Assessment of the Northern Farmland in Tūhaitara Coastal Park with the View to Transforming to Freshwater Wetland

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Executive Summary

Te Kōhaka o Tūhaitara Trust plans to restore farmland in the north of the Tūhaitara Coastal Park to wetland. This report aims to answer the research question: what are the key opportunities and constraints associated with the restoration and expansion of the Te Kohanga Wetlands in the northern area of the Tūhaitara Coastal Park? Key considerations include increased wetland biodiversity, climate change and sea level rise resilience, and enhanced socio-cultural values.

A literature-based research method was chosen due to the project scope, previous research, and time and resource restrictions. Review of key subthemes, elevation data, sea level rise predictions, and black maps were used to create three scenarios for restoration each focussing on a single consideration. These mapped scenarios can be used together to create a tailored final plan for the park.

The Te Kohanga wetlands are culturally, spiritually and economically significant to local iwi. The project aims to incorporate indigenous orientated methods that recognise mātauranga Māori in environmental planning, implement mana whenua orientated policy statements, use Māori environmental indicators (MEPI), and build on previous management plans. Tūhaitara Trust has an established and strong relationship with Ngāi Tahu, allowing for engagement with kaitiaki to gain valuable indigenous perspectives.

Wetland restoration case studies provide insight into methods. The Arihuriri Lagoon used open water bodies to improve biodiversity and enhance mahinga kai. Creating a bog area to resemble the historical landscape with native plantings similar to Moanatuatua Scenic Reserve would form habitat for different species.

Native vegetation dominance improves evolutionary partnerships and increases biodiversity of native organisms. Replacement of introduced species with native multispecies planting can be used to maximise habitat maintenance factors without the expense of native diversity and abundance. Considerations must be made towards maximising conditional biodiversity and planning for changes associated with climate change.

The Park is likely to be inundated within their 200-year vision. Wetlands use vertical building and lateral migration to adjust to changing sea level. Shallow boggy areas rather than open water bodies, use of barrages and levees, and restoring pre-European vegetation and waterways, are methods to build resilience to SLR. Healthy wetland systems are key for adaptability to climate change resilience.

Sufficient water supply is key for successful restoration and there is sufficient ground water available in the Park. Wet bog areas absorb more water than open water bodies and reduce erosion. Thin meandering water flows maximise contact with water, land, and plants, creating a buffer zone for flood and contaminants.

Results from this project can be applied to other New Zealand wetland restoration projects, however there are areas that may require more detailed investigation to create a final plan.

Introduction

Rebecca

The Tūhaitara Coastal Park (Figure 1) is an area stretching roughly 10.5km between the mouth of the Waimakariri River and the Waikuku Beach township. Currently throughout the park there are various wetlands, biota nodes maintained by school groups and used for educational purposes, and Tūtaipatu Lagoon which has significant cultural value to Ngāi Tahu. The aim for Te Kōhaka o Tūhaitara Trust is to extend the Te Kohanga wetland area. Tūtaepatu Lagoon has had a lot of restoration work done with nearby planting, is used for mahinga kai and has high ecological values.

The focus site for this project is located near Pegasus and is currently used as grazing farmland. The restoration goals are to create a self-sustaining wetland environment that will also increase the biodiversity of the site, create an area that is resistant to SLR and ensure the community and cultural values of the rūnanga are met.

Up to 90% of global coastal wetlands are predicted to be lost to sea-level rise (SLR) (Zedler & Kercher, 2005; Schuerch et al., 2018; Spencer et al., 2016). Creating coastal wetlands that are resilient to climate change is key to protecting wetland biodiversity and preserving their ecosystem services.

The report investigates key sub-themes to answer the research question: What are the key opportunities and constraints associated with the restoration and expansion of the Te Kohanga wetlands in the northern area of the Tūhaitara Coastal Park?

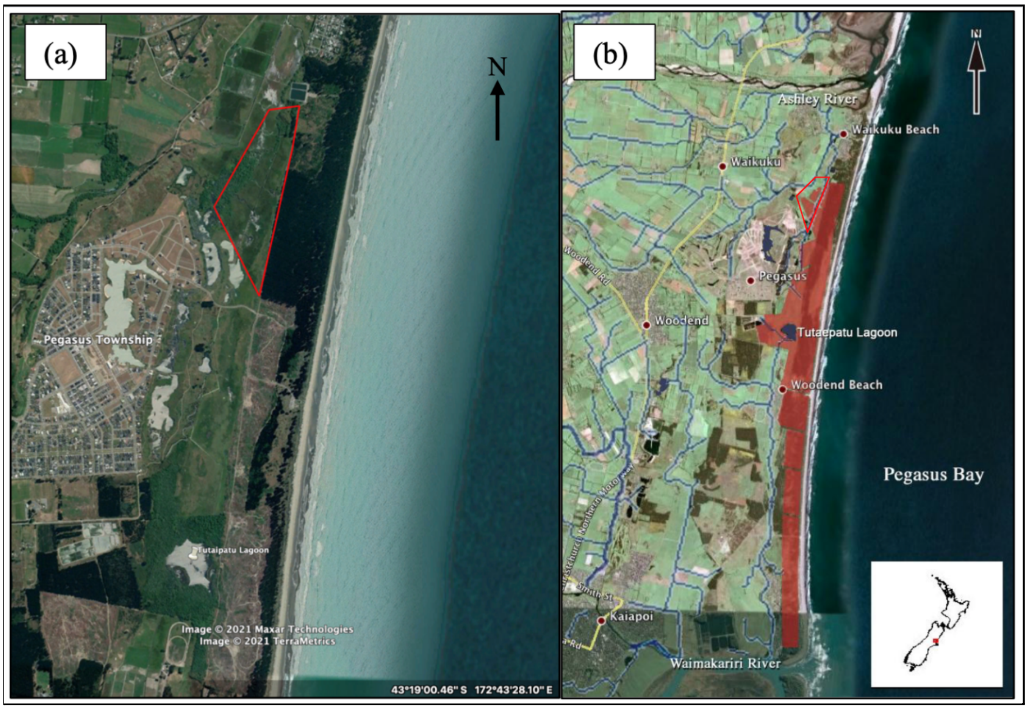

Figure 1. Location of the Tūhaitara Coastal Park (b) and the project site - red polygon in (a) and (b). Sourced from Google Earth (2019) (a) and adapted from Whitelaw (2011) (b).

Methods

Rebecca

Due to the broad nature of our research question, the goals of our community partner, previous research in the area, and constraints due to time, a comprehensive literature-based study was the most effective method for our project.

We began with a site visit, where Greg Byrnes from Te Kōhaka o Tūhaitara Trust showed us the park, our focus site, and explained its history. This enabled us to see what restoration has already been done throughout and identify the key aspects and potential issues for the proposed wetland site.

We conducted in-depth literature reviews on key sub-themes of the project; physical coastal context, biological context, socio-cultural context, wetland water and past case studies on wetland development. We then identified gaps in our research and continued with our investigations. From the information we gathered as well as elevation, SLR prediction maps, and black maps, three maps were created each with a primary consideration; social/cultural, climate change and SLR, and natural character.

Literature Review & Research

Socio-Cultural effects

Zeta

An assessment of literature concerning the socio-cultural effects of New Zealand wetland development showed multiple strategies that could be used by Tūhaitara Trust to provide indigenous orientated outcomes while retaining and improving the cultural, recreational, and community values of the Te Kohanga wetlands.

When considering the development of Te Kohanga wetlands, it is recommended that Tūhaitara Trust uses culturally appropriate methods such as geospatial analysis tools created by mana whenua to recognise mātauranga Māori in decision-making processes (Hudson et al, 2020). Kaitiaki layers can be used to represent the Mahaanui Iwi Management Plan (2013) and digitise scientific indicators in a cultural context. The use of kaitiaki layers would be valuable for evaluating culturally significant mahinga kai sites, and for assessing water quality and vegetation health. Previous research shows that establishing mātauranga Māori as a cultural framework for planning and decision-making empowers indigenous communities and retains cultural values and identity.

The Mahaanui Iwi Management Plan 2013 (IMP) allows communication between iwi, councils and stakeholders regarding resource usage and allocation based on the notions of mauri, and its use would promote better representation of Māori values in the project. It is recommended that Tūhaitara Trust continues to build on relationships with local iwi, participate in hui protocol, and recognise mana whenua as experts when developing the Te Kohanga wetlands (Bennet, 2020).

Tūhaitara Trust could implement MEPIs when moving forward with the project (Harmsworth, 2002). MEPIs include careful evaluation of the presence/absence of indigenous species, lists of taonga and natural character values, and presence of pests and weeds. For example low numbers or absence of eel in the Te Kohanga wetlands would indicate degraded waterways. This method would help to assess wetland health, trend and analysis as well as retaining traditional beliefs and values.

It is recommended that Tūhaitara Trust continues to implement the Tūhaitara Coastal Reserve and Waikuku Beach Reserves Management Plan (2006) as a guideline to improve recreational values of the wetland that are compatible with ecological and cultural values. It would be beneficial to increase the reach of educational programmes to foster wider appreciation of wetland protection in New Zealand.

Previous Wetland Development

Rebecca

Restoration of the Ahuriri Lagoon in Canterbury aimed to increase mahinga kai values, biodiversity, and water quality at the site. Prior to settlement, the site was a large open waterbody that had been drained and used as farmland. The project overview did not indicate which type of farming this site was used for, or how it affected the restoration, if at all. The wetland was created through excavation, connecting the new lagoon via old culverts that allow the water to flow through the wetlands from the adjacent Huritini/Haswell river and back into the river improving the overall water quality with the wetland and aquatic plants planted throughout for filtration. Although the Tūhaitara Trust site does not have a large river flow, the effect of water filtration through plants is a key aspect of wetland benefits. Progress on the biodiversity aims at Ahuriri can already be seen with the eeling island located in the middle of the largest pool being used as a nesting site for pied stilt (Group, 2020).

Another restoration option would be to create a lowland bog area instead of open water bodies, similar to how the land was before farmland conversion, as shown in the Canterbury Black Maps (Figure 2). This would resemble the Moanatuatua scenic reserve in the North Island (Clarkson et al., 1999). This area has been beneficial for many swamp birdlife, successfully creating habitat for fernbirds and harrier hawks. Plant restoration of peatlands can be successful relatively quickly but the ecosystem services, restoration of invertebrate communities, and peat functions and accumulation can take decades to develop (Clarkson et al., 2017).

Figure 2: Composite map; Google Earth overlain by Canterbury Black Maps showing historic vegetation cover and waterways. Red polygon = project area. Red circles = identified low elevation areas. Sourced from Google Earth (2019) and Canterbury Black Maps (2019).

Biological Context

Emily

Replacement of introduce exotic with native species as alternatives for erosion control, water quality management and economic benefit.

Gradual removal of exotic vegetation from habitat and replacement by native species is important for cultural, aesthetic, and native biodiversity values of the Park. Salix cinerea, Pinus insignis, and Festuca arundinacea present at the Tūhaitara wetlands can be functionally beneficial through increased water filtration, soil structure, and habitat complexity. They also aid in soil erosion mitigation and provide economic harvest benefits (Meurk & Swaffield, 2000). Replacement of exotics with dense and diverse native plants with comparable functional characteristics improve water quality, habitat complexity, and native herbivorous species food, thus improving native biodiversity and ecosystem functionality. (Franklin et al., 2015). Variable depth and morphology of native woody species roots associated with multispecies planting reduces erosion and competition due to spatial maximisation (Marden et al. 2005). Pinus insignis has mast events that could negatively implicate native species through the production of unsustainable rodent populations (Schnurr et al., 2002). This species for profitable harvest could be replaced by Leptospermum scoparium for honey and oil production valued from $16/kg to $60/kg and rongoā Māori value. Facilitating pollinator species will allow for increased gene flow and abundance of native flowering plants with resultant frugivorous bird facilitation (Fuller, April 2017). Increased density and habitat complexity of vegetation create micrometeorological climate habitats and reduce edge effects. These habitats increase conditional change and climate change associated disturbance resistance due to transpo-evaporation of vegetation and shading, thus producing stable, biodiverse communities with reduced conditional tolerance exclusion. Less disturbed habitats are also more desirable for nesting birds. (McNaughton et al. 1989).

Reduction of habitat and feeding ability of native insects, amphibia, pisces and aves due to introduced vegetation dominance

Strong evidence suggests a correlation between native vegetation and organismal populations. Beetle communities within four differentially vegetated wetlands of introduced and native compositions had differing functional feeding type dominance and native beetle dominance. Extrapolation of this data to native arthropods shows that native vegetation dominance supports native organisms (Watts et al., 2012). Deciduous characteristics of Salix cinerea increase nutrient loads into waterways, resulting in functional feeding type alterations and exclusion of typical native evergreen system adapted species (Clarkson et al., 2003). Therefore, replacing exotic singular planting species with multi-species collaborative native planting is essential for diversifying habitat structure and food sources for native organisms. Native biodiversity creates a more culturally significant and natively biologically diverse system. Introduced vegetation has bottom-up exclusion effects on native organisms as empirically-based theories state that 90% of herbivorous insects can only live with plants in which they share an evolutionary history. Despite the generalist nature of New Zealand insects, evolutionary development of enzymatic processes to detoxify phytochemical defences produced by introduced plants takes significant time for native insects. Therefore introduced vegetation dominance can exclude native insects through food limitation and intensified interspecific competition of introduced insects. This theory can be extended to other herbivorous species and frugivorous birds (Burghardt et al. 2009; Kelly et al., 2010).

Considerations for a Changing Climate

Particular consideration should be given to finding a balance of producing maximised native biodiversity within current conditions and mitigation planning for saline encroachment, inland migration of tolerance zones, and increased frequency and magnitude of disturbance to maintain biodiversity within a changing environment.

Physical Coastal Context

Lauren

New Zealand is expected to see at least 0.6m of SLR in the next 100 years if we meet our emissions targets, and up to 1.2m if we do not. The park could realistically see over 2.5m of SLR and be partially inundated within their 200-year vision (Figure 3) (Te Kōhaka o Tūhaitara Trust, ND; Whitelaw, 2011). Amplified storm surges, tidal effects, flooding and increased temperatures will also be challenges the Park will face with the changing climate (Whitelaw, 2011). Coastal sand dunes are the primary defence against SLR, and focus has been put on restoring and strengthening these in order to slow its effects (Whitelaw, 2011).

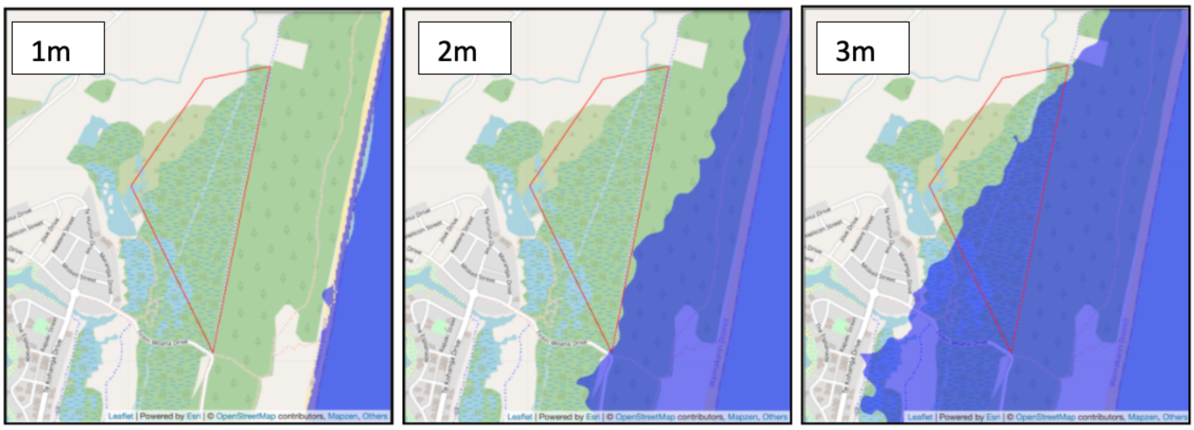

Figure 3: Modeled SLR for the Tūhaitara Coastal Park with 1m, 2m and 3m of relative SLR, research area shown as the red polygon. Sourced from Flood Map (2020)

Wetlands adjust to changing sea level through vertical building and lateral migration (Schuerch et al., 2018). They are a balance of sediment input, organic matter deposition, vegetation production, and losses through erosion and subsidence (Wu, Biber, & Bethel, 2017) (Figure 4). Healthy wetlands can resist some SLR and have done so throughout Earth's history, however current climate changes are too rapid for most wetlands to adapt (Wu et al., 2017). Accommodation space is an increasing issue with coastal squeeze, where wetlands are unable to retreat inland due to human land use. In some cases increased temperatures may assist in wetland resilience by increasing plant productivity and vertical growth, and increased flooding may improve sediment trapping (Spencer et al., 2016; Wu et al., 2017).

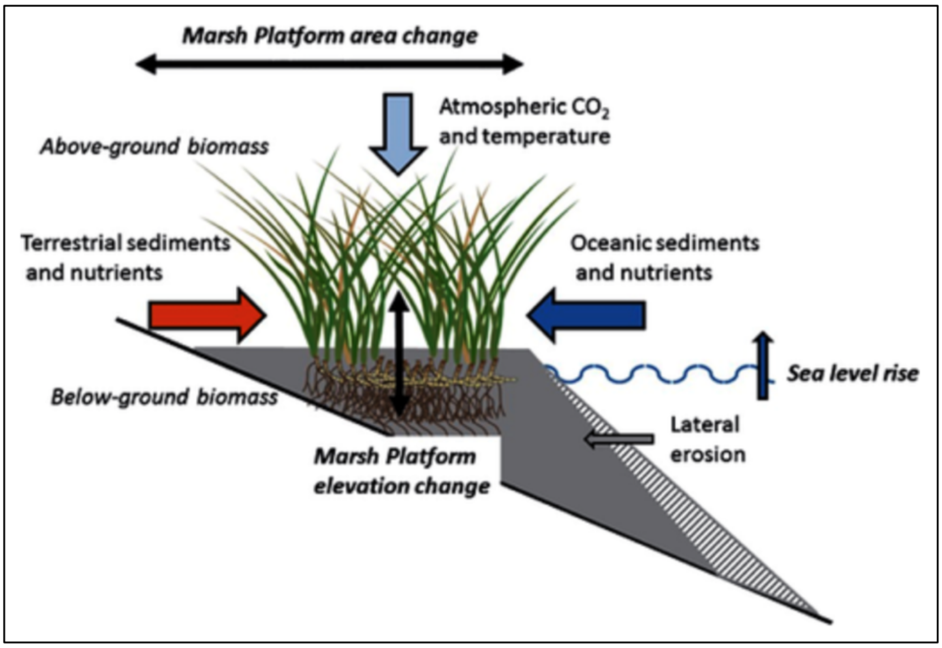

Figure 4: Diagram demonstrating factors contributing to marsh and wetland platform adjustment with relative SLR. Sourced from Wu et al. (2017).

There are multiple methods for increasing wetland resilience. Lateral migration is an important stage in wetland adaptation to SLR (McKee & Vervaeke, 2018). It may be important for the Park to investigate potential inland expansion to retain these unique fresh-water ecosystems. 'Wet areas' such as bogs and fens better accommodate increased flooding and SLR than open bodies of water (Wu et al., 2017), and enhancing these forms of wetland is valuable for increasing their resilience. They also have higher vertical building capabilities by producing larger amounts of organic matter and trapping sediment (McKee & Vervaeke, 2018; Wu et al., 2017).

In Northern Australia, construction of barrages and levees has been successful in slowing saltwater intrusion and allowing wetlands to transition to a stable, brackish ecosystem (Mulrennan & Woodroffe, 1998). The Park does not have ocean connected streams other than the Waimakariri and Ashley/Rakahiri rivers, so this may not be a viable method. It does, however, highlight the importance of continuing restoration of sand dunes and shows that slowing rates of SLR can help wetlands successfully adapt (Whitelaw, 2011).

Chalis (2012) researched different restoration options for Saltwater Creek; the area of wetland south of our project area. Results showed that focusing restoration on pre-European vegetation and waterways would be most effective in building resilience (Figure 2). Robust and healthy wetland ecosystems have higher adaptability to SLR and climate change, and considering the original landscape is key in their restoration.

Wetland Water

Lennart

Improving and maintaining the Tūhaitara Coastal Parks' hydrology (Figure 5) is key for the wetlands health and ecosystem to be sustainable for the Park's 200-year vision. For this to be carried out sufficient water supply must be available which we confirmed with our site visit (Carter, 1997). It could be seen that after a heavy rainfall there was sufficient pooling and surface water collection in low lying areas, biota nodes set up around the park also confirm there is sufficient groundwater available. Groundwater and surface water inflow is not an issue for the health of this wetland, and should continue to be sufficient into the future.

It is important when restoring wetlands to create meandering bodies of water between landforms, and not large open bodies of water as these increase the risks of flooding and pollution (Thompson, 2012). This would also allow more surface area for planting to aid in flood mitigation. The aim is to create wet-land rather than rivers and lakes as the land and plants act as a sponge slowing down and absorbing excess water flow from flooding (Carter, 1997). These meandering streams would then capture suspended material through slowing water flow, for the sediment to then be bound together by the roots of vegetation making the area more structured and less prone to erosion (Finlayson et al., 2018).

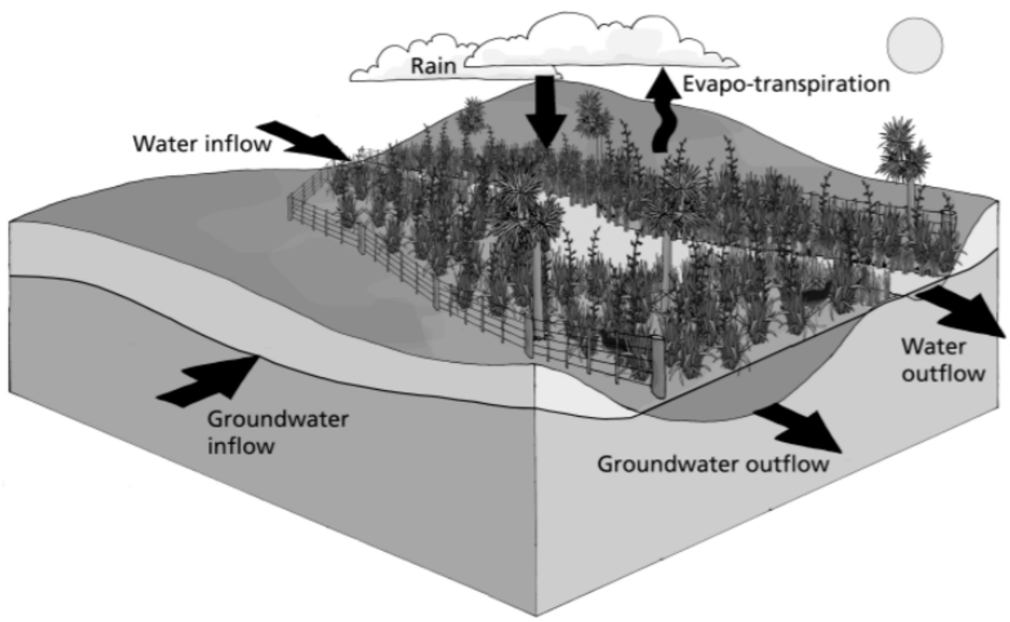

Figure 5: The different key hydrological elements which go into the formation of a healthy wetland water system. Sourced from Greater Wellington Regional Council (2005).

Flat nutrient-rich land with available water makes wetlands ideal for farmland as seen at our site of interest, but this should make the transition from farmland back to wetland even easier (McCartney et al., 2011). It is recommended that the Trust utilizes the methods and knowledge gained from the construction of biota nodes around the park for this restoration. Many of the same factors will apply to this project also, with the groundwater table being rather shallow, saltwater intrusion not being an issue for years to come and the location of the site within the area's water catchment (McCartney et al., 2011). By creating slim meandering water bodies entwining with one another around landforms, this will increase the surface area for plants, therefore, maximizing the contact of the water with the land and plants. This will moderate the water flow and allow the ecosystem to act as a buffer zone for flood and contaminant mitigation (Finlayson et al., 2018).

Results and Discussion

Lauren

Results from this investigation have been compiled into three maps designed to visually represent options for restoration. The maps focus on vegetation cover, the stream and drain, and identified low elevation points (Figure 6), and show size, shape, and placement for features. Each map focuses on one consideration; cultural and social values, biological and ecosystem values, and climate change resistance and resilience. We recommend that the maps be taken into consideration as a collective, and the Trust will be able to select features across all three that best align with their goals and capabilities to create a tailored final plan.

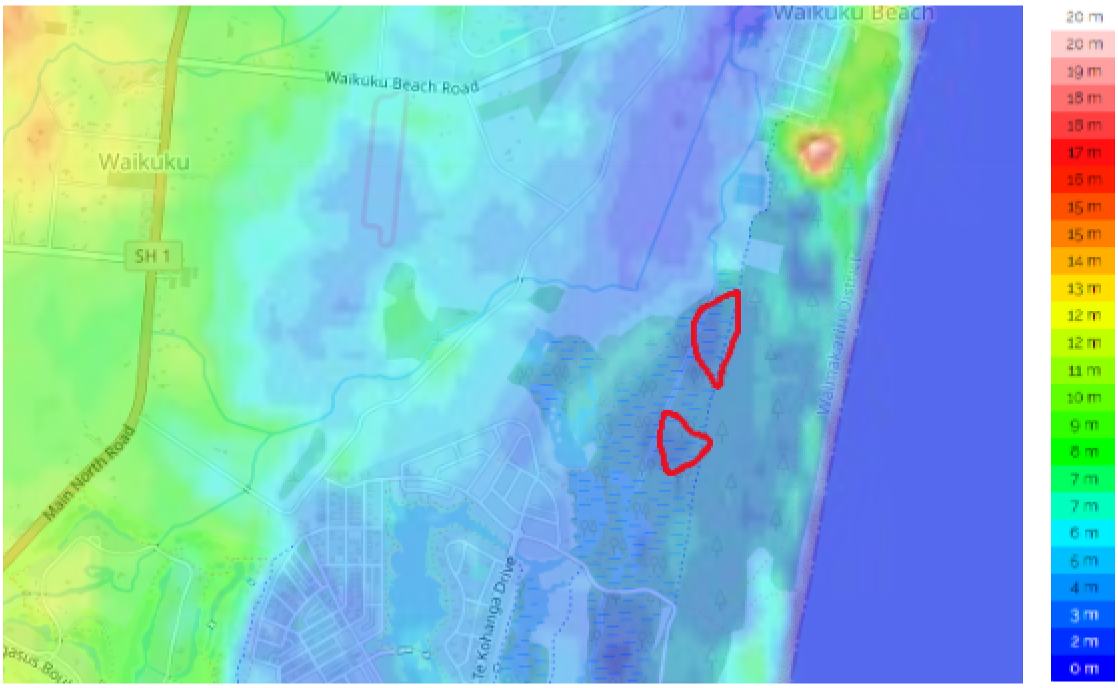

Figure 6. Map showing elevation profile in area of interest - highlights deeper areas/lower elevation areas to use for the wetland expansion sites. Sourced from Topographic-map (n.d)

Cultural and Social map

Zeta

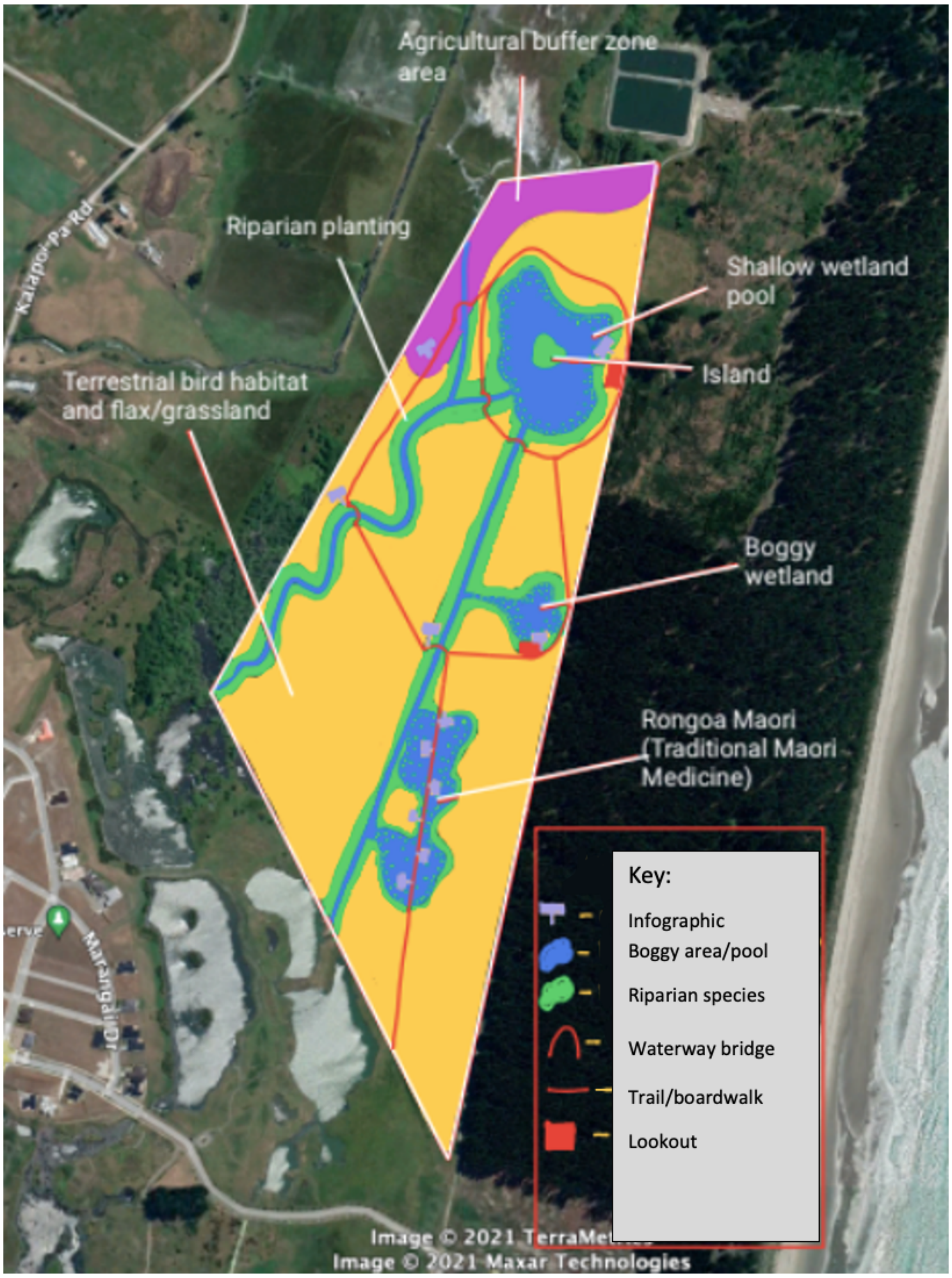

Figure 7. Socio-cultural scenario map for the proposed wetlands in the northern area of the Tūhaitara Coastal Park.

Culturally significant sites – Rongoā Māori & Mahinga kai

As shown in figure 7 an area dedicated to weaving and Rongoā Māori would be planted with indigenous plant species such as harakeke, toetoe and raupō. These sites would be accessible to local iwi to collect and manage resources. The creation of an island for Māori to practice eeling will improve mahinga kai values. These islands increase biodiversity by allowing an eeling area that will not disturb riparian plantings and also create isolated nesting habitats for bird life (Waihora, 2020). Eels migrate through streams as elvers to find suitable freshwater habitats consisting of ponds or waterways with plenty of cover. Eels are able to move over land, generally during wetter periods (Ryan, 2007). Shortfin eels (*Anguilla australis*) can be found in the Pegasus lagoon and other nearby waterways. A new pond would be accessible to migrating eels increasing the available habitat for this species.

Boardwalk/trail systems

Dense vegetation makes it difficult for the public to access and admire the wetlands up close. A boardwalk into the wetland would allow a higher level of public education on wetland functions which would build support for wetland protection and restoration. The recommended location for a boardwalk and trail system is shown in red. The boardwalk would be built around the proposed wetlands, include lookouts and bridges, and connect to existing trails. The key elements for building boardwalks are access trails, parking, maps, and informational signs (Kusler, 1993).

Limitations and considerations

There are limitations associated with constructing a boardwalk system such as the location of endangered species, and deep mud or water posing problems for construction, (Kusler,1993). Available funds will determine the length and width of the boardwalk, and there must be design strategies implemented to mitigate against ecological impacts. There are risks associated with boardwalks such as the weight it can hold, open water hazards and flooding. These risks can be mitigated with careful design considerations, railings and reinforcements.

Natural Value and Biodiversity Map

Emily

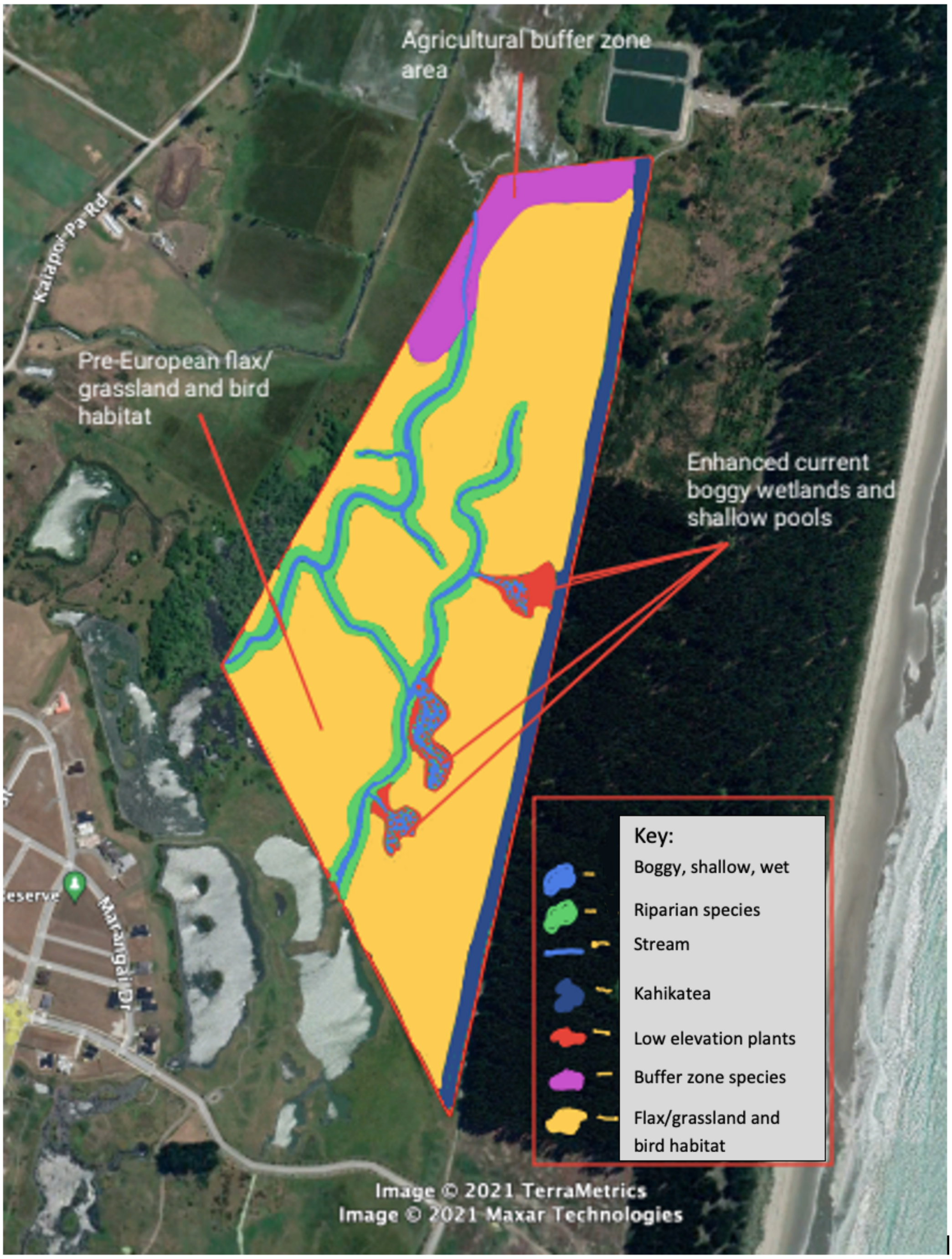

Figure 8. Natural value and biodiversity scenario map for the proposed wetlands in the northern area of the Tūhaitara Coastal Park.

Areas outlined in figure 8 are set coinciding with elevational variance, optimal areas for nutrient runoff absorption, historical character restoration and reduction of sea spray.

Forested Buffer zone and Shelter belt Habitat:

LINKNZ successional process modelling of Christchurch indigenous forest has shown patterns of a colonising nurse crop of manuka and kanuka, succeeded by broadleaf griselinia and finally kahikatea (Meurk & Hall 2006; Walker et al., 2004). These species facilitate native browser, pollinator and seed-dispersing birds, increase soil and water quality, and increase overall habitat functionality (Clout & Hay 1989). Ground cover species could reduce the costs of high-density planting associated with successional elimination and competition, allowing for more low-density planting with reduced weeding cost. These allelopathic species could allow for optimal distance planting of intended species and growth inhibition of weeds (Norby & Kozlowsky. 1980). These species are appropriate within coastal wetlands given their salt spray tolerance and conditional tolerance (Table 3).

Riparian and Wetland Habitat

Anthropomorphologically modified habitats can be physically altered to restore hydrological and potential ecological function. These modifications can include the meandering of streams for habitat conditional variability and biodiversity, reach extension to improve connectivity and migrational ability, and removal of fine sediment in lotic systems to promote interstitial spaces available for habitat, predation avoidance, and deposition of young (Greenwood et al., 2012).

Riparian and wetland margin planting species are highly valuable in the production of bottom-up diversification of functional feeding roles and abundance of invertebrates which provide a food source and maintain waterway quality and energy cycling (Table 4 and Table 2). Increased abundance and diversity of invertebrates and waterway size allow for increased food web complexity, niche complementarity, and trophic level support (Miller et al., 2003). Riparian planting promotes diversity and abundance of organisms associated with lowered pollutant and conditional tolerance requirements through phytoremediation, erosion control and nutrient cycling, allowing for a reduction of abiotic population control. Riparian planting along waterways can also provide Corridors for increased dispersal, gene flow and recruitment of faunal source populations. Biodiversity and abundance are also increased by increased niche availability.

Managing riparian zones and lentic wetlands improves biodiversity and resistance to climate change effects such as drought by lowering and stabilising temperature through shading, deepening of channels, providing increased organic matter resources, and diversifying habitat structure.

The field of dreams hypothesis states that if you make the habitat, they will come. However, sometimes connectivity is not adequate, or distance between habitat fragments is too great, reducing migration success (Waikato Regional Council. 2021). Translocation of species can restore ecological function and complexity, aesthetic value and mahinga kai or cultural value. Some example mahinga kai species include freshwater mussel, canterbury mudfish, shortfin eel, and samples of rich biodiverse arthropods to establish communities (NIWA. March 2021). More research is required to assess potential translocation species of aquatic and terrestrial habitats and their contribution to ecosystem functionality and cultural value.

Grassland Habitat

The example species outlined in Table 1 are potential examples of habitat vegetation types within the site pre-European colonisation given black maps overlay data (Figure 2). Grasslands are important habitat for species of endemic lizards, promoting invertebrate soil communities that aid in ecosystem function and provide food for insectivorous birds. (Environment Foundation, April 2018).

Climate Change Resistance and Resilience Map

Lauren

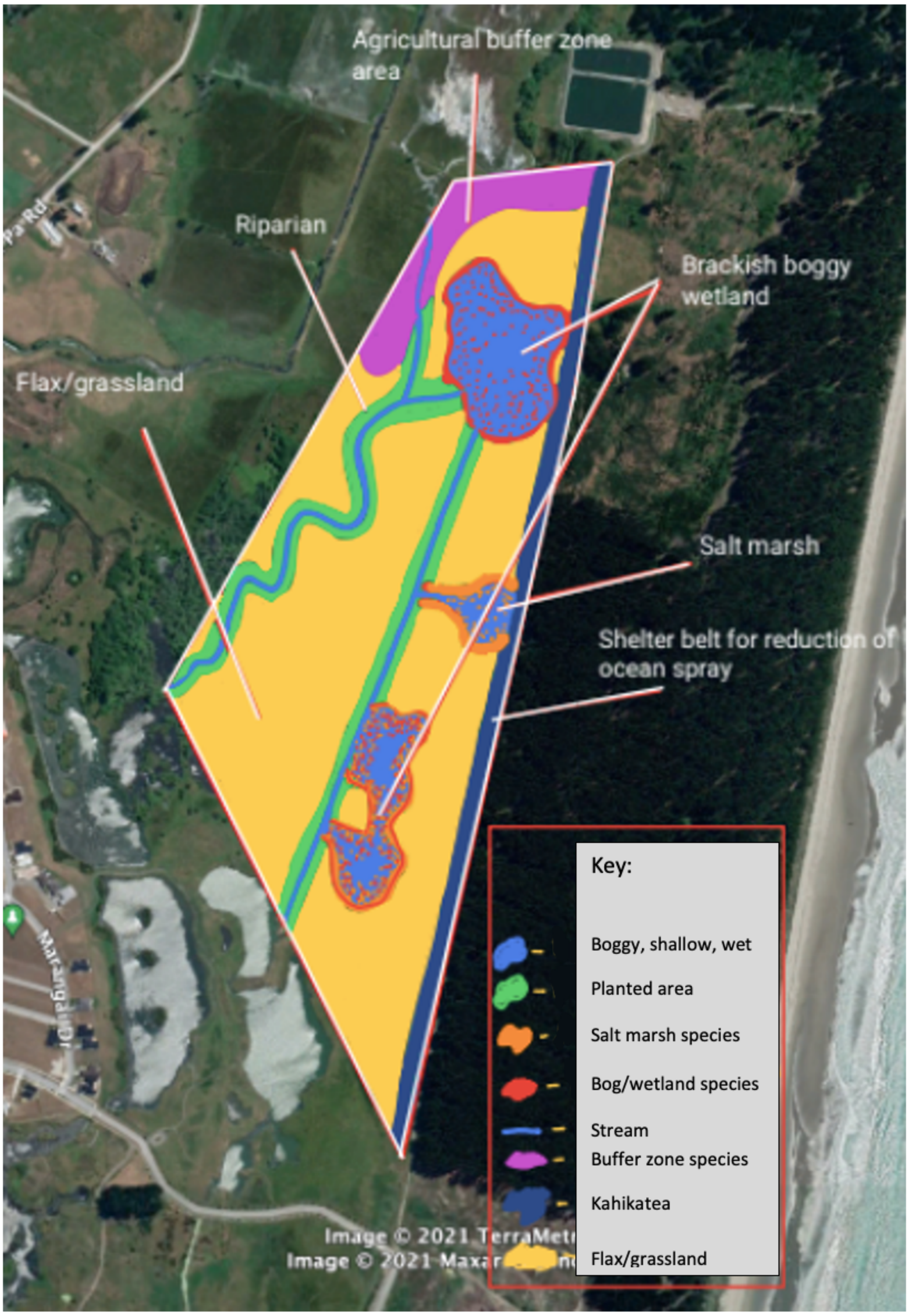

Figure 9. Climate change resistance and resilience scenario map for the proposed wetlands in the northern area of the Tūhaitara Coastal Park.

Waterways and water flows

This scenario (figure 9) aims to future-proof the area and aid the inevitable transition to a brackish or saline ecosystem. A key part of the restoration is enhancing identified low elevation points into wet bog or fen areas, as opposed to creating open pools (Wu et al., 2017). This will improve the wetlands ability to accommodate extra water, and build their platforms vertically. Effective and natural water flows throughout the area are also important in building resilience, and enhancing and naturalising the stream and drain through sediment control and riparian planting will be crucial (Chalis, 2012; Mulrennan & Woodroffe, 1998).

Vegetation restoration

Planned planting and native species will be a part of future-proofing the wetland. We suggest a zone of buffer species (Table 3) on the northwest and western edge of the area to filter contaminants and excess nutrients from nearby farmland. An area of larger, soil-stabilising species along the coastal edge will help slow SLR, reduce erosion, and protect from storm surges and sea spray. It may be beneficial to build up and stabilise this barrier as a levee, for further protection from SLR (Mulrennan & Woodroffe, 1998).

Salt tolerant species will be a key part of a climate resistance plan. Having species such as those in table 5 established will allow for a gradual transition to a salt-marsh ecosystem. As conditions change these species will be able to expand and take over. Also included in the scenario is a specific area of predominantly salt-tolerant species. This in part would be experimental, to investigate if a community such as this could survive in the current fresh-water environment. If it does become well established it will provide a zone of high biodiversity and a large seed pool to further aid with ecosystem transition as the area becomes more saline.

Management and monitoring

Zeta

Monitoring is important for detecting both positive and negative changes in wetland health over time. It is recommended that Tūhaitara Trust continues with implementing management and monitoring strategies that minimise any adverse effects to the wetlands. After the project has been established, monitoring can be done by recording water flows, levels, quality and quantity frequently to assess changes in salinity, nutrient levels, and presence of EPT and indicator invertebrates (Clarkson et al., 2003). Other methods include using MEPIs, weed and pest control, fencing around wetlands near farmland, and riparian planting to mitigate against contaminants and pollution from entering waterways (Harmsworth, 2002; McKergow et al., 2016).

Areas for future research

Lauren

We identified areas that were not within the scope or capabilities of our project but may require further research. There is a small site in the northern corner of our area which has previously been used as a hardfill dump. A detailed site assessment into any implications of the dump and restoration options should be conducted. The southern edge of our area is bounded by Tirititiri Moana Drive. It is a barrier to water flows between the wetlands, and elevation differences and subsequent water levels have been observed. Natural water flows tend to be better for wetland health, however, modelling by Whitelaw (2011) shows that SLR inundation is likely to occur up from the South, therefore the road may act as a beneficial barrier. Options for the barrier could include creating more culverts to enhance water flows, leaving it as it is, or creating culverts with the plan to close them once inundation is better understood and imminent.

Conclusions

Wetland ecosystem study requires consideration of location, ecosystem, environmental influences, water flow, and local communities. We have provided options for northern farmland conversion at Tūhaitara Coastal Park into wetland with considerations for climate change within the park's 200 year vision. Methods for resilience could include creation of wet areas instead of open water bodies, and planting a diverse array of salt-tolerant native species to help the wetland to slowly convert into a saltmarsh over the 200-year vision. These native plant species will also boost the area's flora, fauna and overall natural character. The park has sufficient groundwater and surface water inflow and can sustain a healthy wetland ecosystem. Cultural and community goals can be met by supporting ecotourism, mahinga kai and rongoa māori resources. Previous wetland developments, elevation models, and Canterbury Black Maps were used. The results provide viable options for flexible restoration. More research could be done to produce more detailed descriptions of consideration factors for a final wetland restoration plan. This Tūhaitara Coastal Park research could be extrapolated across New Zealand wetlands particularly in relation to the SLR and climate change effects.

Acknowledgements

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Figure references:

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(b) Whitelaw, S. (2011). The Vulnerability of Tūhaitara Coastal Park to Rising Sea-levels (Graduate Diploma in Sustainable Management). Open Polytechnic of New Zealand

Figure 2: "Tūhaitara Coastal Park." 43°18'35.53'S 172°42'12.72"E. GOOGLE EARTH (2019). Retrieved August 2021

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Figure 3: Flood Map (2020) Waikuku. Retrieved August 2021 from https://www.floodmap.net/?gi=2180219

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Figure 5: Greater Wellington Regional Council (2005). Understanding the 'wet' in wetlands - a guide to the management of freshwater wetland hydrology.. Retrieved September 2021 from http://www.gw.govt.nz/assets/council-publications/wetland_hydrology.pdf

Figure 6: *"*Waimakariri District topographic map, elevation, relief." Topographic-map.com (n.d) Retrieved September 2021. https://en-nz.topographic-map.com/maps/d7il/Waimakariri-District/?fbclid=IwAR0wXGE-q4YjYGxF_MpnmOOKvW6FtFM046oessiYfNzNWSnQK4jB53c-4ws

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"Tūhaitara Coastal Park." 43°18'35.53'S 172°42'12.72"E. GOOGLE EARTH (2019). Retrieved August 2021

Appendix

Emily

The tables contained within this appendix provide context towards potential plant communities within different identified wetland habitat types with reference to why they might be used and their ideal planting spacing. For the sake of space, we have limited the contents to 4 species. However more in depth research could be done on other species and greater multifunctional plant communities.

Elevation/ Conditional type: High elevation grassland		
4 Examples species:	**Reason for planting, conditional tolerance, benefit to biodiversity (habitat/ food/ water quality provisioning)**	**Mature plant dimensions and planting spacing**
Gahnia sedge, Māpere *(Gahnia setifolia)*	Tolerant of wind, full sun and shade conditions. (Waikato Regional Council 2018)	2m sedge, ideal spacing of 120cm. (Auckland Council, n.d.)
Prickly Mingimingi, Mingimingi *(Coprosma propinqua)*	Highly tolerant to frost, sun and wind. Found in dry and boggy soils. Berries for frugivorous birds (Waikato Regional Council 2018)	3m shrub (Waikato Regional Council 2018) 1m spacing (Engineering Standards Manual, November 1999)
Short Tussock, Wī kura *(Festuca novae-zelandiae)*	Dominated grasslands in south east New Zealand pre 1900. Habitat for native lizards and insects.	0.5m spacing (Engineering Standards Manual, November 1999)
Flax, Harakeke *(Phormium Tenax)*	Fast growing hardy pioneer, successful in full sun or shade. Withstands flooding and dry soils. Useful for drain edge protection from contaminants. Provides food to birds with particular attractiveness to Tui, Wax Eye and Bellbird (Waikato Regional Council 2018)	1-3m (Waikato Regional Council 2018) ideally planted in groups of more than 5 with 1.5m spacing. (Engineering Standards Manual, November 1999)

Table 1. 4 Example high elevation grassland species with reasoning for planting for improvement of native biodiversity, ecosystem functionality and quality, as well as mature plant dimensions and ideal spacing for planting. Information provided by Emily Dawson.

Elevation/ Conditional type: Low elevation		
4 examples species:	**Reason for planting, conditional tolerance, benefit to biodiversity (habitat/ food/ water quality provisioning)**	**Mature plant dimensions and planting spacing**
Flax, Harakeke *(Phormium Tenax)*	Fast growing, tolerant of moisture and light variation. Useful for drain edge protection and provision of food for birds such as Tui, Bellbird and Waxeye. (Waikato Regional Council 2018)	1-3m (Waikato Regional Council 2018) Ideally planted in groups of more than 5 with 1.5m spacing. (Engineering Standards Manual, November 1999)
Purei *(Carex secta)*	Can survive in shallow open water and boggy margins. Tolerant of moisture fluctuations. Provides shelter and nesting habitat for ground birds along riparian and wetland margins. (Waikato Regional Council 2018)	2m in size (Waikato Regional Council 2018) Ideal planting in groups with 1m clearance. (Engineering Standards Manual, November 1999)
Cabbage tree, Tī kōuka *(Cordyline australis)*	Hardy tree, tolerant of wet and dry soils. Good for erosion control and provision of food for birds (Waikato Regional Council 2018)	12m (Waikato Regional Council 2018) Ideally planted in groups of 3-7 with 1m spacing. (Engineering Standards Manual, November 1999)
Toetoe *(Austroderia fulvida)*	Fast growing pioneer species tolerant of soil moisture and wind (not pampas). Useful for wind dampening shelter and erosion control. (Waikato Regional Council 2018)	2m (Waikato Regional Council 2018). Ideally spaced by 2m (Engineering Standards Manual, November 1999)

Table 2. 4 Example low elevation moist soil and boggy wetland species with reasoning for planting for improvement of native biodiversity, ecosystem functionality and quality, as well as mature plant dimensions and ideal spacing for planting. Information provided by Emily Dawson.

Elevation/ Conditional type: Forested Shelter belt and buffer zone		
4 example species:	**Reason for planting, conditional tolerance, benefit to biodiversity (habitat/ food/ water quality provisioning)**	**Mature plant dimensions and planting spacing**
White Pine, Kahikatea *(Dacrycarpus dacrydioides)*	Coastally tolerant boggy habitat conifers. Attract native birds such as Tui, bellbird, kaka, kakariki, silvereye and kereru feeding on fruit, nectar and foliage - potential for increased avifaunal diversity and a connective fragment for dispersal.	40-60m tall over 600 years Trunk up to 2m diameter with large buttressed roots 5m spacing. (Farm Forestry New Zealand, 2021; Wilcox, 2010)
Tea Tree, Manuka (Leptospermum scoparium)	Pioneer species, highly tolerant of soil moisture variation, frost, salt spray and low soil fertility. Fibrous woody drought resistant and erosion controlling roots. Mycorrhizal associations with fungi - enrich soil, promote diverse invertebrate communities and improve soil aggregation structure. Aid pest control with promotion of native insectivorous bird and insect species. (Fuller, April 2017).	4-8m height, 2m diameter by 4-5 years (coastal location). 2.5 x 3m optimal spacing - for reduced intraspecific competition, maximised foliage and flower growth, maximised honey and oil production. High expense for high density planting for rapid canopy closure and erosion control. Recommended for smaller areas or wider spacing. (Fuller, April 2017).
Broadleaf griselinia, Kapuka *(Griselinia littoralis)*	Wide conditional tolerance. Dense canopy useful for shelter planting. Coastally tolerant to salt laden winds. (Salmon, J, T. 1980). Produces fruits for birds and leaves are palatable to insects. (Garden Tags, 2017).	3-10m height, 2-4m width 2x2m spacing for singular tree (Kauri Park, 2021) 100cm spacing for a hedge for sheltering from edge effects (Salmon, J, T. 1980).
Brass buttons *(Leptinella squalida)*	Native hardy ground cover species tolerant of salt winds. Provides shading. Flowers facilitate pollinator species (Home Creek nursery, n.d.)	10cm tall and 50cm wide Sprawling ground cover (Goughs Nurseries, 2014)

Table 3. 4 Example forested shelter belt and buffer zone species with reasoning for planting for improvement of native biodiversity, ecosystem functionality and quality, as well as mature plant dimensions and ideal spacing for planting. Information provided by Emily Dawson.

Elevation/ Conditional type: Riparian planting		
4 examples species:	**Reason for planting, conditional tolerance, benefit to biodiversity (habitat/ food/ water quality provisioning)**	**Mature plant dimensions and planting spacing**
New Zealand Willow, Koromiko *(Hebe stricta)*	Flowers and nectar facilitate native butterfly, bee and lizard species. Useful fast growing pioneer shelter species along riparian corridors. (Shaer, n.d.)	Up to 4m tall (Shaer, n.d.) 1m spacing (Engineering Standards Manual, November 1999)
Purei *(Carex secta)*	Tussocks on pedestal-like stems in shallow open water and boggy margins. Excellent food, shelter and nesting for ground birds.	2m in size (Waikato Regional Council 2018) Ideal planting in groups with 1m clearance. (Engineering Standards Manual, November 1999)
Bullrush, Raupo (*Typha orientalis)*	Provide habitat for eel, inanga, native fish, and birds such as the bittern, fernbird, spotless and marsh crakes. Effective water purifier species. Shallow waters or water logged soils, tolerant of slightly brackish waters (Scheele and Sweetapple, n.d.)	4m tall, 90-180cm wide Ideal spacing 120-180cm (Gardenia, n.d.)
Cabbage tree, Tī kōuka *(Cordyline australis)*	Hardy species tolerant of soil moisture variability. Erosion control and bird food provision (Waikato Regional Council 2018).	12m (Waikato Regional Council 2018) Ideally planted in groups of 3-7 with 1m spacing. (Engineering Standards Manual, November 1999)

Table 4. 4 Example riparian planting and wetland with reasoning for planting for improvement of native biodiversity, ecosystem functionality and quality as well as mature plant dimensions and ideal spacing for planting. Information provided by Emily Dawson.

Elevation/ Conditional type: Salt marsh		
4 examples species:	**Reason for planting, conditional tolerance, benefit to biodiversity (habitat/ food/ water quality provisioning)**	**Mature plant dimensions and planting spacing**
Marsh club rush, Kukuraho *(Bolboschoenus caldwellii)*	High salinity, frost and inundation tolerance, found in brackish environments (Auckland Council, n.d.; Canberra Nursery and Landscaping, 2019)	1.5m height, 0.3m width (Auckland Council, n.d.) 10cm spacing. (Canberra Nursery and Landscaping, 2019)
Bare twig rush, kōpūpūngāwhā *(Machaerina juncea)*	Lower salt tolerance, found in brackish boggy environments and coastal streams. (Auckland Council, n.d.)	1.5m rush (Auckland Council, n.d.)
Tea Tree, Mānuka (Leptospermum scoparium)	Partially salinity tolerant pioneer species, good for erosion control.	4-8m height, 2m diameter by 4-5 years (coastal location). 2.5 x 3m optimal spacing (Fuller, April 2017).
Flax, Harakeke *(Phormium Tenax)*	Moderately salinity tolerant, provides habitat and food to birds.	1-3m (Waikato Regional Council 2018) ideally planted in groups of more than 5 with 1.5m spacing. (Engineering Standards Manual, November 1999)

Table 5. 4 Example Salt marsh, coastally tolerant species with information associated with reasoning for planting for improvement of native biodiversity, ecosystem functionality and quality as well as mature plant dimensions and ideal spacing for planting. Information provided by Emily Dawson.