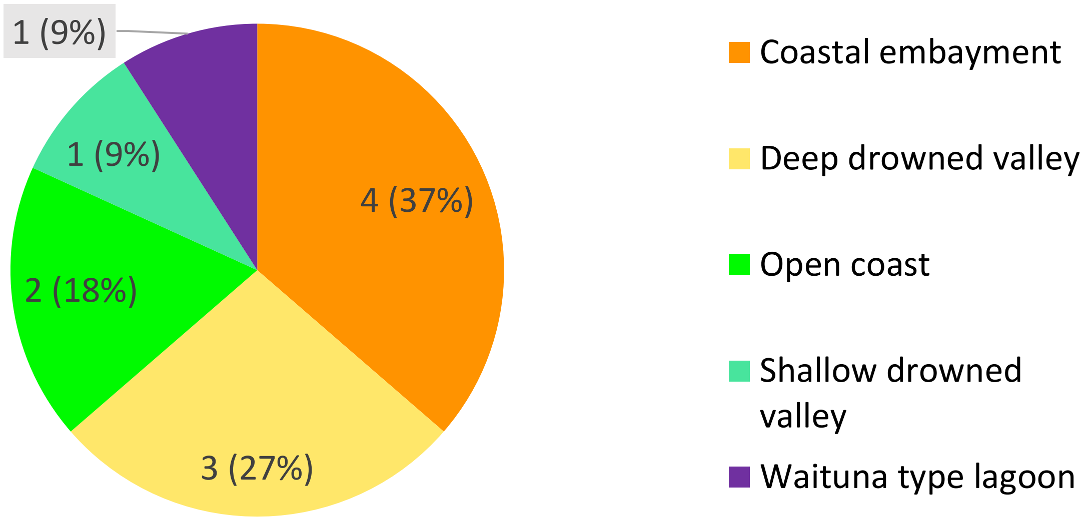


Figure 5-19: Pie graph showing the coastal geomorphology of coastal marae in the Waipounamu rohe

5.4.1 Bay of Plenty coastal urupā

A geomorphic analysis was conducted for coastal urupā in the BOP region covering 9 different types of coastal geomorphologies with the most common being the shallow drowned valley with 58% (24) coastal urupā, followed by 17% (7) being near a tidal river mouth, 4.8% (2) respectively being near a deep drowned valley, open coast and a tidal lagoon. The remaining 4 geomorphologies have 2.4% (1) coastal urupā in each category.

5.5 Geomorphology of coastal marae and urupā potentially exposed to a 100 year ESL

There were 41 coastal marae and 4 coastal urupā detected to be potentially exposed to a 100 year ESL event with 3 m SLR as mentioned in **Section 4.8**, here I assess their coastal geomorphology. The most common coastal geomorphology of these coastal marae and urupā were a shallow drowned valley with 13 coastal marae and 1 coastal urupā, followed by 12 coastal marae and 1 coastal urupā found within a coastal embayment and 6 coastal marae and 1 coastal urupā found near a tidal river mouth. Those 6 coastal marae that are exposed to a 100 year ESL event at current MSL include 3 shallow drowned valleys, 2 tidal river mouths and 1 waituna type lagoon. However, the 1 coastal marae near a waituna-type lagoon is the only coastal marae to have this coastal geomorphology type and hence is unique in that it is deemed at greatest risk to a 100 year ESL event at current MSL **(Figure 5.20)**. The geomorphology of the 4 coastal urupā in the BOP potentially affected by a 100 year ESL event consists of a shallow drowned valley, tidal river mouth, tidal lagoon and freshwater river mouth / coastal embayment.

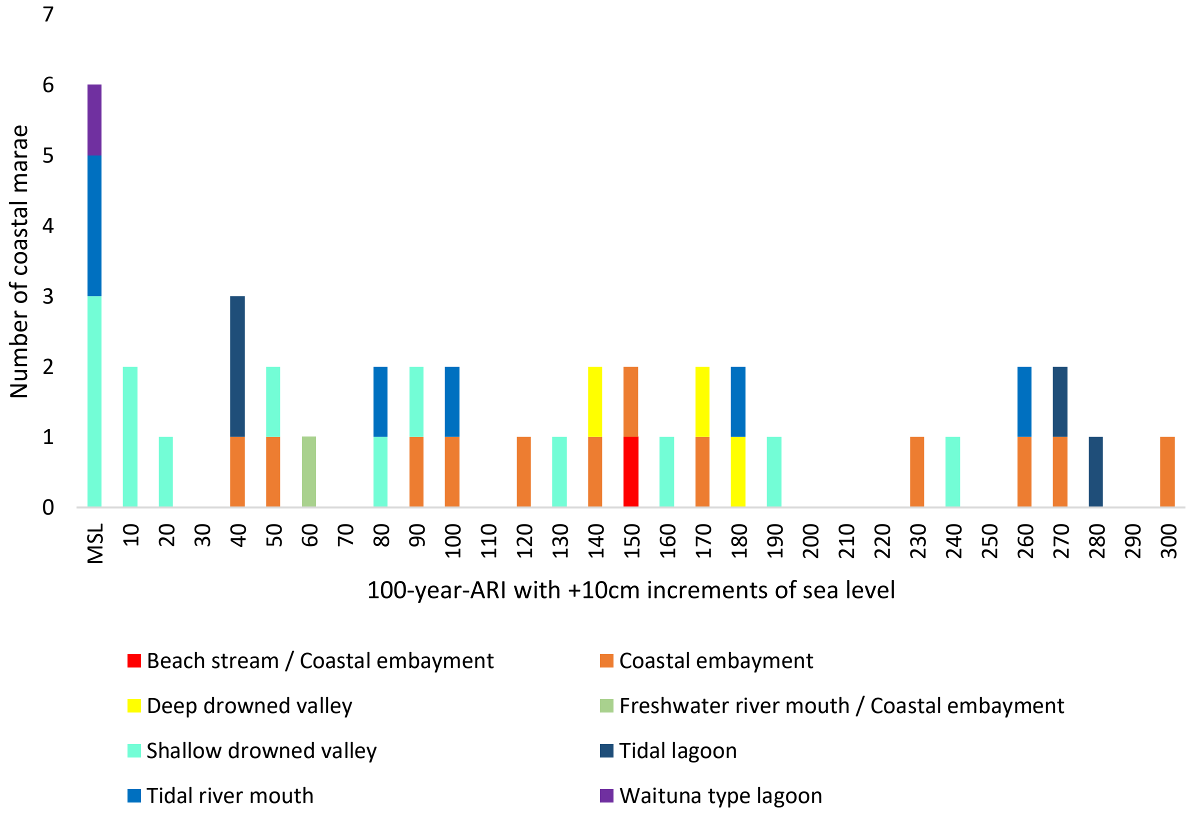


Figure 5-20: Geomorphologies class of coastal marae exposed to a 100 year ESL event with incremental SLR

5.6 Summary

This chapter categorized coastal marae and urupā based on their coastal geomorphology, largely following the Hume et al. (2016) coastal hydrosystem classification system, with the addition of the open coast category. Shallow drowned valleys are the most common geomorphology for coastal marae, with 38% (72) coastal marae nationally and 58% (24) coastal urupā in the BOP having this geomorphology. Coastal embayment was the next most common with 22% (41) coastal marae, followed by tidal river mouths with 7% (13) coastal marae and tidal lagoons having 6% (12) coastal marae. In terms of rohe, the Mātaatua rohe had the greatest variation covering 9 types of coastal geomorphology, followed by Te Tai Rawhiti rohe covering 8 types and Te Tai Tokerau rohe covering 6 types. The geomorphologies of coastal marae that were detected as being potentially exposed to a 100 year ESL event consisted of shallow drowned valleys with 13 coastal marae, followed by coastal embayment with 11 coastal marae, tidal river mouth with 6 coastal marae and tidal lagoons with 4 coastal marae. Those 6 coastal marae that are potentially exposed to a 100 year ESL at MSL follow the same national trend with 3 shallow drowned valleys, 2 tidal river mouths and 1 waituna-type lagoon, with the waituna-type lagoon being the only coastal marae nationally to have this type of geomorphology.

Chapter 6 Discussion and conclusion

“He aha te kai ō te Rangatira? He Kōrero, he kōrero, he kōrero.”

“What is the food of the leader? It is knowledge, It is communication.”

6.1 Introduction

This chapter brings together and discusses key results presented in **Chapters 4** and **5** of this thesis. I outline limitations of this research, future research directions and consider relevant legislation that will influence potential options and directions that coastal marae, hapū and iwi can consider to protect their coastal marae and urupā for the future.

6.2 100 year extreme sea level exposure at current MSL

In **Chapter 4** of this thesis, the potential exposure of national coastal marae to a 100 year ESL event from Paulik et.al, (2020) was conducted. This analysis detected 6 coastal marae potentially exposed to a 100 year ESL event at current MSL **(Table 6.1)**. The elevation of these coastal marae (**Table 6.1)** range from 1.02 to 4.51 m above MSL using the DEM, however, the elevation of TTT01 was collected using LiDAR as the DEM resolution caused a higher than expected result for that marae. The coastal geomorphology of these coastal marae potentially exposed to a 100 year ESL event include 3 shallow drowned valleys, 2 tidal river mouths and 1 waituna-type lagoon.

Table 6.1: The six coastal marae potentially exposed to a 100 ESL event at MSL anonymized with a code

Marae code	**Rohe**	**Elevation (m)**	**Distance (m)**	**Geomorphology**	**Rural / Urban**
WPU01	Waipounamu	1.0	682	Waituna-type lagoon	Rural
TTT01	Te Tai Tokerau	2.7	93.5	Shallow drowned valley	Rural
MAT01	Mātaatua	4.5	584.6	Tidal river mouth	Medium urban
TAW01	Te Arawa	2.8	75.3	Tidal river mouth	Urban rural
TGM01	Tauranga Moana	1.5	69.9	Shallow drowned valley	Major urban
TGM02	Tauranga Moana	2.0	35.5	Shallow drowned valley	Rural

These 6 coastal marae potentially exposed to a 100 year ESL event at MSL are low-lying with elevations less than 5 m above MSL, with distances to the coastline ranging between 35.5 – 682 m. Those 4 coastal marae that are low-lying and close to the coast (< 93 m to the coastline), (TTT01, TAW01, TGM01 and TGM02), are at a higher risk of inundation to a 100 year ESL event as SLR allows the wave-run up to move closer enabling inundation to occur (Ruggiero et al., 2001). The resulting inundation can result in flood damage to the marae and associated wharekai and urupā, but also has the potential to impact infrastructure of the marae including power supply, road and emergency services access, as well endangering vulnerable people when used as shelter during natural disasters (Hudson & Hughes, 2007).

In terms of the coastal geomorphology of these coastal marae, TTT01, TGM01 and TGM02 are in shallow drowned valleys and TAW01 is at a tidal river mouth. In general, shallow drowned valleys consist of many low-lying areas populated by human settlements and are the intersection between the terrestrial land and the marine environment (Kennish, 2002). The 3 shallow drowned valley coastal marae are low-lying with an average elevation of 5.83 m, with an average distance of 66.27 m to the coastline, with 2 being rural and 1 being in a major urban area. The response to SLR of these coastal marae will likely manifest as increased inundation of low-lying land (and coastal marae) as well as the potential for erosion of soft sediment coastlines, exacerbated by the small coastal buffer which exists between these coastal marae and the coast (Sweet & Park, 2014; Hume & Hart, 2020). This jeopardises infrastructure and accessibility to marae and the added complication of being rural, may pose a delay in arrival of emergency services and assistance during storm events (Brabyn & Barnett, 2004; Smith et al., 2011). A rise in sea level will see the permanent inundation of intertidal ecological habitats which may act as mahinga kai (traditional food sources) (Galbraith et al., 2002). Mahinga kai are utilised as food gathering areas for events which occur at the marae, such as hui and tangi, if these are impacted due to SLR, the potential impact on the community overall may be severe (King et al., 2012b).

The 2 coastal marae (TAW01 and MAT01) situated near a tidal river mouth are both low-lying with elevations of 2.81 m and 4.51 m, with distances of 75.25 m and 854.78 m and are classified as urban rural and medium urban respectively. These coastal marae could be potentially exposed to inundation from the river due to their low-lying position and small coastal buffer, as was discussed in Orton et al. (2020), where the Hudson river in the United States of America, saw flooding along the banks during hurricanes and ESL events. This could result in flood damage to the marae and surrounding structures and infrastructure which would be exacerbated by their rurality, hindering accessibility and connectivity.

Of the 6 marae presented in Table 6.1, 2 are low-lying with a large distance between them and the coast (<682 m to the coastline), such as WPU01 and MAT01. To understand the potential exposure of these coastal marae to coastal inundation, the terrain / topography between them and the coast must be considered. For example, if the topography has several rises and falls, and is not flat such as MAT01, inundation due to ESL and SLR may be less likely. However, as MAT01 is at a tidal river mouth (Hume et al., 2016), this coastal marae may also need to consider changes in river dynamics and sediment dynamics due to climate change discussed in **Section 6.4.4**. Whereas, if the topography is flat and with a constant elevation, such as at WPU01, inundation will still pose an imminent potential threat, with the impacts being similar to those coastal marae mentioned earlier. The nature of the tidal river mouth geomorphology of MAT01 was described earlier, but the geomorphology of WPU01 is highly unique as it was the only coastal marae in Aotearoa New Zealand to be located within a waituna-type lagoon.

Waituna-type lagoons are lacustrine, shallow brackish lagoons protected by high wave energy from the open coast by a clastic barrier beach (Kirk & Lauder, 2000). This type of coastal geomorphology had only 1 coastal marae detected nationally, as well as potentially being exposed to a 100 year ESL event. This coastal marae had an elevation of 1.02 m, with a distance of 682 m and was classed as rural. This makes it very low-lying with a considerable coastal buffer in between. However, the topography between this marae and the coast is very flat and hence inundation will pose a significant threat to this marae, exacerbated by the rurality of this marae hindering accessibility and traditional uses (King et al., 2012b).

Another key consideration for coastal marae and SLR is the frequency of extreme events. For example, 100 year ESL events usually occur about once a century, however with global climate change forces, causes these events to potentially occur at least once per year by 2050 (Paulik et al., 2019). This change in frequency may significantly impact availability of emergency services during storm events, significantly impacting the utilisation of marae during civil defence evacuations as discussed in Hudson and Hughes (2007) where Poupatate Marae provided shelter to the Manawatu – Wanganui area during a storm event of 2004. Whether these marae are rural or urban can further impact the accessibility to resources for these marae during natural hazard events as well as could significantly increase the costs of repeatedly post storm clean-up efforts (Pomeroy

& Newell, 2011; Owen et al., 2019). These coastal marae in the high exposure category are a mix of rural and non-rural marae, meaning that those marae in urban areas may experience easier resourcing and access to services both governmental and non when the impacts of SLR are felt (Statistics NZ, 2017). Whereas those in rural areas may struggle to obtain resources such as emergency services, public services and support services in a timely manner due to accessibility to these marae being strained (Pomeroy & Newell, 2011).

6.2.1 100 year ESL with sea level rise

The exposure analysis of coastal marae to a 100 year ESL event also considered and incorporated SLR increments of 10 cm up to 3 m. With 1 m SLR, in addition to the 6 coastal marae potentially exposed at current MSL, a further 16 coastal marae will be potentially exposed, another 11 with 2 m SLR and a further 8 with 3 m SLR. These coastal marae are spread around the country encompassing various rohe, and their elevation, distance and coastal geomorphology were highly variable **(Table 6.2)**.

Table 6.2: Coastal marae potentially exposed to a 100 year ESL event with SLR, showing rohe, average elevation, average distance and range of coastal geomorphology

SLR scenario	No. of marae	Rohe	Elevation average (m)	Distance average (m)	Geomorphology
100 year ESL (MSL)	6	Waipounamu, Te Tai Tokerau, Te Arawa, Mātaatua, Tauranga Moana	2.43 m	301.8 m	Waituna-type lagoon, Shallow drowned valley, Tidal river mouth.
100 year ESL + 1 m SLR	16	Waipounamu, Te Tau Ihu, Te Tai Tokerau, Hauāuru, Tainui, Te Arawa, Tauranga Moana, Mātaatua, Te Tai Rāwhiti, Tāmaki, Hauraki	5.76 m	164.5 m	Waituna-type lagoon, Shallow drowned valley, Tidal river mouth, Coastal embayment, Freshwater river mouth, Tidal lagoon.
100 year ESL + 2 m SLR	11	Waipounamu, Te Tau Ihu, Te Tai Tokerau, Hauāuru, Tainui, Te Arawa, Tauranga Moana, Mātaatua, Te Tai Rāwhiti, Tāmaki, Hauraki	7.66 m	232.7 m	Waituna-type lagoon, Shallow drowned valley, Tidal river mouth, Coastal embayment, Freshwater river mouth, Tidal lagoon, Beach stream, Deep drowned valley,
100 year ESL + 3 m SLR	8	Waipounamu, Te Tau Ihu, Te Tai Tokerau, Hauāuru, Tainui, Te Arawa, Tauranga Moana, Mātaatua, Te Tai Rāwhiti, Tāmaki, Hauraki, Tainui, Te Moana o Raukawa.	8.22 m	224.5 m	Waituna-type lagoon, Shallow drowned valley, Tidal river mouth, Coastal embayment, Freshwater river mouth, Tidal lagoon, Beach stream, Deep drowned valley,

There is a coastal marae in every rohe in Aotearoa New Zealand potentially exposed to a 100 year ESL event. The rohe with the most coastal marae potentially exposed to a 100 year ESL event is Te Tai Tokerau with 10 coastal marae, followed by Mātaatua with 7, Tāmaki with 5, Tauranga Moana and Hauraki with 4 **(Table 6.2)**. The average elevation of these coastal marae **(Figure 6.1)**, ranged from 2.43 – 8.22 m with the median elevation of all SLR estimates below 10 m, with the higher end potentially exposed to a SLR of 2 – 3 m. This highlights the extent of how low-lying coastal marae are nationally, and how many extra marae could be exposed due to SLR. The range of distances to the coast is large for those potentially exposed at current MSL **(Figure 6.2)**.

Some coastal marae were situated above / behind a cliff and may need to consider coastal erosion processes rather than inundation due to their elevation, however with a very small coastal buffer, there is limited time and space for decisions to be made (Bray & Hooke, 1997). An example of a coastal marae on a cliff is Oeo marae which was defined in Taranaki Regional Council (2009) as being situated on a cliff face which is comprised of easily erodible sandstone and mudstones, hence this marae may need to direct management for erosion protection. However, to understand the response of these cliffs to SLR a thorough understanding of the geology, vegetation, vertical land movement, water levels and waves of and around these cliffs is required (Tonkin+Taylor, 2018), however this was beyond the scope of this research. The coastal geomorphology of these coastal marae potentially exposed to a 100 year ESL event is highly variable (**Figure 6.3**). However, the most common type of coastal geomorphology was the shallow drowned valley which is agreeable with the national coastal geomorphology assessment of national coastal marae in **Section 5.4**.

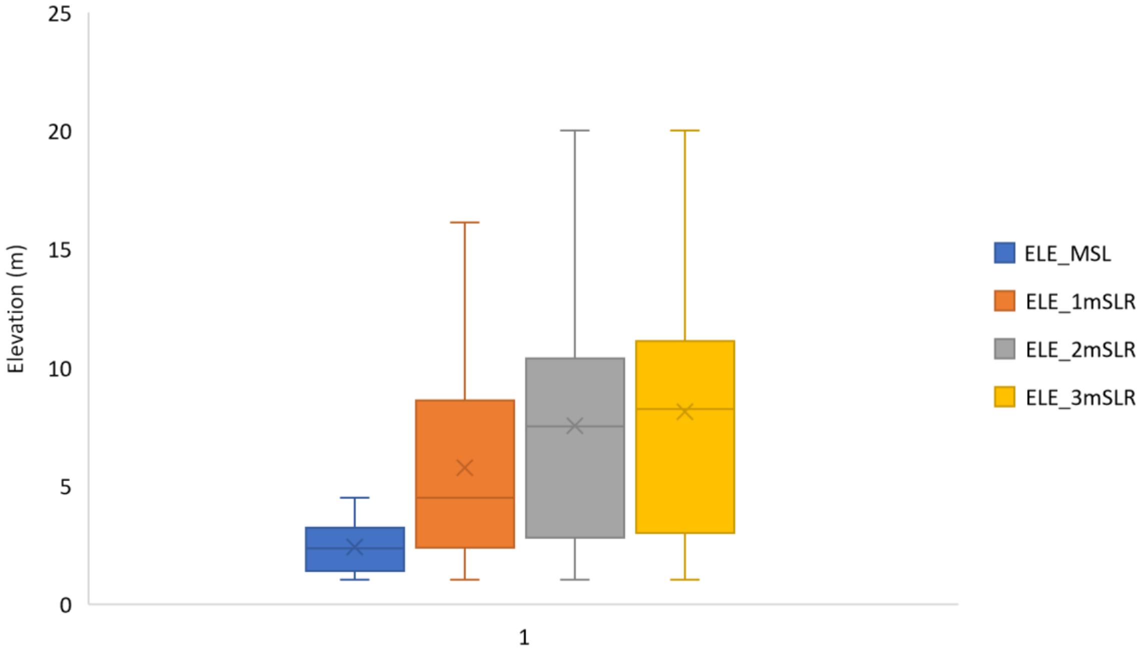


Figure 6-1: Boxplot of the elevation of coastal marae potentially exposed to a 100 year ESL event with SLR

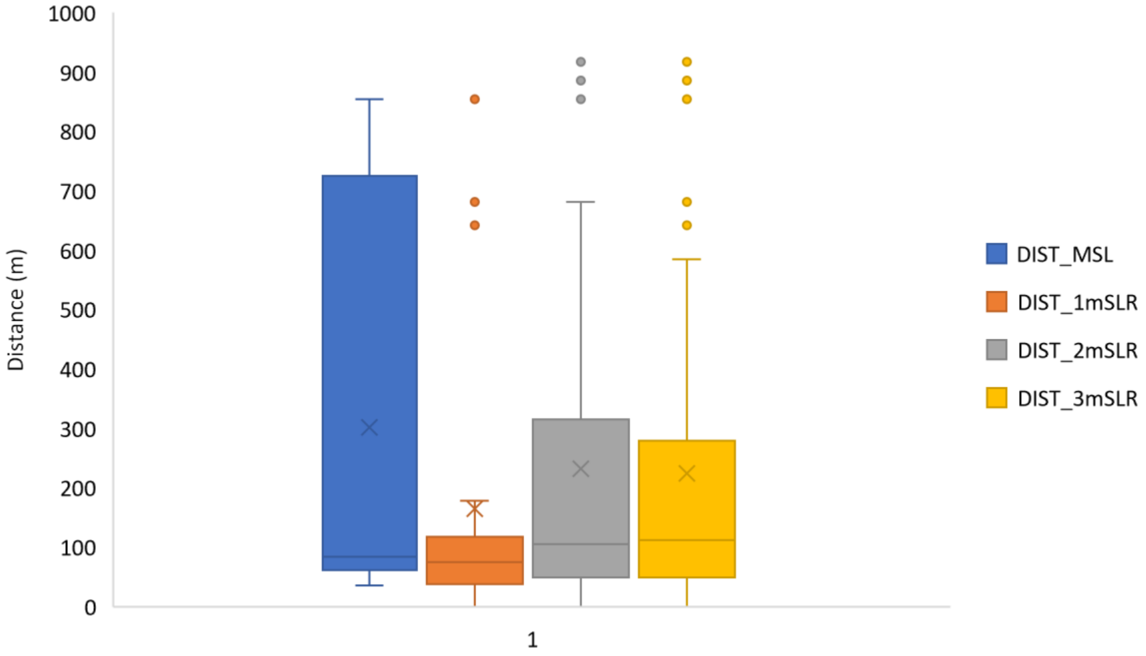


Figure 6-2: Boxplot of the average distance to the coast of coastal marae potentially exposed to a 100 year ESL event with SLR

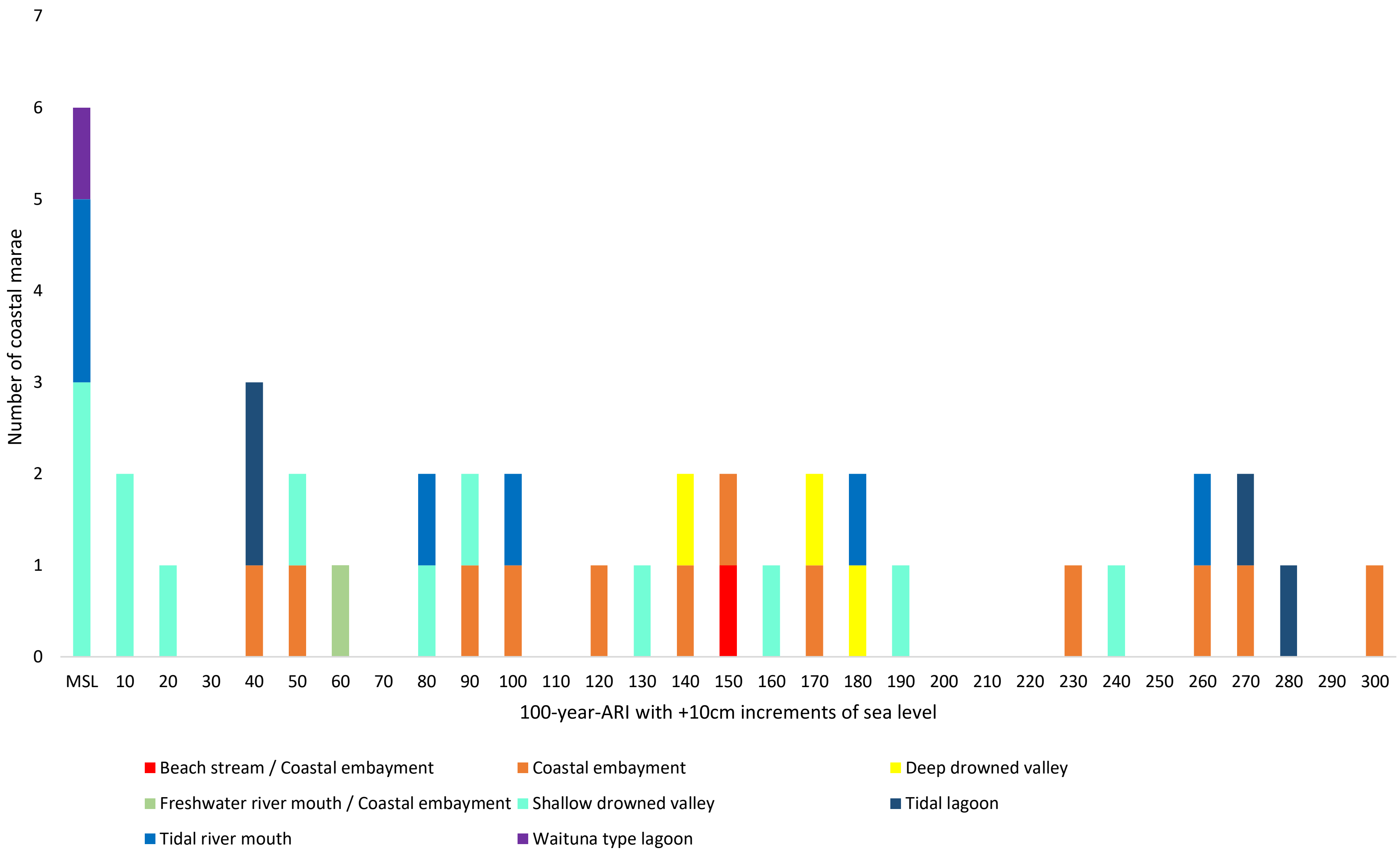


Figure 6-3: Coastal geomorphology of national coastal marae detected to be exposed to a 100 year ESL at incremental 10cm rises in sea level

6.2.2 Geomorphological response to sea level rise

Chapter 5 outlined the wide range of coastal geomorphologies fronting coastal marae in Aotearoa New Zealand. Coastal geomorphology plays an important role in the response of the coast to SLR and is an important factor to consider the overall impact of SLR (Bell et al., 2017; Hume & Hart, 2020). In terms of the Hume et al. (2016) classification applied in this thesis, Hume and Hart (2020) investigated the response of these systems to SLR. These coastal geomorphologies respond to SLR and climate change by the interaction of key factors including local basin morphometry and ocean forcings. It is important to note that some coastal marae in this thesis had a combination of two differing geomorphic types, and hence these coastal marae will experience a mixture of responses due to SLR. The rest of this section will describe the impacts associated with each hydrosystem of coastal marae, and the impact SLR may have on the geomorphology surrounding coastal marae. This is followed by a discussion of **common impacts** across the hydrosystems.

Waituna-type lagoon

There was 1 coastal marae with this type of coastal geomorphology, located in the Waipounamu rohe (South Island). This geomorphology is likely to experience a change in waves and sea level due to climate change and has the potential to restrict outlet drainage, exposing low-lying land to inundation and erosion. SLR can affect the sediment dynamics of these systems and may lead to some barriers breaching and eroding, transforming into hydrosystems such as an estuary or embayment, impacting the biodiversity (Hume & Hart, 2020). The 1 coastal marae in a Waituna-type lagoon is 682 m from the coastline but is low lying with an elevation of just 1.02 m, and potentially exposed to a 100 year ESL event at MSL. The impacts due to SLR for this coastal marae are mentioned in the **common impacts** section below, but specific to this geomorphology include barrier breaching, changes in the water and sediment dynamics and impacting habitats of native birds as well as migratory birds (Kirk & Lauder, 2000).

Beach stream

The 14 coastal marae at beach streams have an average elevation and distance to the coast of 15.4 m and 371.5 m respectively. These marae were found within the Te Tai Tokerau (3), Tāmaki (1), Hauraki (1), Te Arawa (1), Mātaatua (2), Te Tai Rāwhiti (3), Tākitimu (2) and Hauāuru (1) rohe, with only 1 coastal marae near a beach stream to be found to potentially be exposed to a 100 year ESL with SLR in Tāmaki. Three coastal marae are low-lying and their associated beach stream flows along flat, narrow, plains and are potentially more susceptible to SLR than those 11 coastal marae which are situated on steeper terrain, such as on steep cliffed coasts or small hills. SLR could also see tidal intrusion reach further up the beach stream and in some cases squeezed against the steepest point of the terrain (Hume & Hart, 2020). The impacts due to SLR for these coastal marae are mentioned in the **common impacts** section. SLR can interrupt biological processes related to freshwater systems such as tuna (eel) migratory pathways (Todd, 1981) or sedimentation which affects watercress in streams which are an important food source of Māori.

Freshwater river mouth

There were 11 coastal marae that were near a freshwater river mouth and were located within the Mātaatua (2), Te Tai Rāwhiti (6), Tākitimu (1) and Hauāuru (2) rohe, with 1 coastal marae near a freshwater river mouth to be potentially exposed to a 100 year ESL event with SLR situated in Hauāuru. The average elevation and distance of these coastal marae was relatively high at 15 m and 398 m respectively. However, 5 of these coastal marae are less than 200 m from the coastline, whereas the remaining 6 range from 200 – 1000 m from the coast. The impacts due to SLR for coastal marae near a freshwater river mouth are described in the **common impacts** section, specifically those 5 coastal marae that are closer to the coast are likely to encounter both associated impacts from the coast such as SLR and storm surge, as well as changes in freshwater discharge in the river from changes in rainfall from the catchment (van Vliet et al., 2013). SLR is likely to promote erosion, however, it may be offset in some instances by increased river flow from the catchment, resulting in more sediment being deposited (Walling & Fang, 2003).

Tidal river mouth

There were 15 coastal marae at a tidal river mouth. In the Te Tai Rāwhiti rohe there were 4 coastal marae, followed by Mātaatua (3), Te Arawa (2), Hauāuru (2), Te Moana o Raukawa (1), Te Tai Tokerau (1), Hauraki (1) and Tainui (1) rohe. The average elevation and distance of coastal marae with this type of coastal geomorphology is 16.6 m and 487.4 m respectively, with 6 of these coastal marae potentially being exposed to a 100 year ESL event with SLR. Eight of these coastal marae are situated below 10 m elevation to MSL, with distances ranging from 75.2 m – 917.4 m. The topography towards the coast is mostly flat, with some coastal marae having slopes and cliffs at the intersection of the coast. An example of a marae in this type of profile documented in the media is Mirumiru marae situated in the Waitomo, Tainui rohe. In 2018 their marae was at risk of flooding and erosion due to rising sea levels. This marae is situated on a river mouth at the coastline and hence its position will be potentially affected by increased runoff from the catchment as well as the impacts from SLR (Day, 2018). Tidal river mouths typically respond to SLR by tidal intrusion reaching further up the system which can negatively impact our freshwater pumping stations (Hume & Hart, 2020). With rivers providing half of Aotearoa New Zealand's drinking water with pumping stations situated higher up these rivers (Gluckman et al., 2017; Ministry for the Environment & Statistics NZ, 2020), tidal intrusion will be of particular importance for those coastal marae that are in rural settings as drawing of water from rivers and some aquifers supply the marae with its water (Oliver & Steel, 2009). Tidal intrusion can also affect the biodiversity in these systems due to a change in the salinity regime which may impact habitats and species (Neubauer, 2013).

Tidal lagoon

There were 12 coastal marae near a tidal lagoon, with most (7) in the Te Tai Tokerau rohe, followed by Hauraki (1), Te Arawa (2), Mātaatua (1) and Te Tau Ihu (1), with 4 of these coastal marae being potentially exposed to a 100 year ESL event with SLR. The average elevation and distance of coastal marae with this type of coastal geomorphology is 18.1 m and 374.5 m respectively, with 11 marae being below 20 m elevation to MSL with gentle slopes to the coast. Many of the coastal marae with this type of coastal geomorphology have dunes at the coast. This bodes well in terms of protection against inundation processes and acting as a buffer against SLR and associated erosion, however maintenance is required for the dune to continue as a defence mechanism (Doody, 2012; Hanley et al., 2014). The impacts due to SLR for coastal marae near a tidal lagoon are mentioned in the **common impacts** section. However, specific to tidal lagoons is that the wave action will change the rate of erosion of soft sediment coasts and change the entrance dynamics of these systems (Haines, 2008). A change in waves will affect the sediment dynamics inducing larger tidal prisms, causing sediment to accrete on deltas at channel entrances which may require dredging (Hicks & Hume, 1996; Haines & Thom, 2007).

Shallow drowned valley

There were 72 coastal marae within shallow drowned valleys. Te Tai Tokerau rohe had the most (29) coastal marae in this category, followed by Tauranga Moana (19), Tainui (12), Tāmaki (9), Hauraki (1), Te Tau Ihu (1) and Waipounamu (1), with 13 of these coastal marae potentially being exposed to a 100 year ESL event with SLR. The average elevation and distance of coastal marae with this type of coastal geomorphology is 16.3 m and 294.5 m respectively, with profiles ranging from above a cliff, low-lying and some having a dune. Research on SLR impacts on estuaries lack interdisciplinary studies which integrate physical, ecological, bio-geochemical and geomorphic responses (Khojasteh et al., 2021). The dynamic shallow and convergent nature of these systems result in a complex interaction between these features and SLR (Palmer et al., 2019), affecting tidal dynamics (Haigh et al., 2020; Talke & Jay, 2020), sediment dynamics (Prandle, 2009; Coco et al., 2013), inundation of coastal land (Hanslow et al., 2018), coastal squeeze (Sweet & Park, 2014) and damage to intertidal habitats (Mieszkowska et al., 2013; Mieszkowska et al., 2020). Much of the general Aotearoa New Zealand population are positioned within estuaries (Parliamentary Commissioner for the Environment, 2020) including coastal marae and hence careful management is required for coastal marae which are potentially most at risk to the impacts of SLR. Sedimentation may become a problem due to erosion of low-lying coastal land, potentially requiring dredging to maintain channel depth to facilitate larger vessels such as in Tauranga Harbour (Healy et al., 1997). However, dredging can also have impacts on the hydrodynamics, such as currents, tidal amplification and changes in the tidal prism (Winterwerp & Wang, 2013), turbidity (Pennekamp et al., 1996) and potentially adversely impacting the marine ecology such as seagrasses (Erftemeijer & Lewis, 2006).

Deep drowned valley

There were 14 coastal marae in deep drowned valleys. The most coastal marae found within a deep drowned valley were situated in the Te Tai Tokerau rohe with 8 coastal marae, followed by Waipounamu (8), Mātaatua (2) and Te Tau Ihu (1), with 3 of these coastal marae being potentially exposed to a 100 year ESL event with SLR. The average elevation and distance of these coastal marae with this type of coastal geomorphology were 12.5 m and 247.3 m respectively. These coastal marae are very low-lying with a short distance to the coast, this potentially makes them more vulnerable to coastal inundation due to SLR. The impacts due to SLR that these coastal marae may experience are discussed in the **common impacts** section.

Coastal embayment

There were 52 coastal marae in a coastal embayment. The most coastal marae found with this type of coastal geomorphology were situated in the Te Tai Tokerau rohe with 14 coastal marae, followed by Te Tai Rāwhiti (11), Mātaatua (9), Hauraki (5), Waipounamu (4), Te Tau Ihu (3), Tākitimu (2), Tāmaki (2), Tauranga Moana (2), Hauāuru (1) rohe, with 14 of these coastal marae potentially being exposed to a 100 year ESL event. The average elevation and distance of these coastal marae with this type of coastal geomorphology is 19.4 m and 256.5 m respectively. These coastal marae are in elevated positions with a short distance to the coast and with closer inspection of some of these coastal marae, some have a dune at the coast and some have a sandy beach with little or no dunes. Hence, many coastal marae may face coastal squeeze due to this small coastal buffer and lack of dunes, allowing for the increased inundation and erosion to occur at these coastal marae as the wave-runup is bought closer (Pontee, 2013; Hanley et al., 2014; Hume & Hart, 2020). However, due to the limited entry that waves have in these systems compared to that of the open coast, due to the presence of headlands which result in an alongshore wave energy gradient and the degree of embaymentisation (Fellowes et al., 2019), the morphology will adjust to these conditions (Gallop et al., 2020b). However, when wave direction aligns with the orientation of the entrance, they have the potential to cause a shoreline planform rotation (Slott et al., 2006), where the preferential accumulation of sediment occurs at 1 of the headlands of the embayment (Bryan et al., 2013). The change in the wave climate within embayed beaches is likely to be a more imminent threat than SLR (Cowell et al., 1995), with the wave climate around Aotearoa New Zealand and globally already changing due to tropical cyclone intensity (Goodwin et al., 2016; Harley et al., 2017), large climatic systems (Godoi et al., 2016, 2018) and deficits in sediment transport systems (Cowell et al., 1995). This means that for coastal marae situated within an embayed beach, changes in wave climate due to SLR is going to occur quicker than the sea level rising itself, meaning that for some marae where beach rotation occurs or erosion intensifies, the pressure to make decisions will be greater.

Open coast

There were 22 coastal marae along the open coast, with 5 in the Mātaatua rohe followed by Hauāuru (4), Tākitimu (4), Te Tai Rāwhiti (3), Waipounamu (2), Te Tai Tokerau (2), Te Arawa (1) and Tainui (1), with none of these coastal marae being potentially exposed to a 100 year ESL event. The average elevation and distance to the coast of these coastal marae within this type of geomorphology is 21 m and 369.3 m. These coastal marae are relatively elevated with a short distance to the coast. Inspection of the topographical profile of some of these coastal marae, they are highly variable with some being situated above cliffs, some have gentle slopes to the open coast with no dune situated at the intersection and some have dunes. SLR may cause a change in wave action so sediment accumulation can occur with a change in the tidal prism of these systems resulting in an increase surface area (Ranasinghe, 2016). The open coast system can be impacted by SLR similarly to the other geomorphologies mentioned, such as changes in the sediment transport system (Cowell et al., 1995) and tropical cyclone induced erosion (Morton & Asbury, 2003; Harley et al., 2017), creating a similar situation to those coastal marae found with a coastal embayment.

Damp sand plain lake, Hapua-type lagoon and Fjords

There were 3 of the 12 coastal geomorphologies as part of the Hume et al. (2016) that did not have coastal marae located within them. These include damp sand plain lake, hapua-type lagoons and fjords. The lack of coastal marae in these categories is likely down to their attributes that perhaps did not align to coastal Māori settlement requirements for fishing, trade, and waka transport (Wehi et al., 2013). For example, dune lakes are not ideal waterbodies to sustain Māori communities as they are relatively small and disconnected from the sea (Champion & deWinton, 2012). Hapua-type lagoons are the intersection of large braided freshwater rivers and the coast, which means they would have the ability to sustain coastal Māori communities in terms of resources such as the Rakaia river which is a hapua-type lagoon which served as the mahinga kai of the Ngai Tūāhuriri people of Kaiapoi (Tau et al., 1990; Challis, 1995). However, the positioning of Māori communities understood natural hazards pertinent to the area contained within pūrākau (stories) as described in a case study by Hikuroa (2017) where the Waitepuru stream exits at the coast near Matatā, Eastern BOP. To the local hapū, the stream is a taniwha (water spirit) in the form of a lizard, with the head further up the stream and the tail at the coast. During storm events, the tail flicks side to side, causing changes in the position of the stream, and evidence suggests that Māori communities placed their marae in areas where the stream never touches. This was exemplified in a 2005 debris flow event where several houses were damaged, yet the marae were not impacted. Lastly, while fjords, host freshwater and seawater environments with the associated habitats and ecosystems, they could provide as a resource to a Māori community, however, their topography is very steep, with not many locations or beaches where you can set up a settlement. However, they may in the past have had settlements and still been important areas to Māori, where they would go and collect the plentiful seasonal resources the fjord provided such as greenstone (Department of Conservation, 2007).

Common impacts

There are many potential impacts of SLR that are similar for a range of geomorphologies. Such as overland flooding due to SLR is likely across the board, causing inundation of low-lying coastal land (Wang et al., 2005) where coastal marae and urupā are positioned. Flooding can cause access issues for emergency services (Yu et al., 2020), power outages (Wang et al., 2016), flood damage of marae infrastructure (McRae, 2015) and could potentially endanger vulnerable people who utilise marae as civil defence evacuation centres during natural disasters (Hudson & Hughes, 2007). Associated with SLR is the potential for erosion of coastal land that coastal marae are situated on (Gornitz, 1991; Tonkin+Taylor, 2018), changes to the tidal prism (Ranasinghe, 2016), altered sediment transport (Jerolmack & Paola, 2010), increased intensity and frequency of storm surge (Stephens et al., 2016) and tropical cyclones (Harley et al., 2017). These changes in MSL, flooding and sediment dynamics can have an effect on the intertidal habitats within estuarine systems, causing complete submergence and sedimentation (Norkko et al., 2006), compromising mahinga kai of the marae (King et al., 2012b) as well as impacting traditional practices of wananga and hui which occur at the marae. However, all of these changes which occur with SLR, ranging from inundation, erosion, sedimentation and changes in waves and tides, will undoubtedly have an impact on the mauri (life force or essence) of the environment which are key signals to ascertain the health and well-being of the environment as well as the Indigenous Māori who inhabit these areas (Morgan, 2006; Faaui et al., 2017).

6.2.3 Te Tai Tokerau coastal marae

In this section I focus further on Te Tai Tokerau , which has the most coastal marae of any rohe (61), and also had the most coastal marae nationally at elevations less than 10m as mentioned in **Section 4.4**. This rohe has many remote and rural areas with a dense Māori population where the marae counts as both a hub of cultural and historical importance but also to the rural communities surrounding them. The average elevation and distance to the coast of these coastal marae were 18.6 m and 283.8 m respectively. However, 20 of these coastal marae are situated below 10 m elevation, making them very low-lying with the same number of coastal marae are less than 100 m to the coastline. Hence inundation due to SLR may pose a potential hazard to these coastal marae and due to the very small coastal buffer that these marae have, coastal erosion may also pose a potential threat to these coastal marae. Taking a deeper look at these coastal marae, their topographical profiles to the coast are highly variable with some being situated on cliffs represented by their high elevation, some are very low-lying with a very small gentle sloping path to the coast, some with a dune at the intersection with coast and some with rises and falls as undulating hills. This shows the varied and dynamic nature of Te Tai Tokerau. The geomorphology of these Te Tai Tokerau coastal marae include: 29 shallow drowned valleys, 13 coastal embayment's, 8 deep drowned valleys, 7 tidal lagoons, 2 beach streams / open coast and 1 beach stream / coastal embayment**.** The 29 coastal marae in shallow drowned valleys in Te Tai Tokerau are situated within harbours and estuaries which respond to SLR as mentioned in **Section 6.3.1**. Many of the coastal marae in Te Tai Tokerau rohe are identified as being in rural or semi-rural areas (Statistics NZ, 2017). The rural definition can dictate community response and governmental resourcing for natural hazards, as well as vital infrastructure such as emergency response and access to health services can be lacking in rural areas (Brabyn & Barnett, 2004; Pomeroy & Newell, 2011). The reliance on primary industries such as farming, forestry and agriculture of rural communities makes these coastal marae more susceptible to the impacts of SLR (Manning et al., 2011; Reisinger et al., 2014; Manning et al., 2015).

6.3 Limitations and future research

This research has produced some compelling, nationwide baseline data to aid understanding of the exposure of coastal marae and urupā to SLR. However, there remains much research to be done that was beyond the scope of this thesis, some of which is discussed below:

6.3.1 Coastal erosion

It was highlighted in this research that many coastal marae and urupā occur above a coastal cliff or had a dune at the intersection with the coast, thus for many marae and urupa coastal erosion is likely to be a more pressing issue than coastal flooding, and is already occurring around Aotearoa New Zealand. Demonstrated in emotive examples such as "Historical Māori kōiwi bones unearthed by erosion in Nūhaka" Angeloni (2021) and "Calls for council help as extreme weather erodes sacred Māori burial grounds" Perera (2019). With SLR, the increased water depth at the coast means that wave runup can reach further up the shore (Senechal et al., 2011). This can increase coastal erosion, which can also increase the risk of coastal flooding (Ruggiero et al., 2001). In addition potential changes in wave climate, including direction must also be considered (Gallop et al., 2020b). An example of assessing erosion risk to important sites by Reimann et al. (2018) investigated the risk of world heritage sites in the Mediterranean to coastal flooding and erosion due to SLR, highlighting areas which urgently needed support from policymakers to adapt to the issues of climate change.

6.3.2 Bathtub modelling approach

As was discussed in **Section 3.5.5,** while bathtub modelling continues to be the most common way of determining coastal inundation due to SLR (Didier et al., 2019), this approach generally overestimates inundation as it disregards flow obstacles like floodgates and bridges (Kirwan et al., 2016; Seenath et al., 2016). However, for further research at potentially regional or local scales, process-based hydrodynamic modelling would be the way forward to produce accurate estimates of inundation zones to ensure that management is expended at the right locations. However, given that coastal marae and urupā are situated around the entire Aotearoa New Zealand coast, encompassing many coastal hydrosystems, conducting hydrodynamic modelling for every hydrosystem will be very complex, resource intensive and expensive.

6.3.3 Vertical land movement

The 100 year ESL coastal flood maps produced in Paulik et al. (2020) did not incorporate vertical land movement into their predictions of ESL. Relative SLR accounts for vertical land movement (Rovere et al., 2016). Using vertical land movement accurately predicts SLR estimates in a regional setting, especially in a tectonic setting such as Aotearoa New Zealand (Denys et al., 2020) as well as to consider glacio-isostatic adjustment, oil extraction or groundwater extraction (Carter et al., 1989). In terms of vertical land movement, it is important for coastal marae as this can considerably change the response to SLR of the coastline as well as the accuracy of SLR estimates which can lead to overestimation of management structures (Montillet et al., 2018). However, vertical land movement is being factored into SLR estimates for Aotearoa New Zealand as part of the New Zealand Sea Rise programme. This is a $7.1 million five-year project funded through the Ministry of Business, Innovation and Employment and aims to improve SLR predictions and better understand the consequences of SLR on the Aotearoa New Zealand coastline.

6.3.4 Sediment transport and availability

Sediment transport and availability to coastal areas dictates the response of the coast to SLR (Alexandrakis & Poulos, 2014). This thesis did not consider sediment transport and availability, however, they are critical as they control the direction and amount of sediment available to the coast (de Swart & Zimmerman, 2009; Jerolmack & Paola, 2010). SLR will likely result in an increase in the accommodation space (area available for sediment deposition) effectively reversing the progression of estuarine maturity (Liu et al., 2020). However, the impact of SLR can depend on the ability of the intertidal zones to trap sediment at the same rate of SLR (van Maanen et al., 2013; Kirwan et al., 2016), such that if there is insufficient sediment, the estuary will migrate landwards (Cox et al., 2002) and if there is sufficient sediment, the estuary will accrete seawards (Lorenzo-Trueba & Ashton, 2014). The tidal range also affects the sediment dynamics, such that with SLR, many estuaries that are ebb dominant become flood dominant, transitioning from fluvial sediment export to marine sediment import, allowing to compensate the accommodation space created by SLR (Liu et al., 2020). However, the origin of these marine sediments could be from the erosion of ebb-tidal deltas or from the open coast, causing erosive issues elsewhere (Leuven et al., 2019). Hence sediment transport could be infilling at 1 coastal marae within the estuary, however, that sediment could be coming from another coastal marae on the open coast. Most SLR impacts on sediments utilise the Bruun rule which is used to understand shoreline responses due to SLR based on the equilibrium beach profile (Bruun, 1962; Dean & Houston, 2016). It assumes that as SLR, sediment from the shoreline will be eroded to be deposited on the shore floor to a closure depth, deep enough that sediment transport currents are negligible and the sediment is able to maintain the active profile of the beach, causing a recession in the shoreline (Cooper & Pilkey, 2004; Ranasinghe et al., 2013). However, this basic model prevails through time as no significant advancement has been widely accepted, even though the limitations of the Bruun rule are well documented such as in Cooper et al. (2020) and Vousdoukas et al. (2020).

6.3.5 Uncertainty of climate change predictions

With any predictions made about the future there will always be uncertainty, as is the case of climate change predictions, especially when groups ranging from central governments to small local communities are required to establish and implement adaptation or mitigation strategies to combat the issues arising from climate change (Latif, 2011; Jones et al., 2014; Bell et al., 2017). The uncertainty surrounding climate change predictions arise from three main sources: natural variability (Deser et al., 2012), model uncertainty (Kunreuther et al., 2013) and greenhouse gas emission scenarios (Hawkins & Sutton, 2009). However, it is not viable to wait until uncertainties have diminished for those exposed and future generations, as the consequences of acting and not acting can be substantial. Lewandowsky et al. (2014) showed that the greater the uncertainty the greater the risk from adverse impacts. Hence the act of doing nothing in the face of great uncertainty opens yourself to greater risk and impact (Lewandowsky et al., 2014). Thus, it is advised that having a broad range of future conditions being considered to account for that uncertainty leads to better decision making and responses in the future. One such method is the Dynamic Adaptive Policy Pathways (DAPP) (Bell et al., 2017). DAPP is a decision making methodology which aims to create tools to make adaptive decisions under uncertain scenarios through global and regional changes through creating a framework of short-term and longer term actions as well as a framework to guide future decisions in a changing environment set about by climate change (Haasnoot et al., 2013; Lawrence et al., 2019).

6.3.6 Dynamic Adaptive Policy Pathways

The dynamic adaptive policy pathway was recommended by (Bell et al., 2017) for local governmental bodies to utilise and plan for climate change impacts. It was weaved into the 10-step decision cycle **(Figure 6.4)** used in Bell et al. (2017), where the 10 steps are structured around five key questions: 1) What is happening?, 2) What matters most?, 3) What can we do about it?, 4) How can we implement the strategy? And 5) How is it working?. Understanding "What is happening?", involves setting up the structure and understanding what questions need to be answered. This leads into "What matters most?", what values and objectives are important to the coastal marae, hapū or iwi, how vulnerable is our marae to SLR and how can SLR affect the values outlined.

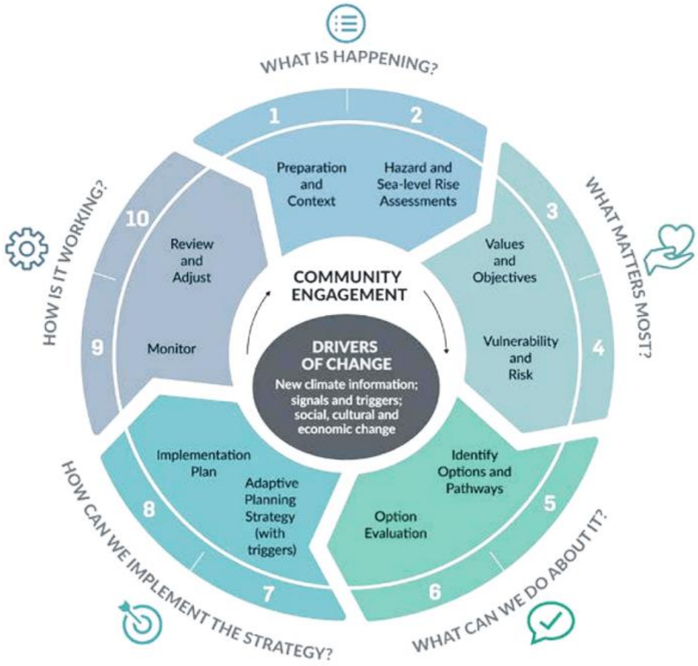


Figure 6-4: 10 step decision cycle for climate change adaptation (Bell et al., 2017)

The next question is "What can we do about it?", this was a common point of discussion brought up by marae I have spoken to, they really wanted to know what they could do. Based on 4 options which could include **Accommodate,** such as adjusting the existing structures and adding measures at the marae that anticipate hazards risk, such as raising the building or creating alternative flood pathways. **Protect,** defend the coastal marae using natural protective structures like dunes, or hard engineering structures like seawalls. **Retreat**, relocate coastal marae to sustainable areas in a managed manner over time, or in response to impact events. **Avoidance**, avoid constructing new marae in zones of potential SLR impact. "How can we implement the strategy?". This is where the DAPP process mentioned earlier becomes useful in that it produces a series of actions/pathways to achieve an objective, of which can change depending on the current climate.

The final stage of this decision cycle is "How is it working", which involves monitoring and regular reviews of the plans and incorporating the latest research so if the plans are not working for the situation, a review can then make decisions to bring the strategy back on track. Throughout the decision making process adapted from Bell et al. (2017), ensuring that collaboration with community stakeholders, scientists, policy makers and iwi/hapū representatives is imperative. This is echoed through many research projects and literature where a high value is placed on Indigenous knowledge of natural hazards and mātauranga Māori disseminated through kaupapa Māori research methodologies which re-enforce engagement and collaboration with Māori stakeholders such as King et al. (2007); Salmon (2008); King et al. (2008); King and Goff (2010); King et al. (2013); Macfarlane and Macfarlane (2018); Paul-Burke et al. (2020) just to name a few.

6.3.7 Planning for the future

With regards to marae and urupā, it is important to understand the impacts of climate change, as these places are important to Māori identity and culture as well as to Aotearoa New Zealand as a whole. Future research regarding marae and urupā needs to understand their exposure to other impacts of climate change, not just SLR and should be inducive of Te Ao Māori and the knowledge and protocol systems which accompany it such as mātauranga Māori. Solutions need to identify cultural aspects which have to be accounted for to ensure safe management as well as robust analysis into the logistical and financial aspects of selected management schemes is vital as many marae and associated urupā around Aotearoa New Zealand struggle to obtain maintenance costs, and understanding the avenues of legislative funding and support is paramount.

Potential funding for climate change adaptation of the Aotearoa New Zealand coastline has been a contemporary issue with the imposing reform of the 30-year-old Resource Management Act (RMA) of 1991, which was ground breaking in its conception, however with climate change the policy has been to blame for many issues facing Aotearoa New Zealand (Iorns, 2021). The reform will consist of three pieces of legislation: 1) Natural and Built Environments Act, to enhance the quality of the environment in order to support the wellbeing of present and future generations. 2) Strategic Planning Act, to provide a strategic and long-term approach for land-use and coastal marine areas and 3) Climate Change Adaptation Act, this act will support the national response to the effects of climate change, addressing the legal, technical and financial complexities that surround managed retreat (Minister for the Environment, 2020). The Climate Change Adaptation Act is of particular interest to this research as in some cases, some coastal marae and urupā will inevitably need to be relocated to a more sustainable area, and hence having central government legislation to provide support for these marae is advantageous.

Other legislation and support for coastal marae include the Ministry for the Environment: coastal hazards and climate change guidance for local government which was discussed in **Section 6.4.5**. Another piece of legislation is the New Zealand Coastal Policy Statement 2010 by the Department of Conservation (2010) which is a national policy statement under the RMA which includes policies that favour the disallowing of developments in areas exposed to natural hazards (Department of Conservation, 2010; Iorns, 2019).These two reports acknowledge and place emphasis on the engagement process with community, with a focus on tangata whenua (Bell et al., 2017). However, when working with coastal marae, hapū and iwi in terms of dealing with the issues arising from climate change, it is imperative that the engagement, integration and management is reflective of the Treaty of Waitangi principles of partnership, right to govern, reciprocity, active protection, good faith, development and redress (Iorns, 2019). The treaty principles are important to uphold as discussed in Iorns (2019) in terms of managed retreat and climate change adaptation because of the strong spiritual and ancestral ties Māori have to the land as mentioned in depth in **Chapter 2**. Iorns (2019) goes on to argue that it cannot and should not be assumed that the land that marae, urupā or wahi tapu are situated on can be easily replaced by that of comparable economic value, as cultural value has the upmost importance, and management should be reflective of this fact.

6.4 Conclusion

The overall thesis aim was to understand the potential exposure of coastal marae and urupā to SLR. This was achieved through understanding the potential exposure of coastal marae to SLR. There were 6 coastal marae found nationally to be potentially exposed to a 100 year ESL event at MSL. These coastal marae were very low-lying and were close to the coastline within their coastal geomorphologies consisting of 1 waituna-type lagoon, 2 tidal river mouths and 3 shallow drowned valleys. When SLR is added to the exposure of 100 year ESL events in 10 cm increments, with a 1 m rise, 16 coastal marae are potentially exposed, followed by 11 coastal marae at 2 m and a further 8 coastal marae at 3 m. These coastal marae were low-lying and close to the coastline, with shallow drowned valleys being the most common type of coastal geomorphology followed by a coastal embayment. 72 coastal marae of the 191 national coastal marae being situated within a shallow drowned valley or estuary. In understanding the exposure to SLR, understanding the role geomorphology plays is vital. The shallow drowned valleys were the most complex geomorphology to respond to SLR with the potential loss of intertidal habitats, destroying mahinga kai of coastal marae and hapū, inundation of low-lying land causing flood damage and the potential disruption to the sediment dynamics controlling the erosive nature that accompanies SLR. Leading to potentially damaging dredging processes to maintain channel depth in large, economic dependent ports such as Tauranga Harbour. The national potential exposure of coastal marae highlighted the scale of this issue in the Te Tai Tokerau (Northland) rohe. Te Tai Tokerau has 61 coastal marae, with 18 coastal marae below 10m elevation, with 9 of these within 100 m of the coast. Shallow drowned valleys being the most common coastal geomorphology of coastal marae in this rohe, following the national trend and would certainly be an area for further research as the cases are numerous. There were also topographical profiles which indicated the coastal marae or urupā was on a cliff face, meaning that inundation due to SLR doesn't pose the greatest risk to these marae and urupā, however, erosion due to SLR may pose a greater potential risk and should be the focus of future research. There were also some coastal marae and urupā which had a dune in front which will act as a natural barrier to SLR as well as a sediment buffer to essentially buy some time for management strategies to be enforced.

Continuing on from this research, addressing the limitations and incorporating them as time proceeds with research and data becoming more available is paramount to ensure the accuracy and dependability of this dataset. As has been the metaphorical elephant in the room throughout this master’s thesis, the “so what do we do about it?” question is ultimately the next thing that needs to be answered. However, this is not an easy question to answer as I outlined in the future research directions, where the utilisation of the dynamic adaptative policy pathways (DAPP) as outlined by Bell et al. (2017) may be one step forward in creating management and adaptation solutions to combat SLR. However, with the RMA reform, creating and funding these solutions for coastal marae and urupā are likely to be easier to achieve. Lastly, the emphasis that these pieces of legislation and governmental documents place on upholding the Treaty of Waitangi principles and engagement with tangata whenua is a first step in the right direction. Future solutions need to be all these things bundled together, with the incorporation of Indigenous knowledge systems such as mātauranga Māori, and ensure that they are valued and accepted in their entirety.

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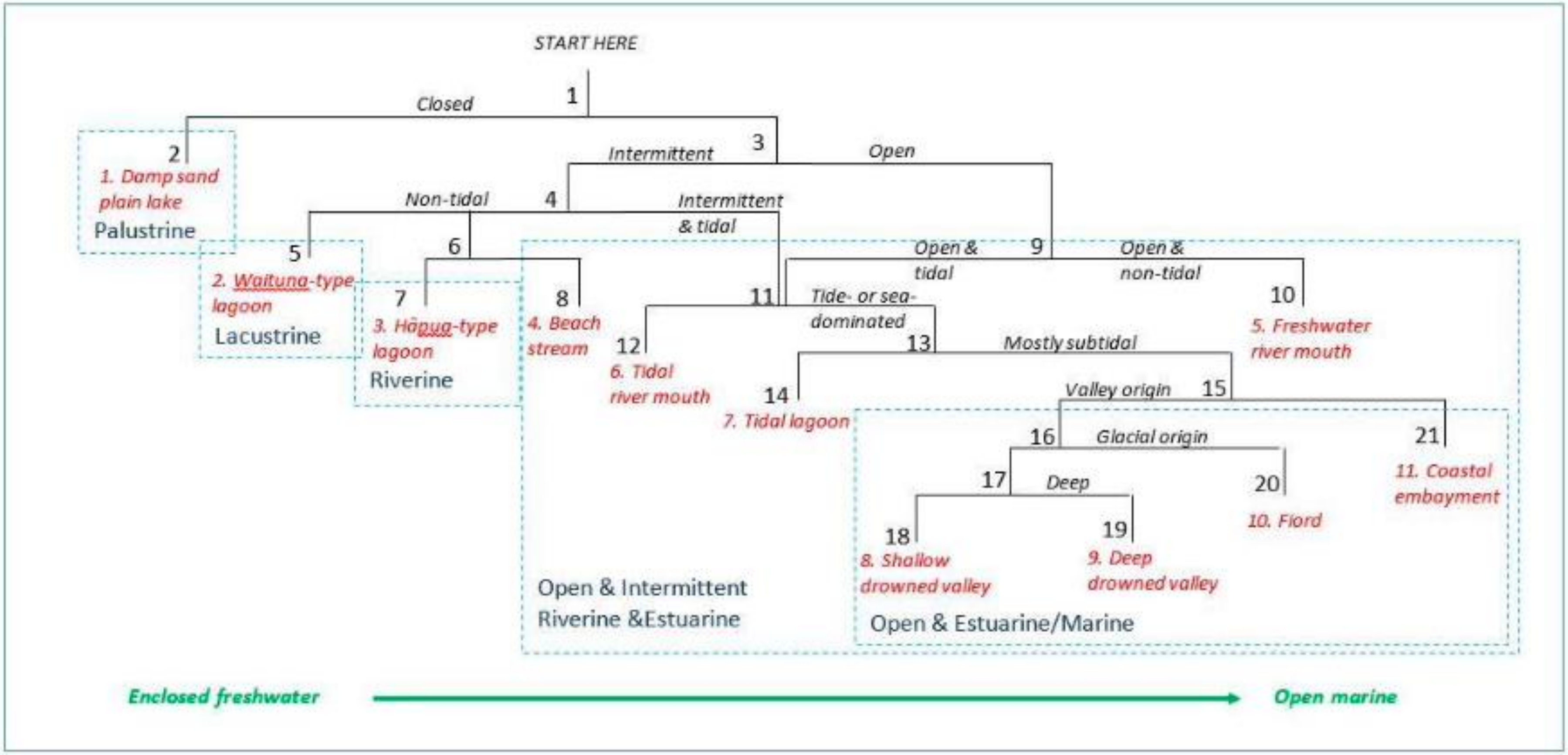
Appendices



Geomorphic decision tree used to identify the type of coastal geomorphology of coastal marae and urupā (Hume et al., 2016)