Shoreline Strategies

Embracing coastal transformation in Aotearoa New Zealand

Special Publication 6, July 2025

Te Hunga Takutai o Aotearoa
NEW ZEALAND
COASTAL SOCIETY

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The New Zealand Coastal Society was inaugurated in 1992 'to promote and advance sustainable management of the coastal environment'. The society provides a forum for those with a genuine interest in the coastal zone to communicate amongst themselves and with the public. The society currently has over 400 members based in New Zealand and overseas, including representatives from a wide range of coastal science, engineering and planning disciplines, employed in the consulting industry; local, regional and central government; research centres; and universities.

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Cover photo credits

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Right – aerial photograph of Whangamata taken in 2021 (Photo: LINZ, CC BY 4.0 https://creativecommons.org/licenses/by/4.0/).

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Foreword

Colin Whittaker and Sam Morgan, NZCS Co-Chairs

The New Zealand Coastal Society Te Hunga Takutai o Aotearoa envisions sustainable coastal and marine environments, guided by effective science, engineering and policy practices, involved communities and impactful partnerships. Our special publications are aligned to our mission of leading robust discussion to educate, inspire and champion sustainable management of our coastal and marine environments.

This is the 6th special publication of the New Zealand Coastal Society, with the theme of *Coastal Transformation*. In it, we draw together and build upon the themes explored in several of our previous publications, which addressed climate change, its consequences for coastal systems and communities, and the need to adapt to these challenges.

The word ‘transformation’ is open to a range of interpretations within our diverse membership of coastal professionals, and we have encouraged this during the preparation of this special issue. Our coastlines are in a state of transformation, and several of the articles in this special issue provide rich datasets and examples to explore and better understand these transformations. Coastal hazards arise where dynamic processes intersect with our communities and what we value. As these hazards transform over time, so to must our approaches and our very relationship with the coast. Our special issue explores both our transforming coastline and the opportunities for a transformative response.

The diversity of articles in this special issue reflects the breadth and depth of expertise within our society, yet many of these articles still share common themes and messages. There is great value in datasets that provide unprecedented detail on our coastal transformations and can inform our future adaptive planning and management. However, datasets alone are recognised as being insufficient to drive truly transformative change and genuine adaptation. Iwi and hapū experiences put this into sharp perspective through investigations into the exposure of coastal marae to extreme sea levels, while also championing transformative responses to these challenges.

More generally, collaborations and partnerships are vital, and our articles provide examples where this is already happening as well as a call to action for the future.

Overall, embracing coastal transformation (in all senses of the word) is challenging. However, it is necessary. This special publication draws together diverse expertise and perspectives from within our membership to enable this transformation.

On behalf of the New Zealand Coastal Society, we would like to sincerely thank all of the contributors who have given their time to create the content for this issue. Particular thanks go to Ana Serrano and Connon Andrews who have put in the hard mahi to get this done. And, as always, Charles our brilliant (if long-suffering) editor has taken all of our ideas and brought out the best in them. Our publications wouldn’t be the same without your input.

We know you will all get something from this publication and look forward to hearing feedback. And don’t be afraid to share it around. The more we have the conversation the more people will hear it.

Typologies and modes of coastal change in Aotearoa New Zealand

By Emma Ryan, Mark Dickson, Murray Ford, Megan Tuck and Teresa Konlechner

Introduction

Soft sedimentary coastlines are naturally dynamic systems that respond to shifts in hydrodynamic processes (e.g. waves and currents), sea level, sediment supply, human interventions (Hapke et al., 2013) and ecological changes (such as changes in dune vegetation). In addition to being dynamic, Aotearoa New Zealand's coasts are highly valued and utilised as sites for traditional food gathering, settlements, infrastructure development, burial grounds, recreation and tourism (Rouse et al., 2016; Whaanga et al., 2018; Wheaton et al., 2021). Extensive development and use of the coastal zone has resulted in exposure of infrastructure, communities and cultural heritage to the risk of coastal inundation and erosion (Jones et al., 2023; Paulik et al., 2020). With climate change and rising sea levels expected to intensify both erosion and inundation (Paulik et al., 2023), there is urgency to evaluate and manage these coastal risks.

Coastal planning and management decisions (such as erosion risk assessments, the delineation of hazard lines, zones and setbacks and the implementation of coastal protection or adaptation measures) in Aotearoa New Zealand are usually underpinned by an analysis of past coastal change rates (e.g. Shand et al., 2015). Past coastal change rates are generated from historical coastline positions determined using aerial/satellite imagery or beach profile data. However, the lack of a standardised national dataset of historical coastal change patterns (and associated lack of a national coastal erosion risk assessment) has led to fragmented and variable approaches to analysing coastal change across the country (see Dickson et al., 2022).

To develop a national coastal erosion risk assessment, we first require a robust knowledge of historical coastal change patterns. This will allow more informed decision making about coastal adaptation to sea-level rise at local and regional scales.

New Zealand's coastal change dataset (NZCCD) (https://coastalchange.nz) was published in 2024 and represents the first time that long-term coastal change rates have been generated at a national scale since the pioneering work of Gibb (1978). The NZCCD provides coastal positions from 1940 to 2023 (at variable time increments according to availability of historical imagery), along with rates of coastal erosion and accretion (i.e. progradation) for most of New Zealand's open coast beaches and soft coastal cliffs. The dataset can be publicly accessed and downloaded at https://data.coastalchange.nz and allows for unprecedented analysis of coastal change around New Zealand's dynamic and diverse coast.

The NZCCD web map visualises coastal change using a weighted linear regression (WLR) method to calculate the rate of change in m/year (+/- weighted confidence interval [WCI]) (Table 1). While, the WLR was selected for visualisation, it is one of several statistical metrics of coastal change that the NZCCD comprises. Details of all metrics of coastal change provided in the NZCCD are in Table 1 together with Tuck et al. (2024).

Interpreting coastal change using linear rates of change (such as WLR) through time is not straightforward (Dolan et al., 1991). There are nuances in coastal change metrics that must be understood and considered before using the NZCCD to make and implement coastal adaptation decisions. For example, a coastline displaying a WLR rate close to zero (such as 0.03 m/year) may imply stability in coastal position, but this may not reflect the reality of coastal change at that place over the time period of analysis, particularly at places where coastal change is non-linear, as the coastal change metrics available best describe linear coastal change. One theoretical example of this is a coastline that accreted in the early half of the temporal record, but transitioned to erosion during the second half of the record, meaning the most recent coastline position in the record is located close to the earliest coastline in the record, despite coastal positions being further seaward of this in the middle part of the record. In this case, the WLR may be close to zero, implying stability, despite the episodes of accretion and erosion. A linear regression (such as WRL) cannot account for a reversal in the direction of coastal change. This highlights the need to use multiple statistical metrics of change to obtain a more detailed understanding about historic coastal dynamics.

Developing coastal change typologies is one approach to account for the nuances associated with coastal change metrics. Typologies are defined here as descriptive classifications that capture the cross-shore temporal dynamics of coastal landforms. Typologies have generally been used to classify landforms of similar geomorphologies (Buddemeier et al., 2008; Hume and Herdendorf, 1988; Mahoney and Bishop, 2018), but can also be useful indicators of change in various geomorphic contexts such as river channels (Sear and Newson, 2003) and coasts (Mack et al., 2020).

This article introduces and outlines typologies and modes of coastal change derived from the NZCCD and aims to guide users of the dataset in leveraging the full suite of coastal change metrics to support proactive and sound coastal adaptation decision making. We provide explanations of how to determine coastal change typologies and modes using a combination of coastal change metrics from the NZCCD.

The National Coastal Change Dataset

The NZCCD presents historical coastline positions and a range of metrics describing coastal change at 10 m alongshore increments around Aotearoa New Zealand. Full details on how the dataset was developed are found in Tuck et al. (2024).

Historic coastal change was mapped using both aerial imagery (from late 1930s to 2023) and high-resolution

Coastal Change Metric	Acronym	Units	Description	What does this mean?
Shoreline Change Envelope	SCE	m	The distance between the most landward and most seaward coastline.	The SCE indicates how dynamic a coastline is. If the SCE is small, the position of the coastline has shown minimal variation over the observed period, suggesting relatively stable conditions.
Net Shoreline Movement	NSM	m	The distance between the earliest and the latest coastline for each transect.	The NSM indicates the net change in shoreline position by utilising the earliest and latest coastlines. A small NSM indicates little net movement of the coastline. This does not necessarily mean that the coastline is not dynamic, because any landward or seaward movement of the coastline may have been cancelled out.
End Point Rate	EPR	m/yr	The rate of change between the oldest and most recent coastal positions is calculated by dividing the distance by the time between the two coastlines.	The EPR provides a rate of change based solely on the oldest and most recent positions of the coastline. It does not account for variations in the position of the coastline between these two points. A large (small) EPR suggests a faster (slower) rate of change.
Weighted Linear Regression Rate	WLR	m/yr	The WLR is determined by fitting a regression line to all coastline points for a transect. The coastlines with lower total uncertainty are given a greater weighting in a WLR.	The WLR provides a rate of coastal change that utilises all mapped coastlines and provides a higher weighting to coastlines of higher quality, e.g. smaller positional uncertainty.
Weighted Confidence Interval	WCI	m	The 90% confidence interval associated with the WLR	The WCI represents the uncertainty for the WLR rate. If the WCI is high, the WLR should be interpreted with caution as the true rate of coastal change may differ considerably from the WLR.
Weighted R-Squared	WR2	–	The WR2 is a dimensionless index (ranging from 1.0 to 0.0) that describes how well the least-squares weighted regression line 'fits' the data.	The WR2 indicates how well the weighted regression model explains the variance in the coastline positions. A high WR2 indicates that the weighted linear regression model explains the variance in the data well and that coastal change is relatively linear at this location.

Table 1: Metrics of coastal change provided in New Zealand's Coastal Change Dataset that are mentioned in this article. Additional coastal change metrics included in the NZCCD, such as LRR (Linear Regression Rate), LR2 and LCI (The R-squared and 90% confidence interval associated with LRR, respectively), are described by Tuck et al. (2024).

(typically between 30 and 50 cm spatial resolution) satellite imagery (from early 2000s to 2023). The images were georeferenced and the position of the coast was manually digitised. The duration and temporal resolution of the coastline record varies around the country due to the availability of historical aerial imagery, which is more abundant along populated coasts. The dataset typically provides decadal temporal resolution, and in some instances sub-decadal, particularly where satellite imagery has been used.

The position of the coastline was defined according to six different coastline indicators that were readily identifiable in both aerial and satellite images, including the edge of vegetation, scarps, storm ridge, cliff top, cliff toe (base), and hard structures, such as the base of sea walls or rock revetements (Tuck et al. 2024). Importantly, we mapped the same coastline indicator at each location through time, ensuring that the indicator was readily visible in all images for a location, so that robust coastal change rates could be derived. The high or mean water level were not used as coastline indicators due to the temporal variability of these positions and difficulty identifying them in the older black and white historical imagery (typically before the 1980s).

A rigorous uncertainty assessment was undertaken to determine the positional uncertainty of the mapped coastlines where the total uncertainty is calculated using the georeferencing error, digitiser error and pixel error. Uncertainty is published as 'Total_UNCY' in the published dataset. Total shoreline uncertainty ranged between 0.4 m and 10.9 m, with the highest uncertainty associated with low resolution, black-and-white historical imagery while high-resolution satellite imagery (typically sourced from Maxar) had the lowest shoreline uncertainty. Full details on the uncertainty assessment can be found in Ford et al. (in press).

Coastal positional change through time was analysed using the Digital Shoreline Analysis system v6.0 (Himmelstoss et al., 2024) to determine coastal change metrics. All coastal change metrics are explained in detail in Tuck et al. (2024) and in the NZCCD's guidance document (https://coastalchange.nz/about/usage) with key metrics discussed in this article described in Table 1. Confidence intervals (90%) provide uncertainty associated with the calculated rates of change. The dataset does not project future changes in coastal position (at this point in time). The data provided are historical rates of change and coastal positions, and while they are measured over a time that we have observed ~20 cm of sea-level rise on average across the country (MfE, 2024), that does not necessarily mean the rate and mode of change will remain the same moving forward.

Coastal change typologies and modes

The NZCCD reveals that Aotearoa's historical coastal change rates are highly variable around the country. Ongoing research is underway to explore the dataset and assess possible drivers of coastal change, but to aid in immediate decision making we have identified and mapped six initial typologies of coastal change (Figures 1 and 2) based on the WLR in conjunction with other coastal change metrics. In the web-map of coastal change, the rate of change (m/year) is illustrated using WLR, whereby higher absolute values represent faster rates of accretion (positive WLR) and erosion (negative WLR). These six typologies describe the overall directional movement of the coast over the study period (i.e. seaward or landward movement). They are named Stable_HC (high confidence), Unresolved, Accretion_HC, Accretion_LC (low confidence), Erosion_HC and Erosion_LC.

Coastlines characterised by any of these typologies (except Stable_HC) can be further described according to the mode of coastal change: linear, non-linear, or fluctuating. These modes indicate the nature of the directional coastal change. We encourage users of the dataset to explore the different modes of coastal change alongside typologies and rates of erosion/accretion. This is especially true of the typologies with higher uncertainty (Erosion_LC, Accretion_LC and Unresolved), whereby these data require a deeper understanding of the modes of coastal change.

Within the typologies, we have not defined a rate that we consider 'rapid' erosion or accretion, because the rate of change (and associated potential socio-environmental impacts) will be locally specific. The typologies presented herein do not allow users to differentiate shifts in rates of coastal change through time, such as accelerating/decelerating erosion or accretion, or a switch from accretion to erosion within the study period and vice versa. 'Unresolved' sites may have experienced temporal changes in coastal change rates, and so we consider that unresolved sites require thorough investigation of the coastal positions, as well as ongoing monitoring to determine whether we may be experiencing shifts, such as a switch from historic stability or accretion to erosion. Every year of additional data that we can collect on these unresolved sites will reduce the uncertainty we currently have in the coastal change rate. Temporal variability in coastal change rates can be explored through generation and analysis of time series of coastal positions (as displayed in Figure 3). We are seeking to integrate time series analysis for each NZCCD rate in the second iteration of the dataset.

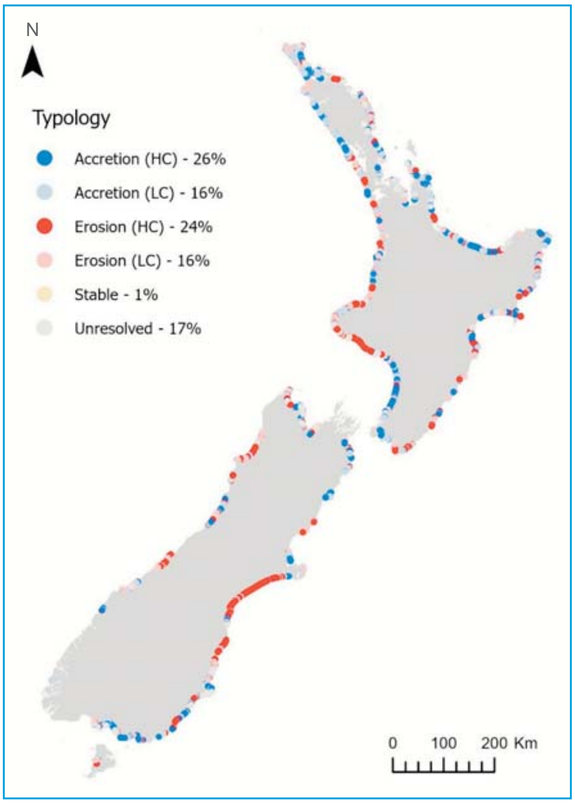
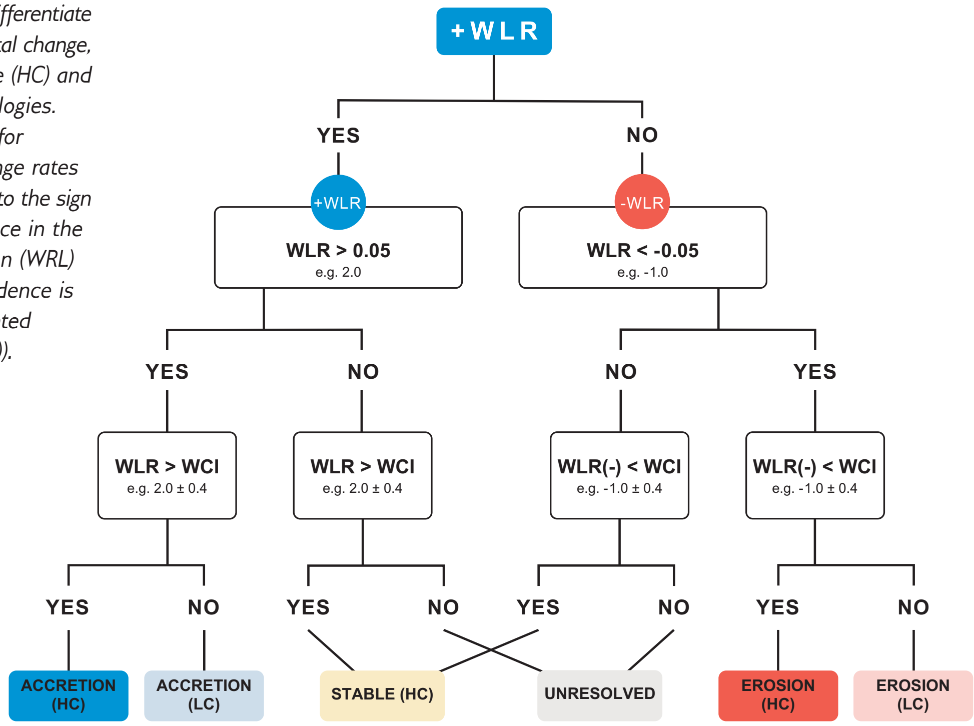


Figure 1: Typologies of coastal change as identified from New Zealand's Coastal Change Dataset. HC and LC refer to high and low confidence, respectively. The percentages refer to the proportion of the analysed coastline that comprises each typology.

How to determine the coastal change typologies

Stable_HC (high confidence) describes coastlines that are stable and we are confident (90% CI) have not moved more than 4 m over the time period of analysis. Only 4% of the analysed coastline is categorised as Stable_HC. Stable_HC points are classified by a WLR between -0.05 and 0.05, which is greater than the WCI. The stronger the WR2, the more stable the coast. The SCE will be small (< 4 m). We selected 0.05 m/yr (-0.05 m/yr) as the rate that distinguishes stability from accretion (or erosion). In selecting this rate, we were guided by the typical length of historic timeseries, and the total uncertainty of data available. For example, a coastal change rate of 0.05 m/yr over 80 years suggests the coastline position remained within 4 m of its initial position over that period. Since 4 meters is typically within the margin of uncertainty for most of the data, it is reasonable to classify this as stable, provided that the rate of change is greater than the WCI.

Figure 2: A flow chart to differentiate the six typologies of coastal change, including high confidence (HC) and low confidence (LC) typologies. Guidelines are provided for categorising coastal change rates into typologies according to the sign (+ or -) and the confidence in the weighted linear regression (WRL) rate (m/yr) (i.e. the confidence is determined by the weighted confidence interval (WCI)).



Unresolved describes coastlines that we cannot confidently ascribe as eroding, accreting or stable; 17% of the analysed coastline is categorised as unresolved. Unresolved points are classified by a WLR between -0.05 and 0.05 that is lower than the WCI. The SCE may be high. There are several reasons why some coastlines are categorised as unresolved, such as coastlines with high total uncertainties associated with poor image resolution, or coastlines that are highly dynamic (i.e. experiencing non-linear change) through time so that a trend cannot be determined. With future updates to the dataset the proportion of unresolved coastlines will decrease.

Accretion_HC includes all coastlines that have prograded seaward (90% CI) through the time period of analysis; 27% of the analysed coastline is categorised as Accretion_HC. Accretion_HC coasts are classified by a positive WLR value that is greater than 0.05 m/yr and is greater than the associated WCI. The greater the WR2, the more consistent the accretion through time. Higher SCE values typically indicate a greater gross amount of accretion.

Accretion_LC (low confidence) includes all coasts that are likely to be moving seaward over the time period of analysis, but there is more uncertainty in the rate and this is usually because the coast has moved back and forth over the time period of analysis (in a range of possible scenarios); 15% of the analysed coastline is categorised as Accretion_LC. These coasts are classified by positive WLR values (> 0.05 m/yr) that are lower than the associated WCI. The stronger the WR2 and the lower the WCI, the more confidence we have that the coastal change trend is accretion. Higher SCE values typically indicate either a higher net amount of accretion, or a more dynamic/fluctuating coast.

Erosion_HC includes all coastlines that have moved landward (90% CI) through the time period of analysis; 24% of the analysed coastline is categorised as Erosion_HC. Erosion_HC coasts are classified by a negative WLR value that is greater than the WCI. The higher the WR2, the more consistent (through time) the erosion. The WR2 value provides a useful indication of how chronic/consistent the erosion is because if the erosion rate is well predicted with a linear model, the implication is that there is a systemic driver of that erosion. A high erosion rate that is accompanied by a low WR2 may indicate that erosion is occurring sporadically in discrete events, with periods of accretionary recovery between events. The SCE gives indication of the amount of erosion that has occurred, with higher SCE typically indicating a higher gross amount of erosion at a location.

Erosion_LC includes all coasts that are likely to be moving landward over the time period of analysis, but there is more uncertainty in the rate of erosion compared to Erosion_HC areas. This is usually because the coast has moved back and forth over the time period of analysis (in a range of possible scenarios), but on average the coast has eroded more than accreted; 16% of the NZCCD points are categorised as Erosion_LC. Erosion_LC coasts are classified by a negative WLR value that is smaller than the associated WCI. While there is uncertainty in the rate of erosion, a higher SCE typically indicates either a higher net amount of erosion, or a more dynamic coast.

How to determine the modes of coastal change

Linear directional coastal change describes continual movement of the coastline in the same direction (either landward or seaward). The rate of coastal change through time may change but the direction of movement is consistent. Linear directional coastal change is characterised by a high WR2 value (closer to 1) and similar SCE and NSM values.

Non-linear directional coastal change describes overall landward or seaward movement of the coastline that is erratic/irregular, where phases of both erosion and accretion occur throughout the study period but one phase dominates, resulting in net accretion (progradation) or erosion of the coastline. Non-linear directional coastal

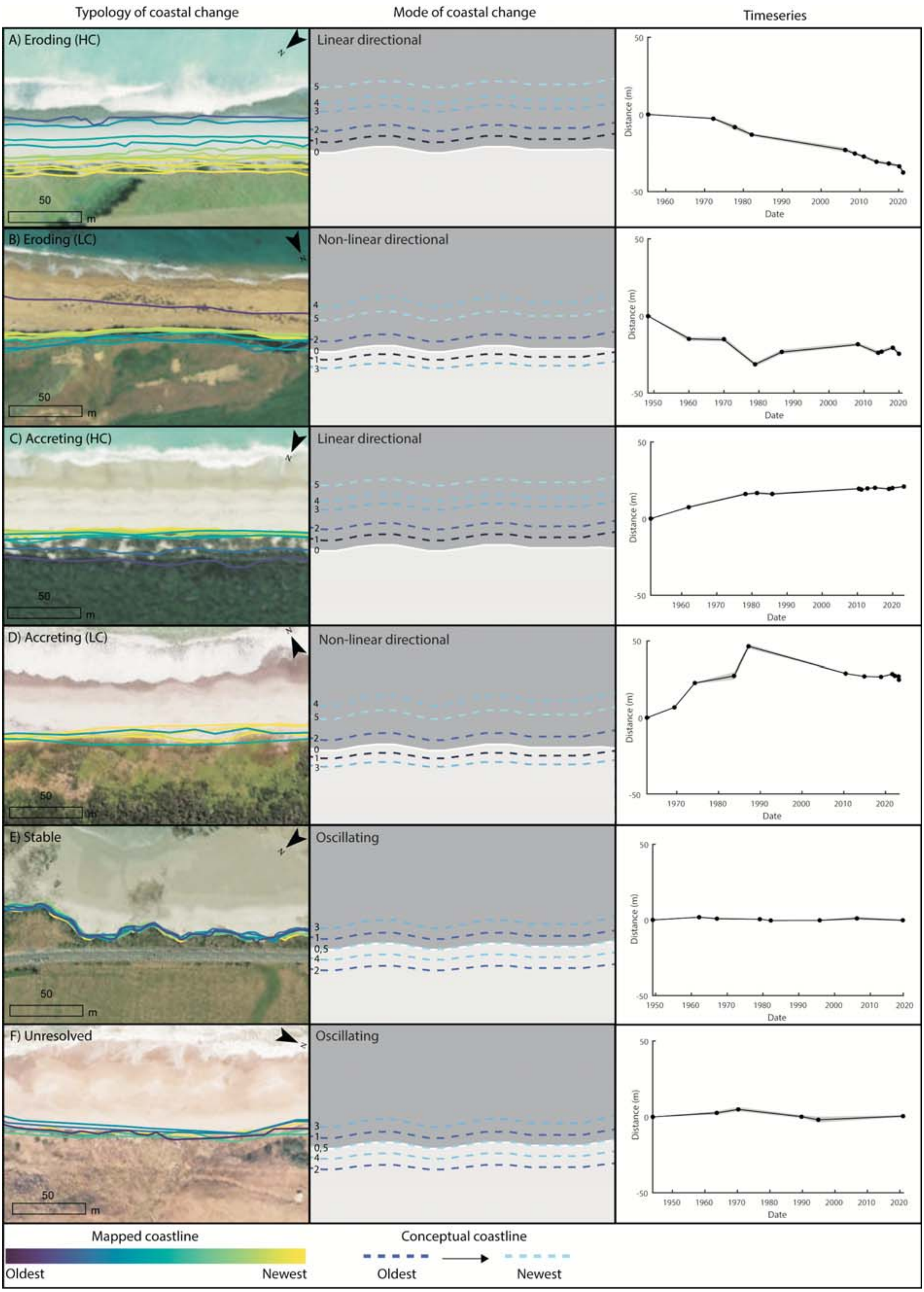


Figure 3: Examples of typologies (styles), modes and time series of coastal change from New Zealand's Coastal Change Dataset. Conceptual coastlines are numbered 0 (earliest) to 5 (most recent). Time series points show coastline positions (distance in metres from the initial coastline position). Grey band in time series indicates coastline positional error (total_UNCY).

change is characterised by a relatively low WR2 due to the inconsistent direction of coastline change, a high WLR compared to compared to oscillating coastal change and typically larger SCE than NSM, although this is not always the case.

Fluctuating coastal change describes landward and seaward movement of the position of the coastline fluctuating around the earliest coastline position available for a site, with the latest coastline position located close to the earliest recorded coastline position. Fluctuating coastal change is characterised by a larger SCE than NSM, as well as a low WR2 and low WLR. This mode of change may indicate that the coast is fluctuating around a mean/average position, but it is important to note that this is not always the case and does not mean the coast is stable in the long term. The fluctuations could be multiple small changes in coastline position, or one large change. Such detail about the nature of fluctuating coastlines cannot be gleaned from the coastal change metrics alone. This reinforces the need to analyse coastal change timeseries, which is further discussed below.

Consideration of alongshore and temporal shifts in coastal change dynamics

The coastal change typologies and modes described here represent shore-perpendicular coastal change. In addition to the six typologies and three modes, we also observe alongshore variations in coastal change patterns within a beach. For example, these include: erosion at one end of a beach and accretion at the other, disappearance or appearance of sand spits over the study period, rapid coastal changes around river mouths and sand spit tips, and breaching of sand spits and barriers. Such dynamic coastal changes are problematic to analyse using typical cross-shore transect-derived coastal-change metrics, such as WLR. We discourage averaging coastal change rates for a beach if there are clear alongshore variations in coastal change typologies and modes. We have largely excluded areas such as spit tips and river mouths from the current version of the NZCCD rates. If users want to examine coastal change around river mouths and the tips of sand spits and barriers, they are encouraged to explore the coastlines data file within the NZCCD (i.e. shapefiles of historical coastal positions). In addition to revealing alongshore variations on dynamic coasts, the historical coastal positions can be used to enhance users' understanding of the temporal variation in coastal change rates.

There could also be spatially variable patterns of coastal change present across-shore, which can be revealed by using more than one coastal change indicator at a location, such as the water line shoreline and the edge of vegetation (Dickson et al., in review). We discuss this in the context of utilising the edge of vegetation as the coastline indicator for most open-coast sand beaches in the NZCCD. Edge of vegetation, which often coincides with the top or toe of the foredune, is a commonly-used indicator of coastal change over multi-decadal timescales (Blue and Kench, 2017; Sengupta et al., 2023), as it reflects longer-term coastal dynamics than indicators that vary greatly with the tide (such as high water mark, or water line). However, there may be instances where the dune vegetation line advances seaward, despite the beachface at the same location remaining stable or decreasing in width or elevation (as observed by Adnan et al., 2016). This may occur in some instances, for example, where vegetation succession processes outpace beach sediment dynamics. It is important for users of the dataset to be aware of that possibility. However, within the NZCCD we strived to exclude coastlines that clearly showed this behaviour (such as vegetation that had colonised previously-barren sand dunes).

This possible discrepancy between the vegetation coastal change indicator and beach width change can be mitigated by using multiple datasets to understand coastal change (such as volume-based measurements of coastal change, and/or using multiple coastal change indicators). Aerial-based mapping of coastal change, whether automated or manual, does not negate the need for ongoing in situ coastal monitoring networks, such as beach profile and drone surveys, wave data collection, and video or image-based monitoring (e.g. CoastSNAP; Harley and Kinsela, 2022). Links to a range of other relevant coastal datasets for Aotearoa New Zealand are provided on our website.

On the use of the dataset for coastal management and adaptation

These typologies and modes can be used as a first pass assessment to identify priority locations for advancing detailed coastal erosion risk assessments and development or implementation of adaptation plans at a range of scales (from local individual beach scale to regional and national scale). A guidance for use of the dataset for tangata whenua is available at https://coastalchange.nz/about/usage, which includes some suggested use cases of the data and case study examples where tangata whenua have used the NZCCD. The dataset will have useability for a range of coastal management and adaptation planning purposes, and, as producers of the dataset, we would appreciate users reporting back to us about how the data are being used, and suggestions for finetuning or future amendments (or additions) to the dataset that would benefit users. If you are a user of the dataset and would like to update the data for a particular location of concern, or add data for a location that is not presently covered in the NZCCD, we would like to discuss possibilities with you.

Future monitoring of coastal change and updating of the NZCCD and other coastal datasets will be crucial in determining the extent of observed impacts on Aotearoa's coast from the signal of sea-level rise. It is necessary to maintain standardised national datasets that are locally applicable, such as the NZCCD, to monitor and understand changing coastal risk profiles and use in dynamic adaptation planning as signals or triggers, or for determining tipping points. We consider it highly important that the dataset is maintained in a standardised manner around the country using the same coastline indicator and basemap through time to ensure meaningful and comparable analyses of spatial and temporal variations in coastal change rates.

Please contact us at coastalchange@auckland.ac.nz if you are seeking to update or add data to the NZCCD. The NZCCD will be most useful to researchers, decision makers and communities when the full suite of coastal change metrics are utilised, along with an understanding of typologies and modes of coastal change, as detailed in this article.

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Coastal erosion hazard management – what have we learned since the 1970s?

By Bronwen Gibberd and Stephen Hunt

Introduction

New Zealand is an island nation, and a large proportion of its population live close to the coast. The coastal communities of the Coromandel Peninsula (Figure 1) are founded on the unique natural values of the local coastal environment and the Pacific Ocean beaches make an indisputable contribution to the quality of life of those who live near and visit them. Dunes provide an easily accessible area for subdivision close to the beach and therefore have been extensively developed. As these areas are built almost entirely from unconsolidated sands there is an inherent erosion risk.

Coastal development is managed on the Coromandel by considering the likely extent of both dynamic and progressive patterns of shoreline change to estimate hazard lines. The District Plan contains development controls that apply seaward of these lines to restrict development and mitigate risk. The intent is to prevent the construction of new dwellings in areas at risk from short-term erosion and to manage risk over time by preventing inappropriate development of existing land use and buildings where there may be a risk from future sea level rise.

Here, we use historical records to demonstrate that coastal experts have recognised and communicated the need to manage development to limit coastal erosion hazard risk at Coromandel beaches for over 50 years. Furthermore, the hazard areas and recommended management approaches identified in the 1970s are strikingly similar to contemporary hazard lines and management approaches. We highlight here that despite timely and sound expert advice and the establishment of policy aimed at mitigating coastal erosion hazard risk and adverse effects, there has been an enormous increase in the scale and value of development at risk. As we work toward adaptive management approaches to mitigate hazard risk into the future, will we be any more successful than our predecessors?

The Pacific beaches of the Coromandel Peninsula

The Coromandel Peninsula is situated in the Waikato Region, in the North Island of New Zealand. The peninsula is bounded by the Hauraki Gulf and the Firth of Thames to the west and the Pacific Ocean to the east (Figure 1a). Here we focus on the beaches on the Pacific side of the peninsula (Figure 1b).

The formation of beaches and dunes was likely initiated by an onshore flux of sediment following rapid sea level rise to its present level around 6500-7100 years ago (Healy and Dell, 1986; Abrahamson, 1987; Dahm and Munro, 2002). This sediment was subsequently reworked by coastal processes and river flow into the contemporary morphology seen today (Marks and Nelson, 1979; Gibb, 1983; Gibb and Aburn, 1986; Abrahamson, 1987; Dahm and Munro, 2002; Wood, 2012). The contemporary beach morphology generally comprises barrier spits enclosing tidal estuaries, bay barriers and pocket beaches (Healy and Dell, 1986).

Available data suggests that Coromandel beaches are generally in equilibrium with no long-term trends of shoreline change in either a landward or seaward direction (Dahm and Munro, 2002; Dahm and Gibberd, 2009). Cyclical patterns of erosion occur in response to occasional storms, from both summer ex-tropical cyclones and winter storms; these periods of erosion are often punctuated by periods of accretion during calmer weather (Dahm and Munro, 2002; Bryan et al. 2008; Dahm and Gibberd, 2009; Wood, 2010). The observed cyclical changes in shoreline position can also be associated with climatic cycles; biennial changes are related to the El Nino Southern Oscillation and decadal changes are related to the Interdecadal Pacific Oscillation (Wood, 2010). Due to the lack of contemporary sediment supply it is likely that sea level rise will cause the beach morphology to move landward where not restricted by development or the morphology of the hinterland (Dahm and Munro, 2002; Dahm and Gibberd, 2009).

The exceptional value of Coromandel sandy beaches for activities such as walking, swimming, surfing and sunbathing is a key driver for the economy of the district, and the value of holiday homes throughout the coastal settlements. The morphology of these beaches is naturally dynamic and particularly vulnerable to the effects of any interruption of natural processes.

The history of coastal setbacks and coastal hazard management on the eastern Coromandel

Subdivision and development of the Coromandel's beaches began in the 1950s and accelerated rapidly through the 1960s and 1970s (cf. Figures 1c and 2a, and Figures 1d and 2b) as road access improved (Morton et al., 1973; Peart, 2009). The picturesque white sand beaches, clear water and relatively safe swimming provided an exceptional holiday destination with rich water-based recreational opportunities. The subdivision was aimed at holiday homes and, in many areas, initially targeted the frontal dunes to maximise views and access to the beaches. The potential risk to this development from coastal erosion was identified relatively quickly and has therefore been a management issue for at least the past 50 years. Historic records and publications provide insight into the early recognition of the implications of inappropriate coastal development and past attempts to manage coastal hazard risk by central and local government.

A specific coastal development setback for Coromandel beaches was first recommended in 1972, when the Hauraki Catchment Board (HCB) provided advice to the Coromandel County Council regarding the management of coastal erosion hazard at beach communities (Harris, 1972). This advice identified the likelihood of cyclic shoreline fluctuations and, in the absence of any detailed investigation, it was recommended that a building line be set parallel to, and

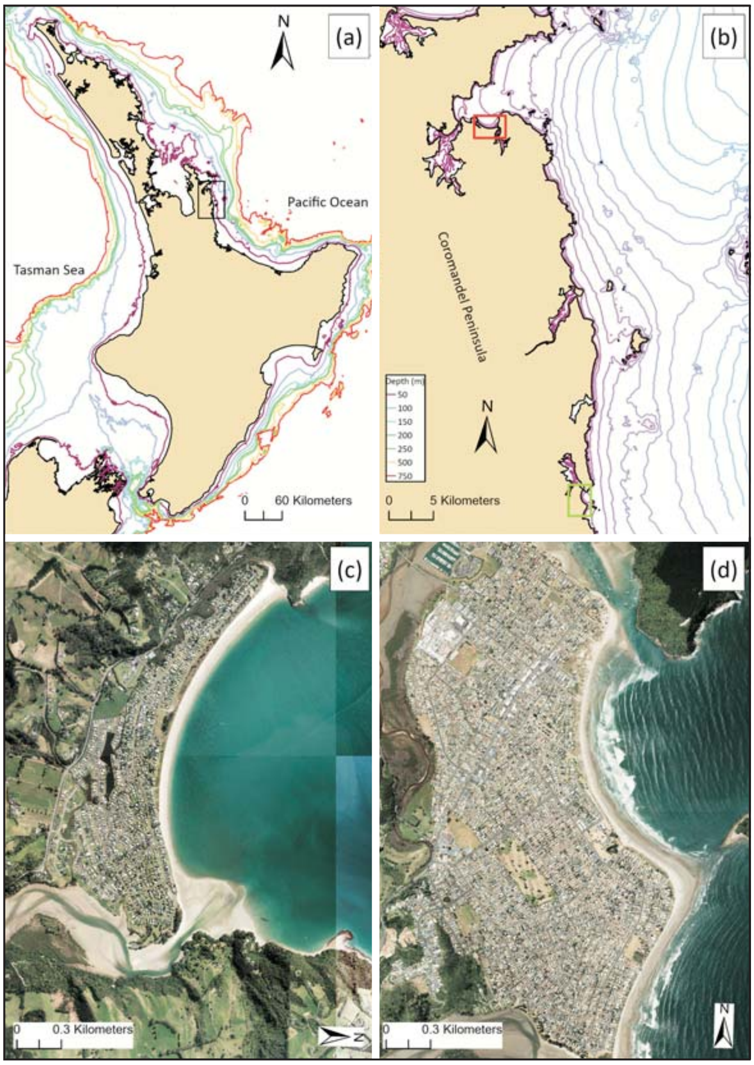


Figure 1: The Coromandel Peninsula and the locations mentioned in this article. The location of (b) is shown using a black square on (a). The location of Cooks Beach (c) is shown with a red square on (b) and the location of Whangamata (d) is shown with a green square on (c). National scale bathymetry in 1(a) from NIWA (2016) and regional scale bathymetry in 1(b) from Gardiner and Jones (2022). Aerial photography in 1(c) and 1(d) taken in 2021 by WRC.

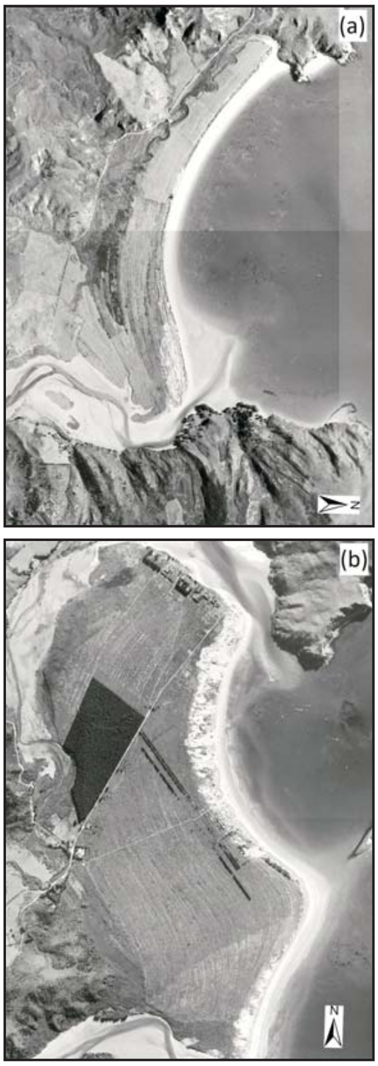


Figure 2: Historical aerial photos of Cooks Beach (a) and Whangamata (b). Aerial photos taken in 1944/45 as part of survey number 292. Survey georeferenced and corrected for WRC by Imagine Map Ltd.

three chains (60 m) from the shoreline to provide for likely periods of erosion and accretion that may threaten coastal development (Harris, 1972).

In 1973 the Ministry of Works (MoW) warned against developing too close to the coastline following a site visit to the Coromandel beaches (Gibb, 1973). The MoW also observed and warned against foredune removal to improve views or increase space for subdivision. The report specifically mentioned the problems already occurring at Waihi Beach and highlighted the 'costly and dangerous implications' of residential development close to the shoreline.

It was recommended that a buffer of intact sand dunes should be retained in areas that are likely to face residential development.

These recommendations reflected nation-wide advocacy by coastal scientists and planners for recognition of the coast as a critical resource, and for better controls on coastal development in the long-term interests of the country (Morton et al., 1973; Healy, 1980; Gibb and Aburn, 1986; Environment Waikato, 2000). Among other policy developments, the earliest advocacy provided support for an amendment to the Town and Country Planning Act in 1973, which identified matters of national importance to be recognised and provided for in regional and district schemes, including: Section 2B(a) *The preservation of the natural character of the coastal environment and the margins of lakes and rivers and the protection of them from unnecessary subdivision and development.*

In 1977 the HCB and Regional Water Board reported that the 60 m (3 chain) buffer had not been applied to coastal development as recommended in 1972 (Harris, 1977). The report also noted the large capital and maintenance costs of structures, and the potential for eventual failure. The report also noted that protection structures are 'likely to damage the beach as a public amenity' and have little or no value to the national economy (and therefore were unlikely to gain central funding).

In response to the possible future financial burden and adverse effects of coastal hazard management being dependent on protection structures, Harris (1977) promoted an 'urgent need for the application of the concept of avoidance' as essential to managing the future implications of coastal development on the Coromandel Peninsula. The report provided recommendations for the management of coastal erosion risk in existing developments, including:

- identification of the dynamic 'foredune zone' as part of the active beach (identified an area typically up to 50-60 m)
- avoidance of the use of coastal defence works unless it has been determined by the Council that there is a long-term commitment to it being a 'defended beach', regardless of future expenditure
- relocatable dwellings in areas of existing subdivision/development (and that 'relocatable') be defined.

The advice was that 'Coastal defence works should neither be undertaken nor permitted to be undertaken, and such funds as might be available in this direction (if any) spent in assisting with the relocation of the houses.'

The HCB and the University of Waikato commenced a research and monitoring programme in 1978 to improve understanding of beach morphodynamics, and to provide a scientific basis for coastal management decisions (Dell, 1981a; Healy et al., 1981a; Healy and Dell, 1982; Healy et al., 1981b; Healy and Dell, 1987). The relevance of coastal erosion hazard and the significance of this work was underscored by particularly damaging storm events in 1978 and 1981.

The investigations included mineralogical analysis of beach sediments, quantification of historic shoreline change using aerial photos, and the establishment of a beach profile network. The network of beach profile sites was established in 1978 and covered every sandy beach on the eastern Coromandel coast accessible by road, and this formed the basis of the current WRC profile monitoring programme. Surveys were undertaken sporadically in early years, but since the mid-late 1990s, data collection became more consistent and regular. At many sites, survey data has been collected at 3-12 month intervals since the late 1990s. Thanks to this prescient work, we now have records of beach change on the Coromandel that exceed 40 years. This data has been instrumental in supporting the establishment of contemporary hazard lines.

In 1981, the HCB undertook an interim review of the data collected since 1978 and reported the presence of coastal problems of concern to authorities since the mid- to late-1960s and re-iterated the issue of existing development in hazard areas and the need for an avoidance approach to management of coastal development (Dell, 1981a). The HCB also assessed the number and value of properties and dwellings within 30 m and 60 m of the toe of the dune at existing settlements and recommended that policies be developed to determine the long term 'fate' of these areas (Dell, 1981a).

Whilst calculating hazard lines at Pauanui Beach, Gibb and Aburn (1986) also expressed concern about coastal development and noted that 'The consequences of such bad planning have been either the loss of housing and services to the sea or the construction of very expensive coastal protection works often resulting in the eventual destruction of the very asset the people chose to live next to, the beach.'

Thames Coromandel District Council (TCDC) applied hazard lines of 30 m (no-build) and 60 m (relocatable dwellings) at the Building Consent stage in the 1980s and 1990s. These setbacks were measured from the toe of dune at the time of building consent application, so resulted in a varying level of protection as the shoreline fluctuated. The Regional Council reviewed coastal hazards and updated setback recommendations in 2002 (Dahm and Munro, 2002). The setbacks were further reviewed in 2009 and are implemented with planning controls in the Thames Coromandel District Plan. The 2002 and 2009 coastal hazard studies identified a dynamic envelope of shoreline change that varied from approximately 25 m to 40 m, as well as estimating the impact of future sea level rise. The setbacks were mapped from a fixed baseline and in many areas are remarkably similar to the 30 m and 60 m zones identified by Dell (1981). Overall, the recommendations made in the 1970s and 1980s were proven to be broadly appropriate considering the lack of data at the time.

Numerous coastal hazard studies, management plans and strategies have been completed over the last 30 years. Regional and District Plans have been through several versions. The latest shoreline management planning exercise by Thames Coromandel District Council (Royal Haskoning, 2022) provides a further iteration of coastal erosion hazard assessment and management strategy for the beaches of the district. The plans and strategies have consistently identified the challenges associated with managing existing development, the need for dune restoration, and the potential adverse effects of coastal protection structures on beaches where public access, public amenity and natural character are central to the character and economy of the local community.

In summary, over the last 50 years there has been consistent identification of the potential coastal hazard within at least 60 m of the shoreline at Coromandel beaches. Development setbacks and design restrictions were first recommended in the early 1970s and have been implemented since the 1980s, with the intent of limiting coastal erosion risk and to signal the potential impermanence of some coastal properties. National, regional and district policy all discourage hard protection works and identify the importance of the natural and amenity values of beaches. Next, we discuss specific case studies to provide examples of the outcomes of these coastal erosion hazard mitigation measures identified in the early 1970s.

Case studies

Cooks Beach

Cooks Beach is a 2.6 km long Holocene barrier beach that partially encloses the Purangi Estuary at the eastern end of the beach (Figure 1c and 2a). Somewhat sheltered in the southern part of Mercury Bay (Figure 1b), the wide white sand beach provides a highly valued recreational asset and a prime holiday attraction. The earliest residential development at Cooks Beach was set well back from the shoreline behind an intact frontal dune along the central and western areas of the beach. By the late 1960s, however, dunes at the eastern end of the beach were cleared and bulldozed to prepare for further development and subdivisions were surveyed in 1971. Within two years, the eastern end of the beach had eroded back into the residential properties (Gibb, 1973; Dahm and Munro, 2002).

Storms in the winter of 1978 caused severe erosion at the eastern end of Cooks Beach, directly threatening approximately nine dwellings with some being undermined by the beach erosion (Figure 3) (Healy et al. 1981). Owners reclaimed the properties with unconsented boulders and reinforced retaining walls (Figure 4). Dell (1981b) refers to another storm in April 1981 that caused further erosion and damaged some of these structures. These structures were subsequently buried by a period of accretion, but they were uncovered again in the late 1990s and early 2000s, threatening the stability of some of the structures, and impacting on beach amenity and access.

In 2006, the Regional and District Council commissioned the Cooks Beach Erosion Management Strategy (Environment Waikato, 2006). This strategy evaluated the environmental, economic and social impacts of a spectrum of options, from land buy-out and relocation to a seawall on the existing alignment. Both qualitative and quantitative assessments suggested that the preferred solution was a backstop seawall. This approach was to locate a simple seawall landward (10-20 m) of the existing structures at the time, so that the structure would be buried by sand under most conditions. The seawall would be exposed only during the most severe erosion phase of the multi-decadal fluctuations in shoreline position. The backstop wall was favoured as it balanced protection of the dwellings

Figure 3: Houses threatened by coastal erosion at the eastern end of Cooks Beach in July 1978 (Photo TR Healy, source: Dell, 1981b).

Figure 4: Eastern Cooks Beach in November 1979, showing some of the repairs and recovery since the July 1978 storm (Dell 1981b).

with the enhancement of natural values and public access. This option would have required landward relocation of 5-10 houses within the section boundaries. The strategy recommended that the regional and district councils proceed with consultation and detailed design.

Following extensive consultation with the affected landowners, an upgraded 'backstop' seawall was consented and constructed in 2013 to give improved protection to affected properties (Figure 5). The landward crest of the upgraded wall is located along the seaward property boundaries. Although this meant landward realignment of the most western section, the toe of the sloping seawall is located very close to the alignment of the previous seawalls along much of the structure (Figure 6). The final outcome was therefore located well seaward of the backstop wall evaluated in the strategy, and the final built design is effectively a 'frontal seawall' (an option recognised as having major adverse effects during the strategy assessment).

The seawall discussed above was constructed immediately seaward of the existing (unconsented) structures and was therefore determined to be outside the Coastal Marine Area (CMA). This negated any requirement for a resource consent from the Regional Council. The consent was processed as a non-complying activity, with limited notification. The decision to grant the seawall was based heavily on the assumption that the wall would be buried under all but the most severe erosive conditions and that there would be no adverse effects on public amenity and access. The upgraded wall has remained exposed since its construction, significantly restricting beach width and public access.

The threat to eastern Cooks Beach properties from coastal erosion has been known since the coastal area was subdivided. The 30 m setback implemented in the 1980s did drive the landward adjustment of some dwellings, but others have been extensively rebuilt over the same footprint as 'renovations' and applying existing use rights. Modest holiday homes have been replaced by much larger, permanent style dwellings, which greatly increased the scale of development in the hazard area even before there were any robust, consented defence works (Figure 6). Beachfront property values have increased tremendously. Dell (1981) estimated that a line 30 m from the toe of dune intercepted $0.5M worth of property and dwellings at eastern Cooks Beach. By 2006, the capital value of the affected properties and dwellings was estimated

Figure 5: Seawall constructed at eastern Cooks Beach in 2013 (Photo: Waikato Regional Council).

at $20M (Beca et al., 2006). This had increased to over $84M in 2017, and the estimated total market value of the affected properties is well over $100M in 2024. Including a general inflationary adjustment, this represents a thirty-fold increase in the value of development at risk since 1980. This increase in value occurred at properties where dwellings were undermined by the sea less than 50 years ago.

The latest Council-funded coastal management plan, the Cooks Beach Coastal Adaptation Pathway (CAP) (Royal Haskoning, 2022), outlines the increasing erosion and inundation hazards and states the intent to remove the rock revetment at the eastern end of the beach when the consent expires in 2048 (or sooner). In 2024, two properties sold on the beachfront behind this seawall for over $3M each, less than two years after the CAP, and only one year after the wall was overtopped by Cyclone Gabrielle.

The continued steep increase in property values where the coastal hazard has been explicitly acknowledged for 50 years, and where a plan for managed retreat is a publicly communicated policy, indicates an underlying disconnect between planning agencies, communities and beachfront property owners, and an assumption that the properties will be protected for the foreseeable future.

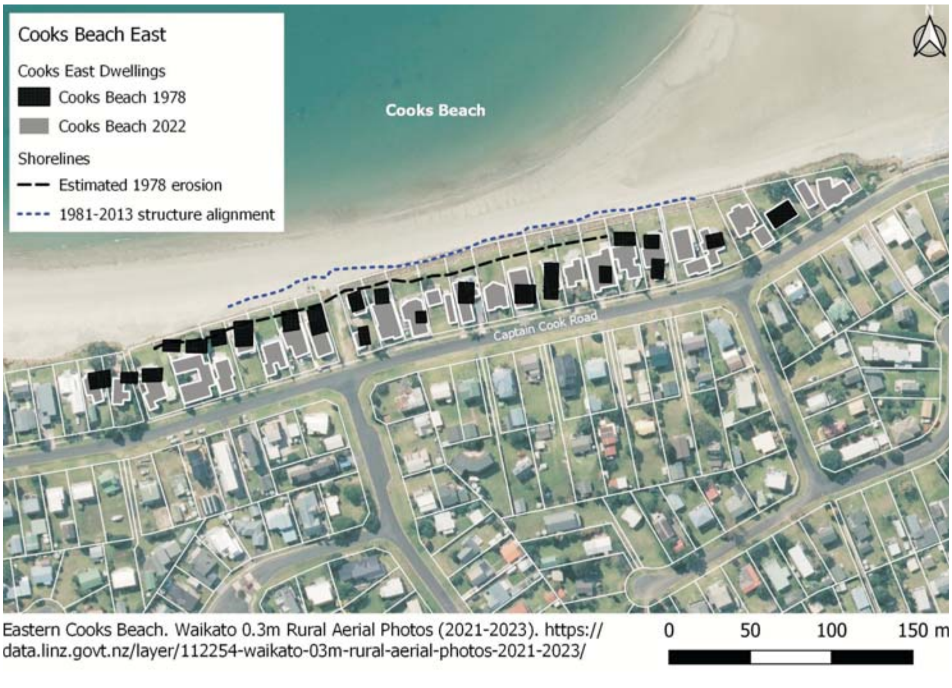
Whangamata

Whangamata Township is built on a wide Holocene barrier that encloses the Whangamata Estuary to the north and the Otahu Estuary to the south (Figure 1d and 2b). Whangamata is one of the region's top beach destinations, and the surf break at Whangamata Bar has been identified as a surf break of national significance in the New Zealand Coastal Policy Statement (DOC, 2010).

Development of Whangamata beach as a holiday resort began in the 1950s and by the late 1950s there were concerns about degradation of sand dunes and of the potential threat to houses close to the sea (Ministry of Works 7/14). Historic aerial photos collated by WRC indicate that the 1959 shoreline was up to 30 m landward of the current shoreline along the northern and central areas of the beach and was within the current beachfront property boundaries on Pipi Road (Figure 7). A storm in 1970 eroded the shoreline south of the Surf Club to within 9 m of the properties (Hauraki Catchment Board 2/11/0). A Thames Coromandel District Council file from 1975 (Thames Coromandel District Council V11/12) also mentions erosion close to a house on the central beachfront (at Pipi Road). By the early-mid 1980s, development at Whangamata was well established and Healy et al (1981a) noted the potential vulnerability of some of this development to future storm erosion.

Observation of all available sources of shoreline change information indicates that the shoreline at Whangamata has undergone multi-decadal dynamic fluctuations in shoreline position that vary alongshore. There was net shoreline advance in most areas at Whangamata between 1959 and 2020. Since 2020, erosion has occurred in the central part of the beach adjacent to Seaview Road and Pipi Road, and along the southern shoreline. Along much of the southern beach, the shoreline in early 2023 was very close to or slightly landward of the most eroded shoreline position in the historical record. Many residential properties on the southern beachfront were within 10 m of the toe of the frontal dune following the erosion from Cyclone Gabrielle in February 2023.

The potential for coastal erosion to impact residential properties at Whangamata has been apparent since the late 1950s, and development controls have been in place since the 1980s. Despite this, the scale of development along the Whangamata beachfront has continued to escalate. Many properties have been subdivided and cross leased within the identified hazard areas, some as recently as just a few years ago, and the scale and quality of dwellings has changed dramatically (Figure 7). Ongoing construction and renovation of dwellings continues with several large new homes established in just the last five years along the central and southern Whangamata coast within identified coastal hazard areas and signed off as relocatable (Figure 8). In 1980, it was estimated approximately $2.5M worth of property was at least partially



Eastern Cooks Beach. Waikato 0.3m Rural Aerial Photos (2021-2023). https://data.linz.govt.nz/layer/112254-waikato-03m-rural-aerial-photos-2021-2023/

Figure 6: Change in intensity of development at eastern Cooks Beach between 1978 and 2022. An estimate of the shoreline following the 1978 erosion (prior to reclamation) is included and the alignment of the coastal defences between 1981 and 2013 is also shown.

Figure 7: The scale of buildings in 1980 (black) and 2022 (grey), and the properties that have been either subdivided or cross leased since 1980 (yellow). The shoreline following the 1959 erosion and the accreted shoreline in 2019 is also shown.

within 30 m of the shoreline at Whangamata Beach (Dell, 1981). By 2017, the value of land and dwellings in the same area had increased to over $400M.

Beach scraping and dune restoration works have successfully mitigated erosion events to date and the beach has remained relatively untouched by structural defence works. Coastal hazard assessments indicate however that the seaward portion of private properties along more than a kilometre of Whangamata Beach could be affected by coastal erosion, even with present sea level. The same properties could be almost entirely eroded due to future sea level rise in the coming century (Dahm and Gibberd, 2009; Royal Haskoning, 2022).

Thames Coromandel District Council's latest coastal management study and strategy for Whangamata (Royal Haskoning, 2022) recommends dune and beach management, and eventual managed retreat, which is consistent with policy at national, regional and district level, and reflects the exceptional value of the beach asset at Whangamata to the community. The proposed trigger point to plan for relocation of assets is when the vegetation line is within a 1% AEP storm demand (indicatively 17 m) away from a property. Severe erosion of the southern beach in 2023 following Cyclone Gabrielle exceeded this trigger in some areas.

The risk of coastal erosion appears to have had little impact on the perceived value of at-risk coastal properties. With a registered land value of up to $6M for a section,

Figure 8: Dwellings on Pipi Road (November 2023). These dwellings were both constructed in the last five years (Photo: B Gibberd).

beachfront properties at Whangamata are among the most expensive on the Coromandel Peninsula. The ongoing willingness of property owners to invest heavily in properties with a clearly recognised short-term hazard vulnerability and a prognosis of managed retreat suggests that there remains an unspoken assumption that regardless of the policy environment, these properties will be protected from erosion when necessary.

Discussion

One of the great challenges of coastal management in New Zealand is controlling land use and development at sandy beaches where subdivision, buildings and infrastructure are already established in a known coastal erosion hazard area. Cooks and Whangamata beaches provide informative examples of the issues that face coastal communities on the Coromandel Peninsula and throughout New Zealand. The existing coastal erosion management problems at these and other Coromandel beaches are mostly due not to an eroding coastline, but to past placement of development within the dynamic envelope of shoreline change and relate to current sea level and climate. Future sea level rise is expected to further exacerbate these issues.

Well designed coastal defences are sometimes an appropriate management solution, particularly when protecting critical coastal infrastructure that cannot easily be relocated (DOC, 2010). However, on dynamic and sensitive shorelines, any physical barrier to natural shoreline movement will inevitably result in loss of beach width and, with it, the accessibility and quality of the public beach resource on which (in the case of many sandy beach locations) the existence of the communities is founded upon. While the severity and persistence of this effect can to some degree be influenced by design and placement of the structure, future sea level rise is likely to continue to exacerbate beach loss where the shoreline is unable to adjust by moving landward. Hard coastal defences are not, therefore, the optimal choice for protecting residential property on the open coast beaches of the Coromandel Peninsula. The organisations responsible for the management of existing coastal development face difficult choices between allowing landowners to utilise and potentially protect high-value beachfront assets and preserving the values of the beach that draw visitors and residents and therefore effectively support the economy of the whole community.

The evidence presented here shows that coastal managers have understood these issues for many decades and have attempted to effect change through a range of planning instruments. Much has been achieved in terms of national and regional policy, which now include controls on development in coastal hazard areas and promote the avoidance of hazards (including the potential for managed retreat) over hard defence structures. Large investments have been made in coastal hazard studies to identify hazard areas, and outcomes are presented on planning maps with associated controls. Hazard information is attached to LIM reports for purchasers of coastal properties. The hazard has been communicated through public consultation and published in coastal hazard strategies, which identify the potential need for managed retreat over time in some areas.

Despite these efforts, we, the coastal management community in New Zealand, have not been able to prevent an exponential increase in the value of development at risk or to prevent degradation of beach values by coastal structures, even when the hazard itself has remained largely unchanged. Furthermore, our inability to generate effective change and slow the increase in coastal erosion hazard risk is not from a lack of knowledge or intent among the scientists, council planners and government policy makers tasked with coastal management.

There are many aspects of our legislation and policy that (unintentionally) undermine the constructive implementation of hazard risk management. Limiting coastal hazard risk relies on strong policy that curbs ongoing investment in hazard areas. In the case of coastal erosion on sandy beaches, key challenges include existing use rights and the pressure for 'reasonable use' (Environment Waikato et al., 2006; Bollard, 2010; Lawrence et al., 2021). While identification of coastal hazard areas and associated restrictions on the location of dwellings should achieve a reduction of hazard risk over time, dwellings are often extensively renovated or rebuilt on a similar footprint within identified hazard areas through the application of existing use rights (RMA S10(1)). Councils are also under pressure to provide for reasonable use (RMA S85), where a large portion of a property lies within an identified coastal hazard area.

The complexity of coastal erosion hazard processes can mean that policy that has been created with the intention to manage hazard risk continues to undermine long-term hazard mitigation. For example, allowance for subdivision or building extensions of the landward portion of a property or dwelling where it is partially in a hazard zone entrenches existing development and prevents landward adjustment away from the hazard.

Sustainable management of development in coastal erosion hazard areas is inextricably linked to the regulation of engineered protection, irrespective of controls placed on land use. Resolute buyer confidence in unprotected at-risk properties reinforces the unspoken belief that properties can and will be protected when the threat becomes severe enough. This is a reasonable assumption given the history of erosion management in the district and the wider region. Property values are inexorably linked to development controls in a circular relationship, the exceptionally high land value is founded on assumption that property is permanent.

While policies in the plans at all levels direct away from hard protection works (with some exceptions when protecting important infrastructure), such structures typically fall under some form of discretionary status, and the opportunity remains for protection of property from erosion. The responsibility then falls on the regional council and/or territorial authority to decline consent if hard structures are to be avoided. The assessment of effects can only consider the individual activity and limited timeframe of the seawall consent. Strategies and adaptive management plans can have support from the community but are non-statutory and hold limited weight in the case of individual consent applications.

The administration of seawall consents is further complicated by the inconsistent and sometimes inappropriate use of the MHWS boundary and the influence of permitted baseline in consent impact assessment. Once constructed, a seawall sets a precedent of protection, has effects on the adjacent shoreline, and is rarely (if ever) removed, even if constructed unlawfully.

Dynamic adaptation planning offers inbuilt flexibility, so that strategies can adjust over time in response to the speed and magnitude of change in the environment. These plans can signal a future shift in management approach (e.g. from 'hold the line' to managed retreat), with associated triggers. This approach can reflect best practice and the outcomes of many detailed studies to forewarn both agencies and communities and provide time for staged adjustment. However, regardless of the efforts of agencies and communities to implement approaches to coastal management that reflect the best 'overall' long-term outcome, the inbuilt flexibility does expose any such plan to future changes that may undermine the original intent, and limit certainty for communities.

Coastal erosion hazard is somewhat unique in that it directly impacts a very small portion of the coastal community, but the mitigation of the hazard can have crucial wider effects as it impacts the key community resource (i.e. the quality of the beach). The costs and benefits of hazard management options to the beachfront property owner and the wider community tend to be diametrically different. Unlike many natural hazards, an individual owner (or small group) can take direct action to protect their property without the endorsement or support of a wider Council programme. Non-statutory plans and strategies hold little weight in the consent process. Arguably, the implementation of community plans that aim to achieve any form of managed retreat depends critically on improving the ability to regulate coastal structures.

While there is real value in approaches that buy time (such as beach push-ups and dune restoration), triggers for any kind of managed retreat approach also need to allow sufficient time for a complex and expensive process, which can be challenging when erosion isn't seen as an imminent threat. The cumulative nature of the erosion hazard can mean that once the erosion hazard is severe enough to meet the retreat trigger, protection can be the only option that can be implemented.

Coastal erosion hazard is not consistent over time on dynamic sandy coastlines. Shoreline changes alter the level of coastal erosion risk at a given site over years and decades. During periods of accretion, there can be little or no coastal erosion hazard, and communities and agencies can become complacent as budgets and attention are drawn elsewhere. This contrasts with (for example) river or coastal flood hazard, for which events are independent, and the statistical hazard risk can be defined with some confidence. The cumulative nature of coastal erosion also means that elevated hazard risk can persist following a major event or period of erosion, driving a sudden urgency for action.

Past records suggest there is often a tendency to delay action while the hazard is better defined. The case studies above demonstrate that those with just a broad understanding of the geomorphology and little concrete data were able to make sensible recommendations about the hazard areas. There have been three district-wide investigations to more accurately define coastal erosion hazard zones since the first recommendations in the early 1970s. While there are differences in the methods used to map the hazard areas, and a more site-specific approach, the spatial extent of the defined hazard areas is strikingly similar in many areas.

Summary

As coastal hazard practitioners, we inevitably have a strong focus on predicting change and working towards management into the future. This article reflects on what we may learn from the past and acknowledges the challenges we face in effecting real change in coastal hazard management.

Those responsible for coastal hazard management have recognised and communicated the existence of coastal erosion hazard risk and associated issues for many decades. Despite the establishment of a range of planning instruments and the clear identification and publication of coastal hazard knowledge, private investment in coastal hazard areas has increased tremendously and continues to grow.

In many coastal towns such as those on the eastern coast of the Coromandel Peninsula, the beach is a key community asset. The use of hard protection structures on sandy beaches has inevitable adverse effects on public access and recreational values, potentially degrading the founding attraction of the community.

Public coastal hazard planning processes generate strategies that reflect community values and present a pathway for sustainable management of coastal settlements. Effective implementation of these strategies is however, threatened by 'loopholes' in national, regional and district level policy. Adaptive management plans are non-statutory, and do not prevent action by affected landowners to protect high value assets.

The risk of coastal erosion appears to have had little impact on the perceived value of at-risk coastal properties. The ongoing investment within hazard areas suggests a disconnect between agency and community visions and expectations for coastal management and those investing in beachfront assets. Based on our past performance, what assurance can we have that the latest management efforts and coastal adaptation plans will gain any greater traction than those that tried in the past?

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Measuring climate change impacts on Indigenous sociocultural wellbeing: Case study of Te Puuaha o Waikato

By Rangi Mahuta, Cheri van Schravendijk-Goodman, Paula Holland, Sarah Harrison, Tekiteora Rolleston-Gabel, Danielle Johnson, Wei Yang, Paula Blackett, Justin Connolly, Donna Kerridge, Tim Manukau, Makere Rika-Heke, Braden Te Ao, Patience Te Ao, Kahurimu Flavell and Alex Fear

Ka maatakitaki iho au ki te riu o Waikato
Aanoo nei hei kapo kau ake maaku
ki te kapu o taku ringa,
Ka whakamiri noa i toona aratau
E tia nei he tupu pua hou.
Kia hiwa ake au i te tihi o Pirongia,
Inaa, hei toronga whakaruruhau moona ki tooku tauawhirotanga.
Anaa! Te ngoto o toona ngawhaa i ngoona uma kiihai i aarikarika
a Maungatautari, a Maungakawa,
ooku puke maunga, ngaa taonga tuku iho.
Hoki ake nei au ki tooku awa koiora me ngoona pikonga
He kura tangihia o te maataamuri.
E whakawhiti atu ai i te koopuu maania
o Kirikiriroa, Me ngoona maara kai, te ngawhaa whakatupu ake
o te whenua moomona,
Hei kawe ki Ngaaruawaahia, te huinga o te tangata.
Araa, te pae haumako, hei okiokinga moo taku Upoko,
Hei tirohanga atu maa raro i ngaa huuhaa o Taupiri.
Kei reira raa, kei te oroko hanganga o te tangata,
Waahia te tuungaroa o te whare, te whakaputanga moo te Kiingi.

I look down on the valley of Waikato,
As though to hold it in the hollow of my hand
And caress its beauty
Like some tender verdant thing.

I reach out from the top of Pirongia
As though to cover and protect its substance with my own.

See, how it bursts through, the full bosoms of
Maungatautari and Maungakawa
Hills of my inheritance.

The river of life, each curve more beautiful than the last.
Across the smooth belly of Kirikiriroa
Its gardens bursting with the fullness of good things.
Towards the meeting place at Ngaaruawaahia.
There on the fertile mound I would rest my head, and look through the thighs of Taupiri.
There at the place of all creation...
Let the King come forth.

He Maimai Aroha. Kiingi Taawhiao, 1863.

Aotearoa New Zealand's (henceforth referred to as Aotearoa) coastal lowlands are flat, low-lying land (or plains) adjacent to coasts and estuaries, valued for their ecological richness, cultural significance, and highly productive agriculture. Sea level rise will force changes to coastal lowlands, with impacts extending beyond environmental degradation to encompass profound social and economic ramifications. These impacts are expected to be felt more keenly by systemically marginalised and vulnerable peoples (IPCC, 2014), including Maaori[1], the Indigenous peoples of Aotearoa. Adaptation needs to be designed to address existing inequities and enhance the integral components of societal wellbeing that support diverse ecosystems, culturally important landscapes, and vibrant communities.

The National Institute of Water and Atmospheric Research (NIWA) is implementing the Future Coasts Aotearoa research programme[2] to identify sustainable adaptive planning and decision-making frameworks for Aotearoa's coastal lowlands. In this research, we are partnering with Swamp Frog Environmental & Tree Consultants Ltd ('Swamp Frog'), a community-based research team who work closely with marae and whaanau from Te Puuaha o Waikato (Te Puuaha) in the lower stretches of Te Awa Waikato (the Waikato river) in Aotearoa's North Island (Figure 1).

Presently, climate change is contributing to a number of effects in Te Puuaha. First, rising sea levels are contributing to enhanced erosion along the coast of the region. Coastal erosion is a natural shoreline dynamic in the area. However, changes in the frequency and severity of extreme weather events and rises in sea level could exacerbate rates of erosion and are increasing the risk of inundation inland, through the mouth of the Waikato river into lowland areas (Waikato District Council, 2014).

Second, rising sea levels are gradually driving the saltwater/freshwater interface inland and upwards, modifying the habitats/ecosystems of lowland freshwater systems. Modelling conducted by NIWA in partnership with Waikato Tainui Te Whakakitenga indicates that sea level rise will not only increase the salinity of the Lower Waikato river over time (Figure 2), but will also be expected to raise average water temperatures in the river in future

Figure 1: Te Puuaha o Waikato – an area traditionally demarcated by tangata whenua as starting near the town of Te Paina (Mercer) and following the flow of the Waikato river westward to the sea at Port Waikato (Photo: Stuart Mackay, NIWA).

[1] Alternatively spelt 'Māori' by some iwi (tribes). We have adopted the dialect that uses double vowels instead of a macron, as this reflects the common practice of those within the Waikato-Tainui region, where this research took place.

[2] https://niwa.co.nz/future-coasts-aotearoa

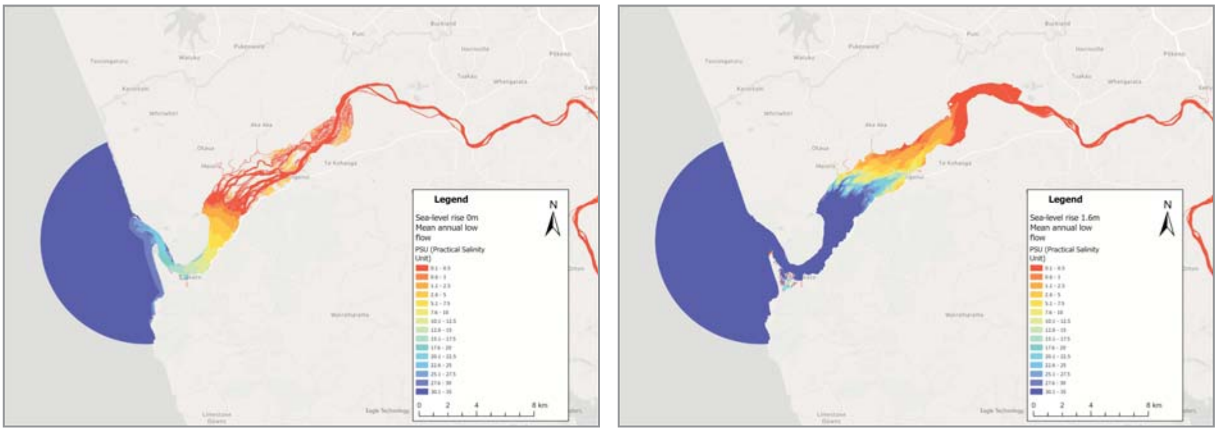

Figure 2: Mean salinity change. '0 meters' sea level rise represents present-day mean sea-level conditions (left), while '1.6 meters' sea level rise corresponds to an extreme greenhouse gas emissions scenario, like SSP8.5 (right). Note: The 1.6 meters sea level rise scenario is projected for the year 2150 under SSP8.5. Source: Reeve et al. (2023).

years (Figure 3). These coastal driven changes can be expected to affect the ecology and habitat of the riverine lowlands. As coastal erosion intensifies with sea level rise, these changes may accelerate.

Third, rising sea levels can be expected to exacerbate existing flood processes in the Waikato lowlands. Modelling conducted on flood level over time indicate potentially sizeable areas of flooding as sea levels increase (Figures 4 and 5).

Combined, these changes have the potential to impact the wellbeing of the community. Moreover, these changes occur in the context of colonialism, potentially exacerbating ongoing wellbeing challenges. In light of this dynamic situation, the Future Coasts Aotearoa research programme is exploring options to support the aspirations and needs of Te Awa Waikato as understood and promoted by its affiliated communities in Te Puuaha in the face of a changing climate. Te Puuaha whaanau are thinking long-term about the opportunities to work with nature and climate change to, firstly, support the health and wellbeing of Te Awa Waikato and secondly, enhance environmental, social and economic outcomes for Te Puuaha and marae, and lower river communities. This partnership provides an opportunity to help build a Maaori worldview into economic assessments of adaptation and associated decision-making processes. Western approaches to planning often rely on economic analysis frameworks – commonly cost-benefit analysis (CBA) – to inform adaptation. In practice, CBAs struggle to capture sociocultural considerations like the effects of adaptation on Maaori connectedness or attachment to place. Technically, economic tools exist to measure non-market values (e.g., Bennett, 2013; Rietbergen-McCracken et al., 2000) and even effects on Indigenous knowledge and culture (Manero et al., 2022). However, these methods can be inaccurate and difficult to apply. As well, Te Puuaha whaanau have expressly stated to us that such assessments are not appropriate for them in the current context of climate change planning and response.

Nevertheless, excluding sociocultural adaptation impacts on Indigenous communities from adaptation assessment may result in poor choices as this can favour market-orientated options at the expense of others. We therefore worked with Swamp Frog and Te Puuaha representatives to improve understanding of how to measure the sociocultural impacts of climate change response. This learning is intended to reduce the bias towards market-based assessments of adaptation, especially when concerning Maaori communities.

Methodology: assessing the sociocultural impact of adaptation

NIWA and Swamp Frog (on behalf of Te Puuaha) co-designed a three-step methodology to consider and assess

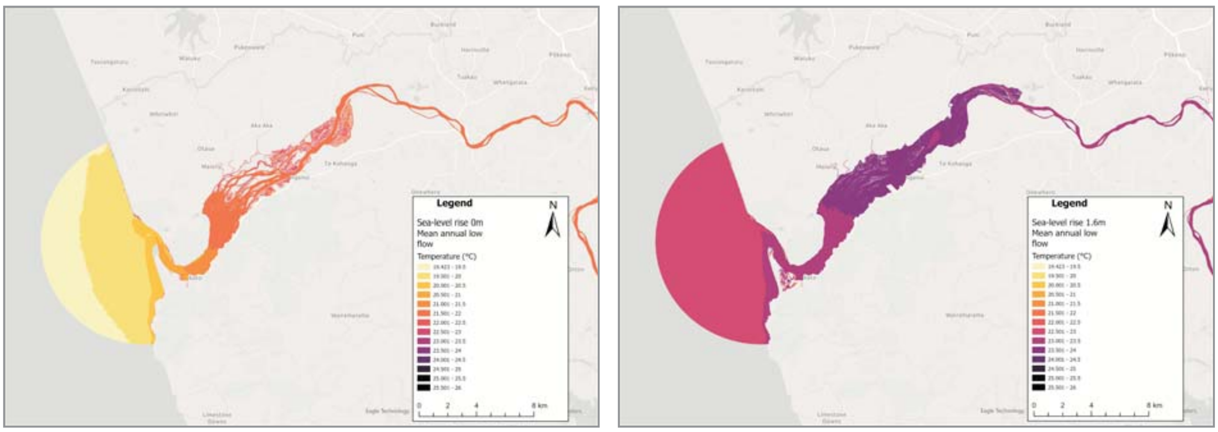

Figure 3: Mean temperature rise. '0 meters' sea level rise represents present-day mean sea-level conditions (left), while '1.6 meters' sea level rise corresponds to an extreme greenhouse gas emissions scenario, like SSP8.5 (right). Note: The 1.6 meters sea level rise scenario is projected for the year 2150 under SSP8.5. Source: Reeve et al. (2023).

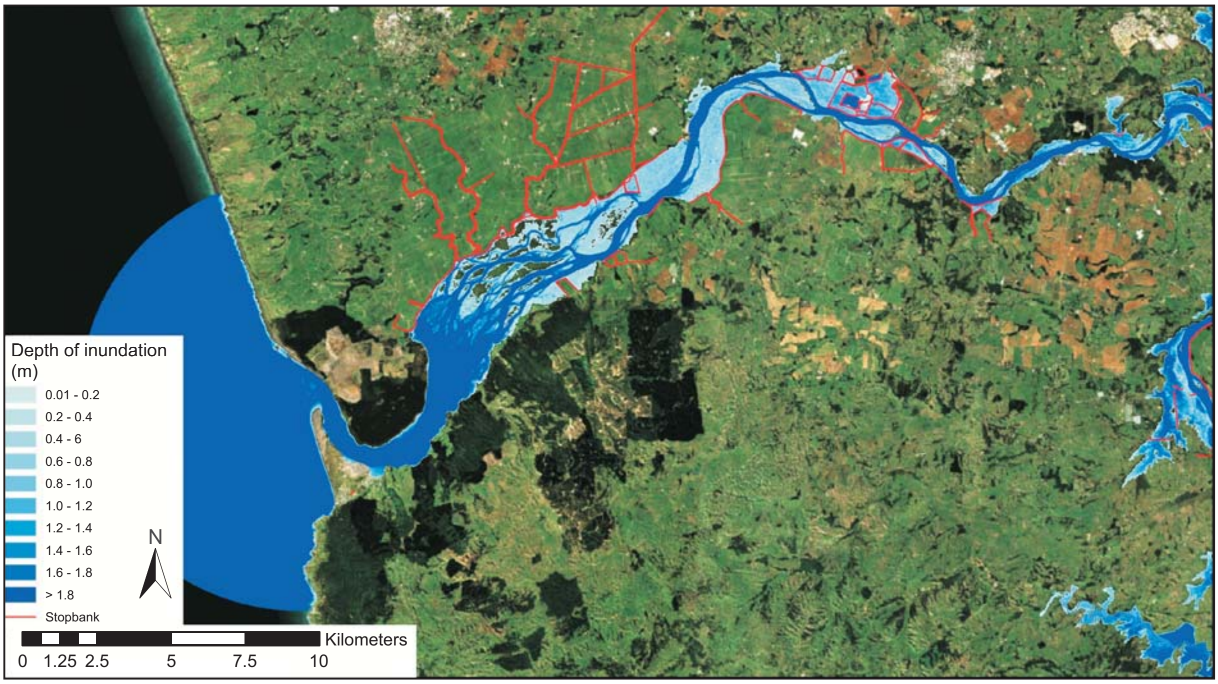

Figure 4: 2-D model scenario for present day inundation depths (100 annual return interval flood event) (Robcke et al., 2024; Reeve et al., 2023).

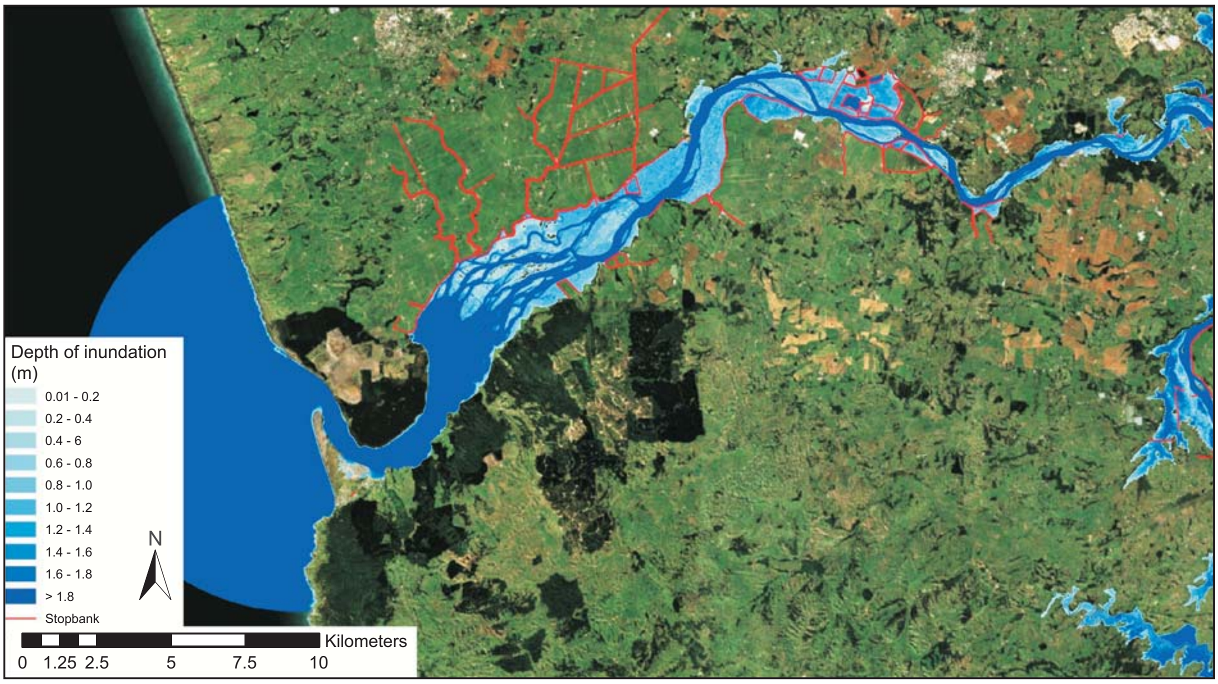

Figure 5: 2-D model scenario for inundation depths under a 0.6 m sea level rise (100 annual return interval flood event) (Robcke et al., 2024; Reeve et al., 2023).

the impact of adaptation on their sociocultural wellbeing:

- Identify wellbeing factors of importance,
- Identify some local options for climate change response,
- Weigh the effects of response options on wellbeing factors.

Identifying some local options for climate change response

For the Indigenous peoples of Te Puuaha o Waikato, the wellbeing of community is inseparable from that of Te Awa Waikato and its environs. The relationship is organic, adaptable and varying over time, but strongly interdependent with their Awa (Te Taniwha o Waikato, 2018). As the wellbeing of the people is dependent upon the Awa, any efforts to adapt to climate change in the eyes of this community should prioritise improving the health of the river and its environment, acknowledging the history of how the health of these have changed over time, and returning them as much as possible to a pre-confiscation state, as encapsulated by the vision of He Maimai Aroha[3]. Via the colonial mechanism of Raupatu (invasion and confiscation), the river and its catchment were confiscated in 1863 from Te Puuaha hapuu, effectively ending their traditional management. They were then extensively drained to enable agriculture and, subsequently, flood control. For Waikato hapuu, this harmed Te Mana o te Awa – the spiritual health and wellbeing of the river – and the status of the river as a source of sustenance and influence for its affiliated communities. Since the health of the community is inseparable from the river and its environs, community health continuously declines while the river remains controlled and the area continues to be treated as a commodity. Conversely, adaptation that improves the health of the river and the area can be expected to enhance the wellbeing of the community:

> *"Restoration should not be about us feeling better that we did something towards improving the physical health and wellbeing of the River; but about ensuring that spiritually and culturally our health and wellbeing is also being enhanced and so we are in fact, better."*
> (Te Taniwha o Waikato, 2018, p 3).

> *"Humans are an integral part of the system that needs to be restored."*
> (Te Taniwha o Waikato, 2018, p 8).

Informed by this perspective and the thinking that emerged in Te Ture Whaimana o te Awa Waikato (also known as the 'Vision and Strategy for the Waikato River' – Waikato River Authority, Undated), Te Puuaha whaanau identified a set of possible actions (responses) during a series of hui group discussions.

Identifying wellbeing factors of importance

To grasp how Te Puuaha o Waikato is potentially affected by climate change and associated changes in the river environment, a causal diagram was produced with representatives of Te Puuaha. Causal diagrams display the various factors concerned with an issue and how they interrelate (Senge, 2006; Sterman, 2000). This helps us understand which parts of a system have the greatest influence and to identify areas where action might be expected to influence matters (Senge, 2006). Although causal diagrams have been used to improve understandings of wellbeing amidst climate change (e.g., Harrison et al., 2023), their use to assess the effect of specific adaptation actions on Indigenous community wellbeing is limited to non-existent. We build such knowledge here.

Weighing up impacts

Assessment of responses was conducted with Rangitiaho Mahuta – affiliated to Te Puuaha and a researcher at Swamp Frog – in a dialogue session by considering how each response would influence the different aspects of the community's wellbeing over time. Using the causal diagram produced, the assessments were formulated as narratives. Te Puuaha representatives in an advisory group preferred this approach to scoring impacts because (i) the extent to which adaptation options might impact a factor is not presently known, and (ii) the community's preferred responses to environmental change could have multiple impacts over time, so a single assessment would be misleading.

Results and implications

The three responses identified for this part of the assessment for Te Puuaha o Waikato were: (i) letting river management fall into disrepair over time to enable river and environment recovery including, potentially, wetlands recovery; (ii) wetlands cropping; and (iii) elevating buildings. These were considered against the wellbeing components identified in causal diagram produced with Te Puuaha whaanau (Figure 6).

The causal diagram developed displays the sociocultural wellbeing of Te Puuaha. The diagram retains its original Te Reo Maaori terminology. This is because several interpretations or meanings may be drawn from a single Te Reo Maaori word, depending upon the context. The nuanced meaning of terms may be lost if those words are translated to a singular and fixed English-translated narrative. While we therefore do not translate these terms, it may be helpful to understand that the term 'te taiao' speaks broadly to environmental matters, 'whaanau' speaks to the concept of families or communities, and 'maatauranga' speaks to broad concepts surrounding knowledge (see also Waikato-Tainui, 2023; Johnson et al., 2024).

The diagram has two main components:

- The unshaded area talks to the difference between the states of the riverine environment and its people today and their state prior to confiscation, as observed by Kiingi Taawhiao when he composed He Maimai Aroha. Placed atop the causal diagram, He Maimai Aroha provides an 'anchor' for movement and is seen as a driver in what would be a multi-generational journey for whaanau and their river. He Maimai Aroha may be viewed as a key indicator framework for assessing and monitoring how successful society is in moving towards that 'anchor' ('the difference between the maimai aroha and reality') (van Schravendijk-Goodman et al., 2023).
- The shaded area talks to the impacts of change on different aspects of community wellbeing for the Indigenous Te Puuaha o Waikato community. Depending on whether a change contributes to He Maimai Aroha, the impact on community (and river environment) wellbeing may be positive or negative.

The causal diagram positively frames impact (e.g., 'ability' to do something, rather than 'inability') and the subsequent assessment of responses focusses on what is needed to support positive outcomes. This positive perspective arises because Te Puuaha recognise that their ancestors accommodated changing environmental conditions every day. Therefore, rather than viewing climate change and associated coastal changes as risks to be managed, whaanau view change as a natural condition, and even an opportunity – for example, discussions about coastal change and climate change prompted talk of flooding, which facilitated dialogue about lifting homes and marae. This in turn inspired a feasibility study into building elevation (WT, 2023). Discussions among whaanau about flooding also reinvigorated cultural memories about tuupuna (ancestors) living with swamps, and how they utilised and interacted with their valued resources in those spaces. This resulted in a feasibility study of current methods of peatland farming (paludiculture) presently

[3] He Maimai Aroha is a heartfelt lament of the second Maaori king – Kiingi Taawhiao – which paints an image of the state of the river catchment before colonisation-related activities had impacted on the environment. This provides a baseline for the natural world as experienced by Waikato peoples, and in the case of this project, specifically for Mana o te Awa – the health and wellbeing of the Waikato River.

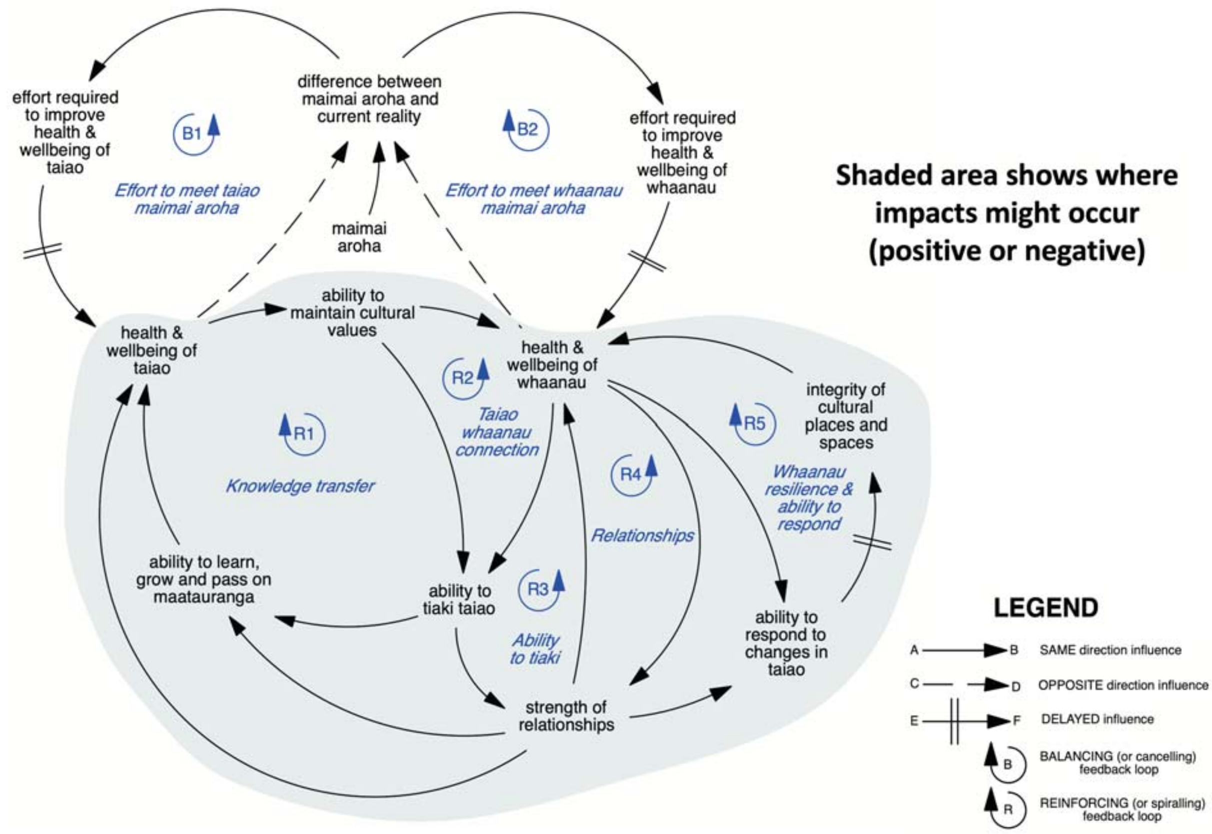

Figure 6: Causal diagram for community from Te Puuaha o Waikato (van Schravendijk-Goodman et al., 2023).

conducted in the Northern hemisphere, but not yet adopted in Aotearoa (Garrett, 2023). The broader idea of wetland farming as a response to increased land inundation has been and continues to be explored via other conversations between Te Puuaha, the National Wetland Trust, Manaaki Whenua, Aarhus University (Dr Brian Sorrell) and University of Waikato, as well as with NIWA.

Sociocultural effects of responses

Different adaptation narratives emerged from the dialogue. These are considered first individually and then as bundles. Without adaptation, there is no movement towards improving the health of the river, so community wellbeing will continue to decline over time. Ongoing drainage of the land for farming and flood management will continue to harm river health. This reduces the ability of the community to maintain healthy cultural links with the environment, setting off a cascade of harmful effects such as reduced ability to access physical spaces and reduced ability to uphold values and tikanga (resulting in the downward sloping curve in Figure 7).

Such impacts on cultural wellbeing in the face of change over time has been noted previously. For example, Taura et al. (2017) observe that environmental decline in wetlands can result in the decline in the use of traditional names for plant and animal species. Over generations, this can generate a gradual decline in the (traditional) knowledge of the origin and purpose of the name. For instance, the name of a plant may provide clues to a whakapapa (connections between and within species) that can also become hidden as the name disappears from the local language (Taura et al., 2017). In the specific case of the Indigenous community at Te Puuaha o Waikato, the localised extinction of the kauri tree in parts of the lower catchment of the river saw the localised suppression of maatauranga regarding its harvest, use and protection by Waikato peoples (Te Taniwha o Waikato, 2018).

As a single response, letting river management go over time reduces harm to riverine wellbeing as the river is able to resume a natural flow. Potentially, this could provide the chance for natural wetlands to emerge, offering environmental benefits like improved ecosystem services and greenhouse gas sequestration. Embracing natural river flow in the lowlands is not only perceived as more sustainable culturally, but also more economically sustainable, as sea level rise will make maintenance of drainage and flood defences in the catchment costlier over time. Without river management, sociocultural wellbeing should increase as whaanau are able to reconnect over time with traditional approaches to living with water and flooding. More importantly, they can strengthen their connection to the river and their own spiritual and cultural wellbeing, enhancing resilience (the upward sloping curve Figure 7).

Notably, this benefit will only be realised if wetlands restoration is properly planned and managed: vegetation needs to be native to the area, and continual management is needed to control pest plants and species. Some negative impacts could also be expected. For example, areas that have previously been accessible under drainage could become cut off over time. Restoring wetlands also requires the community to (re)-learn how to live with the natural river environment. If communities do not learn new coping strategies, wellbeing will remain unchanged or even decline over time until change is accepted and accommodated (Figure 8).

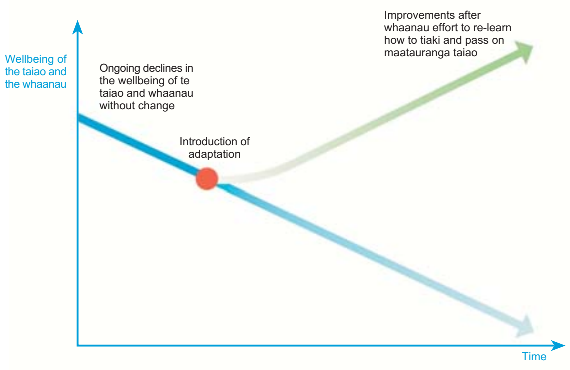

Figure 7: Change in wellbeing with and without adaptation for community from Te Puuaha o Waikato.

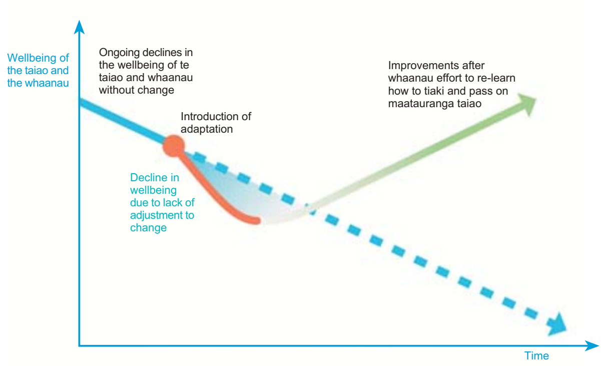

Figure 8: Challenging change: slow adjustment resulting in temporary harm before benefits for community from Te Puuaha o Waikato.

As a single response, cropping atop wetlands restoration would increase whaanau wellbeing by increasing their ability to engage in economic activities, while maintaining sociocultural values and enhancing their ability to look after the environment and pass on knowledge and practices (Figure 7). However, as with changing river management, benefits will only be realised with conditions. Cropping must be properly planned and managed to ensure the ecological health of the area. Crops must be native and a mosaic planting approach (as the 'old people' used) as opposed to monocultures, would need to be adopted. In practice, much of the traditional knowledge of how to do this has been subsumed under the dominant paradigms of pastoralism and commercialisation following Raupatu, and would need to be coaxed 'back to the surface' and/or strengthened. Fairness issues also need to be considered. The wealth generated from cropping would need to be distributed fairly and access to crops and funds would need to be managed. Without these wrap around approaches, benefits may not be secured and/or community wellbeing may even decline over time until traditional knowledge is regained and fairness managed (Figure 8).

As a single response, elevating buildings enables whaanau to choose to stay safely in their area for longer in the face of climate change. Remaining physically connected to their land is important for many Maaori to retain practices associated with the land and ancestry. Enabling people to remain longer in place would strengthen their ability to connect to the environment, learn how to maintain the river's wellbeing, and increase their understanding of how to respond to change such as sea level rise and floods (Figure 3). However, as with other responses, benefits will only be realised with conditions. Whaanau will need to recognise that, while their elevated homes may remain dry in a flood, surrounding areas could still be flooded and they could get cut off from family or facilities. Whaanau would need to learn how to look after the environment, accept and cope with floods, and pass on this knowledge. This will take time, and adjustment could be painful or inconvenient in the interim.

If well-planned individual responses differently offer the chance to enhance sociocultural wellbeing, how do they compare to each other? Discussions conducted with Swamp Frog reveal that letting river management go over time is the priority foundational response upon which other responses build. Without this response, the ability of the community to maintain healthy cultural links with the environment cannot occur. This concern is paramount since – as revealed in the causal diagram – community wellbeing is contingent upon river wellbeing. As well, cropping of wetlands is not possible without this response because wetlands will not be given the chance to re-emerge. Moreover, without allowing the river to resume its flow, any urgency to elevate buildings will decline. Yet the need for the community to be able to stay somehow in place seems inevitable since river management will become increasingly unaffordable over time.

From a sociocultural perspective, other responses therefore only occur in tandem with letting river management go. Ultimately, more responses are better.

How do different bundles of responses then compare against each other? Discussions in the dialogue session reveal that implementing other different responses along with letting river management go will enhance sociocultural wellbeing, but it is unknown which bundle offers most. This sentiment echoes previous sessions with other community representatives who observe that no single response can be relied on to 'best' protect sociocultural wellbeing. Adaptation strategies should focus more on bundling responses, rather than stand-alone ideas.

Key lessons

The results of this research contain important messages which will be used to inform ongoing adaptation planning and decision-making in Te Puuaha o Waikato. First, non-adaptation is harmful to the Maaori community from Te Puuaha. The health and wellbeing of the river will continue to be compromised, harming community sociocultural wellbeing. Second, benefits from response come with pre-conditions. Responses need to be well-planned and well-resourced to improve the wellbeing of the river and whaanau, including providing people time and support to adjust to their changing environment. Importantly, responses may come with potential for short-term costs to wellbeing as it will take time, effort and resources to strengthen how to cope with the new conditions. However, if support can be provided to help whaanau to weather these changes, and if the community can commit to learning to accept the change, reconnect with the environment and pass on knowledge, adaptation can improve wellbeing over the longer-term (Figure 9). Adopting multiple responses (restoring wetlands and or cropping wetlands or elevating homes) could increase wellbeing further, although the adjustment might also be bigger.

Using narratives and causal diagramming to assess the impact of different adaptation options on wellbeing provided a useful platform to capture the complex, highly interconnected factors affecting Indigenous understandings of wellbeing in a changing climate. This method can be used in other communities both nationally and internationally to capture the non-market sociocultural benefits and costs of adaptation in planning and decision-making, and to frame adaptation around opportunities that are driven by community aspirations.

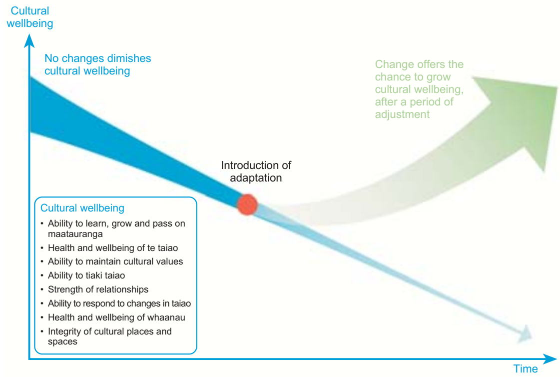

Figure 9: The potential costs and benefits of adapting to change to the community from Te Puuaha o Waikato.

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Increased exposure of marae to coastal flooding with sea level rise and adaptation learnings of Ngāi Tamawhariua and Maketū Iwi Collective

By Akuhata P Bailey-Winiata, Shari L Gallop, Liam Wotherspoon, Ryan Paulik, Hone Winder-Murray, Anne Billing, Elva Conroy, Roana Bennett, Iain White, Joanne Ellis and Tūmanako Fa'aui

Introduction

Culturally significant places are a legacy left by our tūpuna (ancestors) that lend a sense of place, identity and connection to the past (Phillips, 2015; Sesana et al., 2021). These sites have important social, ecological, historical, educational and economic value (Pearson et al., 2023). Globally, there are many cultural heritage sites that are situated on low-lying coastal land (Reimann et al., 2018; García Sánchez et al., 2020). This includes in Aotearoa New Zealand (A-NZ), where many low-lying Māori and non-Māori heritage sites are at risk to increased intensity and recurrence of coastal hazards with climate change (Bickler et al., 2013; Jones et al., 2023).

Sea level rise is affecting peoples, assets, and cultures of flood-prone coastal communities around the world (Hallegatte et al., 2013). It compounds colonial injustices and can contribute to continued marginalisation of Indigenous communities, who despite their generally minimal contribution to anthropogenic climate change, are some of the highest impacted communities (Bronen and Cochran, 2021). However, in response to the climate crisis, Indigenous peoples are reasserting their right to self-determination to be active agents of understanding and managing risks, and safeguarding their land, communities, and environments for future generations (Cochran et al., 2013).

Whānau (families), hapū (sub-tribes) and iwi (tribes), and their marae (Māori meeting grounds), are often located at the coast and/or waterways, some because of their historic proximity to resources, for trade and transport, while others were forcibly relocated by Crown land purchases and/or land confiscations onto what are now hazardous locations (Iorns, 2019; Parsons and Fisher, 2022). Marae are a complex of buildings, each with a role in the functioning of the marae, such as the wharenui or whare tupuna (meeting house) which is the main building used for hui (meetings), wānanga (workshops), and sleeping, and which also provides a connection to ancestors through whakapapa (genealogy) (Kawharu, 2010; Skinner, 2016). Marae typically have a wharekai (kitchen/dining) and wharepaku (ablution facilities). Marae are one of the last places where Māori lore or tikanga (traditions and protocols) still govern, upholding rangatiratanga (authority) of hapū and iwi (Tapsell, 2002). The role and function that the marae buildings and land play, particularly during large events, is very important, with the ability to host, cater and house large numbers of people often at short notice, both within the buildings and surrounding land, such as to store vehicles and equipment. Marae land can provide space for māra kai (gardens), kōhanga reo (early childhood centers) and kaumatua (elder) housing for example (Bailey-Winiata et al., 2022). In recent times and particularly during ex-tropical Cyclone Gabrielle in early 2023, many marae in the Gisborne and Hawke's Bay regions were directly impacted by river flooding and landslide damage, and indirectly by road closures disturbing access to communities (Desmarais, 2023). Climate change will compound these impacts, endangering the heritage, connections, and functionality marae have for tangata whenua and the broader communities they serve.

This research has two objectives. The first objective is to identify the risk of marae land parcels and buildings nationally to coastal flooding with SLR, focused on coastal marae (hereafter marae) within 1 km of the coastline. Building on previous work (Bailey-Winiata, 2021; Bailey-Winiata et al., 2024), we (1) ascertain the potential exposure of the various marae buildings and land parcels to coastal flooding; (2) apply shared socio-economic pathways (SSP) scenarios; (3) identify the impact of sea level rise by using the exposure to extreme sea level events (ESLs); and (4) incorporate higher resolution LiDAR elevation data. The scenarios investigated included SSP2-4.5 (moderate emissions-current trajectory) and SSP5-8.5 (very high emissions >4°C warmer world). Hapū and iwi around the country are planning to adapt, however current policy frameworks support council-led adaptation, and there is a need for policy, processes and practices that enable hapū and iwi to plan to adapt (Bailey-Winiata et al., 2022, Stephenson et al., 2024). Thus, the second objective is to showcase impact case studies of the adaptation planning process of two hapū and iwi to share learnings. These case studies are located in the Bay of Plenty from the hapū of Ngāi Tamawhariua near Katikati, who are leading their own adaptation planning for their papakāinga (communal Māori housing), and the Maketū Iwi Collective who developed a multi-award-winning community climate change adaptation plan. Together, these examples of Indigenous-led adaptation provide important lessons, for other Māori communities, governments and researchers.

Identification of marae land parcels and buildings

A national marae location dataset originally from Te Potiki National Trust (2011) was used as a starting point, and although some marae chose to not be recorded in this dataset, this is currently the best available national information. This was then limited to marae that were within 1 km of the coastline as in the work of Bailey-Winiata (2021) (Figure 1). Following this, these marae locations were manually checked using Google Street View, Google Earth Imagery and Māori Maps. These were also used to include marae that weren't part of the initial dataset. Two marae were identified in an ad hoc manner based on the authors' identification of additional marae not included in the dataset. These locations were used to create two new data layers: (1) marae land parcels using the NZ Primary Land Parcels polygon dataset (LINZ, 2024b), and (2) marae buildings from the NZ Building Outlines dataset (LINZ, 2024a). Google Earth aerial imagery was used to manually verify marae buildings and adjust land parcels. The boundaries of larger land parcels were reduced to focus on the core marae functions, such as car parks, food gardens, and maintained grass areas, to prevent the skewing of exposure results. In total, there were 186 marae, 186 marae land parcels and 874 marae buildings that were used in the exposure analysis.

Exposure of marae land and buildings to coastal flooding with sea level rise

To model potential exposure of marae land and buildings to coastal flooding with sea level rise, we utilised ESL data from Paulik et al. (2023b) who quantified A-NZ land area exposure to coastal flooding from extreme sea levels and relative sea level rise, which includes vertical land movement (VLM) (Kopp et al., 2014; Naish et al., 2024). Paulik et al. (2023b) produced (1) water levels along the coast for 2-to-1000-year ARI extreme sea level events with increasing relative sea level rise increments, and (2) potential land coastal flooding extents and depths using a static model (bathtub approach). This dataset does not account for river flooding, only coastal flooding with sea level rise.

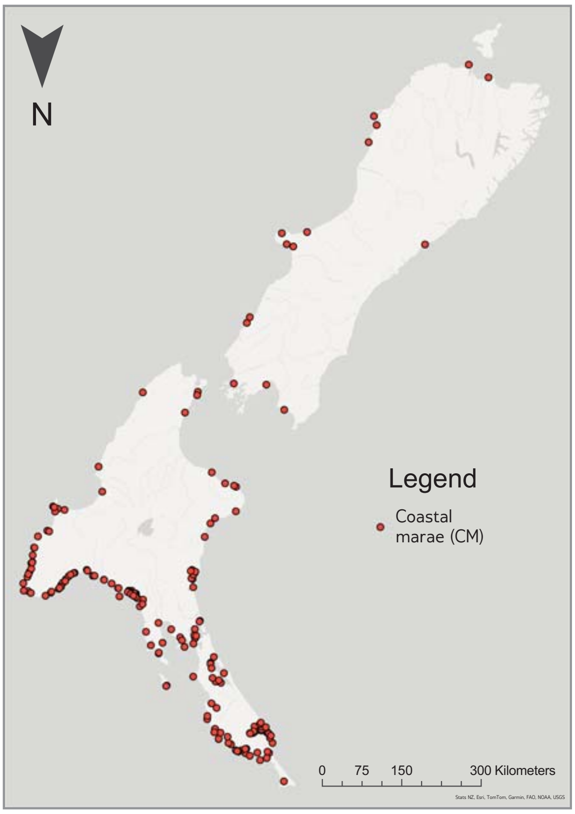

Figure 1: National coastal marae shown on a Te Ao Māori view of Aotearoa New Zealand which is 'upside down' compared to conventional maps. The North Island is Te Ika a Maui (The fish of Maui). The South Island is Te Waka a Maui (the canoe of Maui) (Hikuroa 2020; Ka'ai and Higgins 2004).

Here we focus on the commonly used 100-year ARI (Ministry for the Environment, 2024), as well as an extreme scenario of a 1000-year ARI event under the SSP2-4.5 and SSP5-8.5 p50 scenarios inclusive of vertical land movement (Ministry for the Environment, 2024). We used RiskScape to calculate the maximum water depth intersecting the marae land and individual building polygons (Paulik et al., 2023a) and the percentage of the land or building polygon exposed to coastal flooding in each scenario. Due to the presence of multiple marae buildings inside marae land parcels, and the intersection of these buildings with the modelled flood exposure metrics, there is a possibility that only some of the marae buildings are exposed to SLR, whilst others are not. In these scenarios, the data/model is able to represent individual exposure of these buildings, providing a more accurate representation of building exposure.

Marae adaptation case study interviews

Ngāi Tamawhariua and the Maketū Iwi Collective (consisting of multiple hapū), are leaders in hapū-led climate adaptation planning. Information for these two case studies was shared through four interviews and written questions with two leaders of the adaptation strategies from each case study. These interviews were centered on the five key questions below to share learnings, as well as to share empowering messages of hope and resilience for other whānau, hapū, and iwi who are considering adaptation. These case studies were chosen due to the exceptional leadership of these hapū in national Māori climate adaptation planning. This information was collected in line with human research ethics approval through the University of Waikato (HRECS(HECS)2022#02). All interview data is used with permission of those involved, who are also co-authors of this paper.

The open-ended questions were designed to provide guidance for other Indigenous communities at risk from the experiences of the two-case study hapū (Brinkmann and Kvale, 2018). This is also a culturally congruent method aligned with kaupapa Māori research methodologies for open and honest discussions (Bishop and Glynn, 1999).

1. Do you feel like you have/had enough relevant information and data to support your planning?
2. What additional support do you think would have helped?
3. Are you already experiencing flooding at your marae and/or wāhi tapu?
4. Do you have any plans for implementation?
5. Do you have any messages for whānau who are beginning to think about climate change planning for their marae?

Marae exposure to extreme sea levels

By 2050, 14.5% and 17% of a total of 186 marae may be exposed to coastal flooding with 100 ARI and 1000 ARI ESLs respectively under SSP5-8.5. By 2150, under SSP5-8.5, 27% and 28% of the 186 marae are exposed to 100 ARI and 1000 ARI ESLs respectively.

However, it is the timing that is most concerning as 14.5% and 17% of a total of 186 marae are likely to be impacted by 2050. We further identified the exposure of marae

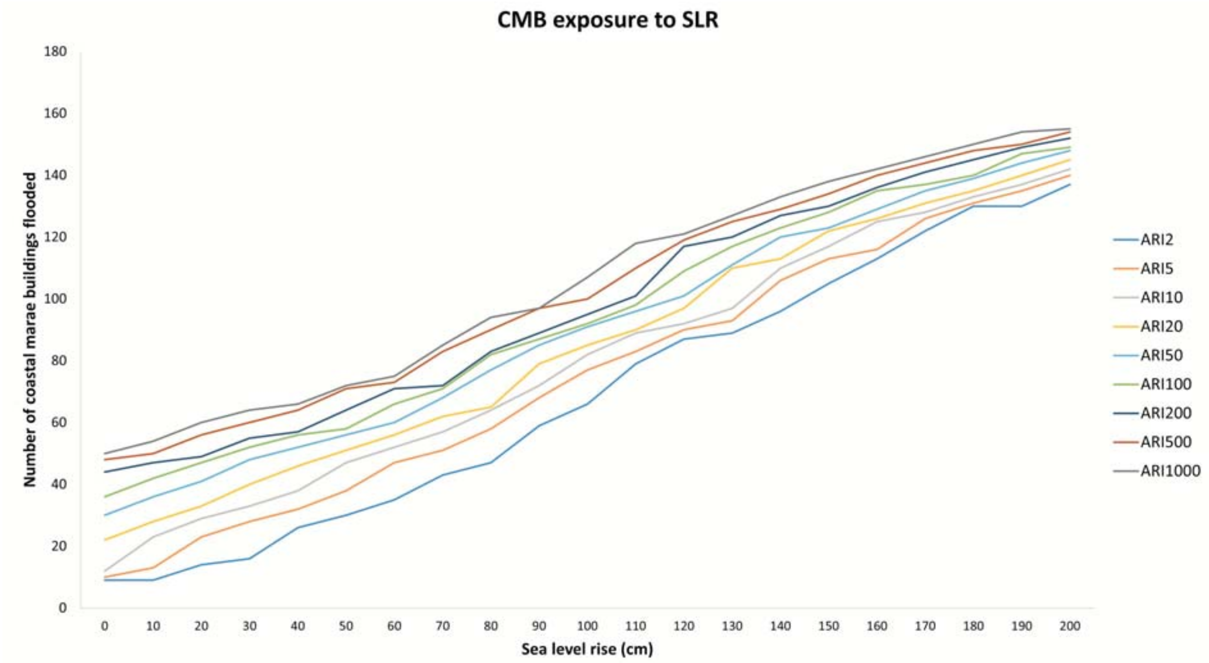

Figure 2: National exposure of marae buildings to coastal flooding with sea level rise for different ARI extreme sea levels and SSPs.

buildings under both 100 ARI and 1000 ARI under SSP2-4.5 and SSP5-8.5 (Figure 2), which shows similar trends of increasing over time.

We identified the percentage exposure of marae land and buildings exposed to 100 ARI ESL under SSP5-8.5 to 2150 (Figure 3). For marae buildings with 75%-100% of their building area exposed, a total of 13% of the 874 marae buildings would be exposed to coastal flooding under the 100 ARI and SSP5-8.5 scenario at 2150 (Figure 3A). In terms of marae land parcels with more than 50% of their land parcel area exposed, a total of 13% of the 186 marae land would be exposed to coastal flooding under the 100 ARI and SSP5-8.5 scenario (Figure 3B). The largest numbers of marae are at both extremes of percent land exposure, i.e. 0%-25% and 75%-100% exposure through time. For example, under a 100 ARI and SSP5-8.5 at 2150, 10% of the total 186 marae land have <25% (not including those with 0%) of their land exposed. This highlights an opportunity for these marae to potentially relocate buildings within their existing land parcels, noting that more comprehensive investigations would be required such as identifying any accessibility issues, suitability of the terrain, and other potential hazards. Lastly, 10% of the total 186 marae land have 75%-100% of their land parcel exposed. These marae have less opportunity to relocate within their marae land parcel, hence either they can relocate within their wider land parcel (given we reduced some of the larger parcels), or to another land parcel elsewhere, or other approaches to adapt such as hard engineering or nature-based solutions.

Predicted water levels at the location of the marae buildings and within land parcels exceeded 5.5 m in some locations. There is a large proportion of marae buildings and land exposed at flood heights between 0-1.5 m by 2150 (Figure 4). In terms of marae buildings (Figure 4A), there is a lack of detailed information on marae building elevations. However, in general, marae buildings are either on concrete slabs with heights of around 0.15 m or on piles with heights of around 0.45 m (Paulik et al., 2024). The majority of coastal flood heights of marae buildings is less than 1 m (Figure 4A), so not only will there be direct flood damage of marae buildings, but other subsequent impacts, such as increased moisture under piled marae buildings, potentially resulting in mould and rot. Marae land also followed similar trends to marae buildings, with more represented at lower water depths, however, is more variable in terms of depth through to 2150 as compared to marae buildings (Figure 4B).

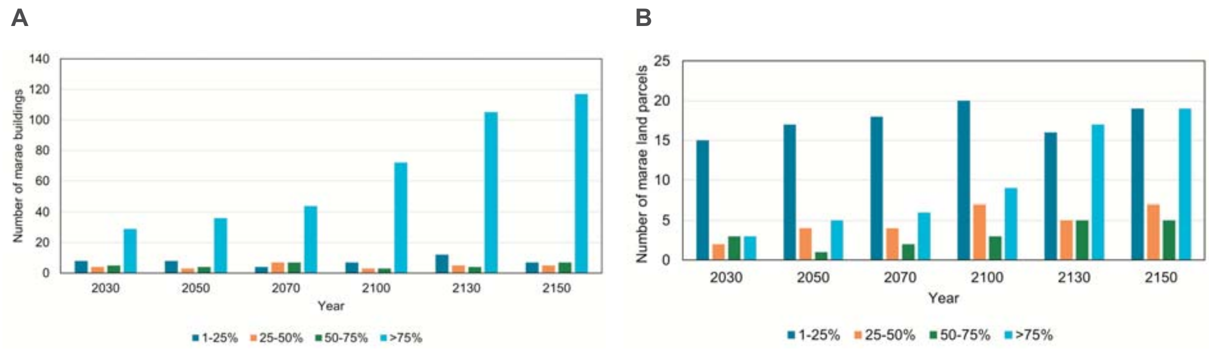

Figure 3: Percentage exposure of (A) Marae buildings, and (B) Marae land to 2150 under ARI100 & SSP5-8.5. These graphs do not include those with 0% exposure.

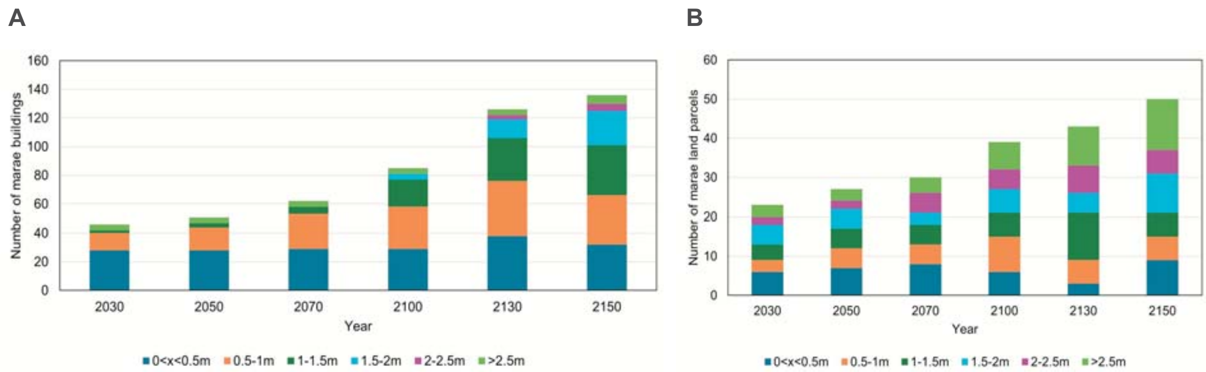

Figure 4: Maximum flood water depth for (A) Marae buildings and (B) Marae land parcel to 2150 under ARI 100 & SSP5-8.5. These graphs do not include those with 0m water depth.

Marae vulnerability – moving forwards

From our discussions with the hapū and iwi who are looking to plan for climate change, accessible and relevant data is important to aid decision making and to guide processes such as adaptation. Importantly, given the absence of consideration for other hazards in this article, such as river flooding, the full picture of risk to marae may be higher. We therefore identify multi-hazard assessments as a critical future research need. However, data is only part of the equation. For the hapū and iwi we interviewed, a number have lived experience of flooding events in recent times, and data confirming what they already know/have seen sometimes can be seen as superfluous in contrast to enhanced support to adapt. Although, it is also acknowledged that such information can help add more detail to the current understanding and provide added impetus to act.

We now showcase two examples of where hapū and iwi are leading their own adaptation and climate change discussions. Both introduce the risk context, discuss the processes and partnerships developed, and share key lessons to feed into discussions on mainstreaming Indigenous climate adaptation.

Ngāi Tamawhariua – Adaptation planning supported by research

Te Rereatukāhia Marae of Ngāi Tamawhariua is situated in the northern reaches of Tauranga Harbour near Katikati, alongside Te Rereatukāhia Awa in the Bay of Plenty. Tamawhariua whare tupuna is elevated more than 15 m above sea level and is not directly impacted by coastal flooding now or in the future based on our analysis (Figure 5A). However, large areas of the papakāinga of Ngāi Tamawhariua is situated below the marae on low-lying land between the awa and the estuary and in places less than 1.5 m above sea level (Figure 5B). The area has been exposed to riverine flooding, and parts of the papakāinga were evacuated three times in 2023 including during ex-Tropical Cyclone Gabrielle. Ngāi Tamawhariua also have an urupā (burial ground) in the estuary on the island Tūtaetaka, which is experiencing coastal erosion on its north-western side, unearthing historical kōiwi (human remains) following large storm events (Figure 5C).

Ngāi Tamawhariua are forging a pathway forward to plan and respond to natural hazards and climate change in a way that is led and informed by their whānau, for their whānau. The Chair of Ngāi Tamawhariua, Hone Winder-Murray, shared the importance of being connected to skilled people who have connections within the research and industry spaces, such as with research groups like Project Kāinga – a Ministry of Business, Innovation and Employment Endeavour funded project around Māori climate change resilience with whom they have been working with. Hone shared:

> *"We are lucky to have some seriously skilled people working with us and for us. Those skilled personnel have been fortunate enough to tap into places and people who have provided the funding required to seek out relevant data needed for the kaupapa. Beneficiaries of the hapū were equally important as they provided the insights into what future they want/wanted. Without their survey data – we could not determine the shaping of a safe, healthy and thriving kāinga for the future."*
> Hone Winder-Murray

As Hone mentioned, equally as important is to have the whānau of the hapū onboard to ensure that whatever decisions are made, are in the best interests of the people and achieve the futures they desire. Ngāi Tamawhariua held a series of wānanga as part of Project Kāinga, centered around hapū and kāinga (housing) resilience in the face of climate change (Figure 5D). These were attended by whānau of Ngāi Tamawhariua and researchers including social scientists, anthropologists and coastal scientists. This community input was echoed further by Anne Billing, project manager for community projects with Ngāi Tamawhariua. Anne shared:

> *"Bring whānau on board who have a background in the climate change space. This will save a lot of time if the right person/people are available and willing to share… We also undertook a capacity and capability survey of all whānau including those who live away, what skills, knowledge, capacity, capability already exists in house."*
> Anne Billing

Moving forward, Ngāi Tamawhariua are in the process of publishing their Kāinga Plan, a 100-year road map to climate adaptation and resilience for Ngāi Tamawhariua, which is the result of five years of research with Project Kāinga. This identifies a 100-year vision outlining key priorities moving forward for their hapū that can be used for informing climate change discussions as well as other decisions. In response to the question, Do you have any messages for whānau who are beginning to think about climate change planning for their marae? Anne responded:

"Get the tamariki and rangatahi onboard, the future is theirs... create a long-term vision and use docs such as hapū management plans to identify what the current generation can do to start building the foundation for future generations to build on." Anne Billing

The Maketū Iwi Collective – A community climate change plan embedded in Te Ao Māori

The Maketū Iwi Collective is a combined working group with representatives from Te Rūnanga o Ngāti Whakaue ki Maketū, Whakaue Marae Trustees and Ngāti Pikiao Environmental Society, in the coastal town of Maketū, in the Bay of Plenty. Maketū is situated between two estuaries, Te Awa o Ngātoroirangi fed by the Kaituna River to the north-west of Maketū town and Waihi estuary to the east. In April 2023, the Maketū Iwi Collective published *He Toka Tū Moana Mō Maketū – Maketū Climate Change Adaptation Plan*, which was supported and developed by the broader Maketū community with support from Bay of Plenty Regional Council (Maketū Iwi Collective, 2023). Their plan encapsulates their collective approach to tackling climate change issues, specifically forging their own pathway forward with climate adaptation for their whānau, hapū and wider community. This plan was informed by a series of wānanga to gather kōrero (discussions) and aspirations for their future as a collective. These were then illustrated in the plans five key priorities: 1: Haumarumaru (Security and self-sufficiency); 2: Te Puna Mātauranga (Collective knowledge and wisdom); 3: Manaaki Kāinga (Caring for our home); 4: Manaaki Whenua (Caring for our lands); and 5: Manaaki Wai (Caring for our waters) see (Figure 6A). Roana Bennett, one of the plan's facilitators mentioned:

"We led our own process. Our facilitators are all from Maketū, and the people came when we put out the call. It was important to centre the wānanga inside our own world view, and our community respected and appreciated that approach." Roana Bennett

Whakaue (Tapiti) Marae, belonging to the hapū of Ngāti Whakaue ki Maketū is situated on the shores of Te Awa o Ngātoroirangi. It has experienced coastal flooding in recent years and was identified in our analysis as being exposed to coastal flooding with sea level rise in all scenarios modelled. This is no surprise to the iwi collective who are pragmatic in the face of this risk for their marae and have included it as one of their key priorities, 'caring for our home', in their plan. Roana Bennett, shared a kōrero of rangatiratanga (self-determination):

"We are not a vulnerable community. We don't need outsiders to determine our future. We are capable. We can respond to climate change as a community. We can help ourselves in an emergency. We expect councils and government to do their share of the work. But when you come into our community, we will lead the conversations, we will advise the priorities." Roana Bennett

Following on from their successful adaptation plan, implementing their key actions and achieving their key priorities is currently underway. However, implementation is slow due to lack of resourcing, but it is still happening, such as the recent Maketū Climate Change Community Day, see (Figure 6B), bringing together hapū, community, community projects and groups, and researchers and scientists to showcase their local and regional work. Elva Conroy, one of the writers of the plan, shared kōrero around implementation:

"Plan development is easy. But plan implementation is hard, additional support could include resourcing for project coordination, community engagement... Small grants enable communities to collectivise and plan – and to connect with councils to ensure that the big investments are done right and are well supported by the community." Elva Conroy

Moving forward, the Maketū Iwi Collective and broader Maketū community are forging their pathway for implementation of their plan, receiving well deserved accolades such as awards at the New Zealand Planning Institute Conference (Figure 6C) and continuing to be role models for other whānau embarking on their adaptation journey. When asked, 'Do you have any messages for whānau who are beginning to think about climate change planning for their marae?' Roana shared:

"Working as an iwi collective with a clear focus on climate change has provided us with a sound foundation upon which to build our climate change whare... Inviting the

Figure 5 [left]: (A) Tamawhariua Whare Tūkpuna. (B) Te Rereatukāhia papakāinga looking from Marae, Tauranga Harbour to the left and Te Rereatukahia River to the right of image. (C) Tutaetaka Island - Urupā experiencing coastal erosion. (D) Whānau climate change wānanga (Images source: A/D – H. Winder-Murray, B/C – A. Bailey-Winiata). Figure 6 [right]: (A) Maketū Climate Adaptation Plan. (B) Maketū Community Day with Rangatahi playing an adaptation serious games with the National Institute of Water and Atmospheric Sciences (NIWA). (C) Maketū community photo at Whakaue Marae (Image sources: R. Bennett).

community into our space, into our climate change whare, has meant that the plan is embedded in Te Ao Māori – and that all members of the community see the plan as relevant to them... We will NOT retreat from the estuaries and rivers where we have been kaitiaki for 800 years... We may build new papakāinga, but we will always be kaitiaki of the rivers and estuaries." Roana Bennett

Lessons moving forward

Beyond technical data, these two case studies share rich, practical examples demonstrating how adaptation is already occurring despite considerable scientific and policy uncertainty. Both examples emphasise key messages to empower other hapū and iwi who are at the beginning of their adaptation journeys. There are key messages for three core audiences: tangata whenua, government, and the scientific/research community.

The case studies share an empowering perspective, but we acknowledge the intergenerational struggle and mamae (pain) that has been endured by those past and present of these two hapū, and others around the nation, to get to this position. While progress has been made, a challenge is how to effectively mainstream these lessons, so other marae can build on tested processes and practices. The goal is to formulate fit-for-purpose policy responses for Indigenous communities by working together to outline a process that centers Māori knowledge, skills, and values, and which can draw from more explicit policy support, similar to other works such as Makondo and Thomas, (2018) and Drake et al., (2023). We also emphasise the value of resourcing communities to act, as well as the provision of more multi-hazard data that can stimulate difficult conversations.

For tangata whenua a key lesson from these stories of hope and resilience is that rangatiratanga (self-determination) can still be pursued and future generations can be protected. There is great value in reaffirming hapū and iwi rangatiratanga in the adaptation process, that allows adaptation to unfold in a way that the state could not achieve alone. Interviewees also emphasised the importance of ensuring multi generations are represented at the decision-making table and to take a multi-generational perspective that prioritises future generations.

Lastly, for researchers and practitioners, to align and co-develop their projects in a partnership with hapū and iwi to help protect cultural heritage and share knowledge and expertise in future climate adaptation plans and practice. These partnerships need to be collaborative and go beyond only providing technical data on climate change and hazards, to generate new community and scientific capacities and capabilities. To provide a resource for hapū and iwi to guide conversations around sea level rise and adaptation, we have summarised some of the key findings in an infographic in Figure 7.

Conclusion

Coastal marae around Aotearoa New Zealand are at risk of coastal flooding with sea level rise. By 2150, under SSP5-8.5, 27% and 28% of coastal marae are projected to be exposed to extreme sea levels from a 100 ARI and 1000 ARI respectively. Looking deeper at the risk of individual marae buildings and their land parcels paints a similar picture; 13% of coastal marae land parcels have more than 50% of their land area exposed under ARI 100 and SSP5-8.5. After Cyclone Gabrielle in 2023, many communities, particularly hapū and iwi, are beyond the need for data to tell them what they already know, with many having lived experience of the hazard, and who are unable to wait for new data, policies or equitable resourcing to protect their marae. The case studies shared from Ngāi Tamawhariua and the Maketū Iwi Collective highlight opportunities around resourcing, partnerships, hapū and iwi autonomy, and the central importance of those who have gone before and those that are yet to come. To quote Roana Bennett, "We don't need outsiders to determine our future, we are capable, we can respond to climate change as a community".

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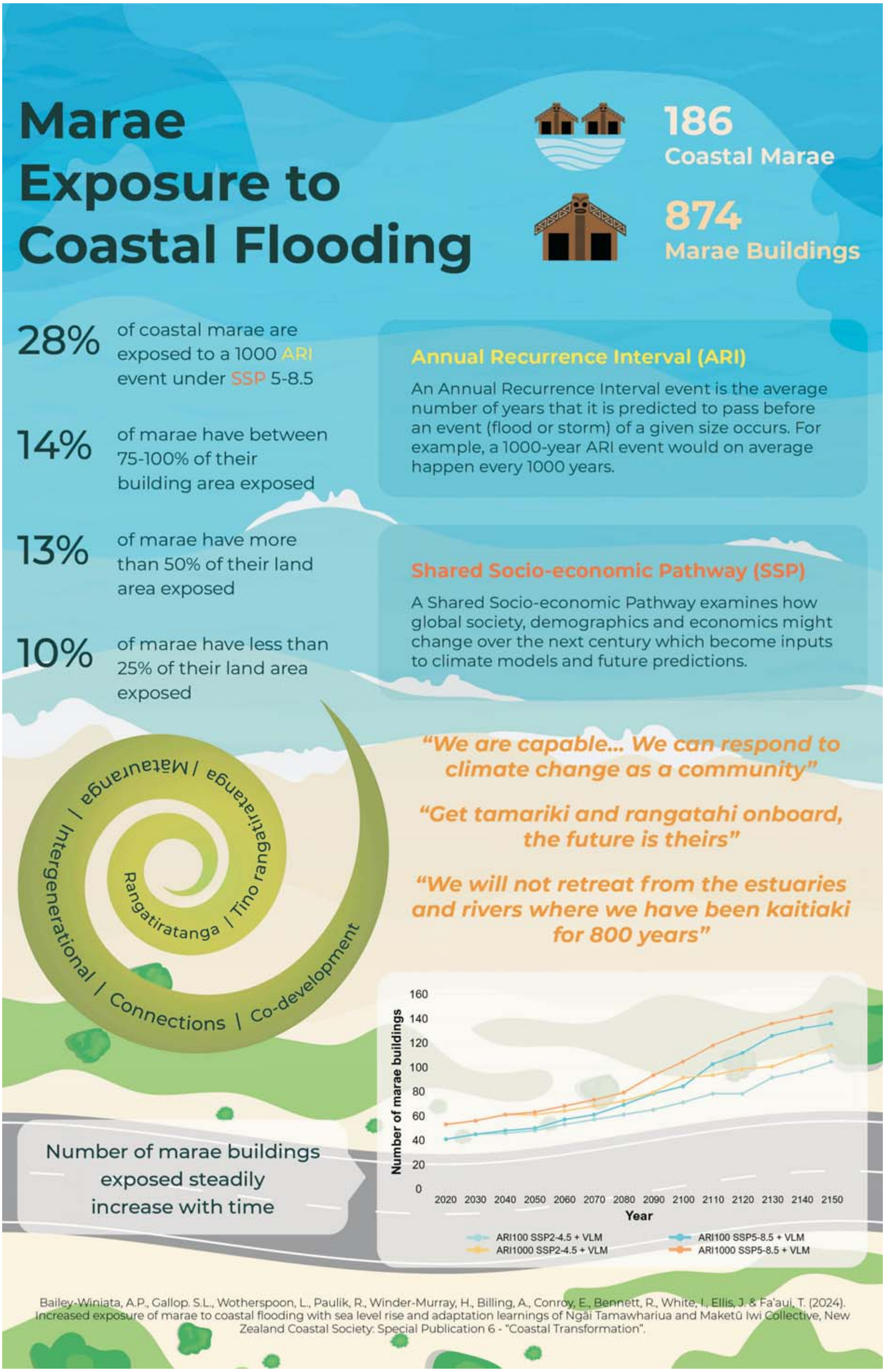

Figure 7: Infographic highlighting key statistics of marae exposure to sea level rise and some messages of empowerment from Ngāi Tamawhariua and the Maketū Iwi Collective.

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Coastal adaptation and transformation: Empowering Waihi Beach Lifeguard Services

By Ana Serrano

Introduction

In an inspiring transformative journey, the Waihi Beach Lifeguard Services Adaptation Planning project witnessed a community in the western Bay of Plenty region transition from a state of ambivalence and fear towards climate risks, to a state of awareness, knowledge, and empowerment. This project saw the Bay of Plenty Regional Council (hereafter the council or BOPRC) partner with Waihi Beach Lifeguard Services (hereafter the club or WBLS) and key stakeholders to develop an actionable plan that will help them navigate climate uncertainties.

The process followed by the club and the different stakeholders, not only transformed the club's relationship with the coast, but also empowered them to act and adapt to climate risks. This article explores the project's journey, highlighting lessons learnt and its success in fostering a climate-ready community.

Project genesis

The project's journey began with the WBLS grappling with escalating climate risks and annual floods. A report by GNS Science (2023) identified the club as a priority site vulnerable to coastal flooding: the need for action was clear. However, the path forward was uncharted territory for the club, and they turned to the Bay of Plenty Regional Council for guidance.

The club and BOPRC agreed that the primary goal of the partnership was to bring key stakeholders together to create a plan that would enable WBLS to continue its mission of protecting the beach community despite climate disruptions.

Methodology – Workshop's structure

The project was managed through a series of structured workshops, co-facilitated by the WBLS board chair and BOPRC climate resilience staff. These workshops followed a step-by-step process, ensuring alignment in purpose, roles and responsibilities. The methodology followed the Ministry for the Environment (2017) guidelines, with an approach focused on stakeholder participation. Workshop content and materials were collectively reviewed, ensuring everyone was on the same page. The efficient coordination ensured a successful methodology:

Figure 1: First workshop, after the collective creation of the matrix.

1: **Workshop 1:** *'What's going on?'* and *'What matters most?'*

- The initial collaborative session explored the club's objectives and identified hazards. Through the development of a comprehensive matrix, stakeholders collectively pinpointed critical issues related to hazards and objectives over time (Figure 1).

2: **Workshop 2:** *'What can we do about it?'*

- The second workshop introduced adaptation management strategies – protect, avoid, retreat and accommodate – to build a collective foundation of knowledge. This was followed by a brainstorming session where stakeholders shared their experiences and proposed new ideas.
- Stakeholders were divided into subgroups to ensure equal representation and diverse input. Armed with crafted materials, they created potential pathways for the club's future (Figure 2).
- Groups then presented and justified their proposed pathways, which sparked healthy discussions.

3: **Closed WBLS Board Session:** deliberation.

- BOPRC presented the information gathered from previous workshops.
- The WBLS board evaluated stakeholder input, considered feasibility, alignment with objectives, and potential impact of the options presented. This was followed by the development of preferred pathways.
- Young lifeguard leaders actively participated, ensuring a forward-looking plan.

4: **Final Workshop:** draft plan presentation.

- Community members and stakeholders reviewed the draft plan, engaging in open discussions.
- The community's enthusiastic response and constructive insights reinforced our confidence in the project's effectiveness.

Collaborative efforts yielded successful project management. By combining expertise, creativity, and community engagement, we secured lasting benefits for the club. Figure 3 shows the key process milestones, together with some of the community feedback.

Relationship management and community participation

The success of this project hinged on strong relationships, community engagement, and direct and transparent communications. The WBLS board was enabled to take ownership of the project to shape their response to climate hazards, with BOPRC acting as a vital partner.

Interactive exercises and inclusive discussions addressing risk head-on ensured that all stakeholders could contribute meaningfully. Engaging the next generation of leaders was crucial, with young lifeguard leaders actively participating in the planning process. Examples of methods used to help encourage contribution include:

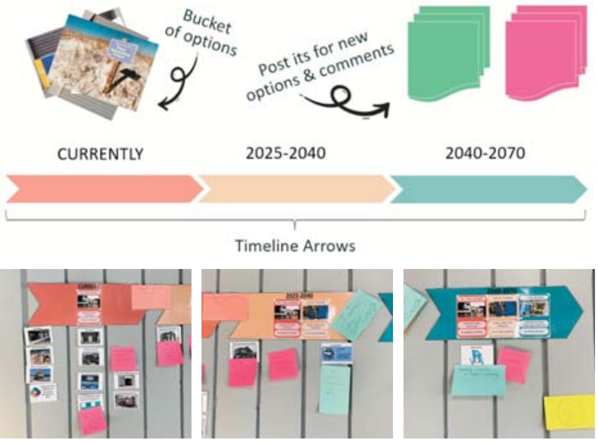

Figure 2: Above – workshop concept developed to support pathway creation exercise. Below – example of a pathway created by stakeholders. Workshop 2.

- **Initial knowledge-building** section at the workshop's outset to help facilitate understanding from climate risk terminology to potential management strategies. Participants' observations were part of the knowledge-building process and were later overlaid with climate hazard projections.
- **Interactive exercises**, including open brainstorming sessions, creating a hazards vs objectives matrix (Figure 1), and collaborative development of potential pathways in smaller groups (Figure 4).
- Inclusive **end-of-workshop round-table discussions** where stakeholders could individually voice feedback, concerns, or any questions.

The importance of the interludes

A crucial element of the community-led approach was the intense knowledge exchange between BOPRC and WBLS during the interlude periods between workshops. These interludes were essential for building a robust understanding and ensuring that both the club's board and the council were aligned. Detailed and fully transparent discussions during these interludes ensured that the board was well-prepared for any questions regarding planning or technical aspects, and that the message between parties remained consistent.

This continuous engagement upskilled the club's board and consequently transformed their relationship with the coast, empowering them to make informed decisions during the project process, but also enabling them to adapt and make changes in their plan in the future as these are needed.

Figure 4: Collaborative planning in action. Pathway's presentations and healthy discussions around the future of the club.

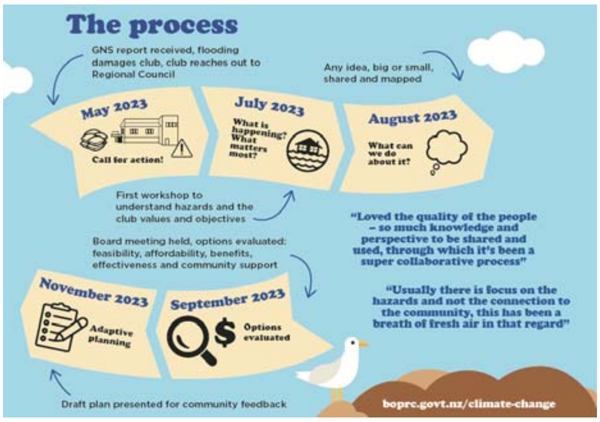

Figure 3: A timeline of events and example of some of the feedback received, as captured in the 'Rising to climate challenges: Waihi Beach Lifeguard Services' brochure.

Successful outcomes

The project process yielded several significant outcomes:

- The club was able to strengthen relationships with stakeholders, but also create new **meaningful connections**. Some of the highlighted connections formed include the addition of the WBLS e-mail to the of Bay of Plenty Emergency warning system, the development of a process template for other surf clubs facing natural hazards through the Surf Life Saving NZ group, and the identification of vulnerabilities in the local road network during extreme events by the NZ Police.
- The first workshop established the basis of the process by achieving a **shared understanding** of what is going on and why the action for planning was needed. A common community understanding of the risks is a great achievement that can enhance climate-related conversations and share the knowledge further.
- Thanks to the methodology and the high level of participation, the process **empowered the community** to propose community-driven solutions.
- The methodology and the importance given to the interludes yielded **informed decision-making**. Comprehensive action plans were developed through stakeholder collaboration.
- The addition of **immediate actions** to the plan provided practical steps, like dune path adjustments and relocation discussions allowed for the implementation of the actionable and adaptable plan.
- The community-led approach allowed the club to take **ownership** of the process. During the last workshop, the WBLS board presented their dynamic adaptive pathway to their stakeholders, gaining control of their past, present, and future narrative. Their understanding of the process now enables them to move forward despite the uncertainties of our changing climate.
- Community members praised the collaborative process and focus on community connections, which gave the project an overall **positive feedback** (Figure 5).

The project's success is evident in the outcomes achieved. The club, which was initially grappling with uncertainties,

Figure 5: Word cloud with feedback generated by stakeholders at the end of the final workshop.

now possesses a robust, community-driven adaptable plan. They are now well placed to navigate ongoing climate challenges as pressures continue to shift. The project has not only empowered a climate-ready community but also offers valuable lessons that can be scaled and shared.

Lessons learned and future implications

The project traversed key barriers, including overcoming inertia, navigating complex information, and engaging the next generation. Valuable lessons from this collaborative approach include:

- **Understanding partners**
  Investing time at the beginning to understand our collaborators is essential. This clarity enabled us to discern viable paths and identify what's feasible. Recognising that WBLS members were action-ready guided our workshops to be focused, actionable, and geared toward immediate steps alongside a strategic plan for the medium and long term.
- **Understanding and keeping values and objectives in mind**
  The project transcended the club's physical location, focusing on sustaining lifeguard and search-and-rescue services in a changing climate.
- **Collaboration as investment**
  The collaborative and community-led process demanded pre- and post-workshop time investment. Ensuring alignment with the WBLS board and volunteers was crucial. They actively contributed to workshop decisions and agenda building. From the outset, we emphasised their leadership role in the process.
- **Clear goals and consistent purpose**
  Each workshop began with a set goal and purpose. This deliberate approach prevented deviations into unrelated topics or individual agendas. Reiterating the workshop's purpose throughout the sessions maintained focus.
- **Workshops, not presentations**
  Our engagement model prioritised workshops over presentations. The process actively involved stakeholders, inviting them to participate on the journey rather than dictating the path. This approach proved effective in achieving meaningful outcomes.

The methodology distilled the adaptation planning process to its key elements via a community-led collaborative process. The output is an actionable and adaptable plan with an accompanying brochure which describes the journey towards climate readiness (Figure 6 and Figure 7).

The project serves as an inspiring model for other communities and councils, demonstrating that adaptability

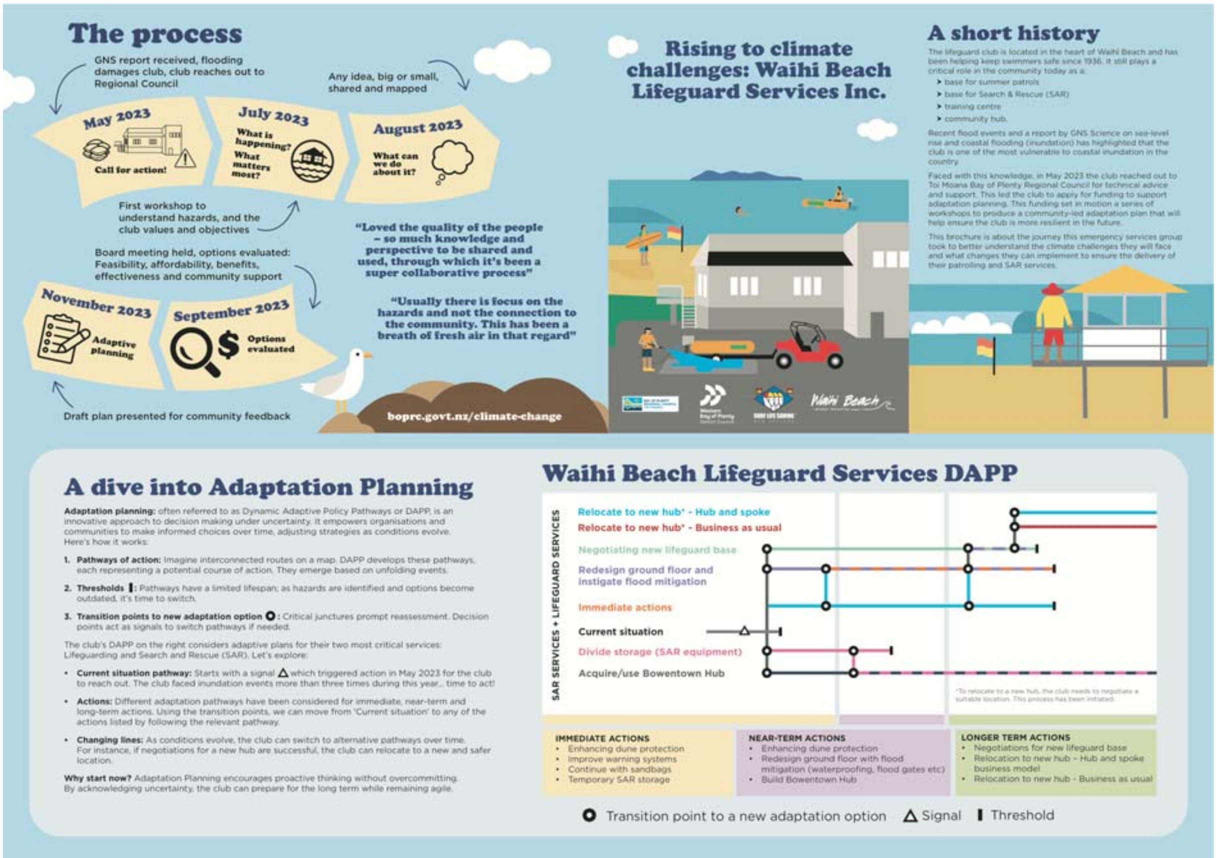

Figure 6: Final co-created brochure (side 1 of 2).

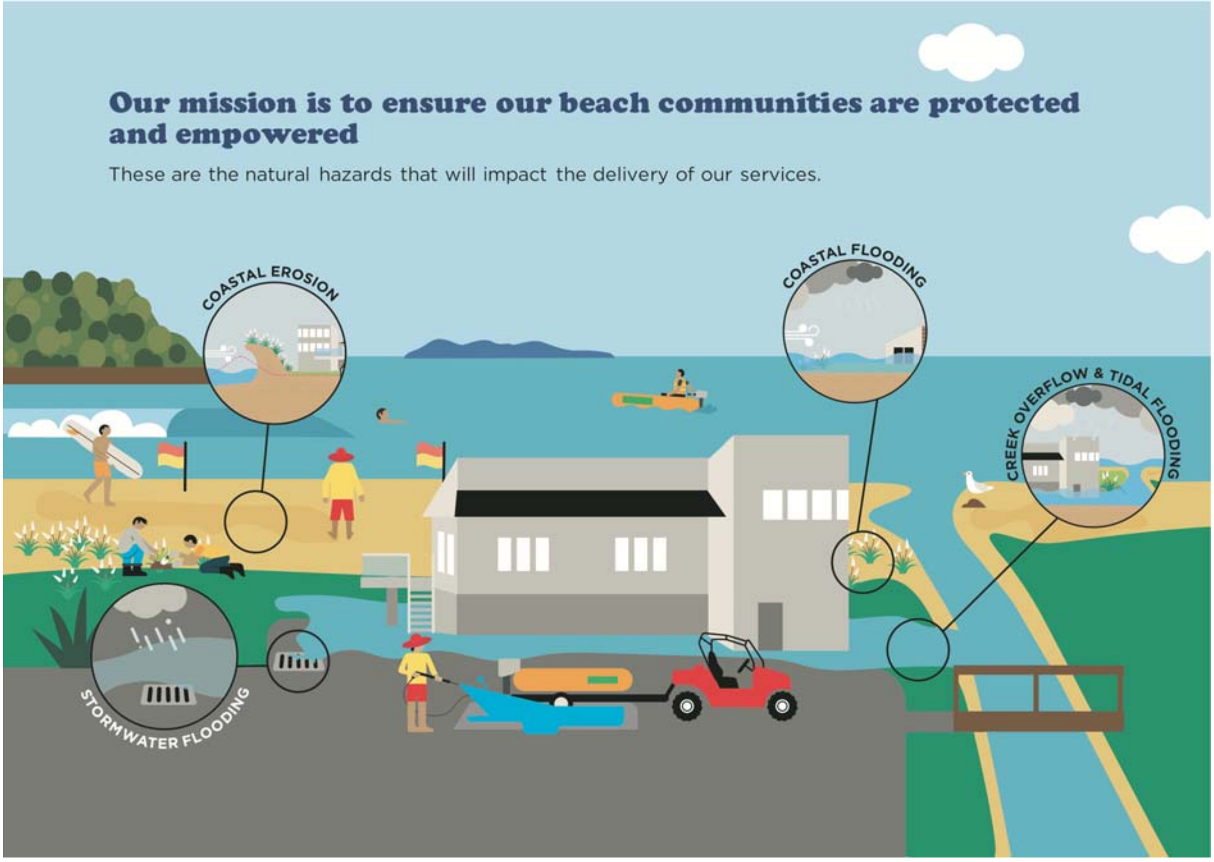

Figure 7: Final co-created brochure (side 2 of 2).

To see the full size version of the brochure shown in Figures 6 and 7, please visit:
https://atlas.boprc.govt.nz/api/v1/edms/document/A4652292/content

is possible, even in the face of uncertainty. It has been showcased as a case study for local government staff across Aotearoa New Zealand, highlighting the effectiveness of community-led adaptation practices.

Conclusion

The collaborative planning process undertaken by WBLS and BOPRC has transformed the club's relationship with the coast. From grappling with uncertainties to possessing a robust, community-driven adaptable plan reflects the success of the club's journey, and the power of community collaboration in fostering a climate-ready future.

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Short-term defence for long-term retreat in the Coromandel

By Sian A John

Background

In April 2019 Thames Coromandel District Council (TCDC) began a shoreline management planning project for the Coromandel Peninsula's 400 km of coast. The aim was to establish a framework for reducing risks to people, property, the environment and tāonga associated with coastal hazards. This framework was provided through a direction-setting shoreline management plan (RHDHV, 2022), which laid the foundation for each community to define local actions. The purpose was to develop Coastal Adaptation Pathways (CAPs) that addressed short- and medium-term issues while focusing on building resilient communities and hapū capable of adapting in the long-term.

Over four years, the project moved through the Ministry for the Environment's (MfE's) dynamic adaptive pathways planning (DAPP) process (Figure 1). This process was used to identify and evaluate options for, and preferred, adaptation pathways, tolerance thresholds and triggers for action, tailored to each community within a 100-year planning timeframe.

The output was 138 CAPs for unique sections of the Coromandel's coastline, based on locals' values, aspirations and risk appetites, supported by multiple agencies, and aligned with the principles of kaitiakitanga.

The pathways are based on science and an understanding of the hazards, the risks (taking account of vulnerability and adaptive capacity) and risk tolerance (see Figure 2). However, the advocated adaptation options and policy pathways are community-led, and values-based. They were unanimously adopted by Council in September 2022.

The CAPs, which provide tailored and flexible solutions to ensure the long-term sustainability of the Coromandel's coastal communities, are now being implemented. The pathways are already influencing planning decisions, such

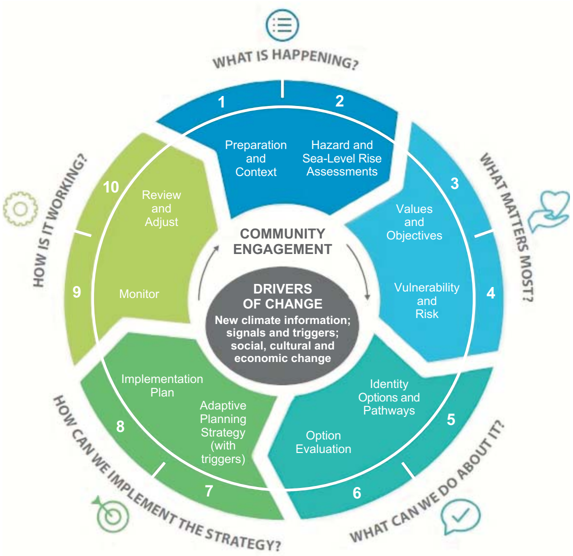

Figure 1: Dynamic Adaptive Pathways Planning (after the MfE's 2024 guidance to local government).

as advocating against hard/rock protection in several locations, like Pauanui, in favour of maintaining the beach. They are also guiding on-the-ground operational actions, such as increasing TCDC's capacity for coastal restoration work across the east coast beaches, and they are informing funding applications.

Additionally, the short-term actions have been included in TCDC's 2024-2034 Long Term Plan (e.g., long-term protection in Thames and Tairua and 'transitional protection' in Te Puru, Tararū and Moanatairi). Overall, the adaptation pathways are making a difference across the Council.

Community involvement

The involvement of the community through Community Panels and wider community workshops was invaluable in gaining support for the initiative and enabling resilience. Four panels covered different parts of the Peninsula, with members selected based on expressions of interest to reflect a range of demographic profiles and interests, representing diverse community perspectives.

Recognising that it would be an educational journey, sufficient time was allocated to upskill the panels and lay a solid foundation, with the panels meeting between September 2020 and August 2022. This foundation was based on an understanding of hazards, vulnerability and risks, as well as the likely performance of different adaptation options (e.g., dune management versus rock revetments). These insights informed the more challenging 'dynamic adaptive' pathway decisions. These decisions were guided by an adaptation menu, regional infrastructure plans, advice on vertical land movement, insurance and climate leases, as well as feedback on how individual communities wanted to respond. Local perspectives on values and risk were leveraged to establish preferred adaptation pathways, including policies, defined actions, thresholds, and triggers specific to each community for a 100-year planning.

The need to prioritise

Of the 138 pathways, 89 required action[1], including 50 pathways that need short-term or urgent action to be taken. Given that TCDC does not have the resources to implement all these actions at once, it became necessary to prioritise some adaptation actions and locations over others across the peninsula. The approach adopted for this needed to be transparent, robust, and appropriate. Hence, a 'dual factor' assessment (an 'Eisenhower matrix') that assessed importance[2] against urgency[3] was adopted. This approach prioritised actions based on 'significance' and enabled a classification of actions to be undertaken in alignment with chronological priorities.

[1] For the other 49 sections of the Coromandel's coastline, it was determined that no action should be required over the next 100 years. This may be because it is a rocky shoreline or because there is space for the beach or estuary to transition landwards.

Assets/ Values	Coastal Inundation								
	King Tide			5% AEP			1% AEP		
	0. 4m SLR	0.8 m SLR	1.2 m SLR	0. 4m SLR	0.8 m SLR	1.2 m SLR	0. 4m SLR	0.8 m SLR	1.2 m SLR
Buildings		94 dwellings and 12 other buildings	127 dwellings and 14 other buildings	124 dwellings and 14 other buildings	135 dwellings and 16 other buildings	141 dwellings and 20 other buildings	128 dwellings and 16 other buildings	137 dwellings and 19 other buildings	147 dwellings and 21 other buildings
Roads		0.32 ha of roads	0.4 ha of roads	0.38 ha of roads	0.38 ha of roads including 0.03 ha of SH25	0.62 ha of roads including 0.17 ha of SH25	0.4 ha of roads	0.57 ha of roads including 0.13 ha of SH25	0.64 ha of roads including 0.18 ha of SH25
Recreation Reserve	0.09 ha	0.5 ha	0.64 ha	0.63 ha	0.64 ha	0.66 ha	0.64 ha	0.65 ha	0.66 ha
Te Puru Boat Ramp	✓	✓	✓	✓	✓	✓	✓	✓	✓
Te Puru Boat Club		✓	✓	✓	✓	✓	✓	✓	✓
Depth of flood waters at Te Puru Boat Club		0 to 300 mm	300 mm to 1 m	300 mm to 1 m	>1m	>1m	300 mm to 1 m	>1m	>1m
Depth of flood waters over Thames Coast Road (SH25)					0 to 300 mm	300 mm to 1 m	0 to 300 mm	300 mm to 1 m	300 mm to 1 m

Type	Year/SLR	Storm	Exposure	Vulnerability	Consequence
Erosion	2020	1% AEP	Moderate	High	Major
Erosion	2040	1% AEP	High	High	Major
Erosion	2070	1% AEP	High	High	Major
Erosion	2120	1% AEP	Extreme	Extreme	Extreme
Inundation	0 m SLR	1% AEP	High	Moderate	Moderate
Inundation	0.4 m SLR	1% AEP	High	High	Major
Inundation	0.8 m SLR	1% AEP	High	Extreme	Extreme
Inundation	1.2 m SLR	1% AEP	High	Extreme	Extreme
Inundation	0.4 m SLR	5% AEP	High	High	Major
Inundation	0.8 m SLR	5% AEP	High	High	Major
Inundation	1.2 m SLR	5% AEP	High	Extreme	Extreme
Inundation	0.4 m SLR	King tide	Low	Low	Insignificant
Inundation	0.8 m SLR	King tide	High	Moderate	Moderate
Inundation	1.2 m SLR	King tide	High	High	Major

Figure 2: Risk assessment: inputs and outputs, Te Puru.

The prioritisation process included measuring progress towards adaptation signals, triggers, and thresholds, especially following Cyclone Gabrielle. It also involved defining both location-specific and cross-cutting 'enabling' actions, further community engagement, and designing 'transitional' defences for specific locations. These defences aim to provide a consistent level of protection and 'buy some time' in the short to medium term, while considering policy approaches to avoid maladaptation.

Implementing short-term actions in Te Puru, on the west coast of the Coromandel Peninsula, ranked third out of 50 for location-specific actions, following the protection of Thames and contaminant testing along Wharf Road in Coromandel Town.

[2] Based on the social value of the assets/services at risk, the environmental consequence, value to tangata whenua, economic value, and the adaptive capacity of community. That is, the benefits of an action in reducing risks to valued assets and supporting communities with less adaptive capacity.

[3] Urgent = 0 to 3 years, short-term = 4 to 10 years, medium-term = 11 to 30 years, and long-term = greater than 30 years.

A transitional defence: Te Puru

In Te Puru, more than 100 properties are at risk now of coastal inundation in 1%[4] and 5%[5] annual exceedance probability (AEP) coastal storm events (Figures 3 and 4).

Several properties are also at risk of erosion (Figure 5). This makes Te Puru a priority location for the implementation of short-term adaptation actions by TCDC.

The CAP developed by the Thames Coast Community Panel for Te Puru, with extensive wider community input, is shown in Figure 6.

The following short-term adaptation measures where proposed:

- Sediment recycling: Using dredged material from the stream mouth (which discharges from the steep stream catchment into the Firth of Thames and creates the fan delta on which Te Puru was built) to 'reinforce' the beach frontage to the south of the stream.
- Storm bund enhancement: Formalising and enhancing the existing storm bund and constructing a new 'transitional defence' where there is no existing coast protection.

An important component of the CAP developed for Te Puru is that the proposed adaptation actions that follow these short- to medium-term measures align with a longer-term managed retreat strategy (see Figure 6). The proposal includes constructing a 'transitional defence' to protect the community from short to medium term (30-year) risks and 'buy time' while developing a cost-effective managed retreat strategy, all while leaving State Highway (SH) 25 in-situ.

The pathway will contribute to the long-term resilience of the area by moving people out of harm's way. In the meantime, the 'transitional defence' will provide protection

[4] With a 1% chance of occurring each day (a so-called 1 in 100-year event).

[5] With a 5% chance of occurring each day (a so-called 1 in 20-year event).

Figure 3: (left and right) Coastal flooding in Te Puru in January 2018.

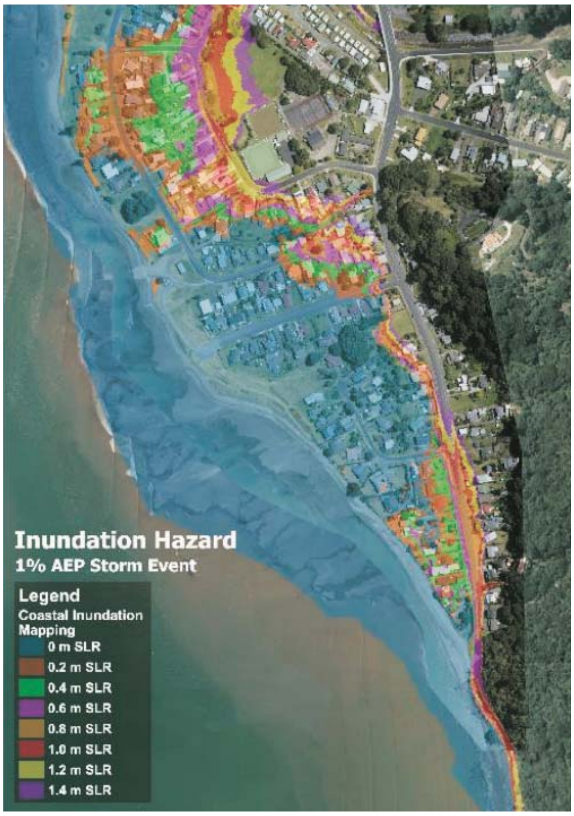

Figure 4: Potential coastal flooding in Te Puru in 1% AEP storm conditions now (blue shadow).

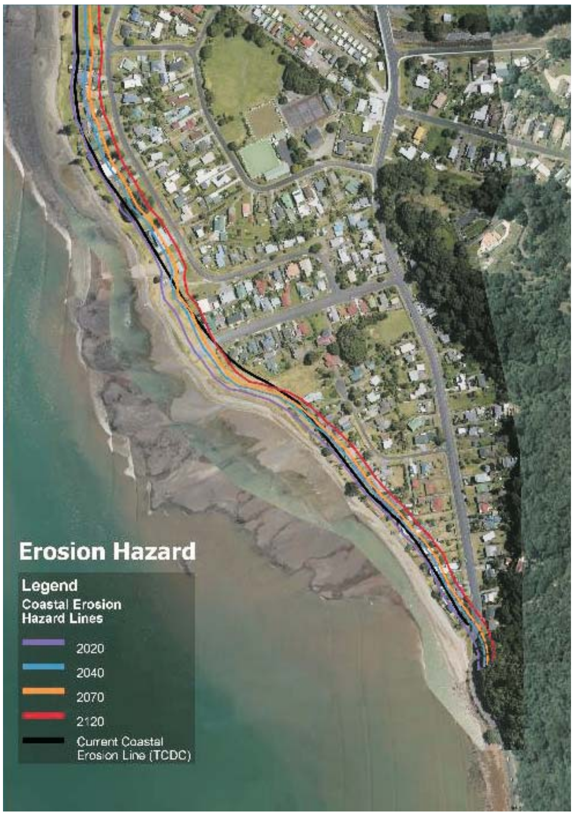

Figure 5: Potential coastal erosion in Te Puru over time.

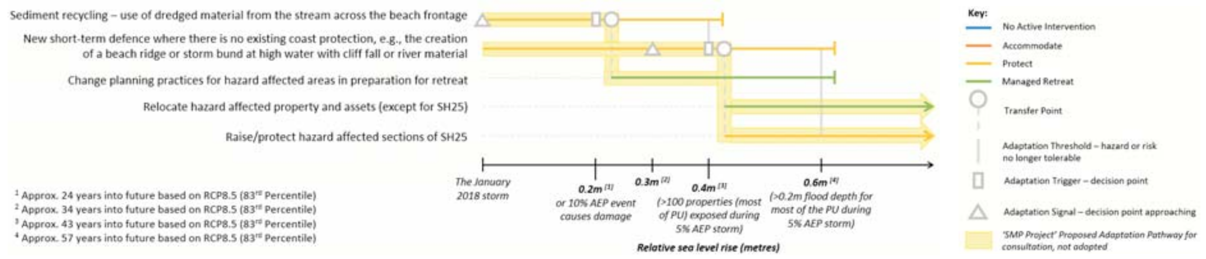

Figure 6: Adopted CAP for Te Puru.

and community resilience, offering comfort while personnel and public plans for retreat are developed. Additionally, it allows the existing community to maintain their current lifestyle and connection to the sea without a large hard structure limiting this (see Figure 7).

The objective is to provide a consistent level of protection across Te Puru (to buy time) and 'fill in the gaps' between existing informal bunds and private seawalls. The proposed minimum crest width is 3 m, with the toe being a minimum of 1 m from private property, and the height approximately 2.7 m RL, matching the existing bunds. This is expected to provide protection against up to 0.4 m of sea-level rise (predicted to occur in 30 to 40 years) and a 5% AEP event (a so-called 1 in 20-year event).

In most cases, the defence will be an earth stopbank with a grassed crest and battered (3:1) slopes. However, rock armoring (with a 1.5:1 slope) is being considered in locations within 10 m of the current shoreline[6]. Further investigations will consider the residual risk, design event limitations, and civil defence requirements.

The cost is expected to range from $1.3 million to $3.8 million, dependent on the requirements for rock. This translates to a cost per property (based on 100 properties being at risk of flooding) of $13,000 to $38,000, which, over 20 years, would equate to $650 to $1,900 per household per annum. This is likely to be collected through a targeted rate (made up of a catchment rate, applicable to indirect beneficiaries, and a direct benefit rate with differentials dependent on degree of benefit).

Planning controls to avoid maladaptation will be the key to success. Residual risks (e.g., a larger storm event that overtops the protection provided) will always accompany a scheme to protect and this should be managed through land use planning. For example, district plans have the ability to set policies and rules to raise minimum floor heights, avoid infill development, discourage redevelopment, and rezone land.

District-wide enabling actions identified as required by TCDC include:

- Reviewing and strengthening the District Plan to restrict inappropriate (i.e., non-adapted or adaptive) development[7] in hazard affected areas, including identified inundation zones, such as in Te Puru.
- Reviewing and refining proposed signals and triggers for action based on on-the-ground monitoring data, and notifying the community when these have been achieved.
- Providing the necessary inputs to NZTA Waka Kotahi to advocate for the required updates to SH25.
- Undertaking a spatial planning exercise to identify locations for displaced communities to move to, where the medium- or long-term action on the pathway is managed retreat.

6 To avoid the risk maladaptation, it will be avoided if possible.

7 Inclusive of new development, redevelopment and in-fill development.

Figure 7: Concept design for the upgrade of the Te Puru coastal inundation defence (Source: IHBEYA).

- Keeping the community informed as change thresholds approach.

Further required enabling actions identified by TCDC include:

- Developing a business case to request co-investment from central government to deliver high-cost priority actions.
- Progressing a global consent for sediment recycling for the west coast fan deltas.
- Taking action that enables the process of raising floor levels (i.e., removing resource consent and cost constraints) in locations where this action is supported by the pathway.
- Reviewing the processes and options to support managed retreat and eligibility criteria. However, leadership from central government is required here.

There is no clear pathway for retreat at this stage and an absence of clarity in terms of which agency or agencies are responsible for implementing and funding managed retreat (MfE and HBRC, 2020). Currently, the only mechanism to 'force' retreat sits with regional councils under sections 10(4) and s30(1)(c) of the Resource Management Act (RMA) 1991.

Responsibility

To complicate things further, different types of infrastructure in Te Puru are managed by both TCDC and Waikato Regional Council (WRC) under different statues.

The RMA sets out that regional councils are responsible for developing policies to avoid or mitigate natural hazards, while district councils manage land to implement these policies. However, the Act does not clearly define who should lead when it comes to the construction and management of the infrastructure. The Soil Conservation and Rivers Control Act 1941 enables regional councils to implement fluvial flood protection measures if they so choose (including measures to manage floodwater). The Local Government Act 2002 requires district councils to manage stormwater infrastructure (including against the effects of climate change); it also encourages collaboration between councils and allows for the transfer of responsibilities. Yet the provision of fluvial and coastal protection works is discretionary for both councils.

Hence, an integrated approach to managing natural hazards and climate change adaptation is required. Effective adaptation necessitates leadership, collaboration, clear understanding of who does what, whilst always keeping in mind what are the best outcomes for the community.

Conclusion

Transitional defence is believed to be a good adaptation strategy for Te Puru, where the risk to life and property associated with flooding is predicted to increase year on year. Faced with the alternative of living behind an increasingly high and expensive bund and/or rock revetment, along with an increasingly significant residual risk (of stopbank failure or overtopping), the largely aging community who live in Te Puru determined that retreat was the better option. They choose to live in Te Puru because of their connection to the sea. Without this direct connection, retreat is preferred.

However, they want to remain in situ for as long as possible and to be able to plan well for their eventual retreat. The transitional defences proposed in the short term will allow for this. But planning policy needs to reinforce the fact that they are only transitional and not permanent defences. Hence, appropriate, robust planning restrictions need to be put in place. Further, government support for, and policy around, managed retreat needs to be resolved urgently.

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The transforming coastline of Tamaki Makaurau in the wake of a triple dip La Niña cycle

By Natasha Carpenter, Matthew McNeil, Christoph Soltau and Megan Tuck

Introduction

The eastern coastline of Tamaki Makaurau, Auckland was subjected to notable change through the three consecutive years of La Niña conditions between 2020-2023, with progressive erosion and beach lowering. This La Niña period culminated with several significant storm events in 2023, including the devastating flood events of Auckland Anniversary Weekend (27 January to 2 February), the extra-tropical Cyclone Gabrielle storm (12-13 February) and the extra-tropical Cyclone Lola storm event (29-31 October). These events placed further pressure on the management of Auckland's eastern coastline, including significant coastal erosion and damage to coastal infrastructure and assets.

This article outlines some of the changes observed during this period of sustained La Niña conditions, the resulting coastal management challenges, and Auckland Council's approach to responding to the range of issues in a sustainable manner.

The La Niña cycle

La Niña is known as the 'cool phase' of the El Niño-Southern Oscillation (ENSO), a major form of climate variability that influences temperature, precipitation and extreme weather patterns worldwide (NOAA, 2023). La Niña conditions develop when the equatorial west to east trade winds intensify, resulting in warmer sea surface temperatures in the western Pacific. This typically increases the frequency of tropical storm events that impact Auckland during a La Niña phase. These ENSO cycles typically last 9-12 months and appear intermittently every two to seven years. However, between 2020 and 2023, New Zealand experienced a rare sequence of three consecutive years of La Niña, known as a 'triple dip' La Niña cycle (Figure 1).

Data from the National Institute of Water and Atmospheric Research (NIWA) showed that it would only be the third time this event happened in New Zealand since records began in 1876 (Brandolino, 2022). In addition to the rare nature of these consecutive events, the La Niña cycle was also unique in terms of its strength. In April 2023, records showed the third highest value for the Southern Oscillation Index, only surpassed by records in April 1904 and 2011. For Auckland Tamaki Makaurau, this phase of consecutive La Niña events resulted in progressive erosion and beach lowering across the east coast beaches. This is demonstrated in Figure 2 for Ōrewa beach using Auckland Councils beach profile monitoring record.

The observed trends can be attributed to the exposure of this coast to the increased frequency of north-easterly winds, which contrasts with Auckland's predominant or more common south-westerly winds. The sustained nature of these north-easterly winds, and subsequent wave energy, reduced the ability of the east coast beaches to recover between storm events.

The 2023 storm events

Over the course of 2023, a series of significant storm events further compounded coastal management issues on Auckland's east coast. These events are further described below.

Auckland Anniversary Weekend flood event

On the 27th of January 2023, the Auckland Region was impacted by a storm event that resulted in extreme flooding across the region. NIWA described the event as at least a 1 in 200-year event, with Auckland's Albert Park receiving 280 mm of rain in under 24 hours (NIWA, 2023). Although the event coincided with a king tide, the storm

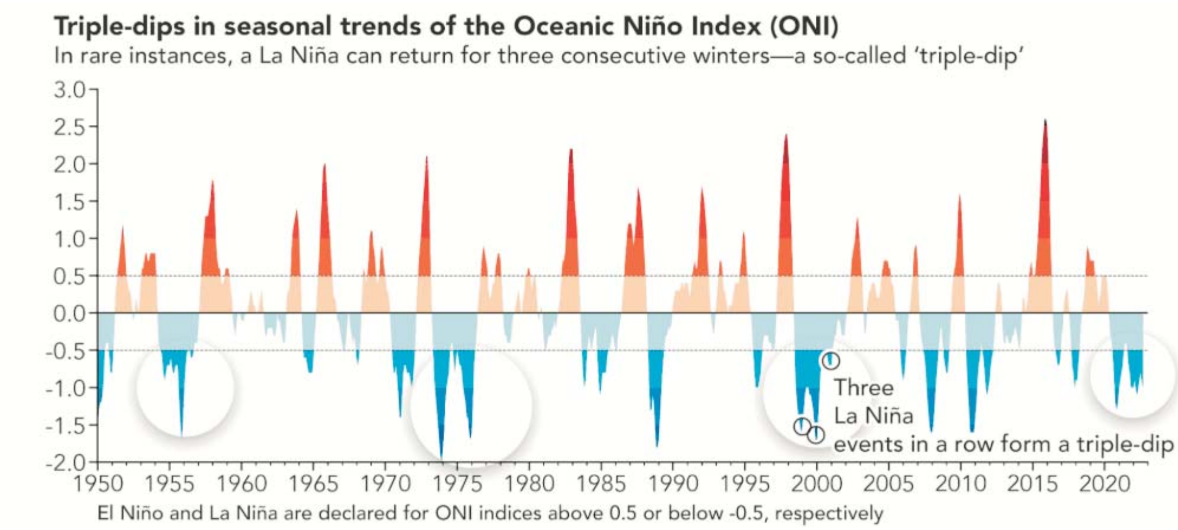

Figure 1: Triple dips in the Oceanic Niño Index (ONI) charts, appearing as wide blue dips below -0.5 (Source: NASA, 2022).

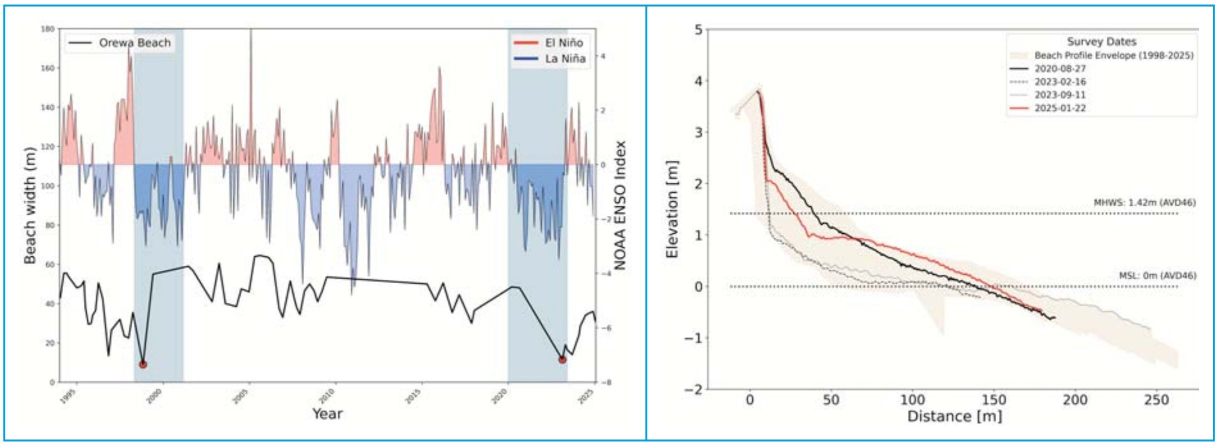

Figure 2: Temporal relationship between the La Niña cycle and coastal erosion at Ōrewa beach for a representative beach profile: (left) measured change in beach width over time with triple dip La Niña cycles highlighted, (right) beach profile lowering and scour measured over 2023 events.

generated relatively moderate wave energies over a short duration resulting in only minor erosion by coastal processes. However, the significant rainfall experienced over the course of this event resulted in substantial scour and erosion of sand levels at coastal stream mouths. This was particularly evident at urban catchments with high surface run-off such as the East Coast Bays beaches such as Ōrewa (refer to 'Maintaining a nature-based response at Ōrewa Beach').

Cyclone Gabrielle

Auckland, as with much of North Island, was significantly impacted by Cyclone Gabrielle (Figure 3). Gabrielle crossed the Auckland Region over the 12-13th of February 2023 as an extra-tropical storm.

This storm subjected the Auckland east coast to significantly strong onshore winds with wind gusts reaching 70 knots on the Whangaparaoa Peninsula, large wave heights, and significant storm surge. Wave data from Auckland Council's hindcast model indicate significant wave heights (Hs) on the open east coast (as shown for Te Arai) exceeded 3.5 m for almost 24 hours (refer to Figure 4). The hindcast covers approximately 45 years, from 1979 to 2024, and indicates that Hs greater than 3.5 m only occurs less than 0.06% of the time. Figure 4 also shows the water levels recorded by the Auckland Council tide gauge at the Weiti River entrance, with LINZ forecast tide peaks superimposed.

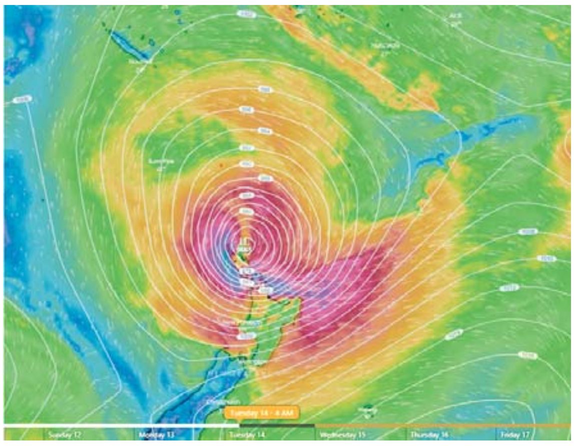

Figure 3: Cyclone Gabrielle forecast. (Source: Windy.com, ECMWF).

The relatively long duration of the storm extended across several high tides. Although tides were neap, the extremely low atmospheric pressure elevated the coastal water levels in the order of 0.5 m above the forecast tide height.

Cyclone Lola

Tropical cyclone Lola impacted the Auckland Region as an extra-tropical storm bringing strong onshore winds and large waves over three consecutive days from the 29th-31st October 2023. While wave heights on the open east coast were marginally smaller than during cyclone Gabrielle (refer to Figure 5), the event coincided with spring tides. The corresponding tide gauge recordings from the Weiti River entrance indicate storm surge up to approximately 0.3 m, bringing coastal water levels above those experienced during cyclone Gabrielle for several tidal cycles.

Coastal impacts on Tamaki Makaurau and responses

The 2023 storm events had devastating impacts across New Zealand, with Cyclone Gabrielle causing more than $8 billion in damage, making it the southern hemispheres costliest tropical cyclone (IDMC, 2024). For Auckland's coast, the triple dip La Niña combined with these storms resulted in coastal erosion and damage to many coastal assets in Auckland.

The following sub-sections detail the issues experienced at key coastal locations. A variety of case studies are provided, presenting the range of coastal management responses considered and their outcomes. In adopting a best practice approach to coastal management, each response has considered what is at risk, the driving coastal processes, and overarching policy direction. Figure 6 shows the location of each of the documented sites.

Maintaining a nature-based response at Ōrewa Beach

Ōrewa Beach is located on Auckland's east coast, immediately north of the Whangaparāoa Peninsula. With an extensive history of development and modification, the beach has been subject to a range of coastal management challenges and approaches.

As noted in the 'Auckland Anniversary Weekend flood event' section, the high rainfall associated with the Auckland Anniversary event resulted in significant scour at coastal

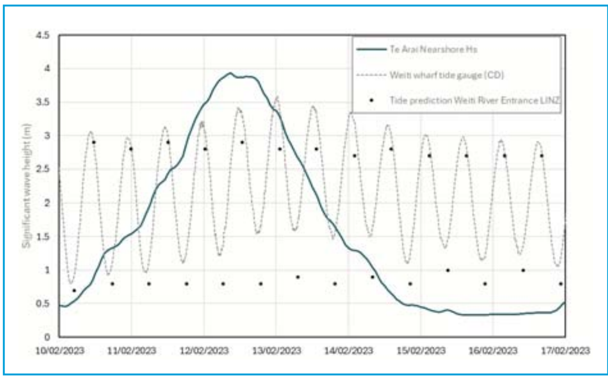

Figure 4: Hindcast wave height for the open east coast (Te Arai, 15 m water depth) during cyclone Gabrielle with measured and forecast tides superimposed.

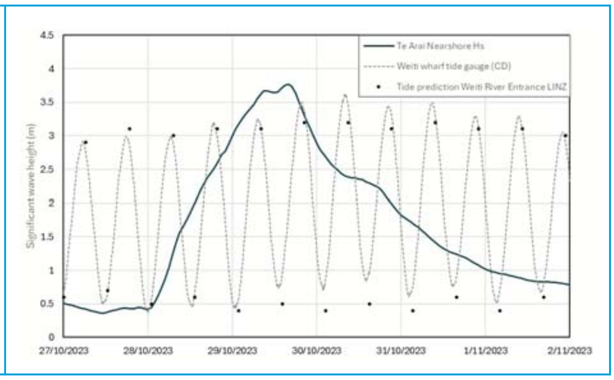

Figure 5: Hindcast wave height for the open east coast (Te Arai, 15 m water depth) during cyclone Lola with measured and forecast tides superimposed.

outfalls and stream mouths in more urban catchments. Effects were well demonstrated at the centre of Ōrewa Beach, Kinloch Reserve. Here, the extreme stormwater discharge scoured the reserve and damaged a footbridge (which subsequently failed during Cyclone Gabrielle, Figure 7). The opening of this stormwater channel has subsequently been realigned to allow a more naturalised opening.

Prior to Cyclone Gabrielle, sand levels on Ōrewa Beach were already relatively low. The beach was exposed to significant wave energy and elevated water levels during Cyclone Gabrielle, which resulted in further lowering of the upper beach and erosion of the adjacent Orewa Reserve edge.

As shown in Figure 8, a scarp of approximately 2 m in height developed at Ōrewa Beach Reserve, exposing the roots of a series of Norfolk Pine trees along the edge of the reserve. The chosen response to this issue was to maintain councils operational, nature-based solution to undertake a sand transfer from the southern end of Ōrewa Beach. This is a well-established practice (since 1988), initially prompted through the realignment of the Ōrewa estuary mouth in the 1960s, and construction of the 'Waitemata' groyne on the estuary mouths northern side, which interrupted the previous natural flow of sediment back to the north.

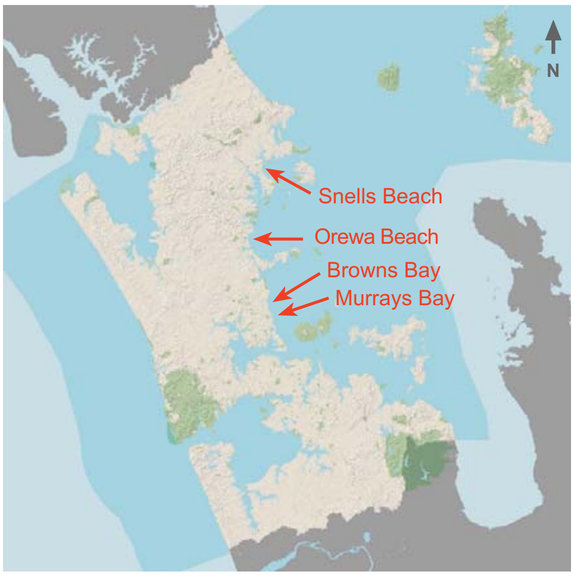

Figure 6: Geographic map of Auckland outlining location of presented case study sites.

Figure 7: Post Gabrielle storm, footbridge failure.

In late February 2023 approximately 14,000 m^3 of sand was transferred from the southern end of the beach and a further 1,500 m^3 of sand 'scraped' from the lower intertidal area and placed along the upper beach, adjacent to the unarmoured northern sections of the beach. This upper beach replenishment restores a natural buffer to the reserves, providing protection from further storm events while enhancing the recreational amenity and increasing the dry high-tide beach space available. Such works are authorised under a current resource consent that enables up to 25,000 m^3 of sand to be transferred from the southern end of Ōrewa Beach, to the central area of the beach each year.

While the above practice can be considered operationally costly it aligns with councils strategic and holistic management plan for Orewa, as set out in the Ōrewa Beach Esplanade Enhancement Project (OBEEP,2014). The management strategy at Orewa Reserve gives effect to the New Zealand Coastal Policy Statement, particularly Policy 15 and Policy 26, to provide for natural defences against coastal hazards and protect natural features and landscapes. This practice is an important offset to contrasting hard protection measures implemented on other sections of Ōrewa Beach.

Holding the line at Murrays Bay

Murrays Bay was significantly impacted by the Anniversary Weekend flood event, with significant scour of the beach from a stream that exits at the northern end of the beach. This resulted in outflanking and failure of a section of seawall that provided protection to the edge of the coastal reserve adjacent to the stream mouth. With upper beach

Figure 8: Orewa sand transfer works: Erosion post Cyclone Gabrielle event (top left and right); completion of sand transfer works (bottom left and right).

sand levels remaining significantly low after the storm event, the coastal conditions driven by Cyclone Gabrielle resulted in the complete failure of an approximately 45 m length of seawall at Murrays Bay (Figure 9). The failed seawalls exposed a range of assets to potential further impact, including a wastewater line, the road turnaround, reserve edge and several large pohutukawa trees. In this situation, a quick response and emergency works were undertaken to remediate the coastal edge and restore protection to these assets, including critical infrastructure.

A new rock masonry seawall was designed to replace the failed, legacy concrete block wall and to visually match the immediately adjacent, existing, rock masonry seawalls. The new wall was designed to follow the same alignment and engineered to accommodate extreme storm events and the potential for future low upper beach sand levels and scour. Delivery of the physical works was complex, with the project team working in close coordination with local asset owners and stakeholders, including the Murrays Bay Sailing Club, to enable key activities and events on the reserve and beach to continue.

Through the rebuild, opportunities to increase the visual aesthetics and enhance the amenity of the area were also considered, reflecting community values of the site. The structure was upgraded to a consistent, basalt rock masonry wall. And the original design was adapted to include a 10 m length of stepped wall. A 3.5 m wide ramp was also integrated into the design adjacent to the main boat ramp to enable recreational use of the wall, beyond its primary purpose as a coastal defence structure. Landward components including the pedestrian path and the road turnaround were reinstated following completion of the works.

Implementing a hybrid solution at Browns Bay

Prior to the La Niña cycle, the southern end of Browns Bay had been subject to high sand levels on the upper beach for several years. The resulting operational maintenance issues – management of windblown sand

Figure 9: Seawall failure, post Cyclone Gabrielle Storm.

Figure 10: Renewed masonry seawall and stepping detail at Murrays Bay.

across the adjacent carparking area, road and reserve – that were making the high sand levels undesirable. The sequence of storms, starting with the Anniversary Weekend floods, brought about a dramatic change to the beach, requiring management interventions.

The storm events resulted in extreme lowering of upper beach sand levels at the stream mouth and along the southern, more exposed, length of the beach. This caused erosion of the adjacent reserve and exposed an approximately 200 m length of legacy, poorly-engineered backstop rock seawall that had not been this exposed since the early 2000s. The main beach carpark was at risk from further erosion events and key pedestrian access points were impacted, including failure of a stair accessway, presenting a health and safety hazard to users.

An innovative response to the works was taken, considering both remediation of the foreshore, dune restoration and provision of new, targetted coastal structures at critical locations. Overall, the works presented an opportunity to implement a more naturalised solution and re-assess the provision of hard protection structures along this stretch of coast.

The design philosophy was driven by the opportunity to recover and repurpose legacy rock armour. This material was recovered, sorted and supple mented by additional imported rock to meet design requirements to construct two sections of engineered rock revetment along a combined length of approximately 130 m of reserve edge. These structures were designed to provide protection to key assets, including the southern carpark, and protect

Figure 11: Exposed backstop rock armouring on Browns Bay beach, to become naturalised dune section, post ex Cyclone Lola Storm.

Figure 12: The southern end of Browns Bay, with reserve erosion, exposed backstop armouring, and failed steps, post ex Cyclone Lola.

Figure 13: Renewed rock armouring and access stair.

Figure 14: Reshaped and naturalised 'dune' section.

the narrower sections of reserve. The reserve crest was realigned slightly landward at the southern end where the reserve is higher in topography to ensure the rock revetment structure did not extend further onto the beach. Improved foreshore access was considered through renewal of damaged access stairs, and reshaping and better defining previously informal beach accessways from the reserve to the foreshore.

The mid section of the reserve, with a significantly wide buffer and lack of immediately adjacent assets, presented the opportunity to implement a more naturalsed approach along a 70 m length of reserve edge. This involved removal of legacy rock armouring and a buried historical concrete seawall. The reserve edge crest was realigned landward, and the slope reshaped to create a dune face. Rope and bollard dune fencing was installed, and 500 native dune grasses planted.

It is anticipated that this natural buffer will be more resilient to future storm events once fully established and will have the natural ability to recover over time. This is supported by similar observations at Stanmore Bay, Whangaparāoa, where comparable works were undertaken following the January 2018 storms, which continue to perform successfully.

This hybrid solution provides a foundation for future adaption along the wider Browns Bay Beach Reserve. It provides an important case study example for the successful removal of legacy protection structures and implementation of a more nature-based solutions.

Managed realignment at Snells Beach

Towards the northern boundary of the Auckland Region, cyclone Gabrielle caused significant damage to a timber seawall armouring a section of esplanade reserve at Snells

Beach. A sheltered location with wide inter-tidal area, the elevated water levels and storm waves resulted in overtopping, loss of facing boards, significant scour of the adjacent reserve edge crest, and loss of backfill material. An adjacent concrete footpath was also damaged.

An initial response involved making the site safe by removing dislodged debris and exposed piles and temporary repair of beach access stairs. A sand push-up was undertaken to protect the scarp and partially regrade the transition from the grassed reserve edge to the beach. These immediate responses provided the council team the time to consider the best longer-term solution for the site, allowing for community consultation, iwi engagement and engineering design. During this process, the later Cyclone Lola event resulted in further lowering of upper beach sand levels, and further erosion of the exposed reserve edge prompting a shift in approach to utilising the emergency works provisions under the Resource Management Act.

The failed timber seawall armoured a section of esplanade reserve that was historically reclaimed as part of a consented former subdivision in the 1970s. This had encroached on the available upper beach space. Ongoing monitoring of the beach had demonstrated that unarmoured sections of the reserve set further landward were more resilient to coastal processes and did not suffer significant erosion during the 2023 storm events. This highlighted the potential benefit of realigning a renewed timber seawall further landward and out of the active intertidal area. This would reduce both the structures exposure to coastal processes and its impact on the dry high tide beach space, supporting both resilience and recreational outcomes.

Figure 15: Failed timber seawall, post Cyclone Gabrielle.

Figure 16: Renewed timber seawall set landward, and adjacent dry high tide beach.

The final design included realignment of the majority of the failed, 125 m long section of timber seawall approximately 4 m landward from the previous position. Further landward realignment was constrained by the need to protect adjacent pohutukawa trees and provide space for a footpath. Setback to the adjacent private property boundaries was also considered.

The final outcome has restored protection to a highly valued stretch of council public esplanade reserve, while making space for the coast through the targeted realignment of the previous structure. While the updated alignment (only approximately 4 m) may be considered a small change by coastal practitioners, part of the community remained highly sensitive to the potential changes at the site, with some advocating for a harder 'hold-the-line' approach.

Implementation of this project has considered the overarching policy direction and coastal management best practice including the NZCPS. Effect has been given to Policy 24 and Policy 26 to both consider the physical coastal processes causing coastal change and the role of more natural defences against future coastal hazard risk. While full naturalisation of the beach has not been possible at this location noting the constraints of the site, the final structure demonstrates a balanced and more sustainable approach to coastal management.

Conclusions

The cumulative effects of the 2023 storm events over the 'triple dip' La Niña cycle significantly impacted the Auckland coastline. The resulting erosion and damage to coastal assets presented a range of challenges and varying opportunities, as reflected in the different sites presented in this article.

While each coastal management response has varied, optioneering has applied the same best practice process of considering (but not limited to): what is happening, what is at risk, what are the values of the site, what are the constraints and what is technically feasible, while ensuring regulatory requirements are met.

In places an urgent response was required, as demonstrated through the operational response at Orewa and the continued protection of critical assets at risk at Murrays Bay. In contrast, the progressive change at Browns Bay and Snells Beach provided opportunity for more adaptive and innovative coast protection options, including provision for removal of legacy structures, partial realignment and adoption of softer, nature-based solutions.

Auckland Council is amid completion of Shoreline Adaptation Plans for the whole of the regions 3,200 km of coast. These plans set out the recommended short-, medium- and long-term management strategies for all council-owned land and assets. These plans are applying the Ministry for the Environments Coastal Hazards and Climate Change Guidance (2024). At the time of the 2023 storm events, plans for the affected north-east coast were in development requiring optioneering to be driven at a site-specific level. Upon completion, these plans will guide the future, long-term management of our coasts. It is anticipated this will provide a foundation to the ongoing, holistic management of the coastline of Tamaki Makaurau, including responses to future storm events.

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Connected realities: Transforming flood risk management to include the sea

By Shane Orchard

Introduction

Severe flood and storm events generate significant environmental damage that accrue in both land and waterscapes. Through erosion and sedimentation effects these events drive consequential changes to river systems and also the coastal environment (Schiel and Howard-Williams, 2016). The downstream impacts may be just as severe as the more visible spectre of eroded land. Consequences may include the smothering of the benthos in deposition zones and light limitation from suspended sediments, both of which may drive catastrophic changes in receiving environments. Examples include the mass mortality of kelp communities and slow-moving kaimoana such as crayfish and shellfish after Cyclone Gabrielle and other major flood events. Across many repeated events these ridge-to-reef cascades present a series of pressures with high potential to degrade the coastal ecosystems and resources on which communities depend. The direction and relative severity of long-term effects depend very much on the interplay between the impacts of pulse events and recovery in the intervening periods. Assessing future risk in these dimensions requires an understanding of periodic setbacks such as those generated by repeated floods and other stressors such as heat waves. Moreover, these effects transcend not only multiple ecosystems, but also the jurisdictional boundaries through which they are managed. With downstream receiving environments being among the most vulnerable to cumulative impacts (Foley et al., 2017), there is an essential need to address the connections between upstream activities and downstream risk (see Figure 1).

Responding to recent cyclones

In the wake of Cyclone Gabrielle there has been renewed attention to the influence of land use on the vulnerability of landscapes to erosion from heavy rainfall and overland flows. The benefits of slope stabilisation are in greater focus than ever before given the severe and cumulative effects of repeated flood events. Woody debris (slash) eroded from plantation forests has been a key focal point due to its destructive potential, including the exacerbation of bank and gully erosion through gouging, and as a direct danger to life and property (Basher, 2013).

Although these effects have long been studied, flood and erosion management has yet to fully embrace the principles of disaster risk reduction over the longer term. For example, there has been a long history of studies on the environmental impacts of forestry in Aotearoa, which were recently reviewed in proposals to amend the National Environmental Standards for Plantation Forestry (e.g. Maclaren, 1996; Ministry for the Environment, 2023) and in earlier work on that standard (Basher et al., 2016; Bloomberg et al., 2011; Orchard, 2011).

Influential work on highly erodible terrain took place in the aftermath of Cyclone Bola (1988) in the same area that has been devastated by Cyclone Gabrielle more recently. Several studies identified forestry as a beneficial alternative to pastoral land use with regards to slope stability. Examples include the Tamingimingi (pastoral) and Pakuratahi (forestry) paired catchment study in Hawke's Bay, which reported less land damage from Cyclone Bola in the forestry catchment (Fransen and Brownlie, 1996). Subsequent work found that post-harvest sediment yields in the Pakuratahi (forestry) catchment were higher than in the pastoral catchment, while also concluding that forestry would offer lower sediment yields when calculated for a full rotation (Fahey et al., 2003).

However, we may be seeing that an essential focus is missing in the conceptualisation of such studies. Is their

Figure 1: Connectivity in action – satellite view of river plumes discharging to coastal waters on the East Cape after heavy rainfall in February 2023 (Imagery: Sentinel Hub).

lens focused on a narrow view of 'less worse' outcomes instead of overall impacts, which is surely the more relevant topic? Additionally, the discussion should be not only around the merits of forestry or farming land uses because other risk factors include the demise of riparian wetlands and floodplains that once contributed to the resilience of the coast and lowlands (Department of Conservation, 2020). What is needed is a better understanding of disaster events in all their dimensions.

The recognition and reduction of ecological risks are essential aspects of community wellbeing that require regular adjustments in human relationships with nature. Often-overlooked components include the connectivity between ecosystems and their relationship with society, which is often marginalised or under-appreciated in sectorial management approaches. Widening our conceptualisation of coastal management provides a pertinent example.

As an island nation we might recognise that all of Aotearoa is intrinsically connected with the surrounding ocean. Indeed, the New Zealand Coastal Policy Statement (NZCPS) 2010 specifically requires that the coastal marine area (CMA) and islands within the CMA are recognised when determining the extent of the coastal environment, which clearly amounts to a consideration of the whole country. However, many regional plans have developed new definitions that reduce the ambit of coastal management considerations by curtailing the geographical reach of the 'coastal environment', thereby undermining the ability of the NZCPS to support integrated decision-making. Might we instead replace a drive for pragmatism with one that recognises relationships? Extending flood and erosion risk management to include the consequences for coastal environments provides a practical and much-needed example. Resilience to disasters cannot be fully addressed without including all affected areas and their values.

Transformative opportunities

In addressing the theme of this special publication, one of the most needed transitions involves resisting the temptation to compartmentalise the management institutions that our environment depends on. Applying a mountains-to-sea, ridge-to-reef approach is a fundamental necessity for improving the health of aquatic environments. Tackling legacy issues alongside new challenges also requires more attention to benefits and synergies as a replacement for a paradigm based on the minimisation of adverse impacts (Orchard et al., 2025). For example, it is likely that many intensive land uses can generate net benefits in the 'right' places and these in turn are enabled by a resilient and regenerative environmental context. Conversely, the pursuit of 'less worse' land use can only amount to the continued degradation of ecosystems, albeit perhaps more slowly.

Internationally this reorientation is being promoted in the nature-based solutions and nature-positive decision frameworks that mark a new level of ambition for human-environment relations. Could Aotearoa become a leader in applying these concepts? Opportunities for transforming the coastal management paradigm in this direction include broadening the discussion on flood and erosion risk away from a narrow conceptualisation of 'productive' land uses as seen in the pastoral farming–forestry comparison that is often the focus of research. Comparative studies could instead consider the full range of alternative land uses that might prove beneficial and expand from there to identify their specific benefits and enabling factors. Upstream innovations that improve downstream outcomes could become an additional focus for policy incentives, for example to facilitate beneficial land use transitions. At catchment scales, however, the recognition of ecological costs and benefits in downstream environments remains a mostly overlooked component of sustainable land management. Connecting upstream influences with downstream consequences at those scales holds the key to meaningful transformation.

Acknowledgements

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Climate transformation on Hokianga Harbour estuarine wetlands

By Mark Bellingham and Alison Davis

Introduction

In 1981 Hokianga Harbour was provisionally assessed by the New Zealand Wildlife Service (NZWS) as a 'High_value' wildlife habitat, as it had the largest areas of tall mangrove forest in New Zealand, large intact sequences of mangrove forest, mangrove shrubland, saltmarsh, and brackish marsh transitioning into freshwater marsh. It had significant populations of a number of threatened species – Australasian bittern, banded rail, spotless crake and North Island fernbird.

With encouragement from NZWS staff we undertook a harbour-wide survey of wildlife and wildlife habitat in 1982-3, funded by the Labour Department's Project Employment Programme.

These significant coastal wetlands are located in the drowned valley systems on the Hokianga Harbour and present a good candidate for monitoring the transformation of these coastal wetlands with climate change. There has been 40 years of baseline monitoring of the 3,500 ha of coastal wetlands and the threatened bird species using these wetlands.

With predicted global warming and sea level rise, coastal ecologists will be able to monitor the potential 'migration' of the wetlands up the harbour's inlets. Rather than assuming the current state of the harbour's wetland vegetation and wildlife populations are the norm, the long-term baseline monitoring of the wetland ecosystems on the harbour show medium- and long-term changes over the past 40 years. Potentially, we will be able to monitor changes to the composition of the wetland vegetation and how wildlife species use potential new wetland habitat areas.

Methods

The survey methods for the wildlife and wildlife habitat survey (1982-83) were designed with long-term monitoring in mind. Wildlife data from fauna habitat surveys in the 1970s collated by NZWS scientist Colin Ogle had shown the benefits of longer-term datasets for predicting changes of threat status in indigenous wildlife species in Ogle (1981 and 1984).

Alison Davis designed the monitoring methods using quantifiable and repeatable methods for recording vegetation (by species, cover, tier and plots) and line transects for encounters of key indigenous wetland wildlife species. Other incidental records of wildlife and threatened species were recorded also. The specific survey methods were:

1. Recording vegetation by species, cover and tier using the vegetation mapping method described by Atkinson (1981 and 1985).
2. Recording all bird species along a continuous 20-metre-wide line transect for each section of the harbour surveyed.
3. Vegetation stations with a 20 m buffer were positioned along the line transect where threatened wetland birds were encountered.
4. Recording wading and wetland birds on intertidal mud and sand flats, shell banks and rock platforms.
5. Incidental records of reptiles and threatened plants were recorded with their habitat and location.

We walked around and through the coastal edge of the entire harbour, surveying wildlife and wildlife habitats and a draft report (Davis and Bellingham, 1984) was prepared for the new Department of Conservation. The data used for this analysis comes originally from the 1982-83 NZ Wildlife Service survey data, our draft report, and a summary DOC report in 2001 (Davidson and Kerr, 2001).

Benefits of long-term monitoring

In November 2019, Mark Bellingham was requested to prepare a report assessing potential Significant Ecological Areas on Hokianga Harbour for CEP Services Ltd, to assist Northland Regional Council assess the extent of coastal wetlands on Hokianga Harbour for the Proposed Northland Regional Plan (PNRP) 2019. That report used the baseline 1984 vegetation and wildlife habitat data (with minor additions) that had been inputted into GIS for mapping and analysis.

The GIS mapping used the original paper maps (NZMS 1 1:63,000 and NZMS 260 1:50,000) and an overlay of aerial photographs from 1982 in order to verify:

- location and extent of vegetation types,
- location of vegetation sampling stations,
- location of bird sampling transects, and
- location of bird sampling stations.

These polygons, lines and points were mapped on the 2018 aerial imagery coverage in ARCGis (V.10.7) with a NZMS 260 topographic map overlay. Areas of wetland vegetation and wildlife habitat lost or gained were identified by comparing the 2018 aerial coverage with 1977 and 1981 aerial photos from the Retrolens Historical Image Resource (retrolens.co.nz) and our 1983 Topographical base map.

The data from the 1982-83 survey has been further analysed using ARCGis with additional data from surveys of other harbours in Northland and Auckland, and some minor resurveying of transects from the 1982-83 NZ Wildlife Service survey to identify wetland vegetation and wildlife habitat lost or gained.

The wetland bird species used the indigenous intertidal vegetation as a large continuous habitat area, flying between wetlands across reaches and across the harbour, and to freshwater wetlands not directly connected to the intertidal wetland complex. Importantly, it is one of the few major areas of intertidal vegetation and fauna habitat in Northland and probably New Zealand that has shown minimal change in area or habitat quality over the past 30 to 40 years.

The middle and upper reaches of the Hokianga Harbour met the Northland Regional Policy Statement Appendix 5 criteria for significant indigenous vegetation and significant habitats of indigenous fauna. These criteria include Representativeness, Rarity/Distinctiveness, Diversity and Pattern, and Ecological Context. Most of these reaches of the harbour meet a number of the sub-criteria within these criteria classes. We note that only one criterion needs to be met to qualify as significant vegetation or fauna habitat.

Significant indigenous vegetation and habitats of indigenous fauna on Hokianga Harbour

The criteria for significant ecological areas (SEAs) were explained in Appendix 5 of the Northland Regional Policy Statement and they have been reassessed using the complete dataset for the Hokianga Harbour from the data from NZ Wildlife Service's wildlife, wildlife habitat and intertidal-brackish-freshwater wetland survey and additional data gathered up until 2011.

The Proposed Regional Plan Significant Ecological Areas only include the harbour entrance to Koutu Point and the Significant Bird Areas cover a few of the larger reaches of the harbour. The assessment for the Significant Bird Areas did not appear to have included the data from the most intensive wildlife, wildlife habitat and intertidal-brackish-freshwater wetland survey of this large harbour by the NZ Wildlife Service in 1982-83 (Bellingham & Davis 1984).

The reaches of the harbour that met the PNRP significance criteria were Mangamuka River, Orira River, Waihou River, Taheke River, Whirinaki River, Tapuwae River, and the smaller estuaries between these major rivers in the catchment. Most of the intact sequences of intertidal, brackish and freshwater wetland vegetation, were occupied by wetland bird species typical of these vegetation types and they occupied about 3,500 ha of tidal wetlands in the harbour.

An area of indigenous vegetation or habitat(s) of indigenous fauna is significant if it meets one or more of the Regional Plan criteria shown in Table 1.

The widespread occurrence of threatened wetland bird species (Australasian bittern, banded rail, marsh and spotless crake, and North Island fernbird) throughout the middle and upper reaches of the harbour was outstanding from our ecological experience throughout the upper North Island. The extensive interconnected mangrove, salt and brackish marshes and freshwater marshes, often fringed with indigenous forests and shrubland, led us to recognise the middle and upper harbour as one large inter-connected wildlife habitat. Further survey work on the harbour and resurvey of selected areas has reinforced this assessment from 1984.

Baseline data for coastal wetland fauna and habitat

Reflecting on the data used for the SEA assessment for the Northland Regional Plan, we realised that we had more detailed data on density and habitat use of a number of threatened wildlife species including:

Banded rail (*Gallirallus philippensis assimilis* – At Risk-Declining)

Estimates of banded rail home ranges have come from a number of harbour surveys of wildlife habitat and estuarine vegetation in the Bay of Plenty, Coromandel, Southern Kaipara Harbour and Northland Harbours, with different methods to estimate population size. The banded rail population for the Hokianga Harbour is estimated to be approximately 2,300 birds. This has been supplemented by intensive surveys of rail home ranges in mangrove/saltmarsh habitat areas on Hokianga, Southern Kaipara, Whangamata and Ohiwa Harbours, where rail home ranges are 2.5-2.75 ha/pair, and home range estimates from Nelson and Marlborough banded rail home ranges in salt marsh rail 3.7 ha/pair (Bellingham, 2013).

Australasian bittern (*Botaurus poiciloptilus* – Nationally Critical)

Bitterns continue to decline throughout the country. It is found throughout the mangrove forest and shrublands, salt and brackish marshes and connected freshwater wetlands in the Hokianga Harbour catchment. Bittern move between intertidal wetlands and isolated freshwater wetlands around the harbour.

North Island fernbird (*Bowdleria punctata vealeae* – At Risk-Declining)

North Island fernbird is found in mangrove shrublands, brackish marshes and connected freshwater wetlands in the harbour catchment.

	Mangamuka River	Waihou River	Taheke River	Tapuwae-Motukaraka	Motuti-Panguru	Whirinaki-Oue Rivers
Representativeness	5/6*	6/6	5/6	5/6	5/6	5/6
Rarity & distinctiveness	2/10	2/10	2/10	2/10	2/10	2/10
Diversity & pattern	3/4	3/4	3/4	3/4	3/4	3/4
Ecological context	3/3	3/3	3/3	3/3	3/3	3/3

* SEA criteria per site/Total SEA criteria

Table 1: Regional Plan criteria for determining if an area of indigenous vegetation or habitat(s) of indigenous fauna is significant.

Spotless crake (*Porzana tabuensis tabuensis* – At Risk-Declining)

Spotless crake is found in the upper reaches of brackish and freshwater marsh throughout the harbour.

Conclusions

This 38-year ecological dataset available for the Hokianga Harbour provides an insight into the significant coastal vegetation and fauna habitat on that harbour and a baseline for monitoring the transformation of these coastal wetlands with sea level rise from climate change. The large wildlife populations, diversity of indigenous vegetation, ecosystem types and wildlife habitats have provided comparable data for wildlife species and estuarine vegetation that occurs on other North Island mangrove estuaries. Recent mapping of the wildlife habitats on the Hokianga Harbour has revealed that most of the vegetated tidal areas identified as SEA have changed very little since 1982 when the NZWS survey started. This has been tracked through aerial photos and topographic maps used in 1982, to the latest online aerial imagery available. Less than a 3% change has occurred to wetlands within the coastal environment of this harbour over the past 40 years and there has been no net loss of wetlands.

The few areas of salt and brackish marsh that were converted to farmland and wetland loss through encroachment of road edges (1983-4) were compensated by the tide reclaiming failed agricultural land. Mangroves and salt marsh have been restored (1984-2019). The few reports in New Zealand of coastal vegetation changes have focussed on small estuaries and coastal systems with significant sedimentation. In these areas, such as the Coromandel there has been community pressure to address the 'problem' of mangrove invasion (NIWA, nd.).

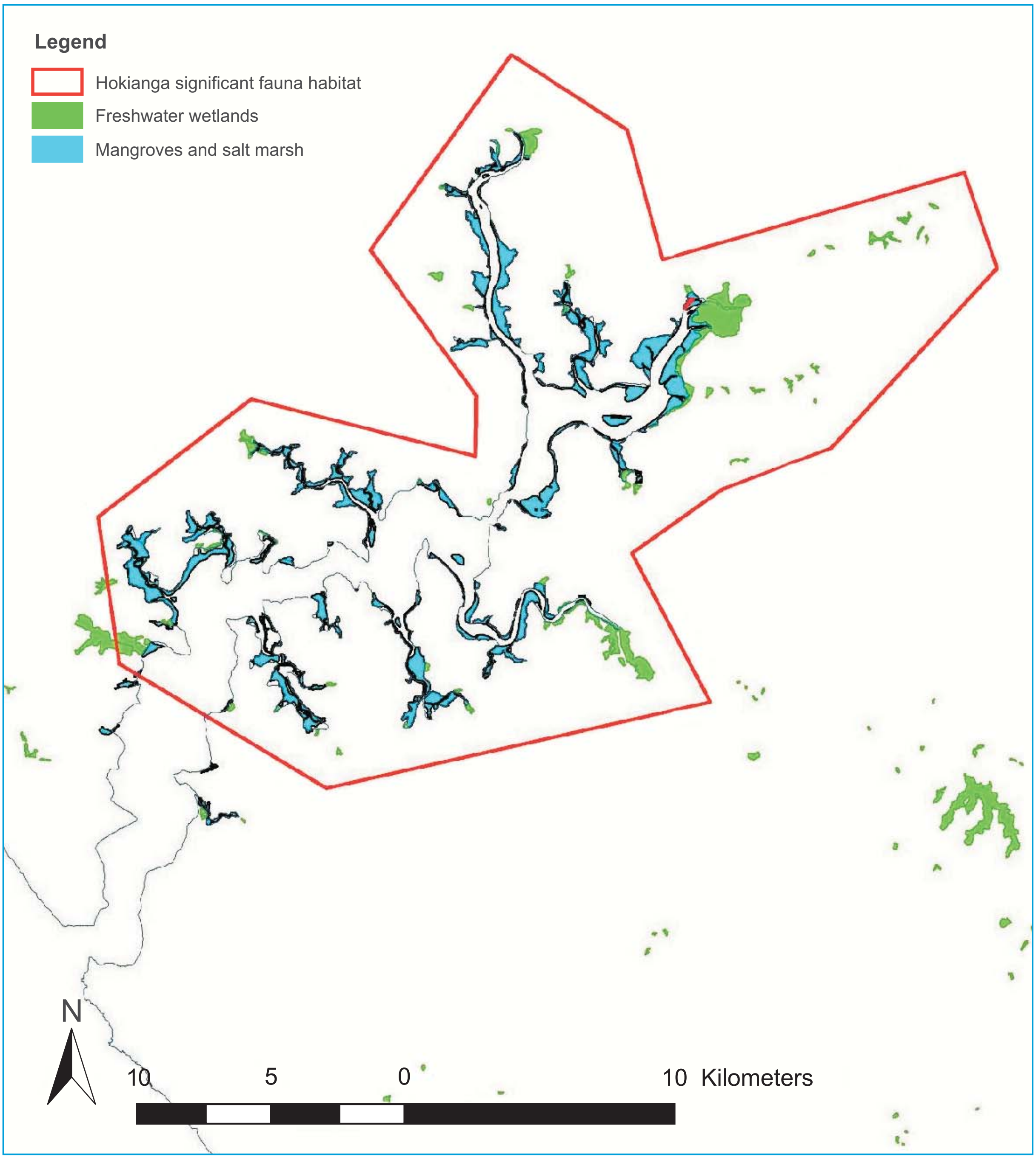

Figure 1: Hokianga Harbour intertidal significant vegetation and fauna habitat

Hokianga Harbour does have moderate to high levels of sedimentation from exotic forestry, although this appears to follow the 30–40-year pine forestry harvest cycles. Our long-term monitoring on this large harbour system has revealed stasis of estuarine systems over many recent decades and this may be more typical and important than short-term monitoring of other coastal wetlands in Northland.

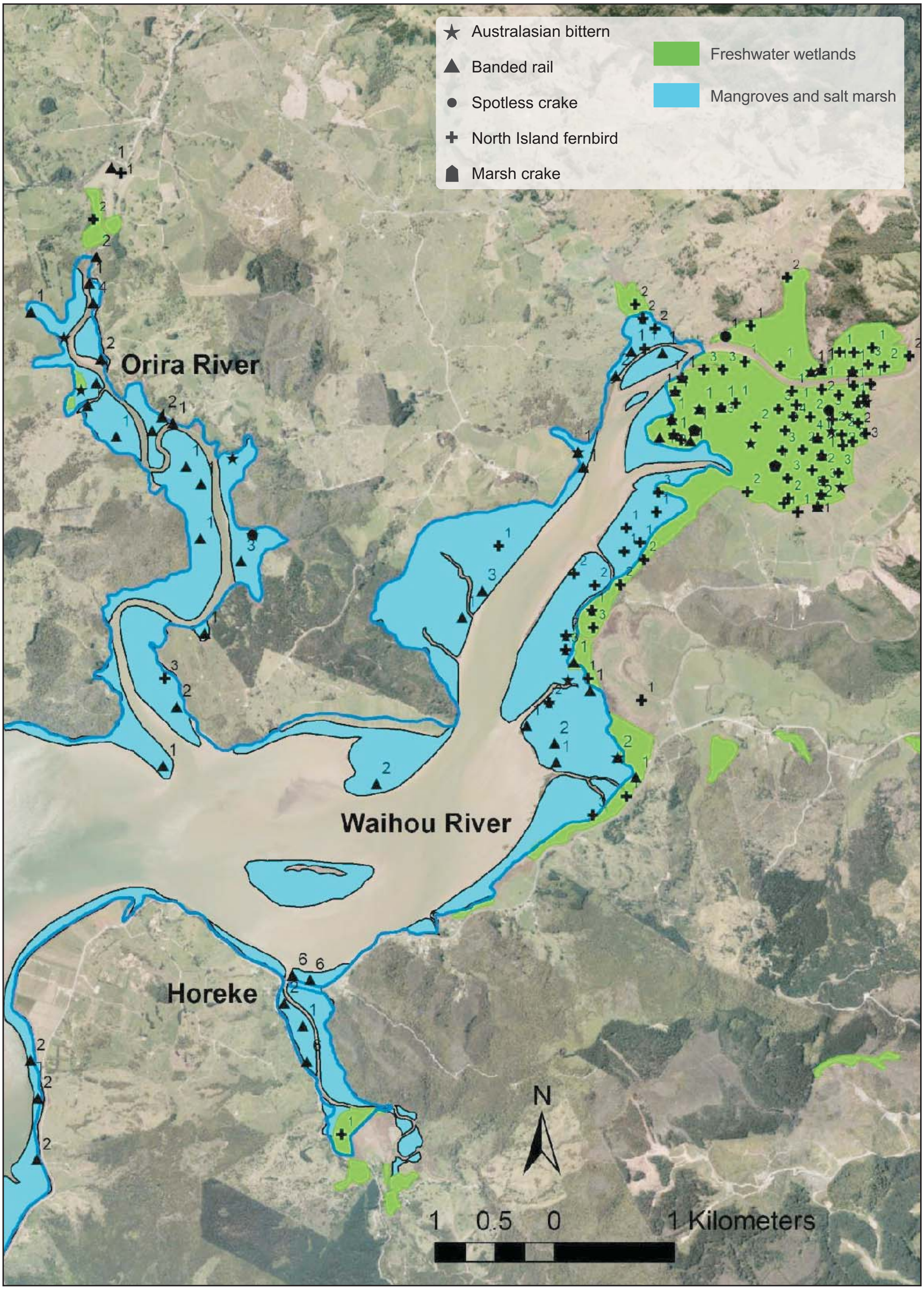

Figure 2: Orira and Waihou rivers. The numbers 1 - 6 beside the species symbols indicate the number of observations of that species at that location (Contains data sourced from the LINZ Data Service (https://data.linz.govt.nz/) licensed for reuse under CC BY 4.0 https://creativecommons.org/licenses/by/4.0/).

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Nature-based solutions and blue carbon: An opportunity for co-funding coastal transformation

By Matt Balkham, Monique Eade and Pene Ferguson

Aotearoa's long and varied coastline is a testament to the natural beauty and environmental richness that define our nation. Our communities, deeply connected to these coastal environments, recognise their unique and invaluable ecological significance. This treasured landscape has been under continual threat and degradation for over a century through drainage, agricultural conversion, industrialisation, and urbanisation. It is under increasing pressure from the dual threats of climate change and continued human activities.

In this context, nature-based solutions (NbS) offer innovative pathways to transform the coastline through restoration and regeneration of degraded environments. By leveraging the concept of blue carbon, we can explore co-funding opportunities to support financing of sustainable coastal transformation while realising a multitude of co-benefits. This approach not only addresses environmental challenges, but also fosters economic and social resilience, ensuring that our coastlines remain vibrant and thriving for generations to come.

Harnessing nature-based solutions for coastal transformation

Nature-based solutions (NbS) use natural processes to address a multitude of challenges that have traditionally been addressed through engineering solutions such as hard structures. NbS have the potential to tackle flooding, enhance water quality, mitigate climate change, and boost biodiversity, all within a single project. Moreover, they contribute to the mauri, or health and wellbeing, of environments and communities by working synergistically with natural systems. Many NbS ideas align well with the principles of Te Mana o te Wai and have been practiced for a long time by Māori.

The discussion and adoption of NbS for infrastructure-related services are increasing in prevalence in New Zealand, though perhaps still considered relatively new/alternative. They represent an evolution from a preference for hard engineering towards soft engineering and more recently towards NbS. Soft engineering (such as beach renourishment and dune planting) often continues to provide risk management functions against the natural/undefended condition, whereas NbS solutions look to leverage natural ecosystems and processes (for example coastal wetland restoration) working with these natural processes.

These ideas have been successfully implemented domestically and internationally as alternatives to engineered solutions and demonstrate a wide range of co-benefits. Projects can be either fully transformative or involve smaller, incremental actions that enhance existing natural features. Embracing NbS can require innovative thinking and a departure from traditional engineered approaches.

Emerging opportunity for blue carbon to support NbS implementation

Recently, NbS projects have shown an interest in blue carbon and the potential financing that carbon credits could offer. As the interest in blue carbon builds momentum globally, it is timely to consider how blue carbon could provide a catalyst for NbS in New Zealand.

Blue carbon refers to the carbon stored and sequestered in coastal and marine ecosystems, including plants and sediments. Coastal wetlands, such as mangroves, salt marshes and seagrasses, are blue carbon reservoirs. Coastal wetland blue carbon projects are projects with the purpose of restoring the ecological integrity and function of coastal wetlands to provide additional carbon storage and sequestration compared to a baseline.

Measuring and verifying the net increase in carbon, using methodologies from international organisations such as Plan Vivo, Verra, GoldStandard and America Carbon Registry, enables the carbon to be certified and carbon credits issued. Credits can be traded on voluntary markets and the income shared amongst project members. Coastal wetland blue carbon projects offer the potential not only to mitigate greenhouse gas emissions, but achieve co-benefits of enhanced coastal biodiversity, and protection against erosion and inundation.

Voluntary markets for blue carbon are emergent, with only 15 projects registered globally in early 2024. However, demand projections for carbon credits from all types of nature-based credits, including blue carbon, is estimated at approximately US$1 billion, with an estimated growth multiplier of 100 by 2050 (Claes et al., 2022; Clean Energy Regulator, 2022). Some countries, such as the United Kingdom[1] and Australia[2], have now included domestic methodologies and carbon credit markets for blue carbon. In New Zealand, NbS projects for coastal protection will likely be a collaboration between landowners, iwi, councils, community groups and others to enable scale and to recognise the complex interests and rights in the coastal marine area. This also create complexity in terms of who finances these projects and how.

Co-benefits

NbS offer a wide array of documented co-benefits, which have been demonstrated through various international projects. These benefits include:

- ***Erosion and sediment control:*** NbS can help to stabilise shorelines and reduce sediment loss.
- ***Water quality:*** Natural filtration processes can improve water quality in coastal areas.

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[1] 2024 Saltmarsh code.

[2] Under the ACCU scheme, Australia has a 'BlueCAM' method, and at least two projects were registered in 2024.

- ***Coastal protection:*** NbS can provide natural barriers against storm surges and flooding.
- ***Increased biodiversity:*** Enhancing natural habitats can support a greater variety of plant and animal species.
- ***Healthier communities:*** Access to green and blue spaces can promote physical and mental wellbeing, restoration/enhancement of mauri, and connection to place.
- ***Improved air quality:*** Vegetation in NbS projects can help filter pollutants from the air.
- ***Economic benefits:*** NbS can boost local economies through tourism and job creation.
- ***Socio-cultural benefits:*** These projects can enhance social cohesion, kaitiakitanga, and provide educational opportunities.

These co-benefits highlight the multifaceted value of NbS, making them a compelling choice for sustainable coastal management.

NbS for flood protection and ecological enhancement

The Steart Coastal Management Project stands as one of the United Kingdom's largest coastal habitat creation initiatives, restoring over 400 hectares of natural habitat. This includes extensive areas of saltmarsh and mudflat, which serve as vital habitats for numerous sensitive species. The project has successfully reduced the risk of flooding for the surrounding community and infrastructure, while also creating significant expanses of saltmarsh, intertidal mudflat, coastal grazing marsh, and freshwater lagoon. These efforts have markedly enhanced the coastal environment and biodiversity.

Steart is located on an isolated part of a peninsula. Flood risk has increased as a result of rising sea levels and the increased frequency of severe storms. The existing defences were deteriorating, and it was no longer economical to maintain them. The works included excavating a channel and system of creeks to divert water, creating tidal lagoons, building flood defence embankments around the perimeter of the inundation zone, and building extensive paths and walkways[3].

Currently managed by the Wildfowl and Wetland Trust, Steart Marshes functions as a natural laboratory, allowing researchers to explore the capacity of saltmarshes to mitigate climate change. This capability is driven by the growth of saltmarsh vegetation and the accumulation of sediment, processes that sequester substantial amounts of carbon dioxide from the atmosphere, up to 40 times more carbon per unit area than rainforests. The concept of blue carbon, which refers to the carbon stored in coastal ecosystems, is gaining significant attention for its potential to contribute to net zero ambitions through initiatives like saltmarsh restoration.

NbS for infrastructure protection

In October 2018, Tyndall Air Force Base, Florida, USA, was devastated by a Category 5 Hurricane, resulting in damage to all of its assets. In response, the base initiated a

Figure 1: Steart Peninsula (WWT Sacha Dench).

comprehensive rebuilding programme aimed at creating a resilient, sustainable, and smart 'Installation of the Future'. The rebuild of Tyndall Air Force Base used a mix of traditional engineered solutions and NbS to achieve these aims.

The Tyndall Air Force Base is vulnerable to extreme weather including high winds, extensive rainfall, and storm surges from the Gulf of Mexico. Storm surges can generate high water levels capable of inundating low-lying parts of the base. Climate change is expected to exacerbate these impacts. Coastal defences can take various forms, typically incorporating traditional structures like walls and levees alongside nature-based approaches such as beaches, dunes, and marshes. NbS are particularly appealing due to their cost-effectiveness, self-maintaining nature, and the array of co-benefits they provide. These benefits include habitats for threatened and endangered species, as well as recreational opportunities. NbS can be implemented alone or in combination with other methods to offer multiple lines of defence against storms.

A key focus of the project was the 'system of systems' approach which integrated grey, green, and natural infrastructure to increase resilience while creating locally relevant shared social, environmental, and economic benefits. Four pilot projects were established with a focus on both the primary and secondary line of defence. These include:

- Pilot 1: Building and reinforcing dunes, including a trial of intertidal or subtidal improvements to reduce erosion, placing oyster reefs, restoring tidal flats, and creating intertidal islands.
- Pilot 2: Rebuilding dunes on the barrier islands south of the base through trapping sand, including sand fences, woody debris, and new planting.
- Pilot 3: Feasibility study for the strategic replacement of subtidal sediments and sand placement to buffer wave energy in storms.

Figure 2: Tyndall Air Force Base (Jacobs).

[3] https://www.ice.org.uk/areas-of-interest/coastal-maritime-and-offshore-engineering/managed-realignment-at-steart-somerset

- Pilot 4: Feasibility study of NbS along the north side of the base evaluating sediment placements to enhance intertidal flats and salt marshes and using oyster reefs to reduce erosion. This was also to consider the feasibility of low-gradient levees[4].

NbS to support human health

Human health is intimately linked to environmental health. Though New Zealand is relatively sparsely populated, many of our urban centres have grown around coasts, harbours, and estuaries.

As our coastline is forced to adapt to the increasing impacts of coastal erosion and coastal inundation, there is an opportunity to consider whether we need to redesign some of our cities to better work with nature and, in turn, respond to other climate change challenges. Transformation of our urban coastal areas can significantly benefit from consideration of NbS concepts as a way to improve human health.

NbS for urban areas include implementing more permeable surfaces, creating elevated green corridors, increasing canopy cover, installing green roofs, and using lighter-coloured building materials that reflect sunlight. Green and blue infrastructure can significantly enhance the quality of life and sustainability in cities and improve people's connection with the natural environment.

NbS to protect our cities

Many of New Zealand's urban coastal areas are vulnerable to coastal erosion, inundation from storm surge and wave overtopping, and other natural hazards such as groundwater and stormwater flooding, which may be exacerbated by sea level rise. NbS also offers opportunities to work with nature to find resilient solutions to natural hazard risk management.

The San Francisco Waterfront is renowned for its historical significance. The construction of the Embarcadero Seawall in the late 19th century transformed the city into a major trade and financial hub, laying the foundation for the thriving Port of San Francisco we see today. However, over the past century, the waterfront and the historic seawall beneath the Embarcadero have deteriorated and are now vulnerable to hazards such as seismic activity, flooding, and sea level rise. These immediate and long-term threats are being addressed by the Waterfront Resilience Program, a top infrastructure priority for both the Port and the city.

The Waterfront Resilience Program aims to strengthen and adapt over 11 kilometres of waterfront.

This seawall protects critical regional transportation assets, utilities, and over US$100 billion in assets and annual economic activity. The project has considered a range of NbS, including a naturalised shoreline, wetlands, ecotone levees, living seawalls, ecological armouring, and green stormwater infrastructure.

The project considered seven alternatives for each compartment including: no action, non-structural intervention (including retreat), holding the line, and managing the water. The net benefit of each of the alternatives were considered across National Economic Development, Regional Economic Development, Other Social Effects and Environmental Quality. Generally, shore-based construction and landward retreat was found to have a greater impact on human resources, while in-water construction was found to have a greater impact to natural resources. Offsetting adverse effects was also considered.

The alternatives put forward in the Draft Plan were in response to six years of community feedback where they reached tens of thousands of community members.

Blue carbon credits to offset project emissions

Nature-based solutions may also provide an opportunity to offset New Zealand infrastructure project emissions while delivering broader environmental outcomes. This could be achieved through carbon credits.

In 2019, the UK Government set an ambitious target to reduce the nation's greenhouse gas emissions by 100% relative to 1990 levels by 2050. Achieving net zero requires a dual approach: organisations must significantly reduce emissions and support the removal of residual emissions from the atmosphere once decarbonisation measures are in place. NbS play a crucial role in this effort, addressing both emission reductions and removals.

A carbon offset represents a reduction, removal, or avoidance of greenhouse gas emissions that would not

[4] https://tyndallcoastalresilience.com/

Figure 3: Tentatively selected plan initial actions (US Army Corps of Engineers; Port of San Francisco, 2024).

have occurred otherwise. These offsets can be generated through third-party projects and sold for use by other organisations or produced through investments in bespoke projects.

While immediate carbon reductions are essential, they alone cannot achieve net zero. For example, degraded peatlands are a significant source of greenhouse gas emissions, with the UK's peatlands estimated to emit over 20 megatonnes of CO_2 annually, approximately 4% of the country's total emissions. Reducing these emissions through peatland habitat restoration is vital for the United Kingdom. to meet its net zero targets.

The North West Hub location has calculated the carbon footprint for its flood and coastal risk management programme. Using this data, various scenarios have been developed to understand the magnitude and timing of likely carbon emissions over the project's lifetime. Through active collaboration with key stakeholders and landowners, nature-based opportunities to meet net carbon emission targets have been identified, encompassing both blue carbon and terrestrial or 'green' carbon approaches. These opportunities were then prioritised based on criteria such as cost, ease of implementation, carbon benefit, and broader environmental benefits.

Blue carbon credits as a financial instrument to support NbS investments

The costs for coastal resilience and adaptation will likely fall mostly on councils, central government and landowners. Designing NbS with a blue carbon component can provide income from carbon credits, supporting financial viability and potentially attracting outside investors. To create certified credits, the carbon has to be additional to any activity that would have taken place. Therefore, carbon credits must be a key driver of the project (the project would not be viable without the carbon credit) or would have to be an additional component to a project.

Blue carbon credits are based on the increase in carbon stored in the coastal wetland and therefore there will be lag time between the initial development costs and the first sale of credits. Over time and in the long run, income would be regular.

Blue carbon project owners in New Zealand currently need to determine the rights to carbon, apply blue carbon methodologies, monitor and verify carbon before carbon credits can be issued and traded. A benefit sharing agreement between project partners is required to explain how income and benefits will be shared amongst participants (landowners, iwi, community and others).

Pilot projects are exploring the opportunities and barriers[5]. An analysis on the financial feasibility of blue carbon projects funded by the Nature Conservancy (Weaver et al., 2022) found that blue carbon credits can contribute to project feasibility, but there are a number of variables across projects and markets presently. As outlined below, there is a strong case for strategic policy and market development to reduce monitoring and verification barriers and accelerate access to markets to reduce uncertainty and risk and create a sustainable source of finance for NbS.

Research into NbS and blue carbon

There is a growing body of international evidence that NbS are effective, offer multiple benefits, and are often well-received by communities once implemented. However, in New Zealand, interest in NbS is still developing and the full potential of these solutions has yet to be realised. Interest in coastal blue carbon is increasing across New Zealand, with collaborative efforts among government, iwi, non-governmental organisations, researchers, landowners, and community members to share knowledge and create momentum.

The Coastal Wetland Blue Carbon Policy Research in Aotearoa report (The Nature Conservancy, 2024) was funded by The Nature Conservancy Aotearoa New Zealand and Ministry for the Environment and was commissioned to look at the barriers and opportunities for enabling blue carbon projects in New Zealand to create carbon credits. The research explores the following themes:

1 Greenhouse gas inventories and nationally determined contributions

[5] For example, Te Repo ki Puukoroko (Miranda), Wainui Repo Whenua and Pukehina/Waihi (Bay of Plenty), Waimeha Inlet (Tasman).

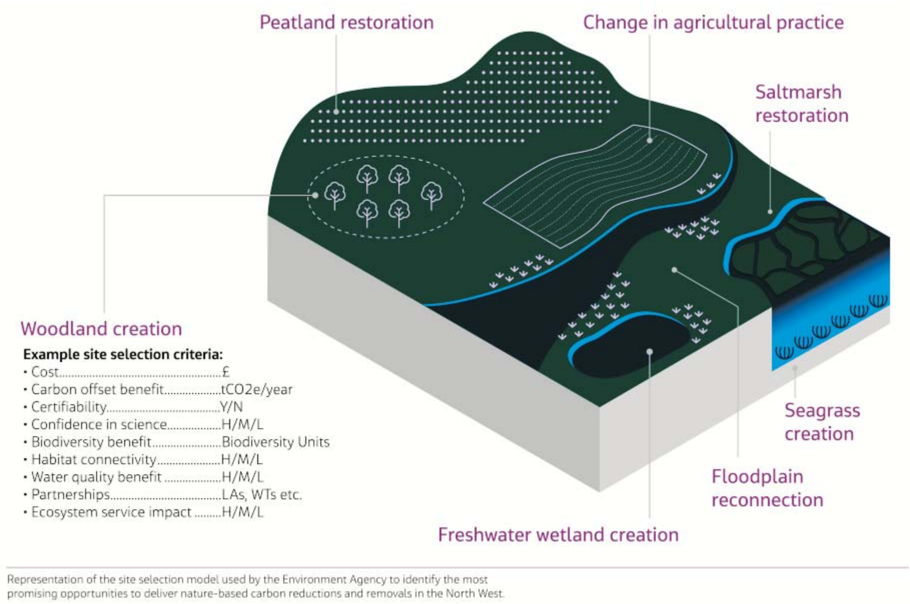

Figure 4: Representation of the site selection model used by the Environment Agency to identify the most promising opportunities to deliver nature-based carbon reductions and removals in the North West (Jacobs 2022).

2 Carbon markets and carbon trading
3 Environmental policy and law
4 Coastal land tenure and carbon rights
5 Blue carbon schemes and methodologies
6 Co-benefits of blue carbon projects.

Some of the barriers and challenges identified in the research are:

- Clarifying the rights to land use and carbon in the coastal marine area, especially for projects that involve rewetting of land and subsequent changes to the land/sea boundary.
- High data collection and analysis costs to comply with the voluntary carbon standards and accounting methodologies. These could be reduced with national data sets and methodologies.
- Sharing the costs and benefits across landowners, iwi, government and other project partners. Most projects are likely to have a number of participants and interested parties.
- Navigating the complexity of laws, regulations, permits and consents in the coastal marine area, even when natural habitat restoration is a primary purpose.
- Future policy decisions about the NZ Emissions Trading Scheme, NZ Greenhouse Gas Inventory and the NZ commitments to the Paris Agreement such as clarifying the cross-boundary trade of carbon so projects will be able to sell carbon credits to offshore buyers. This will all influence the costs and complexity of blue carbon projects.
- Unpredictability of demand and prices for blue carbon credits in voluntary markets because they are still very new, although indications are that demand for nature-based carbon credits on voluntary markets will continue to grow.

Transformation of Aotearoa's coast

Natural hazards pose a significant and increasing threat to our daily lives. Across New Zealand, we have vulnerable communities, exposed transport and power infrastructure, and modified coastlines with encroaching land use and degraded habitats.

Proactive risk management is the most cost-effective way to address these hazards. Taking action before the next storm and in advance of rising sea levels will be cheaper than dealing with the aftermath. There is a significant opportunity to adopt NbS and utilise various funding sources, including blue carbon credits, to build resilience.

Restoring and making space for our coast allows us to work with nature rather than against it. These interventions are likely to be more sustainable and adaptable to our changing climate, helping our communities thrive and enabling our ecology and environment to restore and flourish.

There will be some areas that still require conventional engineered approaches (i.e. 'hard structures) to manage flood and erosion risks. This may include areas where there is significant development reliant on the hard structure and the costs of adapting, upgrading, or retreating

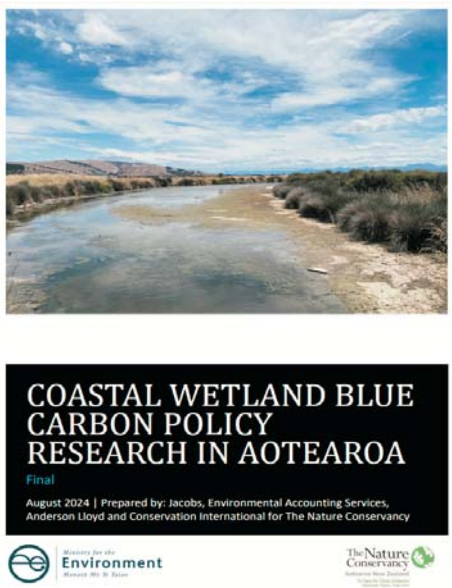

Figure 5: Blue carbon research report (Source: The Nature Conservancy).

the development does not outweigh the environment and economic cost.

Conclusion

Coastal transformation will take time, funding, and leadership. Blue carbon presents a unique opportunity to help fund coastal transformation in New Zealand. By restoring and protecting coastal wetlands, such as mangroves, salt marshes, and seagrasses, projects can increase carbon storage and sequestration and generate blue carbon credits. These credits can be traded in carbon markets, providing a financial incentive for conservation and restoration projects. This funding mechanism can support large-scale NbS projects, driving sustainable coastal management and resilience.

Blue carbon is well placed to support transformational change. As recent policy research identifies, there are strategic policy and market developments required to accelerate the opportunities in New Zealand and capitalise on an emerging global market for NbS carbon credits. However, a bigger question is whether New Zealand is ready for transformational change. NbS is an opportunity to do something different instead of reverting back to what we have always done. NbS doesn't have to be transformational – it is still a step in the right direction. Transformational change may have a more comfortable home in adaptive planning, where we can plan now but have time to adjust to the idea of transformation change.

Investing in NbS offers numerous benefits to our communities:

- ***Environmental resilience:*** NbS enhance the natural resilience of coastal ecosystems, providing protection against storm surges, flooding and erosion.
- ***Biodiversity:*** Restoring natural habitats supports a diverse range of species, contributing to healthier ecosystems.
- ***Economic opportunities:*** NbS can boost local economies through eco-tourism, job creation, and sustainable fisheries.

- ***Health and wellbeing:*** Access to green and blue spaces promotes physical and mental health, fostering a sense of community and belonging.
- ***Climate mitigation:*** NbS contribute to climate change mitigation by sequestering carbon and reducing greenhouse gas emissions.
- ***Social cohesion:*** Community involvement in NbS projects strengthens social ties and kaitiakitanga, collective stewardship, of natural resources.

By learning from global best practices and adapting them to local contexts, New Zealand can lead the way in sustainable coastal management. Investing in NbS not only fosters environmental resilience, but also creates vibrant, healthy, and economically robust communities. Finding additional and sustainable funding sources, such as blue carbon credits, to support the investment in NbS is essential for catalysing change.

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Digital twins as emerging technology for integrated coastal management

By James Lear, Bryan Li, Akuhata Bailey-Winiata and Shari L Gallop

Introduction

What is a digital twin?

A digital twin is a virtual or digital representation that looks like (such as in terms of appearance/structure/architecture), behaves like (such as in terms of output or response), and connects to (via data flow) a physical environment, system, component or process (Yu et al., 2022). While digital twins can be developed for a wide range of physical environments, systems, components, and processes, their purpose is ultimately to enhance decision making by providing a realistic and current reflection of the physical counterpart it represents (Yu et al., 2022). Figure 1 illustrates the digital twin concept and the relationship to its physical counterpart.

Any model can be considered a 'digital twin' if its appearance, behaviour, and data connectivity are sufficiently aligned with the physical system it represents (Miedtank et al., 2024). To this effect, whether a model can be considered a digital twin is largely dependent on the specific requirements of its use case. For example, in coastal management, a 'simple' digital twin might simulate coastal erosion processes or coastal flooding (Brown et al., 2006; Dai et al., 2021; Wadey et al., 2015). However, the frequency of data required for these two components varies, for instance, in a digital twin simulating long-term sea level rise might only require periodic data updates. In contrast, a digital twin designed to simulate and monitor coastal flooding events would need real-time or near-real-time data updates to accurately reflect the rapidly changing conditions during extreme weather events.

Enabling technologies for digital twins

Digital twins are powered by the convergence of several advanced technologies, each contributing to the critical 'look-like', 'behave-like' and 'connect-to' attributes. These technologies include the Internet of Things (IoT), remote sensing, cloud computing, artificial intelligence (AI), and extended reality (XR).

Among other technologies for data collection, IoT and remote sensing are among the most significant to digital twins and enable the critical 'connect-to' function (Attaran and Celik, 2023). These technologies can capture 'big data', including key coastal environmental data like sea surface temperature, turbidity, sea level variations, and shoreline position. The continuous flow of this data is vital for keeping a digital twin appropriately synchronised with its physical counterpart.

Cloud computing is crucial for handling the vast quantity of data required for digital twin applications (Attaran and Celik, 2023). It has been applied in flood risk management in Miami-Dade County, Florida, which is effective in evaluating community adaptation strategies, potentially avoiding up to US$3.44 billion of total community damage (Han and Mozumder, 2022). Scalable cloud infrastructure meets the computational demands of real-time simulations and predictive modelling, leveraging distributed computing

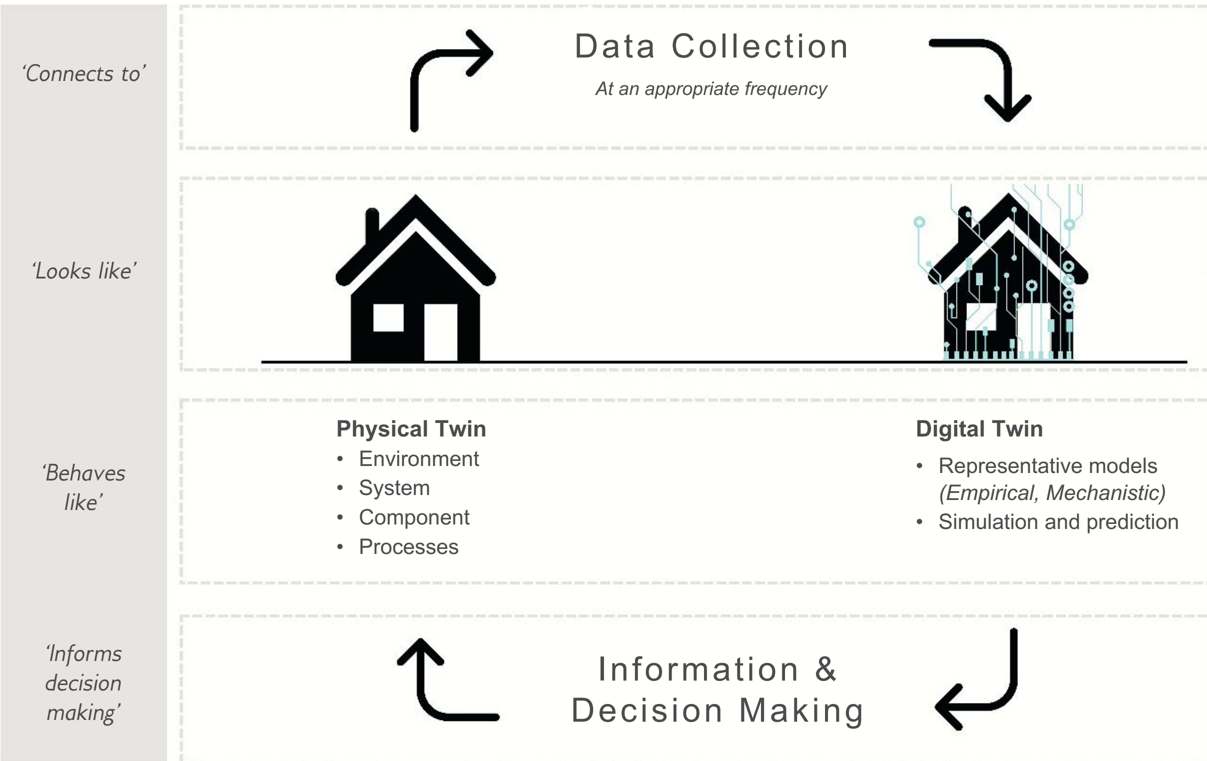

Figure 1: Conceptual diagram illustrating the relationship between a digital twin and its physical counterpart. Data collected from the physical twin informs the digital twin, which simulates and predicts behaviours to support decision making.

architectures. In these architectures, large datasets are partitioned and processed in parallel across multiple servers or nodes, significantly reducing the time required for complex computations. By distributing the computational load, cloud platforms ensure that digital twins can scale to model systems of increasing complexity and size without compromising performance.

Artificial intelligence (AI) can significantly enhance the 'behave-like' attribute of digital twins by enabling accurate modelling and prediction of system behaviours (Attaran and Celik, 2023). Machine learning (ML) algorithms can process data from IoT sensors and remote sensing platforms using techniques such as neural network, regression analysis, clustering, and classification to uncover patterns and relationships. ML has been applied in a range of coastal applications including the monitoring and prediction of shoreline change in the Coromandel Peninsula, New Zealand (Gomez-de la Peña et al., 2023) and Australia (Davidson et al., 2017; Simmons and Splinter, 2022; Vos et al., 2019), forecasting beach and dune changes in North Carolina, United States (US) (Itzkin et al., 2022), and predicting recreational coastal water quality in Auckland, New Zealand (Xu et al., 2020). Neural networks, an ML technique, include convolutional neural networks (CNNs) for complex feature extractions, recurrent neural networks (RNNs) for handling time dependencies, and generative adversarial networks (GANs) for addressing data imbalance. Neural networks have been used to build a prediction model of tropical storm surges in the US east coast (Hashemi et al., 2016), ocean acidification in Ría de Vigo (NW Spain) (Li et al., 2024), and habitat quality evaluation and pattern simulation of coastal salt marsh wetlands in Jiangsu, China (Huang et al., 2024).

Interactive platforms, such as extended reality (XR) technologies including virtual reality (VR), augmented reality (AR), and mixed reality (MR) along with game engines (e.g. Unity, Unreal Engine) and other user-centric interfaces, can play a critical role in the user interaction with digital twins (Attaran and Celik, 2023). For example, VR has been effectively used in planning for sea level rise in coastal communities by providing immersive experiences that helped residents of Long Beach, California visualise future flooding scenarios and test potential adaptation strategies, enhancing public engagement and decision making, stating that 63% of users reported a significant or very significant change in their awareness of sea-level rise after participating in the VR experience (Calil et al., 2021). These platforms can make complex systems interactions accessible to both technical and non-technical users and enhances the 'look-like' and 'behave-like' attributes of digital twins. This allows stakeholders to test strategies and make informed decisions in a virtual environment before applying them in the real world.

A review of digital twin applications

Digital twins are transforming decision making in industries like agriculture, healthcare, and manufacturing (Attaran and Celik, 2023). In agriculture, they optimise resource use by integrating data from drones, satellites, and IoT sensors to monitor crops and predict yields (Wolfert et al., 2017). In healthcare, digital twins support personalised medicine by simulating treatment outcomes based on patient-specific data from medical imaging and genomics (Bruynseels et al., 2018). In manufacturing, they enhance efficiency by using real-time sensor data to optimise workflows and predict maintenance needs, as seen in automotive assembly lines (Tao et al., 2017).

The following sections explore specific digital twin applications in Aotearoa New Zealand (hereafter A-NZ) and coastal examples internationally.

Digital twins in Aotearoa New Zealand

Aotearoa New Zealand has embraced digital twin technology across various sectors, particularly in urban planning and resilience, with digital twins developed for Auckland, Tauranga, Christchurch and Wellington, alongside other more specific applications (MBIE, 2024). These digital twins, which vary in purpose and sophistication, are being used to enhance urban management, improve infrastructure resilience, and support more informed decision making.

Wellington City Council (WCC) has developed a digital twin that serves as an interactive virtual representation of the city (Silver, 2024). Built on Unreal Engine (a game engine), users can navigate a photorealistic visualisation (looks like) of Wellington's urban landscape in an immersive and interactive experience. The Wellington Digital Twin integrates data from IoT sensors (connects to), including traffic and cyclist counts and travel direction, air pollution, temperature, weather and car park availability. It is also capable of simulating/predicting outcomes for proposed developments or infrastructure projects (behaves like).

The capabilities of the digital twin allow the testing and refining of proposed developments by simulating their impacts on traffic, air quality, and overall city dynamics before implementation. It has also been trialled to simulate and visualise the effects of sea level rise and coastal flooding on communities, helping residents understand the various futures under different adaptation strategies including seawalls, raising floor levels, and managed retreat (Gourley, 2023). The digital twin not only enhances decision making but also improves public consultation and stakeholder engagement processes by providing a clear visualisation of potential outcomes. WCC continue to develop the digital twin, and it is likely to become a key tool in raising the climate literacy of their communities.

Similarly, a prototype flood resilience digital twin has been developed to reflect, assess and manage flood risk for Kaiapoi, Canterbury (Wilson, 2022). The digital twin integrates various data sources, including LiDAR, topographic, bathymetric, and landcover data, infrastructure assets (e.g. stormwater infrastructure, stopbanks, buildings, and roads), and dynamic environmental data like river levels and rainfall (connects to). The digital twin also simulates different flood events using machine learning and physics-based (mechanistic) modelling (behaves like). While the prototype currently includes some basic visualisation capabilities (Figure 3) (looks like), future work will focus on developing an improved user interface, dynamic 3D visualisations, and immersive VR/AR experiences to enhance decision making, public engagement and flood risk education.

Digital twins for coastal management internationally

Digital twins are an emerging technology for coastal management, although uptake is increasing globally. For instance, a digital twin of the Emilia-Romagna coast in Italy incorporates wave and circulation models to simulate storm impacts and evaluate the efficacy of seagrass as a nature-based solution (NbS) to reduce shoreline retreat (Pillai et al., 2022). Moreover, the Coastal Zone Information Model (CZIM) is a digital twin developed to monitor coastal changes in real-time and simulate the impact of sea level rise and human activity on coastal ecosystems in China's coastal regions (Yu et al., 2024).

North Norfolk District Council in the United Kingdom (UK) developed a digital twin to enhance the resilience of the Bacton to Walcott coastline, which faces significant risks from coastal erosion and storm surges (Clipsham et al., 2021). Using high spatial and temporal resolution topographic and bathymetric data, the twin provides a detailed 3D visualisation (looks like) of the coastline, coastal infrastructure, and a local settlement. Data is integrated from near-real-time environmental monitoring systems (connects to), including tide gauges, meteorological data, and historical shoreline erosion data. It is also capable of simulating a range of coastal processes, such as storm surges, sea level rise, and long-term erosion using machine learning and physics-based models (behaves like).

The digital twin's capabilities have been instrumental in the ongoing monitoring and management of a sandscaping scheme involving the placement of 1.8 million cubic metres of sand to provide natural protection by absorbing wave energy, protecting cliffs, communities, and the Bacton Gas Terminal which processes up to one third of the UK's gas demand (Clipsham et al., 2021). This includes prediction of the remaining life of the scheme, systems analysis to determine factors affecting the remaining life, and

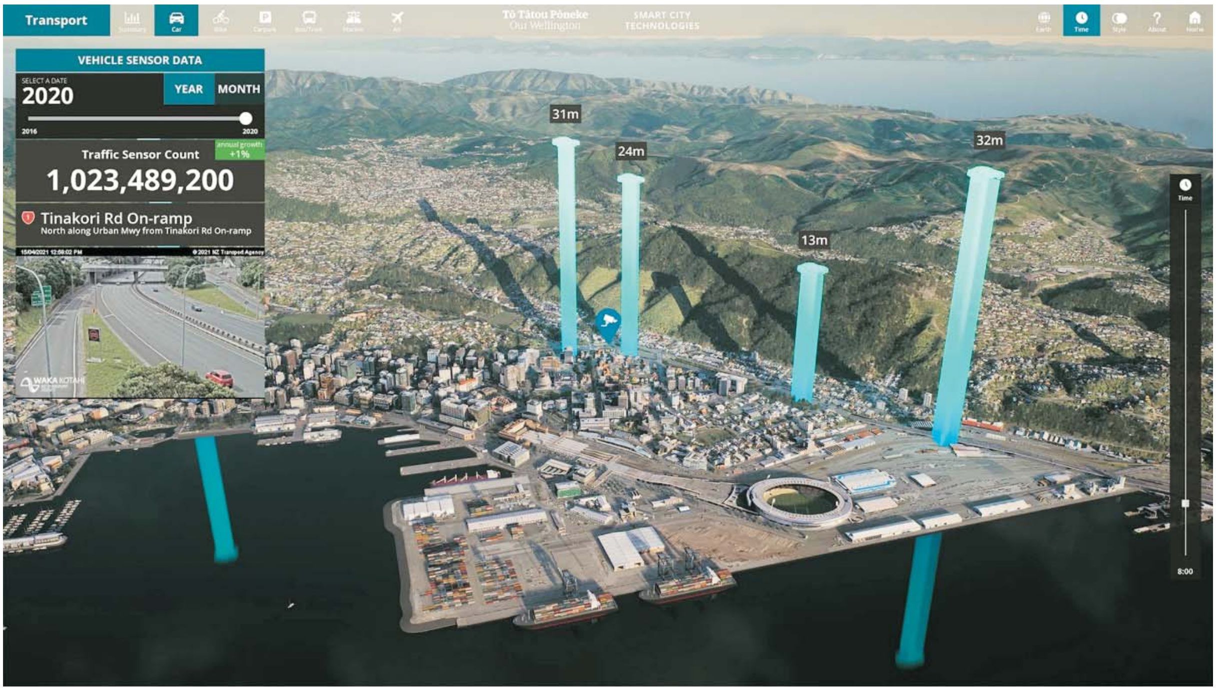

Figure 2: Unreal Engine 3D visualisation of the Wellington City Digital Twin (Silver, 2024).

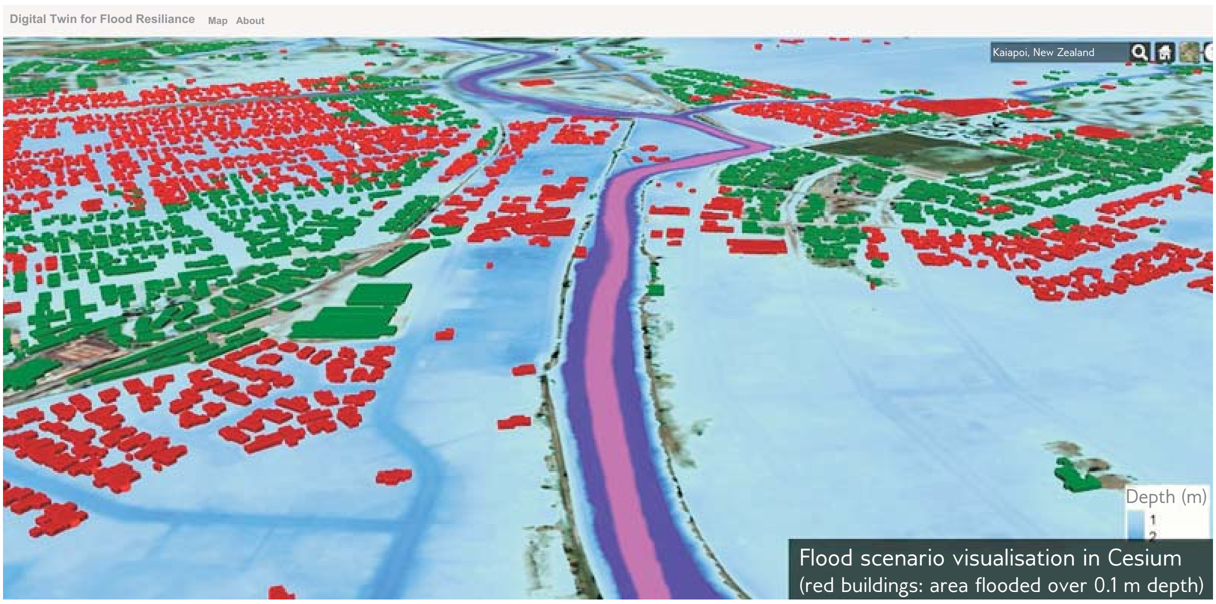

Figure 3: 3D visualisation from the prototype flood resilience digital twin, visualising flood levels in Kaiapoi, Canterbury. Buildings highlighted in red are flooded at a depth of 0.1 m or greater (Wilson, 2022).

visualisations of coastline change. This helps to avoid the risks of decision makers either waiting too long, potentially leading to critical infrastructure damage and casualties, or investing too early, which could result in unnecessarily high costs. The digital twin also supports operational decision making and communication with the public and other stakeholders.

Another example of a coastal digital twin is EDITO (European Digital Twin Ocean), which ambitiously aims to develop a detailed, interactive, and real-time digital replica of the ocean (looks like) (Bauer et al., 2021). EDITO integrates vast datasets collected via satellite, IoT and in-situ sensors, and even citizen-collected data (connects to). EDITO also includes a range of models to simulate complex processes, including NEMO for large-scale ocean dynamics, SHYFEM and Delft3D for unstructured grid and coastal modelling, wave models like WAM and WW3 for simulating wave dynamics, and PISCES and ECOSMO for simulating marine ecosystems and nutrient cycling (behaves like) (European Commission, 2022).

Combined with ML techniques to optimise how these models work together, improve the accuracy of predictions, and enhance the efficiency of processing complex data, EDITO enables decision makers to explore 'what-if' scenarios like the impact of restoring coastal vegetation on erosion (Eparkhina and Nolan, 2023). For example, one EDITO model allows users to explore the efficacy of NbS for erosion, by adjusting various parameters (including sea level rise, NbS extent, and storm intensity and frequency) for a defined area of interest. Figure 4 provides several example outputs, sourced from the GitLab Repository, including an illustrative cross section of seagrass extent, and 2D maps of wave height reduction, and change in erosion risk (Jacob, 2024). Similar tools exist for investigating 'what-if' scenarios for marine biodiversity, zero carbon aquaculture, and management of microplastic pollution (Eparkhina and Nolan, 2023). This 'what-if' functionality exemplifies how digital twins can be used to inform complex environmental decision making.

Digital twins for coastal management in Aotearoa New Zealand

Digital twins are increasingly being leveraged in A-NZ and internationally to enhance decision-making processes in complex systems (both environmental and non-environmental) and to facilitate public engagement. What if we could develop a digital twin specifically for coastal management and adaptation in A-NZ? Such a tool could address critical challenges in managing our unique and diverse coastal environments. This section explores the potential of a coastal management digital twin for A-NZ, considering the key challenges it could address and conceptualising how such a twin could be structured and developed to meet these needs.

Objectives

The objective of this conceptual digital twin would be to create a dynamic and interactive digital representation of A-NZ's coastlines which:

- facilitates complex systems understanding, unlocking integrated management approaches that reflects ki uta ki tai (from the mountains to the sea);
- enables the exploration of 'what-if' scenarios including the effects of different climate scenarios, and physical or policy adaptation/management interventions; and,
- enhances community engagement, involvement in adaptation decision making and climate literacy.

Conceptualisation

The following sections constitute the conceptualisation of a digital twin. Each section describes the features of a digital twin which achieves the objectives set out in 'Data governance and compatibility' below.

Looks like

To facilitate complex systems understanding and enhance community engagement, the digital twin must accurately visualise A-NZ's coasts and associated features in a high-

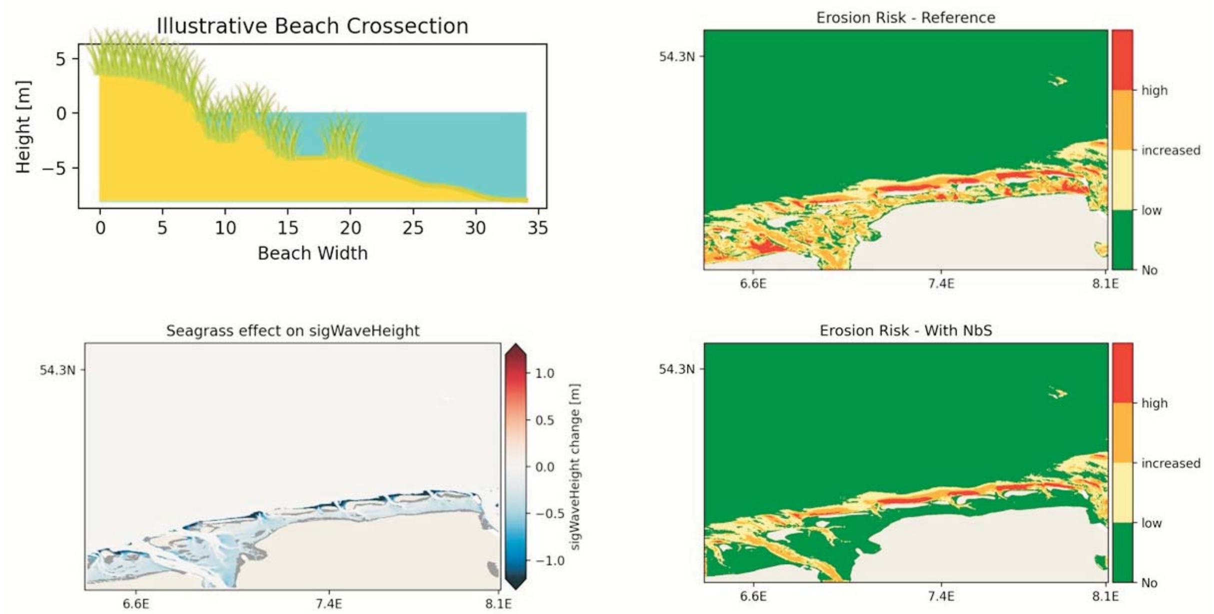

Figure 4: Example outputs from the EDITO GitLab repository 'What-if Scenarios (WiS) for Nature based Solution (NbS)' illustrating the efficacy of seagrass for reducing erosion risk (Jacob, 2024).

resolution, multi-dimensional digital model. This model should be grounded in recent topographic and bathymetric data, accurately capturing the detailed landforms and underwater features essential for coastal management. The model must also capture: the characteristics of our communities important to decision making, including their physical form, location, diversity and adaptive capacity; critical infrastructure (water, energy, transport), and interactions beyond the immediate coastline including freshwater catchments, marine ecosystems, and the broader oceanic context, supporting an integrated management approach.

Serious games can allow communities to explore different climate futures, while building capacity to manage complex challenges and socialise climate change adaptation priorities (Flood et al., 2018). Serious games are already being used in A-NZ to support creating climate change adaptation pathways for localised flood adaptation. Such games can draw together detailed local knowledge including mātauranga-a-hapū/iwi (local, place-based knowledge from a hapū/iwi's rohe/area) to create credible gaming experiences that support decision making (Blackett et al., 2021; Wilkinson et al., 2020). Co-development of such games is fundamental to success (Blackett et al., 2021). These are various learnings such as the above that could contribute to the creation of digital twins. Such a twin could be rendered in 3D, such as using a game engine like Unreal Engine, to create an immersive, interactive visualisation that allows users to explore and analyse the environment in real time. It is well established that this visualisation capability supports the translation of complex environmental systems and management scenarios into a format that is accessible and meaningful to diverse stakeholders (Hajrasouliha and Amos, 2024; Park et al., 2024). For example, the value of 3D interactive visualisations on community knowledge and engagement has been investigated in an urban infrastructure context (Ma et al., 2020). They found that the 3D interactive visualisations significantly improved the stakeholder understanding about the complexities of infrastructure management and the interactions between infrastructure features when compared with a typical participatory engagement approach like 2D static mapping. Hence leveraging a game engine to develop 3D visualisations is likely to significantly improve the capacity of a digital twin for coastal management to support decision making and enable community understanding of, and participation in, coastal management/adaptation decisions (Hajrasouliha and Amos, 2024).

Behaves like

To enable the exploration of 'what-if' scenarios and facilitate complex systems understanding, the digital twin must accurately replicate the dynamic processes and interactions characteristics of A-NZ's coast. Achieving this will require integrating multi-scale process models that simulate key physical, chemical and biological processes, ranging from fluid dynamics and sediment transport to nutrient cycling and ecosystem responses.

These models should incorporate feedback loops and the interactions between terrestrial, coastal, and marine systems, and allow users to adjust key variables (to investigate 'what-if' scenarios), including sea-level rise, management/adaptation interventions, and storm severity and frequency. Furthermore, the incorporation of te ao Māori (Māori world view) could be explored to integrate into the models, such as by including mātauranga Māori (intergenerational Māori knowledge, values, principles and ethics) (Wilkinson et al., 2020), which may include pūrākau (ancestral stories including codified knowledge), and tohu (indicators) for example. The importance of mātauranga Māori and its relevance to digital twins was highlighted in the Microsoft lighthouse collaboration with Ngāti Toa and the Ministry for the Environment, which utilised stories and videos of mana whenua (Māori with territorial rights over a specific area) and kaumatua (elders) sharing stories of how the environment has changed to construct a digital twin of Porirua city (MBIE, 2024). This will enable the exploration of potential outcomes and the assessment of intervention effectiveness, whether through NbS, engineered infrastructure, or policy changes. We highlight that mātauranga is a taonga (treasure), and following Wilkinson's work (Wilkinson et al., 2020), there is no expectation that mātauranga be given, although we encourage exploration of inclusion of mātauranga when it is tika (right), pono (honest) and appropriate. See also 'Data governance and compatibility' below for some high-level discussion of Māori data governance and ethics.

Connects to

The digital twin must be supported by a sophisticated data integration layer that continuously ingests, processes, and synchronises both real-time and historical data from diverse sources. This layer is vital for ensuring the fidelity (the degree to which a model represents reality) of the digital twin's simulations and for enabling accurate, real-time scenario testing.

Key data inputs should include sea level, sea-surface temperatures, wave conditions, water quality parameters, meteorological data (including wind speed, atmospheric pressure, and precipitation patterns), bathymetry and topography, and river discharge. Additionally, integrating datasets like the recent Resilience to Nature's Challenges 80-year coastal change data of shoreline position will provide crucial historical context for long-term predictions (Dickenson et al., 2024). The data integration layer must be capable of handling large volumes of data with low latency and will likely need to utilise distributed computing (multiple computers working together as a single system) to ensure scalability and performance.

Notably, for digital twins in environmental applications there is significant value in interoperability with other digital twins, such as those focused on freshwater management or urban planning (Deng et al., 2021). Therefore, a digital twin for coastal management should consider connections with other digital twin projects as well as data sources, to enable a comprehensive, whole-of-environment perspective (catchment-coast-ocean). By emphasising interoperability and focusing on the individual strengths of each digital twin, complexity can be minimised, and data sharing and standardisation becomes simpler, enhancing the accuracy and utility of each twin.

Conceptual framework

A digital twin's objective is to enable better decision making and engagement, and should consist of four layers: data layer, modelling layer, collaboration layer, and user interface layer. Input data, such as tidal levels, wave height, land-use, water quality, and shorelines, is fed into the data layer to be processed. This layer's aim is to understand the correlation between input variables and conform the input data such that they can be effectively organised, used, and safely stored. The processed data is then used in the modelling layer, where models (data-driven, mechanistic, or hybrid) are trained and validated. Upon successful validation, the developed model is ready to be deployed in a form that is easily accessible by users, enabled by the user interface layer, where future projections and what-if scenarios can be investigated in webapps, ESRI ArcGIS, and Unreal Engine at ease by the users. The collaboration layer enables feedback, result sharing, and model updates.

Challenges and limitations

While the potential of digital twins for coastal management in A-NZ is immense, there are multiple challenges and limitations, particularly concerning data governance, interoperability, collaboration, funding and technical complexity.

Data governance and compatibility

One of the most significant challenges in developing a high-fidelity digital twin for A-NZ's coastlines is ensuring robust data governance. Integrating vast amounts of data from various sources may raise concerns about data ownership, privacy and security (Deng et al., 2021). Establishing clear protocols for data sharing and usage is essential, particularly when dealing with potentially sensitive data. Moreover, safeguarding data accuracy when working with multiple sources is critical for the integrity of the digital twin's simulations. Without stringent data governance frameworks, the digital twin risks being compromised by incomplete, outdated, or inaccurate data, potentially leading to misguided decision making (Deng et al., 2021).

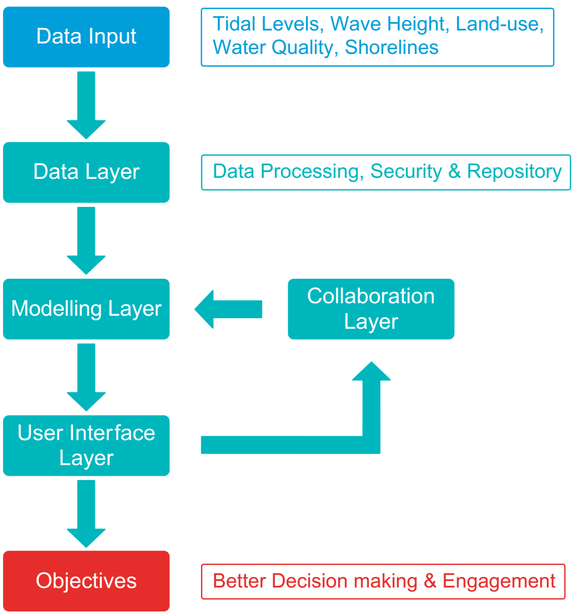

Figure 5: Conceptual architectural framework for a coastal management digital twin including four layers (Data, Modelling, User Interface and Collaboration).

Furthermore, when digital twins are being created with the incorporation of Māori data, for instance, mātauranga Māori, it is fundamental to have appropriate Māori data sovereignty protocols to ensure the ethical storage, use and dissemination, and ownership arrangements of a digital twin and its data (Kukutai et al., 2020).

Collaboration and funding

The successful development of a digital twin for coastal management necessitates extensive collaboration between multiple stakeholders, including government agencies, hapū/iwi, academic and other research institutions, private entities, and local communities. A key challenge is negotiating data-sharing agreements and joint-development initiatives, particularly when data is held by private entities or across different jurisdictions. These factors, combined with a desire for competition can stifle collaboration, essential for an effective and comprehensive digital twin. A recent report from the Parliamentary Commissioner for the Environment highlights precisely these issues in the context of freshwater catchment modelling in A-NZ, stating that a lack of collaboration, driven by competition and 'a desire to own the model and underlying data', have led to freshwater catchment models with overlapping functions, varying underlying assumptions and data, and a lack of transparency (Upton, 2024).

Navigating complex stakeholder relationships alone is a challenging/difficult task; however, securing the necessary funding also poses a significant challenge, particularly when long-term investment is required for maintenance and updates (Attaran and Celik, 2023). For comparison, the cost for developing a digital replica of Singapore was estimated at US$73 million (Tzachor et al., 2023). Public sector funding is often limited and competitive, potentially restricting the project's scope and ambition. In contrast, private sector funding may be tied to specific outcomes or deliverables, narrowing the focus of the digital twin. Therefore, a digital twin for coastal management must avoid wasting scarce resources on developing multiple, similar, and expensive models, as has occurred with freshwater catchment modelling, and instead prioritise interoperability and national-level collaboration and knowledge sharing (Upton, 2024).

Technical complexity

The technical demands of creating and maintaining a digital twin like that described are considerable (Jia et al., 2022; Tzachor et al., 2023). High-performance computing infrastructure is required to handle the computational intensity of real-time data processing, multi-scale simulations, and 3D visualisations. The digital twin must leverage distributed computing frameworks and parallel processing techniques to ensure scalability and efficiency. However, implementing such infrastructure is resource-intensive and costly (Jia et al., 2022).

Moreover, integrating complex multi-scale process models presents its challenges. These models must accurately simulate interactions between physical, chemical, and biological processes across different spatial and temporal scales. Achieving this level of model fidelity requires not only advanced modelling techniques, but also the continuous calibration and validation of models against real-world data.

Conclusion

The use of digital twins in coastal management in A-NZ represents a significant advancement in our ability to understand, simulate, manage, and communicate complex coastal systems. Through high-fidelity 3D visualisation of landforms, infrastructure, and ecosystems, the dynamic simulation of physical, chemical, and biological processes, incorporating mātauranga Māori and real-time data connectivity, a coastal management digital twin could significantly enhance the efficacy and inclusivity of our decision-making processes. However, the development of such a system is not without its challenges. Robust data governance frameworks, interdisciplinary collaboration, and substantial technical infrastructure are essential to overcoming these challenges.

As climate change continues to impact coastal areas, affecting ecosystems, communities, and infrastructure, the potential of a well-constructed coastal management digital twin becomes increasingly compelling. The challenge now lies in collaboratively transforming this conceptual vision into a reality to help safeguard A-NZ's unique coastal environments for future generations.

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Don’t mention the C Word… Collaboration

By Tom FitzGerald

collaboration | k*uh*-lab-*uh*-**rey**-shuhn |
noun *[mass noun]*

1 the action of working with someone to produce something: he wrote a book *in collaboration with* his son

2 traitorous cooperation with an enemy: *he faces charges of collaboration.*

ORIGIN: mid 19th century: from Latin ***collaboratio(n-)***, from ***collaborare*** ‘work together’.

Collaboration, the hardest of the ‘c’ words. Not collusion, not coordination, not cooperation, not cohesiveness, not even community. Collaboration. This is a ‘c’ word we dare to whisper in the continued hope of improved coastal adaptation outcomes. But what does it mean in practice and why does it promise so much?

Being a collaborator used to mean something quite different during World War II, but how can we be a collaborator for good today? The IAP2 community engagement manual places collaboration toward the right-hand side of a spectrum (Figure 1) based on an ability to influence the decision at hand. In this context the spectrum speaks to a commitment between communities and decision makers and sets out a goal for a level of public participation. But what does collaboration mean between coastal adaptation practitioners? Between professions? How can collaboration support transformative adaptation? This article examines the importance of collaboration in coastal and climate adaptation, explores its challenges, and suggests ways to strengthen partnerships.

Introduction

Climate change presents one of the most significant challenges to humanity, with coastal regions being particularly vulnerable to its impacts. Rising sea levels, increased frequency of storms, coastal erosion, and flooding all pose serious risks to communities, ecosystems, and economies along coastlines globally. To address these multi-faceted, pervasive challenges, collaboration across disciplines, sectors, and jurisdictions is crucial. Effective adaptation at the coast requires (and has always required) a coordinated approach that brings together government bodies, local communities, scientific institutions, and private sector actors. This has long been the goal of coastal managers since the advent of integrated coastal zone management (ICZM) at the Rio Earth Summit[1]. However, collaboration in this space is consistently fraught with challenges, including conflicting priorities, resource limitations, political complexities and the inertia of incrementalism (Kates et al., 2012). Rather than identifying the multitude of overlapping, interconnected reasons for slow progress in delivering ICZM, instead in this article, I’ll try and emphasise why such a simple principle (not a dirty word!) is even more relevant today in the face of an already changing climate and the increasing need for transformative adaptation.

[1] See https://www.coastalwiki.org/wiki/Integrated_Coastal_Zone_Management_(ICZM)

INCREASING IMPACT ON THE DECISION →

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input inflenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Figure 1: IAP2 public participation spectrum (Source: Adapted from IAP2).

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

'My strength is not that of a single warrior but that of many.'

The importance of collaboration

Collaboration is important for a number of reasons and can have multiple benefits:

Integrating diverse expertise and knowledge

Climate adaptation, particularly in coastal areas, is a complex endeavour requiring expertise from multiple fields, including climatology, oceanography, engineering, mātauranga, ecology, urban planning, and social sciences. Collaboration enables the integration of scientific research, traditional knowledge, and local expertise to create a more comprehensive understanding of the risks and to design appropriate responses.

For instance, climate scientists provide data on sea-level rise projections, ecologists offer insights into habitat conservation, while urban planners develop infrastructure solutions that mitigate risks to property and human lives. Additionally, local knowledge is invaluable, as community members often possess a deep understanding of their environment and may identify areas at risk or potential solutions that might not be immediately apparent to external experts. This community input is critical in tailoring adaptation strategies to specific regions, ultimately making adaptation efforts more effective and sustainable. By bringing together diverse perspectives, collaboration can lead to innovative and creative solutions to complex problems.

Enhanced resource flows

Collaboration allows for the pooling of financial, human, and technological resources, which are often scarce in climate adaptation efforts. Government agencies may have access to funding and technical resources, while private sector entities may contribute through expertise and technology. Local governments provide connections to communities, and project impetus. Academic institutions often provide research expertise and data, while non-governmental organisations (NGOs) can assist with community engagement and capacity building. By combining these resources, collaborative efforts are not only likely to be more efficient, they are more likely to be successful and sustainable. Partnerships also can present greater opportunities to attract funding and investment.

Building social capital

By bringing together diverse perspectives, collaboration fosters a shared understanding of the complex issues at hand. This includes scientific knowledge, indigenous wisdom, local community insights, and policy considerations. Collaboration can strengthen social connections and build trust within communities. This is essential for implementing long-term adaptation strategies.

Shared risk management

Climate adaptation, especially in coastal areas, involves substantial risk and uncertainty due to the unpredictable nature and deep uncertainty posed by climate change. Collaborative efforts distribute the risks associated with adaptation projects, making it easier to pursue innovative and long-term solutions. For example, by sharing data on climate impacts and adaptation responses, partners can collectively evaluate the effectiveness of different approaches and adjust strategies as new information becomes available. The shared responsibility also makes it easier to implement costly adaptation measures, such as building seawalls or relocating communities, by distributing the financial burden among various stakeholders.

Improved governance

Coastal adaptation requires an integrated policy approach due to overlapping jurisdictional responsibilities in coastal areas. Collaboration fosters policy coherence by bringing together different governmental levels – local, regional and national – and ensuring alignment in adaptation goals and regulations. Improved governance (policy and institutional) structures not only streamline decision-making processes, but also reduce the risk of policy fragmentation, which can hinder effective adaptation. Collaborative governance allows for the establishment of standardised guidelines and regulations, providing clarity for stakeholders on compliance and expectations.

So, this is all well and good, but what does it actually mean on the ground?

In 2022, the IPCC made a useful summary for what truly transformative adaptation might mean across dimensions[2]. They noted a complete a change in mindset and entirely new practices had a high potential to encourage transformative adaptation (Figure 2).

What stops us from collaborating?

Conflicting priorities and interests

One of the primary challenges in collaboration is the alignment of priorities among stakeholders. Government agencies, businesses, environmental organisations, tangata whenua and communities often have differing objectives. For instance, while environmental groups may prioritise conservation, governments might focus on economic development and job creation, even if it means approving projects that may compromise coastal ecosystems. Reconciling these interests requires extensive negotiation and compromise, which can be time-consuming and may result in suboptimal adaptation measures.

Power imbalances between different stakeholders can also play a significant role in hindering effective collaboration.

Resource constraints

Limited financial, human, and technical resources are a common constraint in climate adaptation. Adaptation projects, such as constructing flood defences or restoring wetlands, are costly and often exceed local governments' budgets. Additionally, hapū, smaller or rural communities may lack the technical expertise or capacity needed to engage in adaptation planning effectively. Unequal resource distribution can disrupt collaborative efforts, allowing well-resourced partners – often governmental bodies or large

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[2] See https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-16/

	Transformative potential of adaptation		
Dimensions	Low	Medium	High
Overall	Adaptation is largely sporadic and consists of small adjustments to Business-As-Usual. Coordination and mainstreaming are limited and fragmented.	Adaptation is expanding and increasingly coordinated, including wider implementation and multi-level coordination.	Adaptation is widespread and implemented at or very near its full potential across multiple dimensions.
Depth	Adaptations are largely expansions of existing practices, with minimal change in underlying values, assumptions or norms.	Adaptations reflect a shift away from existing practices, norms or structures to some extent.	Adaptations reflect entirely new practices involving deep structural reform, complete change in mindset, major shifts in perceptions or values, and changing institutional or behavioural norms
Scope	Adaptations are largely localised and fragmented, with limited evidence of coordination or mainstreaming across sectors, jurisdictions or levels of governance.	Adaptations affect wider geographic areas, multiple areas and sectors, or are mainstreamed and coordinated across multiple dimensions.	Adaptations are widespread and substantial, including most possible sectors, levels of governance, and actors.
Speed	Adaptations are implemented slowly.	Adaptations are implemented moderately quickly.	Change is considered rapid for a given context.
Limits	Adaptations may approach but do not exceed or substantively challenge soft limits.	Adaptations may overcome some soft limits but do not challenge or approach hard limits.	Adaptations exceed many soft limits and approach or challenge hard limits.

Figure 2: Description of the transformative potential of adaptation depending on its depth, scope, speed and adaptation limits (Source: IPCC AR6, WGII Chapter 16, Table 1, p. 2435).

private organisations – to dominate, potentially sidelining local needs and priorities, or perpetuating colonialism.

Jurisdictional and institutional barriers

Coastal adaptation often involves multiple levels of governance, including local, regional, and national authorities. Navigating these overlapping jurisdictions can be challenging, as each level will have different regulations, priorities, and resource capabilities. Furthermore, institutional silos within governments and organisations can impede the flow of information and resources across departments, hindering cohesive action. Silos can very rarely be recognised from within, reinforcing the need and useful ability for 'boundary organisations' like professional networks and others to translate (Figure 3).

Data sharing and knowledge gaps

Effective climate adaptation requires ready access to up-to-date, high-quality data on climate impacts and local vulnerabilities. However, data sharing among stakeholders is often hindered by concerns over intellectual property, profit, confidentiality, and security. Additionally, some data may be incomplete or inaccessible, particularly in remote areas with limited scientific research. Without reliable data, adaptation strategies may be based on inaccurate assumptions, reducing their effectiveness. Addressing these knowledge gaps and establishing clear data-sharing protocols are essential to support informed decision making in collaborative efforts. This point was well made during the adaptation inquiry completed in 2024.

Political and social challenges

Political factors also pose significant challenges to collaboration in climate adaptation. Short political cycles and changes in leadership can disrupt adaptation plans, as new administrations may prioritise different issues or retract previous commitments. We've seen this in places like the Kaipara, Westport and the Kāpiti Coast. Additionally, climate adaptation efforts may face resistance from local communities due to perceived social or cultural impacts, such as restrictions on private property rights and economic

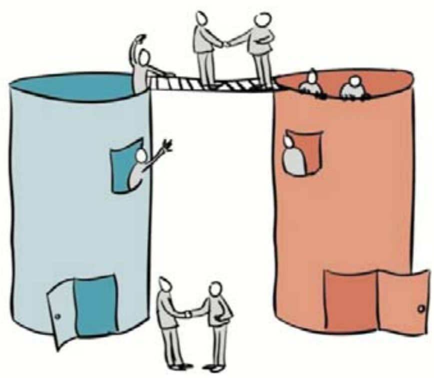

Figure 3: Silos are a quintessential element of many workplaces, many teams and many problems. Adaptation is no different.

value or traditional access to the coastal area and resources. Building trust and securing buy-in from local populations is crucial, but challenging. Adaptation measures often involve difficult trade-offs, such as relocation or changes in livelihood, and require significant work with communities.

Silo thinking is a common trope in many professions. It can be the enemy of good adaptation. Narrow thinking can lead to maladaptation; for example, seawalls put in to protect private interests in urgent need may not be cognisant of the wider solutions that would provide a long-term, more resilient solution. We see this all the time on nearly every developed beach in New Zealand. There is an element of self-interest at play. We are fine-tuned in our professions to continually improve, get more specialised, more expert, and this is held up to be the pinnacle of our professional lives, our careers. Generalist skills, and the ability to speak across professions, are not yet valued as highly.

Strengthening collaboration for transformative adaptation

Fundamentally, the idea of transformation recognises that our current way of doing things is not fit for purpose. Changing the way we collaborate is just one of many levers or agents of change that we may employ. The graphic below borrows the conceptual framework for transformation offered by Shi and Moser (2021). This concept illustrates how policies, practices and flows of resources manifest at the surface. These elements are influenced at a deeper level by processes, relationships and power dynamics – which in turn reflect the mindset, values and beliefs of those involved. The concept, using the iceberg as a metaphor, articulates that transformative adaptation requires deep change beyond what can be achieved at the surface. Working collaboratively is a key pillar in supporting this change (Figure 4).

Developing clear frameworks and agreements

Establishing clear frameworks and formal agreements can help align stakeholders' roles, responsibilities, and expectations in collaborative efforts. These frameworks can specify decision-making processes, resource contributions, and conflict resolution mechanisms, providing a structured approach to collaboration. International agreements, such as the Paris Agreement, emphasise the importance of multilevel cooperation in climate adaptation and can guide local and regional collaborations by offering shared goals and standards (e.g. UN Sustainable Development Goals). Innovative approaches to this have been trialled in parts of the Taranaki and the Manawatu-Whanganui regions (see Glavovic and Smith, nd.).

Capacity building and technical support

Capacity building initiatives are essential to empower stakeholders, especially local communities, and equip them with the skills and knowledge needed for effective adaptation planning. Training programs, workshops, and knowledge-sharing platforms can enhance technical expertise and foster a collaborative mindset. Support from governmental agencies and NGOs in terms of technical assistance and funding can help bridge resource gaps and ensure that local perspectives are integrated into adaptation strategies.

Enhancing data sharing and transparency

Promoting data transparency and accessibility can address knowledge gaps and support evidence-based adaptation strategies. Developing centralised databases and encouraging open-access data sharing can facilitate a more collaborative approach to climate adaptation[3].

Community engagement and trust-building

Building trust and engaging communities throughout the adaptation process can help overcome resistance and ensure the long-term success of adaptation efforts. Including local voices in decision making fosters a sense of ownership and can improve the social acceptability of

[3] Climate Change Commission, Progress Report – National Adaptation Plan 2024. https://www.climatecommission.govt.nz/our-work/adaptation/nappa/nappa-2024/

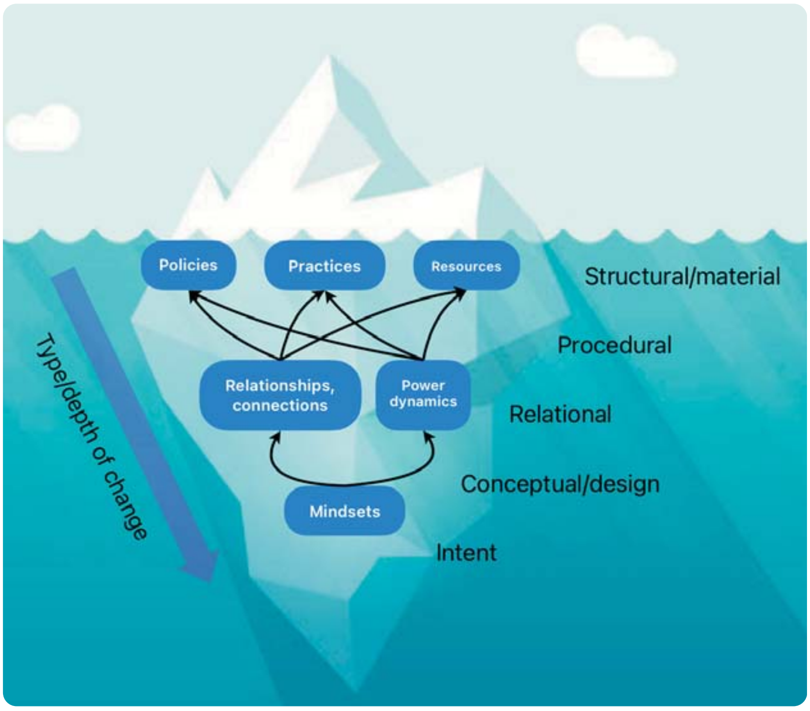

Figure 4: Six key conditions of system change – how deep changes can overcome inertia and begin to transform systems. Adapted from Shi and Moser (2021).

adaptation measures. Transparent communication about the risks and benefits of adaptation projects is essential, as it helps communities understand the rationale behind difficult decisions. Identifying entry points to start conversations around adaptation that are empowering and provide actors with a sense of agency is critical. Fear will only get you so far.

What changes can you make to your practice?

Figure 5 summarises some key actions you can take to improve your collaborative practice. Practice them!

Conclusion

The importance of collaboration in coastal and climate adaptation cannot be overstated. Effective adaptation requires integrating diverse expertise, pooling resources, sharing risks, and aligning policies, which can only be achieved through coordinated efforts. However, collaboration in this space is challenged by conflicting priorities, resource limitations, jurisdictional barriers, and social resistance. Addressing these challenges requires establishing clear frameworks, building capacity, enhancing data sharing, and fostering community engagement. Strengthening collaboration across disciplines, sectors, and jurisdictions is essential to developing and implementing robust adaptation strategies that transform the way we live at the coast.

Transformation requires thinking differently. So, think like an ecosystem – *ecosystems are interconnected; adaptation practitioners should be too*. If you consciously start with a collaborative mindset, you've made an excellent first step.

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Why collaborate?

- Urgent need
- Commonalities
- Adaption across many disciplines – requires a new way of working
- Wicked problem requires gnarly solutions
- There is so much to learn!
- Everyone has something valuable to contribute
- Working towards the same goal
- Improving/influencing the rules of the game
- Efficiency
- Value for money
- Improve professional practice
- NZ is small...

Key Actions:

- Take the time and create space to look outside your silo
- Give time
- Be open, show humility
- Sharing + caring – adaptation can be hard
- Keep in mind the greater good
- Practice and implementation oriented
- Involve others - partnerships
- Embrace the fail, celebrate the wins
- Encourage diverse thinking + understanding
- Reach out

Figure 5: Recommendations and opportunities for powering up collaboration.

The final word

By Ana Serrano and Connon Andrews

Aotearoa's 15,000 km coastline – from subtropical north to temperate south – is dynamic and constantly transforming. This coastline is home to long, sandy beaches, sheltered estuaries, dramatic cliffs, wild dunes, and magnificent fiords. With over 70% of New Zealanders living within 10 km of the coast, these areas are vital both ecologically and socially. This Sixth Special Publication by the New Zealand Coastal Society explores 12 articles on adaptation, research, and case studies that reflect our evolving relationship with the coast.

The journey began with *Typologies and modes of coastal change*, offering a framework for understanding coastal dynamics – essential for informed, adaptive management. *Coastal erosion hazard management – What have we learned since the 1970s?* revisited past challenges and progress, emphasizing the value of historical insight in shaping future strategies.

The sociocultural impacts of climate change were explored in *Measuring climate change impacts on indigenous sociocultural wellbeing*, which stressed the importance of integrating Indigenous knowledge into adaptation planning. Similarly, *Increased exposure of marae to coastal flooding with sea level rise and adaptation learnings of Ngāi Tamawhariua and Maketū Iwi Collective* showcased Indigenous-led resilience efforts, highlighting the power of self-determination and cultural grounding.

By highlighting community-led adaptation, *Empowering Waihi Beach lifeguard services* demonstrated how collaborative planning can build climate resilience and empower local actors to take meaningful action. In parallel, *Short-term defence for long-term retreat in the Coromandel* demonstrated adaptive pathways that balance immediate protection with long-term planning.

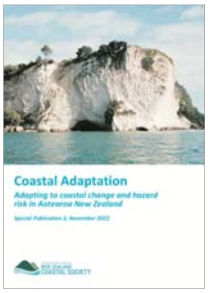
The transforming coastline of Tāmaki Makaurau examined the effects of La Niña and storm events on Auckland's coast, reinforcing the need for flexible, sustainable responses. Integrated flood risk was addressed in *Connected realities: Transforming flood risk management to include the sea* and *Climate transformation on Hokianga Harbour estuarine wetlands*, both advocating for holistic coastal and inland water system management.

Nature-based solutions and blue carbon: An opportunity for co-funding coastal transformation explored innovative funding for sustainable coastal projects, emphasizing biodiversity, climate mitigation, and co-benefits. *Digital twins as emerging technology for integrated coastal management* introduced emerging tech for simulating coastal environments, enhancing planning and engagement.

Finally, *Don't mention the C word... Collaboration* reflected on the challenges and rewards of cross-sector cooperation, essential for transformative adaptation.

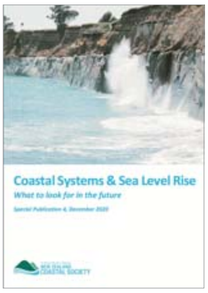
This publication unites diverse voices – Māori, scientific, engineering, and community – to guide coastal transformation. It's more than a collection of articles; it's a call to action for researchers, policymakers, and communities to collaborate, share knowledge, and build a resilient coastal future.

Other titles in the Special Publication series



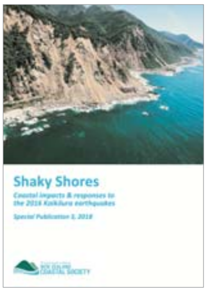
Coastal Adaptation: Adapting to coastal change and hazard risk in Aotearoa New Zealand (2022)

This publication offers insights on how communities can respond to coastal hazards and climate change risk, and support the development of dynamic adaptive pathway planning to inform future community decision making. Many of the articles share leading edge work, forging new ground for responding to coastal hazards and climate change risks. Covering planning/policy frameworks; engagement, collaboration and partnership; advances in coastal science; and adaptations to coastal change in urban and built environments, there are many practical learnings from those working in this complex area.



Coastal Systems & Sea Level Rise: What to look for in the future (2020)

This publication presents an insight as to how our coastal systems have and can be expected to behave in response to past and future sea level rise. It is intended to complement the existing and rapidly growing knowledge base on climate change impacts, with the aim of conveying that diverse coastal systems behave in different ways, and this needs to be considered and understood by practitioners addressing coastal planning, management and engineering issues. Articles in this publication seek to contribute to the existing literature by focusing on coastal systems, evolution, response, and – importantly – Māori perspectives on environmental change.

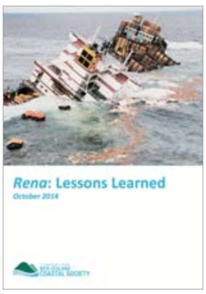


Shaky Shores: Coastal impacts & responses to the 2016 Kaikōura earthquakes (2018)

Just after midnight on 14 November 2016, the 'Shaky Isles' of New Zealand shook for two minutes as a series of faults unzipped in the north-eastern South Island from Culverden to Cape Campbell. Starting in the first hours after the earthquake, NZCS members, from emergency responders, to engineers, planners and scientists, were involved in the response and recovery efforts. This publication offers an assessment of the response and recovery and shares some of the lessons learnt, written by some of New Zealand's leading scientists, engineers, coastal and emergency managers.

Adapting to the consequences of climate change: Engaging with communities (2016)

The aim of this publication is to encourage the development of best practice in working with communities as they adapt to the consequences of climate change. It includes examples of how local authorities are engaging with the public and working to create climate-smart communities. Some of this work includes considering when and how to engage with communities in planning processes, as well as how to make general and site-specific information, such as estimated sea-level rise, available in a way that supports better decision making.



Rena: Lessons learnt (2014)

At 2.20am on the 5th October 2011, the 37,000 tonne cargo ship *MV Rena* grounded on Astrolabe Reef in the Bay of Plenty. When it grounded, the *Rena* had 1368 containers and over 1700 tonnes of oil on board. Following the incident, Maritime New Zealand declared a Tier 3 response and mobilised the National Response Team. This publication was produced to complement the growing knowledge base on oil responses in New Zealand, including the independent review of Maritime New Zealand's response and the *Rena* environmental *Recovery Monitoring Programme* 2011-2013 report, both released in December 2013.

Special Publications 1 to 5 can be downloaded in pdf format from the NZCS website (www.coastalsociety.org.nz) or the University of Auckland's figshare site (https://auckland.figshare.com/coastalsociety). Some paper copies may still be available, but please email the NZCS administrator (nzcoastalsociety@gmail.com) to check what is in stock.

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Te Hunga Takutai o Aotearoa
NEW ZEALAND
COASTAL SOCIETY