SEA-LEVEL RISE RESILIENCE THROUGH VOLUNTEER GROUP ACTIONS IN THE LOWER CATCHMENT OF THE ŌPĀWAHO - HEATHCOTE RIVER, CHRISTCHURCH

SOUL O'REILLY, CHLOE BETONY, AMANDINE BOSSERELLE, AND PIPPA SHEPPARD

Community Partner: Ōpāwaho Heathcote River Network
Supervisor: Ed Challies

ABSTRACT

Sea-level rise and climate change will increase flood risk and threaten many community group projects along the Ōpāwaho-Heathcote River in Ōtautahi Christchurch. By investigating the specific concerns and issues for groups active in the lower catchment, this research aims to provide a description of the impacts of sea-level rise on these groups, and how they can best prepare their sites and activities for sea-level rise to support wider community resilience. Data was collected through geospatial mapping, a review of available literature, and interviews with community groups to understand the flood risk and further impacts of sea-level rise on the lower catchment groups of the Ōpāwaho Heathcote River. Mapping showed the hazards that already exist from the estuary to further upstream, and the future risks of changing sea level. Interviews found that all groups had concerns surrounding sea-level rise regarding erosion, temperature changes, groundwater rise and salinisation. We drew on the concerns raised in interviews to inform our research to set recommendations for the groups and suggest areas for further research. We found that nature-based solutions could play an important role for community groups to help build resilience with their sites and the wider community.

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1.0 INTRODUCTION

The Ōpāwaho Heathcote River (OHR) is located between the Avon River / Ōtākaro catchment and the Port Hills. It meanders through south-west Christchurch City in a catchment that covers approximately 118 km², stretching from the estuary of the Heathcote and Avon Rivers / Ihutai in the east to Ruapuna Park in the west (Figure 1). The river has strong mana whenua, European, and natural histories which highlights the significance of the river to multiple groups of people. The river has been part of the extensive network of rivers and wetlands that formerly made up Ōtautahi Christchurch and now is one of the few remnants of this network. The river provided Ngāi Tahu with a means of transport to connect settlements and to provide the all-important mahinga kai. The river also holds significance to European settlers, providing a trade route and an attractive location for industry settlement (Ōpāwaho Heathcote River Network, 2021). In the current day, the urban river has ongoing issues with pollution, flooding, and sediment load inconsistency. These issues decrease the ability of the river to function the way it did before urbanisation occurred on either side of the river. Urbanisation has altered the way the river acts and has created the need for human engagement with the river to restore its health and character.

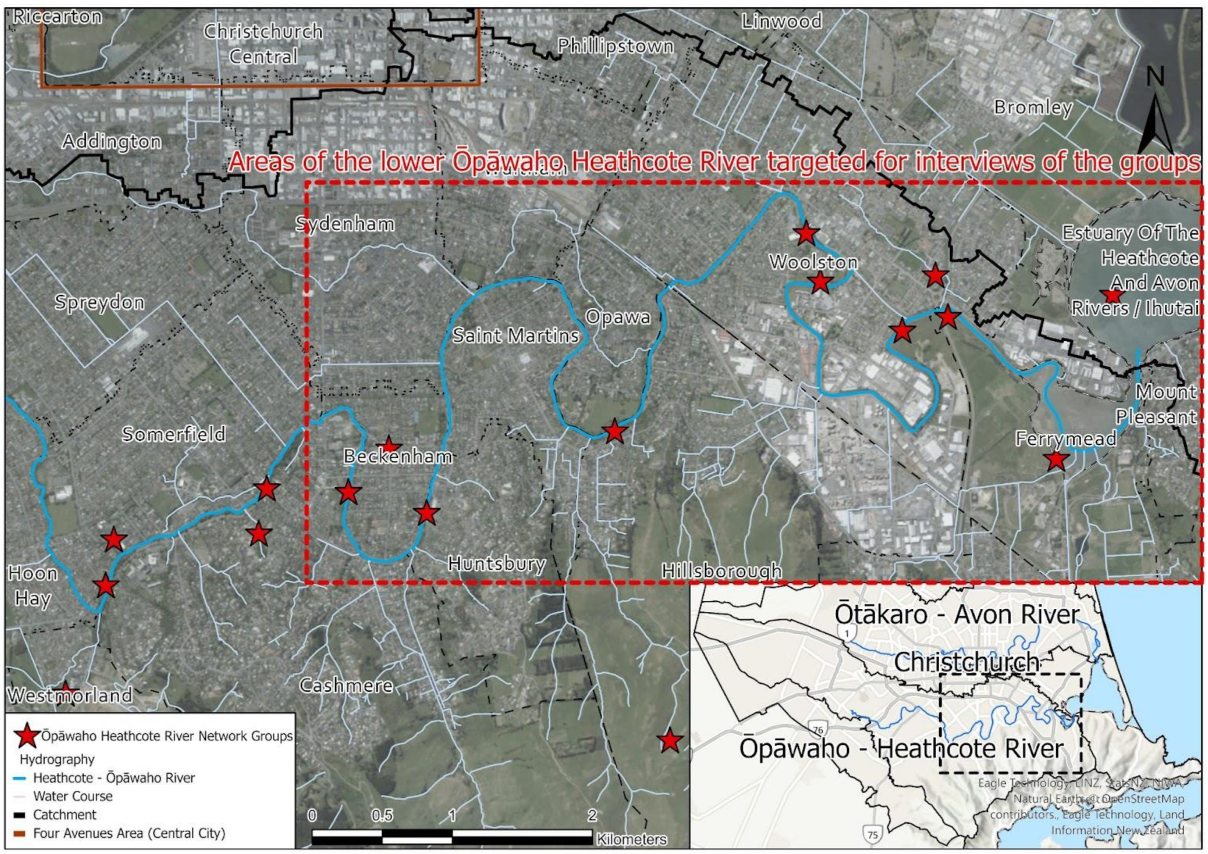

FIGURE 1: LOCATION MAP OF THE STUDY AREA (BOSSERELLE, 2022)

The aim of this research is to summarise how sea-level rise (SLR) will impact the reserves along the lower part of the river which are maintained by the groups under the umbrella group, Ōpāwaho Heathcote River Network (OHRN). The lower catchment is defined for the purpose of this investigation from the ŌHR mouth at the estuary Ihutai in Ferrymead and up to Woolston. Some ŌHRN groups further upstream within the suburbs of Beckenham and Opawa were considered for the study (Figure 1). The research draws on targeted interviews with key informants, geospatial mapping and a review of the relevant literature. The objectives include investigations on (1) how the blue-green infrastructure (BGI) systems including those parks and reserves are currently distributed, used and perceived by the groups, (2) the volunteers perspectives on impact from SLR and (3) how those spaces could mitigate SLR effects, then (4) provide recommendations for future planning and projects. From this research, both the role of BGI in coastal urban areas and the resilience to SLR can be discussed and further provide more flood security for residents living by the river and protect the nature and ecosystems.

2.0 LITERATURE REVIEW

***2.1** FLOOD MITIGATION STRATEGIES, A FOCUS ON NATURE BASED MITIGATION*

The lower ŌHR is located in a flat and low-lying area that has historically been affected by flooding and will additionally be impacted by climate change-induced SLR. The surroundings of the river have experienced flood events in the past which have been exacerbated by the 2010-2011 Canterbury Earthquakes Sequence (CES). This elevated the tidal portion of the river by 0.4m, increasing the water volume in the area (NIWA, 2011). The flood history of the river (2000, 2006, 2008, 2010, 2013, 2017 and 2018, to cite a few in the last two decades) has brought great concerns to residents as there is a genuine fear that their properties will be inundated by future flood events. Concerns are beginning to centre on what the impact of coastal flooding will be with climate change and increased sea levels. It is important to be aware of coastal flooding resilience strategies and frameworks that will help to protect assets and the natural environment. With SLR being a reality for coastal settlements, the need for understanding the impact that this will have on riverine areas becomes increasingly important as people are drawn to blue spaces for the multiple benefits on health and wellbeing. There is an expanse of literature that explores the ways in which coastal flood resilience can be achieved. The review of the literature and background information presented in this section aims to summarise ways in which flood resilience is achieved and how these means could be applicable for the lower OHR.

Resilience can be achieved through nature-based risk mitigation through the conservation of wetland ecosystems. With hard engineering having the ability to negatively impact the natural environment through enhanced erosion, disturbance of habitat, and sediment supply disturbance, communities globally are making the shift towards more environmentally sustainable ways of achieving resilience. Many studies that focus on nature-based risk mitigation are centred on coastal communities in the United States, and there is also some focus on communities in Europe. In the New Zealand context, relatively less studies investigate this topic and there is an opportunity to integrate some research from the global scene and the Asia-Pacific region into the local scale. To further understand the specifics of flood impacts on rivers, literature is limited to case studies analysing Chinese, South Asian, and Southeast Asian rivers. As well as this niche geographic focus area, the major rivers (Amazon, Niger, Ganges, Brahmaputra, Mekong, and Pearl River) make up a majority of case studies exploring the impact of coastal flooding on rivers (Eccles et al., 2019). Thus, the gap in literature is further identified and the need for studies exploring nature-based risk mitigation in the southern hemisphere is needed. Not only are studies needed that centre on the Southern Hemisphere, they are needed to explore the impact that coastal flooding under changing climate conditions will have on riverine environments and criteria will be needed to determine the changes that may be seen. A study by Van Coppenolle and Temmerman (2020) examined tidal wetlands and the influence they had on mitigating storm flooding in 114 countries. The study found that 91 of the countries benefited from tidal wetland flood protection and those that didn't primarily had rising coastlines, mitigating the threat of flood. The study states that the features of the tidal wetland such as vegetation type, area, and topography do have an influence on the level of flood protection that is offered. For example, mangroves on the coast can attenuate up to 50 cm per km of water (Zhang et al., 2012) whereas open water and channels only have the capacity to attenuate 0.1 cm per km.

2.2 BLUE-GREEN INFRASTRUCTURE

Green spaces are essential to a functioning large city and are used in innovative ways to enhance urban resilience. BGI is an urban planning concept for an integrated network of natural or artificial (man-made) spaces that aims at enhancing the environment and improving resilience to climate change (Brears, 2018). Widely used in urban flood risk management, BGI benefits land and water ecosystems health, social, economic, agricultural and recreational activities (Ghofrani et al., 2017). Rapid urbanisation is a challenge to the sustainable development of many cities. Expanding and retrofitting BGI becomes an essential part of transitioning towards a resilient city.

In the case of Christchurch, the two main tidal rivers, the Ōtākaro-Avon and the Ōpāwaho Heathcote rivers, flow through the low-lying city on relatively flat land. The CES caused considerable damage to the city public infrastructure, community facilities and the land in the eastern suburbs (Quigley et al., 2016). The central government red-zoned 537 ha of residential area in Christchurch (and 197 ha in the Port Hills) creating available space to create a Green Spine along the "Ōtākaro-Avon River Corridor" (Greater Christchurch Regeneration, 2019). Although the OHR is located in a reasonable size catchment, it doesn't benefit from extensive available space to allow expansion of BGI for climate change adaption and mitigation like the Ōtākaro-Avon River Corridor. Prior to the establishment of Christchurch City, the area was primarily indiginous land within an alluvial and coastal landscape. Along the OHR, wetlands and native vegetation indicated the presence of many surface water features (ponds and rivers) and shallow groundwater (Figure 2). As the flax, fern, grass, tupaki and cabbage trees have been replaced by residential and industrial zones, the river remains. Nature and the community along the OHR try to reclaim some places that used to be wild to enhance urban resilience and bring back the biodiversity of a city that calls itself the garden city.

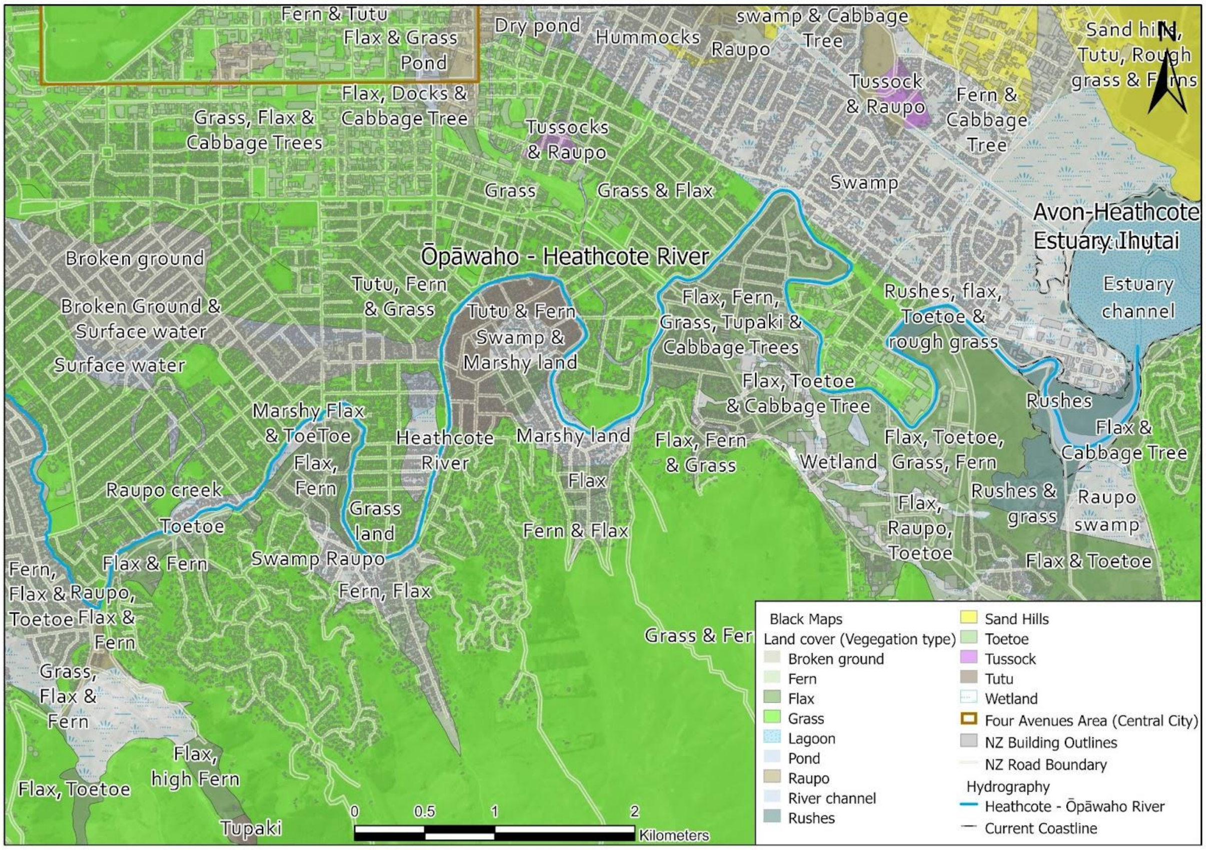

FIGURE 2: 19TH CENTURY BLACK MAPS (NGĀI TAHU & ENVIRONMENT CANTERBURY, 2019)

2.3 CHRISTCHURCH CITY COUNCIL AND THE ŌPĀWAHO HEATHCOTE RIVER

The original 1998 ŌHR floodplain management strategy (Canterbury Regional Council, & Christchurch City Council, 1998) was replaced by the Christchurch District Plan reviewed in 2017 to include the framework for managing flood and high hazard areas. The Land Drainage Recovery Programme, set up in 2012, contributed many reports addressing the issue of flooding in the OHR catchment.

The Christchurch City Council established a Flood Intervention Policy to try to purchase properties in high flood hazard management areas (Christchurch City Council, 2017). The focus following some buyouts was to invest more in flood risk reduction in the Ōpāwaho Heathcote River catchment with the construction of stormwater facilities upstream and maintaining dredging and bank stabilisation downstream. These projects temporarily solve the challenges from flooding but more investment will be needed to cover the extent of the effects from climate change (Christchurch City Council & Newsline, 2021). In 2022, the Christchurch City Council recommended the cancellation of the project on low stopbank options for the Ōpāwaho Heathcote River catchment (Christchurch City Council, 2022a). Now the floodplain management options project has been set as a low priority and the future stopbanks response to flooding risk has to be integrated into the early stage of development of the Coastal Hazards Adaptation Planning Programme which is also looking at the impacts of climate change in tidally affected areas.

2.4 *FLOOD MANAGEMENT OF THE ŌPĀWAHO HEATHCOTE RIVER*

Flood protection and control works alongside stormwater drainage construction are currently occurring or are at a design phase and set to finish in the next couple of years in Christchurch City. These projects particularly aim to minimise flood risk in the OHR catchment and use a range of interception tools such as basins, ponds, swales, pits, traps and rain gardens (Christchurch City Council, 2003). The term 'Blue-Green Infrastructure' is not directly used by the council organisation but they are referred to in this research as such as the definition given above. Specifically to this research, the term BGI refers to a wider range of community assets, such as the river itself and the green spaces (parks/reserves) along its length. Some of the most common BGI for stormwater management in the OHR catchment are retention and detention basins as they can significantly reduce flooding risk and can provide filtering of water for sediment before it reaches waterways. There are 51 detention basins and 91 retention basins in the OHR catchment (Christchurch City Council, 2022b), mainly located in the upstream part of the catchment in drainage reserves and usually coexisting side by side for example, along Sparks Road, and in the Cashmere Valley in Cracroft. These account for approximately 800,000 m^3 of water storage in the OHR catchment (Christensen, 2019a). A retention basin is essentially a man-made pond or wetland. They are used to retain water that would otherwise enter rivers and help to reduce peak flow rates during rainfall events. Retention basins are never dry, they always maintain a minimum water level. As sea level rises, the infiltration rate of the retention basins will be reduced which in-turn will increase the pond volume recovery time and hence reduce the ability for the retention ponds to lower peak flow on consecutive rain events (Davtalab et al., 2020). Detention basins, on the other hand, temporarily hold water then slowly release it into the ground/aquifers. Detention basins are expected to dry out between rain events. For a detention basin to operate properly it requires the water table to be at least 3 meters subterranean (NZWERF, 2004). This is so there is adequate soil space below the basin for 1) water to infiltrate and 2) for water to be filtered before it enters the water table. As sea level rises, existing detention basins may experience longer pond recovery times which will reduce their ability to lower peak flow rates (Davtalab et al., 2020).

2.5 *SEA-LEVEL RISE AND IMPACTS ON RIVERS*

Many BGI projects require the use of plants for 1) aesthetics, 2) soil stabilization and 3) to filter water. Increasing the number of green spaces is crucial in the way stormwater is managed in an urban environment and will benefit the entire catchment. As sea level rises, surface water and groundwater near the coast and tidal rivers will rise consequently and can in some places become more saline. When the groundwater becomes saline it reduces plant's ability to absorb water through their roots and in some cases may even draw water out of the plants through reverse osmosis (Queensland Government, 2013). There are, however, multiple salt-resistant plants that can be used in areas prone to salinization. The Department of Conservation (DOC) has a number of resources that provide recommendations for coastal planting as shown in Figure 3 (Department of Conservation, 2021). The loss of plantlife will affect many aspects of BGI including soil structure, aesthetics and the ability for retention and detention basins to filter water. Plants are important structural components of BGI as their roots help to hold the soil particles together. Plants also work as biological filters, trapping sediment and harmful chemicals with their roots. Sea-level rise will also mean that tidal movement will reach further up coastal rivers. Tidal movement causes the lower part of rivers to slow down or temporarily reverse flow during incoming tides. The slowing of the river may cause eluvial deposition which will decrease their depth over time. The reverse movement may also cause sediment to be pushed up the rivers from coastal deposits which overtime may raise the river bed. The shallowing of rivers will lower their capacity to hold water which may increase the impacts of flood events (California Institute of Technology, 2020). The OHR catchment was regularly dredged up until the late 1980s (Christensen, 2019b). Sea level rise is likely to reverse the positive effects of this dredging. The increase in salinity and higher water levels are some of many already existing and future challenges that the lower part of the catchment will experience and those need to be addressed in an integrated coastal hazard management plan.

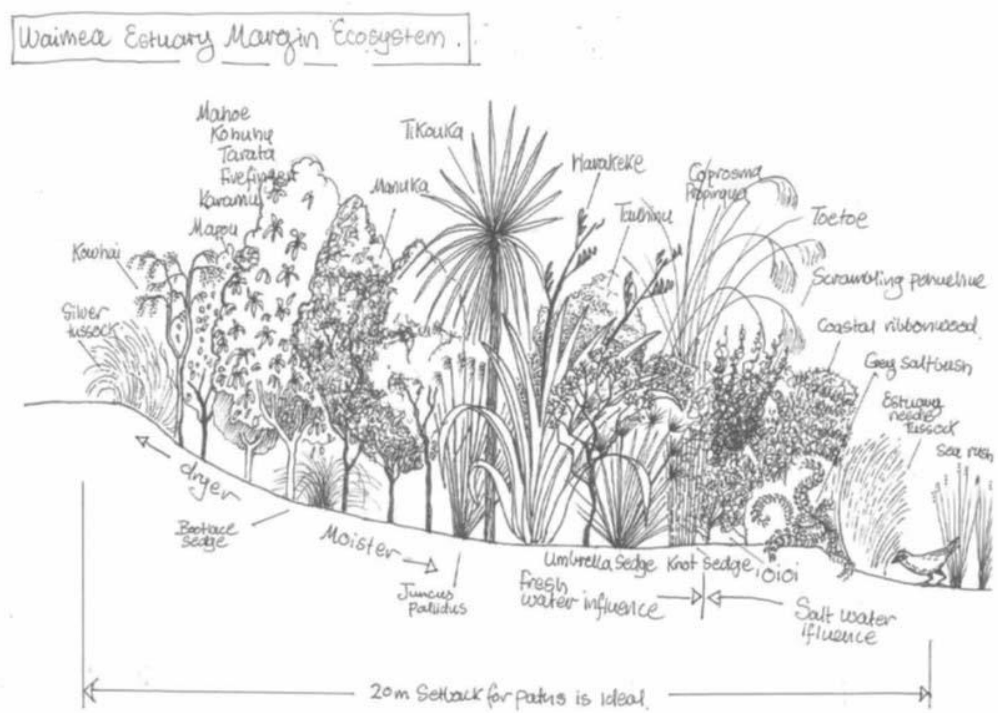

FIGURE 3: DOC’S RECOMMENDATION FOR PLANTING NEAR AN ESTUARY DESIGNED FOR WAIMEA (GASKELL, 2021)

3.0 METHODS

3.1 *INTERVIEWS AND ETHICS*

Planning for the report began with a meeting with members of ŌHRN where they discussed the river, the upper catchment flood management and the corridor of the O-H River. As ŌHRN is an umbrella group of many smaller groups, we decided to conduct interviews with lower catchment groups under the umbrella to understand lower catchment flood risk. After obtaining human research ethics approval, we reached out to all lower catchment groups through the ŌRHN website and selected four groups to interview across three meetings. Groups 1 & 2 were further inland and Groups 3 & 4 were on, or close to the coastline. Our questions helped us form an understanding of how our groups understood the area their site was in, what has already been implemented to mitigate flood risk in the whole catchment, and how their work would be affected by, and could mitigate the impacts of, SLR and climate change. The semi-structured interviews identified the key concerns of the groups, the actions they were taking, and how this research could inform an improved understanding of risks and opportunities of SLR and climate change.

3.2 *LITERATURE REVIEW*

The Literature Review process enabled the group to explore our individual areas of interest that related to our aims. Whilst exploring our areas of interest and expertise, the group has been able to identify areas of concern and areas in which further research is needed to provide evidence as to how climate change and SLR will impact riverine environments. The literature review aimed to provide the purpose for the investigations and to provide supporting evidence for mapping spatially the results.

3.3 *GIS MAPPING*

For mapping, tools from ArcGIS Pro (ESRI Inc., 2019) are used in this study to create outputs that reflect the research findings. The Christchurch City Council (CCC) has an open data portal with geospatial information available to download which is used in this research (Christchurch City Council, 2022b).

4.0 RESULTS

4.1 INTERVIEWS

From the interviews, it was clear that for most, SLR was a growing concern. Group 1 and 2 were more inland and were not as directly threatened by SLR so their focus did not consider the potential impacts of SLR as much. These groups raised the issue that their work was focused on the restoration of their sites and thinking so far ahead was impractical for what they had resources for. Group 3 and 4 both were aware of SLR as an issue that would affect the work they had done and will do in the future.

4.1.1 EROSION

The main concerns of the groups were first and foremost erosion. More inland, Group 1 had previously had issues of erosion from high flow, however, from heavy rain, not SLR. Higher frequency and severity of high river flow from climate change could become more damaging and make the space more vulnerable to further climate change impacts. Group 3 has concerns over coastal erosion as nine sites around the estuary were previously rubbish dumps. There are already issues with rubbish emerging at the mouth of the river at Ferrymead. Higher sea levels and more extreme weather will exacerbate this issue.

4.1.2 TEMPERATURE CHANGES

Another concern of the groups was the possible changes to temperatures, both of water and air, and how that may affect the whole river. Group 2 and 4 both raised well founded concerns around the Inanga spawning at Steamwharf Stream which is a regular spawning site. The groups were concerned about how the rising sea temperatures may affect the Inanga's ability to spawn and that if they are negatively impacted, the effects of that may spread throughout the catchment. MPI found that warmer seas in summer affected the reproduction of some species like hoki and snapper. The same effect could certainly be seen with Inanga at Steamwharf Stream (Ministry for the Environment & Stats NZ, 2020).

A further concern raised from changes to temperatures is the possibility that the climate may suit weed species and a proliferation of weeds across the catchment may be seen. Group 4 raised the example of the Roimata Food Commons where sea buckthorn was planted and was unexpectedly successful in the area. As they did not expect it to do so well, there are already concerns it may spread across the catchment and what the impact of that will be on the ecosystem. With rising temperatures, the concern is further weed proliferation in more favourable conditions, a concern also raised by Group 2.

4.1.3 GROUNDWATER

Group 2 and 3 addressed the possible impact of groundwater rising significantly inland to the coast, Group 2 suggested 2-3kms. Group 3 mentioned the Linwood Paddocks which have already experienced seawater coming into the paddocks and expects to see higher flood risk from saltwater intrusion in groundwater.

4.1.4 SALINIZATION

A final concern raised particularly by Groups 1 and 2 is the possible salinization as the sites are not prepared for the increase of salinity. This could impact the plants ability to grow and destabilise the river banks which will further increase flood risk in the area.

TABLE 1: SUMMARY OF INTERVIEW ANSWERS

	Group 1	Group 2	Group 3	Group 4
Is SLR in the main goals and activities of the groups?	No	No	Maybe	Yes
Is flooding from SLR an issue for this site?	Maybe	No	Yes	Yes
Do groups think SLR will impact existing projects?	Maybe	Maybe	Yes	Yes
Is SLR being planned for by these groups?	No	No	Yes	Yes

4.2 GIS MAPPING

The CCC spatial database reveals 375 parks located (completely within) in the OHR catchment, from a small green patch of less than 100 m² to the regional parks of the Port Hills, together approximately 8 km² (Christchurch City Council, 2022b). Defining a OHR corridor with a distance of 200 m from the river, 104 of those parks are located near the OHR and includes a cemetery, garden and heritage parks, local/community parks, regional, sports and utility parks. In addition, 15 schools and one public hospital are located in the defined OHR corridor for this study, and the Opawa Community Garden, although community gardens are not currently mapped by CCC and their use and locations could be further investigated. The dataset collected in this research is shown in Figure 4, and is also used to illustrate the results in the following sections which locate the OHRN groups which participated in this research.

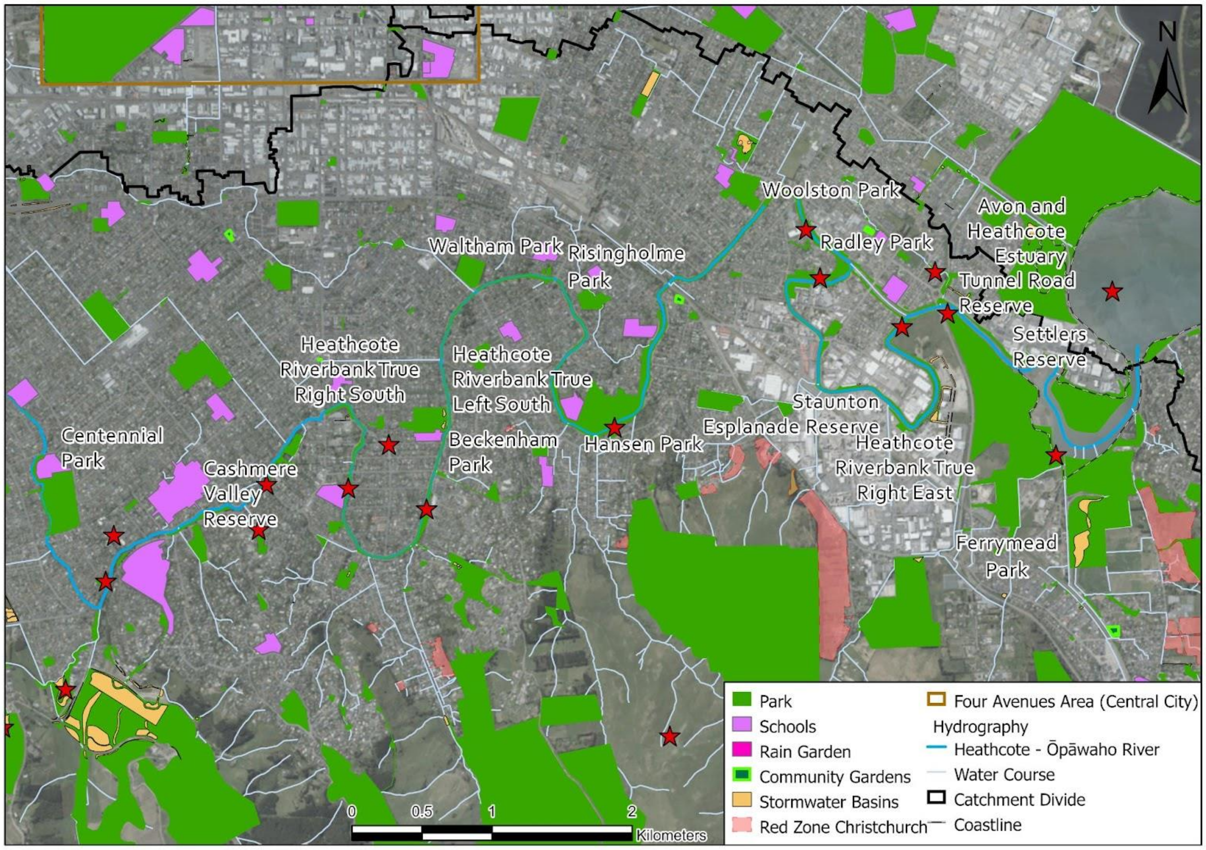

FIGURE 4: LOCATION MAP OF THE CHRISTCHURCH CENTRAL CITY PARKS AND RESERVES IN GREEN (NAMED IF AREA GREATER THAN 20 HA AND WITHIN 200 M FROM THE RIVER), SCHOOLS IN PURPLE (INCLUDING PUBLIC HOSPITALS) ALONG THE ŌPĀWAHO HEATHCOTE RIVER CORRIDOR RELATIVE TO THE OHRN.

5.0 DISCUSSION

5.1 *LOCATION*

The activities of the groups interviewed in this research mainly occur in different size parks and reserves and are located within a larger network of BGI along the OHR. Between Ferrymead on the estuary side to Beckenham upstream, 33 green spaces are connected via the riverbanks along the first 15 km of the river from Ferry Rd bridge. Out of this distance, 11 km of river are currently in the tidally influenced part and are likely to be exposed to the effects of SLR. There are also 21 large parks / reserves (greater than 1 ha) in this lower catchment zone and those are quite distant from each other (500 m to 1,500 m in a straight line). However they are usually located close to schools which could benefit from local participation and involvement in restoration. The connection between education and restoration projects might be an important consideration for future studies on urban resilience to SLR in this area. The current vision in the lower catchment of the OHR (Christchurch City Council, 2022b) is to coordinate and integrate restoration efforts to improve the connection to the river and its health. The plan doesn’t address the sea-level rise effects on the based actions that constitute a significant gap in this guidance document.

5.2 *RIPARIAN PLANTING*

Whilst individual groups along the lower OHR have tried their hand at individual nature-based risk mitigation through riparian planting (Figure 5), there is a lack of network wide planning for coastal flood mitigation. As the Ihutai estuary is a large area of 8 km², there is the potential to enhance the already existing conservation to provide planting such as salt mash which is shown to increase attenuation. What we can hope that conservation of the Ihutai estuary will do is mitigate storm floods from impacting the river itself too extensively. Not only will these reserves provide environmental resilience, but they are also of huge benefit to the communities that surround them. Groups 1, 2 and 3, all spoke of the mental and community benefits to preserving the sites. Group 1 specifically mentioned the community finding the space special and were gradually learning to appreciate the environment. Group 3 spoke of the impact their advocating work was having on the community as people began to care more about the environment and the restoration work of the group. Group 2 also spoke of the impact of the community simply caring about the environment as it gives the groups more support to continue the work they are doing. While the groups mostly do restoration work, the impact of the community seeing them working and the results and benefits that arise from the restoration provides greater support for the groups and increases mental wellbeing to ultimately build community resilience.

Figure 5: Riparian planting along the Ōpāwaho Heathcote River in Fifield Terrace in Opawa (photo credit A. Bosserelle, 2022)

5.3 SEA LEVEL RISE CONCERNS

From the summary of findings in Table 1 and Figure 6, the more inland groups could be less directly affected with SLR until it reaches 1 m or above, while the coastal groups are currently thinking about SLR. Groups 1 & 2 are less concerned with SLR as their sites are further upstream from the estuary, but their resources do not facilitate a capacity to be concerned. Their work on restoring the habitats is hugely important to biodiversity and strengthening the ecosystems and community for climate change. However, as SLR is not a main priority in their planning meaning salinization and possible flooding will likely have an impact on these groups if they do not plan accordingly. Groups 3 & 4 are more aware of their risks as they are directly connected to the coastline. As the conceptual summary map shows (Figure 6), volunteer groups have SLR take priority in their goals and activities as their sites would be affected from flooding risk increase due to SLR. They are planning to be impacted and implementing projects which will help mitigate the impacts of SLR on their sites and provide transitional habitats to help protect the wildlife at their sites.

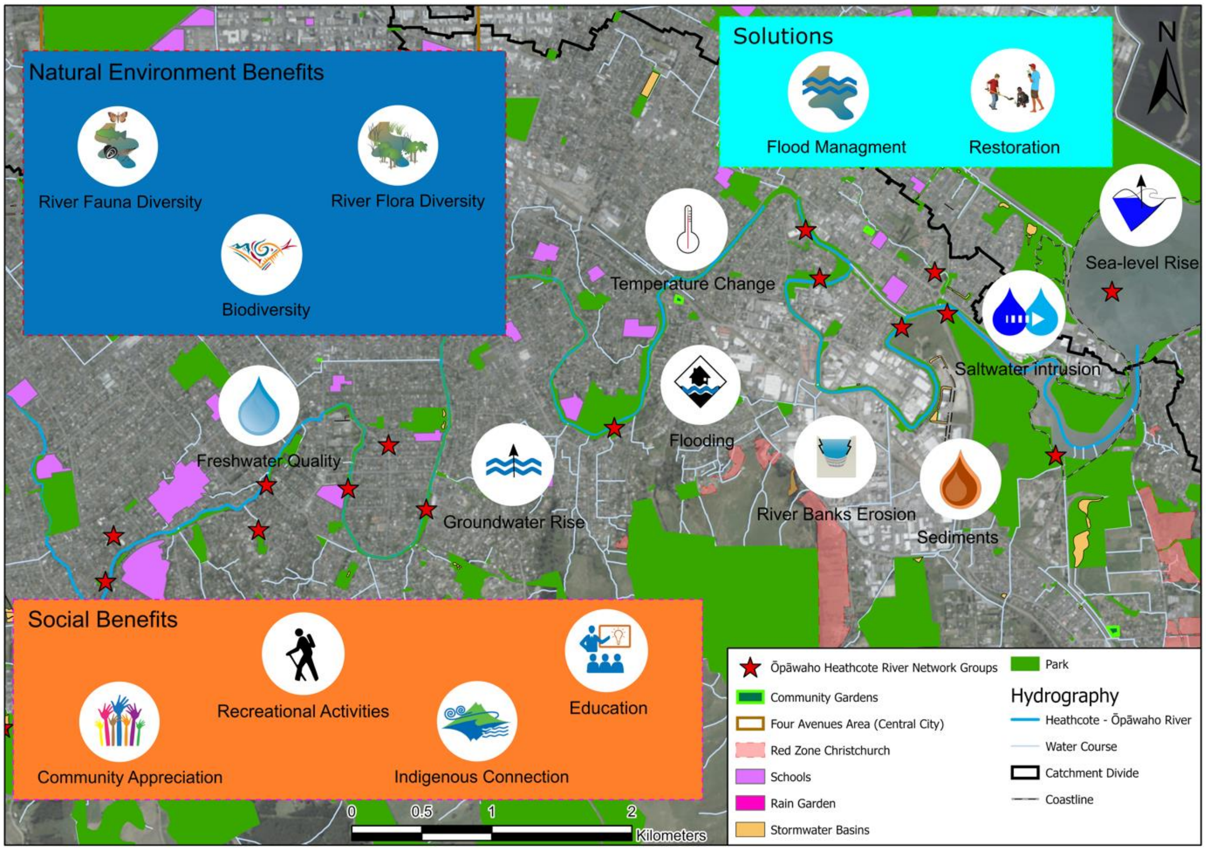

FIGURE 6: CONCEPTUAL MAP SHOWING A SUMMARY OF THE FINDINGS FROM THE GROUPS INTERVIEWS. THE ISSUES / HAZARDS LABELS ARE NOT SPECIFIC TO A LOCATION ON THE MAP.

5.4 SALINIZATION

Groups 3 and 4 both had knowledge of the risk of salinization and plans to work with it, as their sites become transitional habitats as the sea moves inland. Group 3 is planning to incorporate sea meadow into their projects and Group 4's project goals is for transitional habitat and overall restoration, so salinization is the plan for their site. Group 1 had concerns with salinization, having already suffered the consequences of plants dying and an increase of crabs which burrow into, and subsequently destabilise the banks. To ameliorate this, and the concern of bank erosion, planting suitable plants with expansive root networks for stabilisation, and a tolerance to saltwater is the best way forward. DOC has a guide on salt-tolerant plant species that provide bank stabilisation (Appendix 1). Dune hollow and Fore dune species will be beneficial but for Group 1 which is further from the coast, Back dune will also provide benefits to their work. These species meet the requirements of Group 1 who were looking for native species, tolerant to salt, with extensive root networks to provide stabilisation and build resilience for their site to prepare for SLR and climate change impacts.

5.6 EROSION

As erosion is an already prevalent issue for the groups on the bank of the OHR, it is important that the extent of which this may further impact groups is understood. Under changing climatic conditions, SLR is going to impact groups and communities that have historically not been impacted before. This concern has been raised in many IPCC climate reports, and further studies with a very high confidence that coastal systems and low-lying areas will increasingly experience flooding and erosion through the 21st century and beyond due to SLR (IPCC, 2014). Groups on the OHR are already experiencing the effects of erosion, it is only a matter of time before the severity of erosion increases. As Ihutai Estuary is at the interface between the OHR and the Pacific Ocean, it will be amongst the first locations to experience enhanced erosion levels as a direct result of SLR. Enhanced erosion will alter the characteristics of Ihutai and negatively impact the ecosystem through changes in water composition (Wong et al., 2014). With increased SL, it can be expected that there will be an increased volume of water in river systems, especially those with a tidal influence. The increased volume of water will pose a physical challenge to river systems that are not naturally able to handle extreme volumes of water. This is likely to result in increased flooding and bank erosion as the water adapts to the space available. There is limited research based around the impacts of climate change on riverine systems and so it cannot be said for certain how erosion will impact the OHR in the near future. We can make an educated guess based off of case studies such as Mirza et.al. (2015) to imply how erosion may impact the communities on the OHR.

6.0 LIMITATIONS

6.1 INTERVIEWS

There were a few limitations with the interviews. As a short research project, we did not have too much time to run the interviews with an inability to follow up with groups who did not respond to our initial proposition, or follow up with the groups we did interview. Further research and interviews could expand on the questions asked and the answers given in the initial interviews. Also due to time limitations, we had to interview multiple people per meeting which meant if there was a lot of people, it was a challenge to make sure everyone had their voice heard in the interviews. As the interviews were informal and more of a discussion, we believe there were some points that may have been missed and the interviews were also sometimes off topic as the discussion progressed away from the main question. If further research on this topic is done, it would be beneficial to have another meeting or two with each group to reaffirm answers and relate the interviews more to the research and previous interviews. To further build on our research, conducting interviews with Christchurch City Council staff who have worked closely with ŌHRN would be beneficial to understand their perspectives of issues raised in the interviews relating to the council and policies that affect the groups.

6.2 LITERATURE REVIEWS

Whilst a literature review provides the opportunity for us to shape our project by identifying the need for the research, it also acts as a limiting factor for the scope and extent that a project can adopt. The key limitation of our literature review ended up being the time that we had available to complete this task. As a literature review is often preliminary and the project had a short period of time in which it needed to be completed, we did find that we ran out of time to have a fully comprehensive literature review. If we did not have the time constraint our literature review would be comprehensive and could have covered a larger variety of subtopics relating to BGI.

6.3 GIS MAPPING

The creation of maps is principally constrained by the availability and accuracy of public information. All data for mapping and used in this research are licensed under Creative Commons; New Zealand Crown and the Department of Internal Affairs, on behalf of the Crown, licenses and allows copies, distribution and adaptation that content in accordance with the Creative Commons Attribution (CC-BY) 4.0 International Licence.

7.0 RECOMMENDATIONS

From the interviews with the groups situated in the lower catchment of the OHR, we were able to comprehensively understand where the groups concerns with SLR and climate change lay. From these interviews, we were able to get a gauge of the awareness and concern levels of each group which has allowed for us to make key suggestions to the groups.

7.1 *PLANT RESTORATION*

To increase bank stabilization with the threat of erosion, it would be beneficial for groups to invest in plant restoration with plants that are proven to have a high salinity tolerance and extensive roots. Plants with high salinity tolerance are more likely to survive in an environment that will gradually have increased salinity levels. This initial investment will ensure that the groups are not having to constantly replace plants that cannot survive the conditions.

7.2 *NZ SEARISE*

It is in the best interests of the groups in the lower catchment of the OHR to consider how land subsidence and heave is likely to impact SLR in the coming years. We strongly recommend that this is something that the groups look into. The mouth of the OHR is expected to heave by +3mm a year whilst the New Brighton spit is expected to subside at a rate of -3mm a year (Ministry of Business, Innovation and Employment et al., 2022). With the New Brighton Spit subsiding, SLR impacts are likely to be stronger in Te Ihutai and therefore reaching further upstream. Although some groups have taken into consideration of how the river mouth is supposed to change with climate change, there is still room for further education. The groups that have understandings of what will happen to the river mouth and Ihutai in the future would benefit from educating groups further upstream of what this may mean for them.

7.3 *A COLLABORATIVE ENVIRONMENT*

The final key suggestion is an acknowledgement that the individual groups on the OHR are doing their individual pieces to mitigate the impacts of SLR on their section of the river. However, individual work can only go so far. It is our final key recommendation that the groups operating as a part of the OHRN need to become more cohesive in their SLR mitigation approaches. The communication between groups is crucial to the health of the river as resources can be more strategically applied to the landscape.

8.0 CONCLUSION

Sea-level rise is a growing concern for the Ōpāwaho Heathcote River Network, especially among the volunteer groups in the lower catchment due to the historical frequency of flooding events. Through the means of mapping, literature review and interviews we were able to analyse the impacts of current flood risk and sea-level rise. Through the interview process we found sea-level rise was of mixed concern for groups in the lower catchment. All groups interviewed were aware that SLR will have impacts on their sites, but some had limited resources to prepare and plan for those impacts. Effects of climate change conditions are already felt in the catchment and it will continue to threaten the resilience of the local river community. We found that nature-based solutions will contribute to mitigation against SLR to help build resilience for the groups and wider community. Through the interviews we were able to understand the value of the reserves managed by the groups along the river and how the groups understood and were managing the reserves to protect against SLR. From the research following the interviews, we were able to provide recommendations to continue building resilience. Overall BGI is beneficial in mitigating flood risk particularly regarding SLR. This understanding helps us to inform the overall ŌHRN on how best to plan for future SLR in their restoration projects and build community resilience.

9.0 ACKNOWLEDGEMENTS

First and foremost we would like to thank the Ōpāwaho Heathcote River Network for providing the inspiration for the topic and identifying an area of research that would be of use to them. We would also like to thank Edward Challies for his invaluable guidance and feedback for this research assignment. Further acknowledgements are extended to Dr. Rita Dionisio for her feedback and ideas, the community groups who partook in our interviews, and to our peers who provided us with feedback throughout.

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11.0 APPENDIX ONE

UC School of Earth and Science
Phone: +64 3 369 0655
Email: cbe75@uclive.ac.nz
29/03/2022
HREC Ref: *[Provided by HREC when study approved]*

How can blue-green infrastructure provide flood resilience against sea level rise
Information Sheet for participants

Kia ora

You are invited to participate in a research study on sea level rise and flood infrastructure. This study is being conducted by Chloe Betony and Soul O'Reilly from the University of Canterbury | Te Whare Wānanga o Waitaha (UC). Other research team members include Ed Challies, our supervisor, and Julia Harvey, Amandine Bosserelle and Pippa Sheppard. The study is being carried out as a requirement for GEOG402 – Resilient Cities.

What is the purpose of this research?
This research aims to determine how sea level rise is impacted by, and may further impact, flood infrastructure. We are interested in finding out about flood infrastructure and the role of community groups. The information from this study will help to inform future flood mitigation infrastructure in light of climate change and sea level rise. .

Why have you received this invitation?
You are invited to participate in this research because your group is within our study area and you responded to our request for participants.

Your participation is voluntary (your choice). If you decide not to participate, there are no consequences. Your decision will not affect your relationship with me, the University of Canterbury, or any member of the research team.

What is involved in participating?
If you choose to take part in this research, you will participate in an interview. This interview will take place online via Zoom. I will contact you to arrange a suitable time. The interview will involve Chloe and Soul introducing ourselves, answering any questions you have, and confirming your consent to participate. Then, we will begin the interview and will ask you questions about your group, your projects, and sea level rise. We estimate the interview will take around 20-30 mins.

Will the interview be recorded?
With your permission, the interview will be audio-recorded using Zoom's audio-recording feature. The recording will be used to create a written transcript of the interview, which we will analyse as part of the research. If you choose to review a copy of the interview transcript, I will provide this to you within 1 weeks of the interview. I will ask you to provide any amendments or additions via email within 1 week.

Are there any benefits from taking part in this research?
A potential benefit is that participants will develop further understanding of sea level rise and flood management within the Ōpāwaho Heathcote River.

Are there any risks involved in this research?
We are not aware of any risks to participants in the research.

Support Agency	**Contact Information**
[Name]	*[Phone number or web address]]*.

What if you change your mind during or after the study?
You are free to withdraw at any time. To do this, please let us know either during the interview or after the interview has finished. We will remove any information you have provided up to that point from the data set if it is still possible. Once data analysis has commenced on 02/05 removal of your data may not be possible.

What will happen to the information you provide?
We will transfer the audio recording to a password-protected file on the University of Canterbury computer network and then delete this from the recording device as soon as practical. All data will be confidential. To ensure your identity is not known to anyone outside the research team, we will keep your signed consent form in a file separate from your interview transcript. If you choose not to be identified, your name will be changed to a pseudonym (a fake name) whenever it appears in the transcript and anywhere else. We will store the file that links your real name and your pseudonym) individually on a password-protected, secure device.

All study data will be stored in password-protected files on the University of Canterbury's computer network or stored in lockable cabinets in lockable offices.

All data will be destroyed after completion of the study. Chloe will be responsible for making sure that only members of the research team use your data for the purposes mentioned in this information sheet.

Will the results of the study be published?
Results will also be presented during conferences or seminars to wider professional and academic communities. A summary of results will be sent to all participants who request a copy.

Who can you contact if you have any questions or concerns?
If you have any questions about the research, please contact: Chloe Betony cbe75@ucliv.ac.nz or Soul O'Reilly sno48@uclive.ac.nz

This study has been reviewed and approved by the University of Canterbury Human Research Ethics Committee (HREC). If you have a complaint about this research, please contact the Chair of the HREC at human-ethics@canterbury.ac.nz).

What happens next?
Please review the consent form. If you would like to participate, please sign, scan/take a photo of, and return the consent form to cbe75@uclive.ac.nz *and* sno48@uclive.ac.nz

Chloe Betony and Soul O'Reilly

12.0 APPENDIX TWO

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

UC School of Earth and Science
Phone: +64 3 369 0655
Email: cbe75@uclive.ac.nz
29/03/2022
HREC Ref: *[Provided by HREC when study approved]*

How can blue-green infrastructure provide flood resilience against sea level rise
Consent Form for Participants

- I have been given a full explanation of this project and have had the opportunity to ask questions.
- I understand what is required of me if I agree to take part in the research.
- I understand that participation is voluntary and I may withdraw at any time without consequences. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain possible.
- I understand that any information or opinions I provide will be kept confidential to the researcher [*state who else may have access to the data, if appropriate*]. I understand that any published or reported results will not identify me [*or my employer, organisation, etc., if appropriate*].
- I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form. I understand the data will be destroyed at the end of the project.
- I agree to being video recorded. I understand how this recording will be stored and used.
- I understand that I can contact the researcher Chloe Betony cbe75@uclive.ac.nz or Soul O'Reilly sno48@uclive.ac.nz, or supervisor Ed Challies edward.challies@canterbury.ac.nz for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Research Ethics Committee, Private Bag 4800, Christchurch, (email: human-ethics@canterbury.ac.nz).
- I would like a summary of the results of the project.
- By signing below, I agree to participate in this research project.

Name: Signed: Date:_

Email address *(for report of findings, if applicable)*:_

Thanks for completing this consent form. Please send back a completed copy to Chloe Betony at cbe75@uclive.ac.nz and we (Chloe and/or Soul) will be in contact if there is anything else. Ngā mihi.

13.0 APPENDIX THREE

Interviews will be done with the various groups around the lower catchment to help us understand their role in the OHRN and how they understand the risks of sea level rise on their areas of the catchment. This information will help us meet our objective of defining flood management strategies along the O-H river to compliment the GIS mapping of pre- and post-Earthquake infrastructure.

What are the main goals and activities of your group?
What have been the main benefits of your work
What is the nature of flood risk in the areas where your group works?
What is your understanding of the flood protection and control work in the upper catchment?
How do you think sea level rise might impact on the existing projects?
Have you taken sea level rise and climate change impacts into consideration in planning your existing projects?
How could your work mitigate the impacts of climate change and sea level rise?

14.0 APPENDIX FOUR

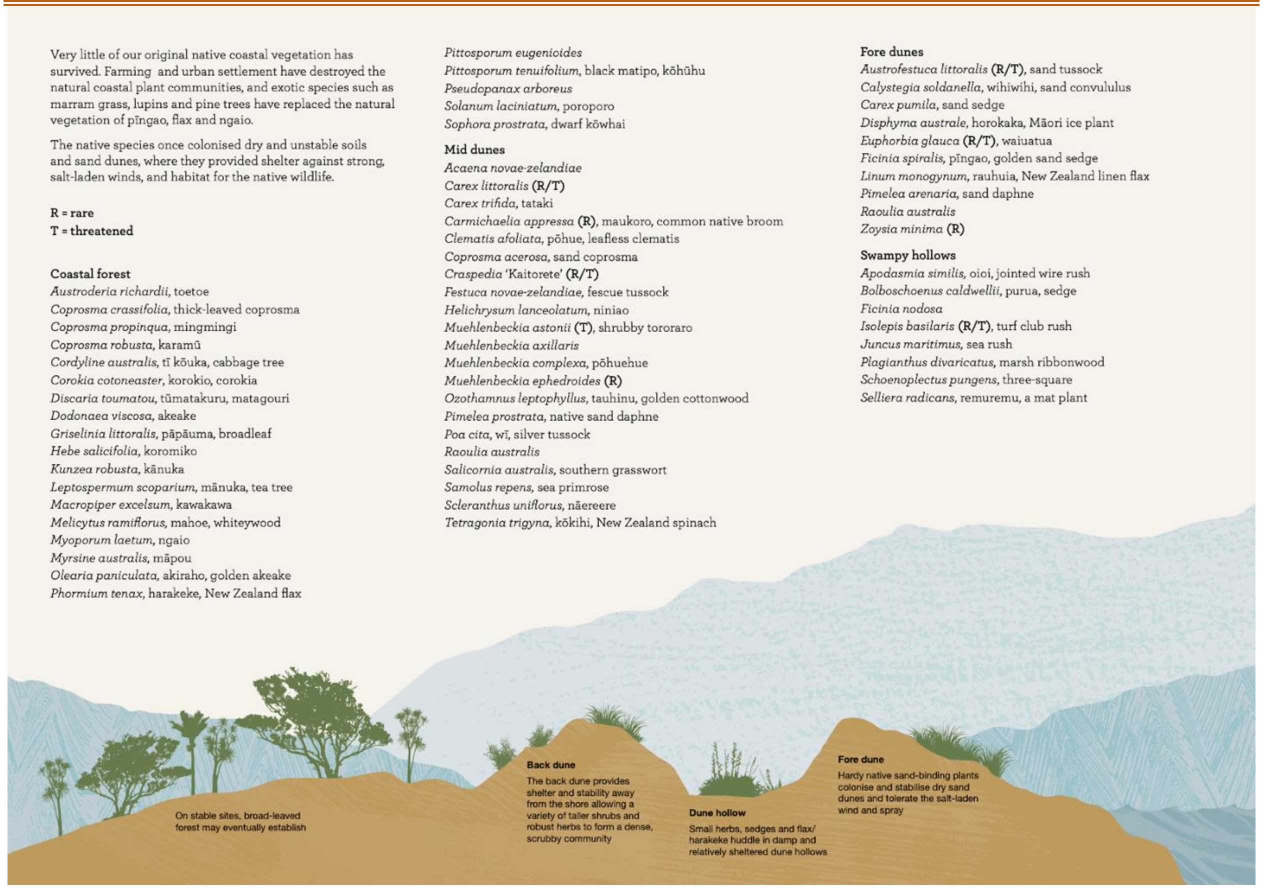

FIGURE 4: SALT TOLERANT PLANT SPECIES (DOC, 2021)