Programme Manager Comment

Tēnā koe,

I am proud to present this special edition of SITJAR as a showcase for student-staff research outputs in the SIT Department of Environmental Management. During the last decade, Environmental Management has emerged as one of the most important fields in New Zealand and internationally. With growing demands on the planet, there is a vital need for kaitiaki to manage and care for the environment and ensure a sustainable future. The students in our programme have made the choice towards a career path that will make a difference in our world, and to them I say: manaaki whenua, manaaki tangata, haere whakamua!

While the staff research accomplishments of the department are mounting and impressive – high calibre publications, international conferences, international research collaborations, overseas exchanges, to name a few – I see student research as complementary to this and would like to recognise their research accomplishments:

In 2019, as final year students of the Bachelor and Graduate Diploma programmes completed their research dissertations, many partnered with community and industry to provide a tangible contribution to society. I believe that the examples set by our world-class faculty researchers, along with the hard work and dedication of supervisors, have fostered incredible research students. Four of our students presented at a national conference, winning Best Overall Poster and Excellence awards, and one graduate has been awarded a research scholarship with Ngā Pae o te Māramatanga. We see bright futures for all our students, and we share with you but a sample of their outstanding work in this edition.

Within, you will find a diverse range of topics in Environmental Management across Southland: from e-waste management (an audit of schools and industries in Invercargill city), to water quality management (riparian planting by dairy farmers in Waituna; and a hydro-chemical assessment of Long White Lagoon), ecology (intertidal ecology of Ulva Island; and ephemeral turf communities in Long White Lagoon), and a socio-environmental study (an examination of public engagement with the Manapōuri hydro-electric power scheme).

I trust you will enjoy this edition of SITJAR and the exciting findings revealed about the environment of Southland and beyond.

Nāku noa,

Dr Christine Liang
Programme Manager
Editor Comment

Kia Ora

Welcome to the Student-Staff Special Environmental edition for the Southern Institute of Technology Journal of Applied Research (SITJAR). Students and staff have worked hard in both carrying out this research and presenting it in a publishable form. All the articles in this edition have been peer reviewed.

Students involved in this edition have been engaged in environmental projects with various organisations including Environment Southland, Fish and Game and the Invercargill City Council to name a few. Contacts with these agencies may be valuable for future employment opportunities. The publications from the student’s perspective is also a valuable asset for their CVs. Several students have expressed an interest in continuing their research at a graduate school level and a publication such as this is a good start. One student was awarded a research internship/scholarship after graduation because of their research project. Also, four students presented at the New Zealand Coastal Society conference where they disseminated their research findings. These are all positive outcomes for the students.

Staff also need to be congratulated for all the hard work they have put into these published proceedings. This includes the supervision of the projects and helping the students get their research up to a publishable, peer-reviewed standard. As the senior editor of SITJAR I can highly commend the staff involved in this special edition for their professionalism, diligence and academic rigour. These staff teach these students the necessary research skills while sharing their passion for the subject area. This was a motivating factor for the students to pursue this research. As experienced researchers these tutors pass on their skills to the students to assist them in their future endeavours.

So again, congratulations to students and staff for a job well done and this special edition is a valued addition to SITJAR.

Dr Jerry Hoffman
Senior Editor SITJAR
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A SURVEY OF THE ADOPTION OF RIPARIAN PLANTING BY DAIRY FARMERS IN THE WAITUNA CATCHMENT

Rebecca Crack and Tapuwa Marapara

ABSTRACT
Throughout the years increasing agricultural development and intensification of farming in the Waituna Catchment, has significantly contributed to the decline of water quality and environmental health of the Waituna lagoon. A range of sustainable land use management strategies are being put in place to reduce the amount of sediment and nutrient inputs to the lagoon. These strategies are envisaged to prevent further decline of water quality and improve the health of the lagoon. The aim of this research was to carry out an investigation on the knowledge and application of riparian planting by dairy farmers in the Waituna Catchment. To fulfil this aim, a questionnaire survey and a vegetation survey of riparian zones were carried out to assess the adoption of riparian planting by dairy farmers along the Waituna Catchment. It was found that farmers were aware of the importance of planting vegetation in the riparian zone and were aware of the general functions a vegetated zone provides, i.e. managing runoff and erosion. This research noted that some dairy farmers surveyed are showing a positive approach to managing water quality deterioration, by adopting the idea of vegetated riparian zones as a source of mitigating agricultural impacts on streams and waterways within their properties. Through this study, it was found that the adoption of vegetated riparian zones, may benefit the catchment as a whole by mitigating negative impacts of unsustainable farming practices. It is recommended to carry out more vegetation surveys in Waituna and other catchments around Southland, to allow for further understanding of the application and establishment of riparian planting by the farming community at catchment level.

BACKGROUND
The Waituna Lagoon is located 40 km east of Invercargill and is part of the 20,000 ha Awarua Waituna Wetland Catchment (Living Water, 2018, para 1). There are three major creeks that flow through the catchment across farmland and discharge into the Waituna Lagoon. These creeks are named the Waituna Creek, Moffat Creek and Currans Creek (Baines, 2015, para 1). In 1976 the Waituna Lagoon and surrounding wetlands were designated under the RAMSAR Convention as being of International Significance. Water quality in the Waituna Catchment is poor due to high levels of suspended sediment and nutrients as a result of increasing agricultural development (Environment Southland, 2012, p1). One of the solutions to achieving sustainable land use for improved water quality is to harness the abilities of riparian zones. Riparian zones absorb excess nutrients and process waste minerals before they enter waterways (Collier et al., 1995, p 4). Below is a map showing the location of the Waituna Catchment (Figure 1).
The aim of this study was to determine the knowledge and application of riparian planting by dairy farmers in the Waituna Catchment.

This research adopted two methods to achieve the aim:

- **Qualitative Method – Phone Surveys**
- **Quantitative Method - Vegetation Surveys**

**Phone Survey**
A survey was created with both open and closed questions for the participants to respond. Contact details for 12 possible participants were collected, and subsequently called to ask if they would like to participate in a 10-minute survey. Once the survey was completed, all participants were asked for permission to undertake a vegetation survey on their property (Please see Appendix A for a copy of the survey questions). A total of 10 out of the 12 possible participants decided to participate in the phone survey.
Vegetation Survey

Six vegetation surveys were undertaken, and the locations of these surveys are shown as GPS points on the map to the right (Figure 2).

Vegetation Survey Method

Random site selection was used to select a sample site. A GPS was used to record the coordinates of the selected vegetation site for the survey.

A measuring tape was used to quantify the width of the riparian zone (width measurement was 3m-5m) and an 8m long strip was measured out and a standard was placed at each end to create a quadrat. This quadrat is shown on the diagram to the below (Figure 3). Three planting zones (lower bank, upper bank, grass strip) were identified and the width of these zones were measured.

Figure 3 shows a vegetated riparian zone that was randomly selected, and the measurements used for a quadrat in the vegetation survey.
The plant species from within the 3 planting zones were identified, counted and recorded (Figure 4). Around 5 plants were then randomly measured to record the width between each planting in the upper and lower bank zones. Specifically, this was carried out by measuring from the middle of the first plant to the middle of the second plant.

There were two sites where the riparian planting zone was too thick and overgrown for the researcher and assistant to enter so the method had to be adapted for these two sites. The width measure of the whole riparian zone was taken at a crossing and was measured by eye from the waterways edge to the fence line. The three zones were measured this way. A random site was then selected by the researcher and assistant, a standard was placed into the ground near the fence line. When measuring the plant width, the researcher and assistant measured this by holding the tape up to the fence line and start at the middle of a selected plant and measuring to the centre of the next plant.

RESULTS

Phone Survey Results

In total ten participants completed the phone survey (Figure 5). All of the participants knew what a riparian zone was and knew the functions of a riparian zone. The two functions of a riparian zone stated the most by the participants was reducing run off and nutrient leaching, other functions mentioned and known about was riparian zones up take excess nutrients, act as a filtering zone, they provide shade for the waterway, the roots stabilize the stream banks to help stop erosion and riparian zones are fenced to keep stock out of the waterway (Figure 6).

Participants planted out their riparian zones to serve as a buffer to stop pollutants from entering the water way (Figure 6). Reasons such as shelter for animal species and to stop bank erosion were mentioned (Figure 6). Other reasons for participants planting out their riparian zones were due to needing plantings for consent and to add character to the property (Figure 6).
**Do you know what a riparian zone is set to achieve?**

*Please State*

![Figure 5. Results from survey questionnaire Question 2.](image)

<table>
<thead>
<tr>
<th>Functions Stated</th>
<th>Number of Times Mentioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run off</td>
<td>12</td>
</tr>
<tr>
<td>Up take of Nutrients</td>
<td>2</td>
</tr>
<tr>
<td>Filtering Zone</td>
<td>4</td>
</tr>
<tr>
<td>Shading of Waterway</td>
<td>6</td>
</tr>
<tr>
<td>Erosion</td>
<td>8</td>
</tr>
<tr>
<td>Visually Appealing</td>
<td>10</td>
</tr>
<tr>
<td>Keeping Stock Out of Waterway</td>
<td>12</td>
</tr>
</tbody>
</table>

**Why did you plant out your riparian zone?**

![Figure 6. Results from Survey questionnaire – Question 10.](image)

<table>
<thead>
<tr>
<th>Reasons why the riparian planting zone was established</th>
<th>Times Mentioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop bank erosion</td>
<td>0</td>
</tr>
<tr>
<td>Serve as a buffer to stop pollutants from entering waterways</td>
<td>5</td>
</tr>
<tr>
<td>To serve as shelter (Wind Breaker) for animal species</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>
Seventy percent of participants stated they had planted out their riparian zones while 30% stated that they had not planted their riparian zones (Figure 7). Participants that did not have planted out riparian zones were asked if they would consider planting. 33% stated that they would consider planting while 67% stated they would not consider planting (Figure 8).

Common concerns of riparian planting zones were plant roots blocking tile drains and the maintenance of the plantings (Figure 9). Cost was another major concern and Time was also mentioned as a concern (Figure 9). Participants stated that there "Main concern is that it is very costly and found out that willow and deep-rooted plants block tile drains and this therefore can ruin the paddocks" and that "Cost is a major concern it cost $12.50 per plant each day from when you buy the plant to planting the plant and for the maintenance of that plant and this can last up to three years before the plant is well established or mature. Maintenance is very costly I spent $10,000 before even planting a plant – this was just preparing the area for planting."

**Concerns about riparian planting?**

- Blocking of Tile Drains
- Management of Riparian Zone
- Time
- Maintenance
- Cost

*Figure 9. Results from Survey questionnaire – Question 12.*
Vegetation Survey Results

Six vegetation survey sites were randomly selected. Majority of the upper and lower bank zone measurements were 1 metre wide and that all of the Grass Strip zones measured were 1m wide (Figure 10). A further two Lower bank zones were measured at 1.5m and 1 was 2.5m. With the last 3 Upper Bank Zone measurements being one at 1.5m, 2.3m and 2.5m wide (Figure 10).

Figure 10. Results from vegetation survey – Total Measurements of Riparian Zone.

Toe Toe was a common plant found in the lower bank zone along with carex and red tussock. Many pest plants were identified in this zone (Figure 11). Red Tussock was the most common planting found on the upper bank zone along with toe toe. Other plantings that were found on this zone were flax, manuka, wire rush, cabbage tree, mingimingi and hebe. In one site a sprayed gorse plant was found (Figure 11). The grass strip did have some plant species identified but this was mainly pest plant species such as buttercups and broom. One plant species that was identified in this zone was wire rush but these were self-seeded plantings.

Majority of plantings in the upper and lower bank zones had a 1.2m-1.5m width between plantings. At 2 sites the lower bank zone did not have any measurement taken as this was due to there being no planting width between them or no plantings in the zone. Plantings in the upper bank zone had a 1m planting width between each planting.

Figure 11. Results from vegetation survey – Total Plant species identified.
DISCUSSION

Phone Survey

Figure 5 shows that all participants know that a riparian zone reduces run off, acts as a nutrient filtering zone, shades the water way, reduces erosion, keeps stock out of waterways and is visually appealing. This finding suggests that the participants may have been educated on riparian zone functions by Environment Southland (Environment Southland, 2017, p 2). Results from Figure 5 correlate with Environment Southland (2017), as they state that riparian zones have been proven to decrease the amount of sediment, bacteria and nutrients entering waterways due to runoff (Environment Southland, 2017, p 2). By creating an effective Riparian Zone this can significantly reduce impacts on water quality and biodiversity. In farming a Riparian Zone is created is to keep stock out of the waterway and to create a buffer between the land and water to reduce bacteria while also reducing soil and nutrient losses (Environment Southland, 2017, para 3). Environment Southland have Land Sustainability Officers who offer on-farm advice, organise field days and work with community groups to raise awareness of issues and good environmental management practices and these officers may have educated the dairy farmers in the Waituna Catchment. Figure 6 shows participants have chosen to plant out their riparian zones to stop bank erosion, and pollutants from entering waterways, as well as to serve as shelter, and other (Retired Land, comply with consent). This result correlates to an article written by Environment Southland (2017), as the article states that riparian zones have been proven to decrease the amount of sediment, bacterial and nutrients entering waterways due to runoff (Environment Southland, 2017, p 2), and that creating an effective riparian zone can significantly reduce negative impacts on water quality and biodiversity. In farming a riparian zone is created is to keep stock out of the waterway and to create a buffer between the land and water to reduce bacteria entering the waterway while reducing soil and nutrient losses from the land (Environment Southland, 2017, p3).

Environment Southland have Land Sustainability Officers who offer on-farm advice, organise field days and work with community groups to raise awareness of issues and good environmental management practices and these officers may have educated the dairy farmers in the area. There are other organisations such as DairyNZ and the Living Water programme who may have also educated and answered questions from dairy farmers in the Waituna Catchment on the functions of a riparian zone. Figure 7 shows that 70% of the participants had planted out their riparian zones while 30% hadn’t planted out their riparian zones. This suggests that 70% of the participants that had planted out their riparian zones may be part of the 48 dairy farms within the catchment that have worked away at reducing the effects of certain farming practices (Land &Water, 2014). Figure 8 shows Sixty-seven percent of the participants stated that "No", they would not consider planting while 33% stated that "Yes" they would consider. The results from Figure 8 were a follow up question to Figure 7 and was asked to the participants that had stated that they had not planted out their riparian zones. This question was asked if they would consider planting out their riparian zones. Sixty-seven percent of the participants stated that "No", they would not consider planting while 33% stated that "Yes" they would consider. The researcher did not question the participants further on why they would and would not consider planting. The researcher can only assume that the participants that would consider planting may be consulting with DairyNZ’s on-farm consultants and/or Environment Southland Land Sustainability Officers to create a riparian planting management plan and just have not gotten underway with the preparation and planting process. While the participants that are not considering planting out their riparian zones may have a viable reason for their decision, the researcher did not ask for any further detail to discuss this result further. In Figure 9 it was found that participant’s main concerns in this order, was the blocking of tile drains, cost, maintenance, time and management of the riparian zone. One participant stated that when planting the riparian zone, there is a "need to keep in mind that cleaning of waterways is a requirement, so don’t want wide riparian zones. Don’t plant trees as they tend to block up drainage systems as they have large roots. Can be time consuming and hard to establish the riparian vegetation.” This statement is backed up by DairyNZ (2013) as their step by step riparian planting guide, mentions that maintaining access to drains is important and to only plant one side of the waterway – preferably the north bank, to provide shade in the summer. DairyNZ (2013), states planting deep-rooted plant species should
be avoided especially in the upper bank zone as many tile drains are located in this zone. Cost is the next major concern participants had. In a report prepared for the Ministry for Primary Industries (MPI) by The Agribusiness Group (TAG) (2016), this report identifies the costs of fencing and riparian planting in the context of eluding stock from waterways across New Zealand. This report discusses and looks into Environment Southland’s, in-house calculator that can be used to calculate the total fencing materials and labour costs of Sheep/Beef at $10.00 per metre, Dairy at $4.14 per metre and Deer at $16.80 per metre fencing as well as the cost per metre of riparian planting of native grasses at $1, poplars at $2 and native shrubs and trees at $3 (TAG, 2016, p 9). This in-house calculator could be beneficial for participants that were concerned about cost, to give them an idea of a budget to work to with no surprise costs involved.

The last three concerns of maintenance, time and the management of the riparian zone can be explained further by stating that once a riparian zone has been established, it needs regular maintenance in order to stay functional and effective. Creating an effective riparian zone is an investment and to keep the riparian zone functioning properly regular maintenance must be undertaken. This includes checking and maintaining fences especially after strong winds and flooding – this is to keep stock out as they can damage the riparian zone (Environment Southland, 2016, p 1). Keep pest weeds to a reasonable level, have control plans for pest animals, prevent or repair damaged plant protectors and only remove when plants are well-established and secure, as well as preventing or repairing any bank erosion to protect fences and plantings (Environment Southland, 2016, p 2). Maintenance and Management of the riparian zone does take up time but as stated above, an effective riparian zone is an investment and to keep the riparian planting zone functioning properly regular maintenance must be undertaken.

Vegetation Survey

The results in Figure 10 show that all five of the grass strips measured were 1 metre wide. There were only five grass strips measured as one site did not have a grass strip, due to the plantings maturing and expanding into this zone. The 1 metre measurement of this zone correlates to the Riparian Planting Guide published by DairyNZ (2006), that states that the Grass Strip should be one metre wide and be left unplanted to act as a buffer between all fences and waterways, to help filter sediment, phosphorus and faecal bacteria from runoff before it reaches the water (DairyNZ, 2006, para 1). The grass strip is used to prevent plants from shorting out electric wires – due to as plants mature they expand in size. The upper bank zone had a range of different measurements with half of the measurements (3) being 1 metre wide and the other half (3) ranging from 1.5, 2.3 and 2.5 metres. The lower bank zone also had a range of different measurements with half of the measurements (3) being 1 metre wide, 2 measurements being 1.5 metres and 1 being 2.5 metres. The Riparian Planting Guide published by DairyNZ (2006), recommends that each zone should be at a minimum 3 metres wide (DairyNZ, 2006, para 1) and this compares to the results above discussing the riparian buffer zone width of 3 metres. As majority of the riparian buffer zone width measurements were 3m this means that majority of the planting zone measurements will be 1 metre wide. Reasons for the upper and lower bank zone measurements being 1.5, 2.3 and 2.5 metres is due to two of the sites were a vegetation survey was undertaken had buffer zone width measurements of 4 metres and 5.8 metres. Another reason for these planting zone measurements is that, one site did not have a grass strip that could be identified. Overall, it was found that from undertaking a vegetation survey on six different sites that there were ten main plant species identified (Figure 11). These plant species are all indigenous to New Zealand and were identified as being Carex secta (pukio), Chinochloa rubra (red tussock), Austroderia richardii (toetoe), Cordyline australis (cabbage tree), Phormium tenax (flax), Coprosma propinqua (mingimingi), Hebe salicifolia (koromiko), Leptospermum scoparium (manuka), Coprosma lucida (karamu) and Apodasmia similis (wire rush). Pest Plants such as bracken, blackberry, broom, gorse and buttercups were also identified along with some sprayed pest plants such as nodding thistle, bracken and gorse. The sprayed pest plant species show that maintenance and management of the riparian zone is undertaken by the landowner, but this can only be assumed as there was no investigation into why these plants were dead. Five of the plant species mentioned above cabbage tree, pukio, red tussock, mingimingi and flax were all mentioned by DairyNZ (2006) as being ideal to start off in a riparian planting zone as they hardy,
fast growing and can be planted straight into pasture and don’t require shelter / nursery plants to grow (DairyNZ, 2006).

Environment Southland and DairyNZ both have Riparian Planting Guides that are easy for landowners to access. Both of these guides recommend plant species suitable for planting in the riparian zone and also recommends which planting zone (upper or lower bank) to plant each species mentioned. Looking at the results collected, all plant species that were identified are all listed within these Riparian Planting Guides from Environment Southland and DairyNZ. It can be assumed that landowners have had access to these guides and researched into plants suitable for riparian zones or landowners may have been educated by organisations such as DairyNZ who have on-farm consultants and also hold field days where farmers are welcome to come along and see different farming practices being mitigated through different farm management practices. Landowners may also have been educated by the Regional Council (Environment Southland) who have Land Sustainability Officers who offer on-farm advice, organise field days and work with community groups to raise awareness of issues and good environmental management practices. Some of the Participants mentioned that they had help through the Living Water programme as this programme is a 10-year partnership between Fonterra and the Department of Conservation whose focus is to find game changing and maintainable solutions to enable farming, freshwater and healthy ecosystems to thrive in harmony (Living Water, 2018, p 1).

CONCLUSION

Farmers within the Waituna Catchment are aware of the importance of planting vegetation in the riparian zone and of the general functions a vegetated zone provides i.e. managing runoff and erosion. This research showed that some of the dairy farmers surveyed within the Waituna Catchment are showing a positive approach to managing water quality deterioration, by adopting the idea of vegetated riparian zones as a source of mitigating agricultural impacts on streams and waterways within their properties. Through this study, it was found that the adoption of vegetated riparian zones, may benefit the Waituna Catchment as a whole by mitigating negative impacts of unsustainable farming practices. However, vegetated riparian zones are not the sole solution to improving water quality. Other supportive measures such as fencing, reducing overland flow pathways, and integrated catchment management can be adopted.
REFERENCE LIST


APPENDIX A – PHONE SURVEY

Research title: A Survey in the Adoption of Riparian Planting Zones in the Waituna Catchment

Survey Questionnaire:

1) Do you know what a riparian zone is?
   - Yes
   - No

2) Do you know what the planting of riparian zones is set to achieve? Please state:
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

3) Do you have any waterways running through or around your property?
   - Yes. How many? __________ (go to question 5)
   - No (go to question 4)

4) If you did have waterways running through your property, would you consider planting out your riparian zone?
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

5) Have you planted your riparian zones?
   - Yes (go to question 6)
   - No (go to question 5a)

5a) If no, would you consider planting them?
   - Yes (go to question 11)
   - No (go to question 12 and survey is completed)

6) What age is your riparian planting zone?
   - < 1 year
   - 1 to 5 years
   - 5 to 10 years
   - Over 10 years
7) Do you keep expanding your current riparian zone with new plantings?
- Yes
- No

8) Can you state what species have been planted?
_____________________________________________________________________________________________________
_____________________________________________________________________________________________________
_____________________________________________________________________________________________________

9) Are they exotic or indigenous species?
- Mostly exotic
- Mostly indigenous
- Mixture of both species

10) Why did you plant out your riparian zone?
- Stop bank erosion
- Serve as a buffer to stop pollutants from entering waterway
- To serve as shelter for animal species
- Other: Please specify ________________________________

11) Do you know the water quality status of stream(s) on your property?
- Yes (go to question 11a)
- No (go to question 11b)

11a) If yes, has the water quality of the stream(s) improved with the planting out of riparian zones?
- Yes
- No

11b) If no, would you like to know the water quality of the streams running through your property?
- Yes: Please specify why
- No: Please specify why

12) Please state if you have any concerns about riparian planting, in terms of cost, maintenance, time and the management of the riparian zone.
_____________________________________________________________________________________________________
_____________________________________________________________________________________________________
_____________________________________________________________________________________________________
13) What was the biggest cost of creating your riparian planting zone?
- Fencing the riparian buffer zone off
- Pest Management
- Spraying/clearing of area pre-planting
- Stream bank reconstruction
- Planting of riparian vegetation
- Other: Please specify _____________________________________________________________________________

14) What have you spent on your riparian zone so far?
- Less than $10,000
- $10,000 to $15,000
- $15,000 to $20,000
- Over $20,000

15) Would you recommend other farmers to plant out their riparian zones? State reason.
- Yes __________________________________________________________________________________________
- No
DAMMING THE DAM SIXTY YEARS ON: CONTINUED CONFLICT OVER THE MANAPŌURI HYDRO-ELECTRIC POWER SCHEME, NEW ZEALAND

Debbie Ellis and Anna Palliser

ABSTRACT

Almost half of New Zealand’s electricity is generated from hydro-power and the Manapōuri Hydropower Scheme, which first began generating in 1969, is New Zealand’s largest, with a current maximum output of 800MW, enough for 619000 homes (Meridian Energy, n.d.). The Manapōuri plant takes water from a lake and river system largely located in Fiordland, a National Park located in the mountains of Southland, South Island, New Zealand. This is an unusual hydro scheme in that its freshwater take is diverted directly into the ocean after passing through turbines, thus it can be considered as freshwater abstraction rather than diversion. Most New Zealand river or lake based hydro power plants retain or divert freshwater, releasing it after use back into the freshwater system (Young, Smart and Harding, 2004).

Before the plant was built, freshwater from the lake and river system flowed out to sea via the Lower Waiau River, which used to be New Zealand’s second largest river, with a flow of around 400 cumecs\(^1\) (“Waiau River”, n.d.). However, this river was deemed a sacrificial river\(^2\) (Guardians annual report, 1994) and most of its flow was diverted to the ocean once the power plant began operating. Any water allowed to flow down this river would not pass through the turbines and thus would entail a loss of electricity production for the Manapōuri Power Scheme.

This paper examines public involvement with environmental impacts of this hydro plant through the lens of Environmental Communication literature. It discusses the history of this public involvement, with a focus on the Lower Waiau River. Three participatory groups are examined: The Guardians of the Lakes, originating in the early 1970s, the Waiau Working Party, originating in the early 1990s, and the Waiau Rivercare Group, originating in 2017. All three groups are still operational. Using desktop research as well as interviews with locals living along the Lower Waiau River and email and telephone communications with members of relevant community groups, the paper probes the changing picture of public involvement with Manapōuri power plant impacts.

Despite exemplary approaches to public participation with environmental decision-making related to the hydro plant from the 1970s through the 1990s, the paper concludes that the power of community participation groups to effect change has reduced in recent years due to a combination of increased formality in New Zealand public participation processes and drives for increased profitability from the plant managers. This research is still ongoing.

\(^1\) Cumecs means cubic metres per second

\(^2\) Sacrificial river means there would be no attempt to keep the river flowing well, it would be sacrificed for the power scheme.
INTRODUCTION

The Manapōuri Hydropower Scheme

The Manapōuri Power Scheme (MPS) is owned by Meridian Energy, a company which generates over a third of New Zealand’s electricity, with 51% of its shares owned by the New Zealand Government (“The New Zealand Government”, n.d.). The main driver for the construction of this plant was generating enough electricity to power an aluminum smelter located near Bluff, Southland, South Island (Fitzgerald, 2000). This smelter, which is now owned and operated by Rio Tinto (a global mining company), currently requires a high percentage of Manapōuri’s generating capacity (“New Zealand’s Aluminium Smelter”, n.d.).

The MPS can be seen in Figure 1. The Upper Waiau River links Lake Te Anau to Lake Manapōuri, while the Lower Waiau drains Lake Manapōuri. The Mararoa River also flows into Lake Manapōuri. Control gates at Lake Te Anau control water flowing through the Upper Waiau River to Lake Manapōuri. The Manapōuri control structure ensures the waters of the Waiau and Mararoa rivers initially flow into Lake Manapōuri, with a controlled outflow to the lower Waiau, which can be seen to the left of the control structure shown in Figure 2 (ringed in red). The Mararoa river can be seen to the right of Figure 2, as it flows into the larger body of water seen in Figure 2. This larger water body is actually the Lower Waiau River, with most of its waters diverted from its natural flow to be sent back into the lake.

The power station is located on the West Arm of Lake Manapōuri, inside a large constructed tailrace tunnel that leads through the mountains to Deep Cove in Doubtful Sound, a fiord linked to the Tasman Sea. In 2002 a second tailrace tunnel was completed, running parallel to the first, as it was discovered the single tailrace did not allow the generating capacity originally proposed (Meridian, n.d.).
"The Save Lake Manapouri Campaign"

Initial plans for the MPS proposed raising the Manapōuri Lake level by 25 metres, (although this was later amended to 8.2 metres) and raising Lake Te Anau levels to their maximum natural level for unnaturally long periods of time. The proposal resulted in a rapidly growing protest from the New Zealand public, who opposed damage to the scenic values of this iconic area of natural beauty and the environmental values of the surrounding native vegetation (Fitzgerald, 2000). Under the National Parks Act 1952, areas so designated, like Fiordland National Park, should be preserved as far as possible in their natural state in perpetuity, for the benefits of the New Zealand people, principles the hydro proposal was overriding (Mark, Turner & West, 2001).

By the late 1960s the protest had become a nation-wide "Save Lake Manapōuri Campaign". A petition organised by Forest and Bird, the largest New Zealand conservation NGO, was signed by 10% of New Zealanders and nation-wide marches took place (Mark et al., 2001). This was New Zealand’s largest ever environmental campaign to that date. Nationally co-ordinated, it included speaker tours around the country, selling one dollar share certificates to support the campaign and free boat tours on Lake Manapōuri (Warne, 2009). The protest is widely considered to have been the birth of environmental awareness in New Zealand and to have toppled the government of the time; in the 1972 general elections, the Labour party ousted the National party Government on the strength of Labour’s commitment not to raise lake levels (Warne, 2009).

Figure 2. Lake Manapouri control structure showing the Waiau River and the Mararoa River. From Palliser, 2019, personal photograph at Lake Manapouri control gates

3 Lowland podocarp forest and beech forest
In an unprecedented move, the incoming Labour prime minister then appointed a group of six of the most prominent campaigners to become the “Guardians of the Lakes”, to supervise the management of the two lakes and associated rivers (Warne, 2009). Provision for the “Guardians of the Lakes” was enshrined in legislation under the Conservation Act 1986 and the Guardians continue in their role to the present day. Their role will be discussed further below in the results section. Figures 3 and 4 show a rock placed near Lake Manapōuri at the point the lake level would have reached had it been raised and a placard commemorating the campaign, which is placed on the rock.

LITERATURE REVIEW

Some impacts from hydropower dams

The use of dams for hydropower can have a significant number of impacts. If natural water levels are raised by the dam structures, shoreline natural and human habitats can be flooded, leading to changed ecosystems and human resettlement. Sediment flow patterns are also disrupted, while rapid changes of river flow rates and lake levels can also impact ecosystems. In addition, dams create an obstacle, both to natural water flows and to the movement of fish and other wildlife (Young, Smart & Harding, 2004). Diadromous fish, which migrate between sea and fresh water, such as New Zealand eels and lamprey, may be blocked from their natural migrations to the sea, or may be killed by passing through turbines, while their young may be blocked from migrating back up river to mature. For more detail on hydropower impacts in New Zealand see Young et al. (2004).

A brief overview of the Resource Management Act 1991: aspects relevant to this paper

This act replaced more than 50 previous Acts and provided an integrated approach to the management of New Zealand’s natural resources (Mark et al., 2001). Underpinning this Act is the concept of sustainable management of physical and natural resources. Any development requires environmental impacts being appropriately managed (“Environment Guide: Introduction”, n.d.). Under this Act, New Zealand’s regional councils are responsible for developing regional plans that detail activities that are permitted and activities that require a range of different consents or permissions before they can be carried out (Waitaki District Council, n.d.). For example, if an activity is classed a controlled activity in a regional plan, the council must grant consent for this activity, although it may impose conditions under which the activity must be carried out. Another activity may be classed a discretionary activity, in which case the council may either withhold or grant a consent and if it grants the consent, may impose conditions under which the consent will be granted (Ministry for the Environment, n.d.).
If activities are classed as notified, then the public must be informed and have a right to put in a submission for or against the activity. Resolving the issues raised in these submissions may require a hearing organised by the Regional Council, where people can discuss their submissions with the council forming a decision after this (Ministry for the Environment, n.d.). If submitters are unhappy with this decision, they can apply to the Environment Court, which holds a hearing and makes a final decision after this (Ministry for the Environment, n.d.). When regional councils update or write new plans, the public can follow the same process of making submissions, attending hearings and appealing to the Environment Court regarding the contents of the proposed plan. The Regional Council that covers the area occupied by the MPS is Southland Regional Council (SRC).

Environmental Communication

It is increasingly being recognized that effective public participation is essential for successful environmental governance (Conley and Moote, 2003; Cundill, Cumming, Biggs and Fabricius, 2012; Philips, Carvalho and Doyle, 2012; Senecah, 2004) and many studies aim to understand what constitutes effective participation (Brulte, 2010; Philips, 2011; Spangenberg, 2011, Stirling, 2010). Reed (2008) considers empowerment, equity, trust and learning to be key principles underlying participatory approaches. However, in practice stakeholders may have a limited degree of input; for example, local knowledge and perspectives may be marginalised in favour of those from government agencies and scientists. This can undermine the development of the collaborative relationships that appear necessary for successful governance approaches (Ulrich and Reynolds, 2010). Scientists may assume their role is to present the facts, with local roles limited to presenting local values (Healy, 2009) or government agency representatives may consider locals are not able to grasp the complexity involved and so not able to make reasoned decisions (Senecah, 2004). Policies may call for public participation, yet participants may become disillusioned and demotivated if their knowledge is devalued (Linke & Jentoft, 2014) or if science is presented in ways opaque to non-experts (Wilson and Jacobson, 2013).

If participatory processes are not considered meaningful by participants, conflict can result (Senecah, 2004). Locals may develop a deep distrust of authorities if participatory approaches do not allow access to participants (that they are heard and can engage with understanding), standing (that their perspectives are given respect, esteem and consideration) and influence (that they can play a meaningful role in decision-making) (Senecah, 2004). Formalising participatory approaches into institutionalised processes, for example formal hearings and submission-writing, rarely fulfil these three criteria (Philips, 2011; Senecah, 2004). Such formalised processes are usually designed and controlled by the government authorities who have the final decision-making power (Philips, 2011) and having no say in how such processes should happen can leave local people feeling disempowered and
resentful (Adger, Brown and Tomkins, 2005). In addition, even if local groups work collaboratively towards good environmental outcomes, national legislation may mean they are excluded from any meaningful final decision-making (Dodson, 2014).

Well-designed stakeholder engagement brought in early in a policy-making process can build outcomes which are effective and socially legitimate (Kemmis and McKinney, 2011). Processes that engage the public in dialogue and deliberation and the co-production of knowledge are increasingly being considered more likely to lead to such outcomes (Irwin, Jensen and Jones, 2014; Philips, 2011; Popa, Guillermin and Dedeurwaerdere, 2015). The ‘deliberative turn’ in public participation theory and practice calls for dialogue and deliberation about the knowledge used to inform policy and the management options available. When stakeholders deliberate together they can form understandings regarding diverse perspectives and different knowledges and can have discussions that lead to effective decisions (Daniels and Walker, 2001; Philips, 2011; Walker, 2007). One deliberative participatory approach that has been used successfully for over twenty years is ‘collaborative learning’ (see Daniels and Walker, 2012). Such approaches are still not common in New Zealand (Eppel, 2014).

The challenges of environmental governance arise from the complex social-ecological systems in which such governance is embedded. In these systems all available knowledge usually contains inherent uncertainties, while the values and perspectives of stakeholders may be diverse and even conflicting (Anderies, Walker and Kinzig, 2006; Armitage, 2008; Waltner-Toews, Kay and Lister, 2008). In such situations, effective participatory approaches require knowledge holders to be transparent regarding uncertainties, assumptions, their values and interests and to be open to questions, criticism and discussion from stakeholders regarding the value of their knowledge for the situations in question (Jasanoff, 2017; Urlich and Reynolds, 2010; van den Hove, 2007). Consequently, when the knowledge used to inform environmental governance is uncertain and incomplete, dialogue and deliberation between stakeholders becomes of key importance (Lindenfield, Hall, McGreavy, Silka and Hart, 2012). ‘Deficit approaches’ to science communication, which simply inform the public of scientific results can impede effective participation, reducing the opportunities for stakeholders to work together in problem-solving (Brulle, 2010). As Dutta (2011) explains, dialogue builds trust and assists groups with different cultures and values as they strive to reach common understandings.

**METHODOLOGY**

*Desktop research*

This paper relies quite heavily on desktop research because the researchers were asked to delay interviews planned for this year until after the Environment Court Hearings discussed below. Consequently, the history of public involvement of the MPS, and much of the information about the Guardians of the Lakes, the Waiau Working Party and the various consents and hearings discussed has come from material found on-line.

*Interviews*

In early 2018 the researchers were invited by the Waiau Rivercare Group to interview local residents in the Lower Waiau area about the changes they had seen in the Waiau Estuary and coastal region over their time in the area. Eight interviews were undertaken with residents who had mostly lived in the area all their lives (several residents were over sixty years of age). These interviews all took place in the homes of the residents and lasted between an hour and three hours. The interviews were semi-structured, so although there was a list of topics to be covered, the conversations ranged over a wide variety of topics depending on what interviewees considered important. The interviews were recorded and notes and quotations taken from the recordings. Information sheets and consent forms were given to all interviewees. All notes were examined in detail multiple times to look for themes.

Two telephone conversations took place in 2019 with stakeholders involved with the local groups discussed in this paper. These were approximately of

*Topic areas:*

1. How long have you lived here?
2. How do you understand the rivers cycles and changes taking place before and after the Manapōuri Scheme?
3. Species are indicators of the health of these systems, what changes have you seen in species?
4. What have you seen from modifications to the river system?
5. Do you think the community has been heard or considered by the developers or councils?
30 minutes duration and were not recorded; notes were taken throughout the conversation. The focus of these conversations was on group processes. This is a small community, so all identifiers were removed from quotations in this paper, with interviewees given a numerical identifier only in order to protect anonymity. Relevant information from these interviews and telephone conversations, information from statements submitted for an Environment Court hearing, and details from the Guardians of the Lakes annual reports are discussed in the results section below.

RESULTS

The Guardians of the Lakes

The Guardians were chosen for their relevant expertise and included a plant ecologist, a civil engineer, a farmer and the manager of a local tourism operator (Mark et al., 2001). Their remit was to recommend MPS operational limits to preserve the health of the lakes and associated rivers (Warne, 2009). They were also required to make recommendations related to any ecological or social impacts arising from the MPS. They were to produce an annual report to the Department of Conservation (DOC) and were allowed access to all relevant information gained over time by the government and to request any information they needed to carry out any required studies (Mark et al., 2001).

The guidelines for management eventually proposed by the guardians were approved by government in 1977 and formally gazetted in 1991. They have changed very little since 1991 although a review of them has recently been proposed (Guardians annual report, 2018). The power company must comply with these guidelines to their best endeavours, reporting on any exceedances (Mark et al., 2001). The Guardians are also involved in environmental monitoring of the lakes and rivers system. Intrinsic to the role of the Guardians is building good relationships with the company controlling the MPS. Initially this was the Electricity Corporation of New Zealand (ECNZ), a New Zealand State-owned Enterprise. However, in 2000 this company was split into three and Meridian Energy took over the MPS, with the government selling off 49% of Meridian’s shares to a private company in 2013. Annual reports of the Guardians from 1994 show many examples of MPS consulting with and asking permission from the Guardians. Examples are:

‘Consultation between ECNZ and the Guardians during these periods of low inflows was important’ (Guardians annual report 1997);

‘The Guardians were notified of a possible flush of dirty water entering lake Manapouri from backflows of the Mararoa River during construction of the fish pass’ (Guardians annual report 1999);

‘The year ending June 2013 saw a continuation of the strong consultative and advisory processes established throughout the long history of the Guardians…… Meridian Energy responding by keeping in close contact with Guardians (Guardians annual report 2013).

Annual reports also show several examples of the Guardians opposing MPS proposals; for example, in 2009 they submitted against a proposal from Meridian to SRC to increase the maximum discharge to Doubtful Sound (Guardians annual report 2010). SRC acted against the Guardians submission in this case, which is discussed further below. In 2018 the Guardians opposed a proposal by Meridian to lower the minimum level of lake Te Anau; subsequently, Meridian decided to withdraw this proposal (Guardians annual report 2018).

Waiau working party

The passing of the RMA 1991 meant consents had to be issued for the MPS by Southland Regional Council (SRC). During the process of developing these consents (with attached conditions) the Waiau Working Party was established. Funded by ECNZ, it consisted of interested members of the community, Guardians representatives, conservation NGO representatives and was chaired by a member of SRC (Mark et al., 2001). Focused on MPS impacts to the Waiau River, this group decided on scientific studies to be carried out and proposed conditions that should be applied to any consents granted to the MPS. The Waiau Working Party is still in
operation (Mark et al., 2001).

While the Upper Waiau River had minimum flow levels established to preserve ecological values, under original agreements the Lower Waiau did not. Severe effects on the Lower Waiau were noted in the Guardians annual report of 1994, including the loss of a clean fresh water supply to Tuatapere township (located on the Lower Waiau), polluted water from the Mararoa River being passed into the Lower Waiau to prevent pollution building up in Lake Manapōuri, loss of recreational fishing and boating in the river and the development of silt banks inundated with non-native vegetation.

In response to this, one of the conditions imposed on MPS consents, because of the work done by the working party, was a minimum flow down the Lower Waiau of 16 cumecs in the winter and 12 in the summer (Mark, 2001). Studies have shown these flows have increased populations of fish and invertebrates (Jowett and Biggs, 2006). Despite this achievement, this flow is much reduced from the natural 400 cumecs natural flow (“Waiau river”, n.d.).

Figure 5. Shows the size of this river before the hydro plant, while Figure 6. shows the increased sedimentation and reduced flow currently seen. Another outcome of the new consents process was the formation of the Waiau Trust, which “was designed to mitigate and remedy the adverse effects the Manapouri Power Scheme had, and continues to have, on the fisheries and wildlife values of the Waiau Catchment, Southland, New Zealand” (Waiau Trust, n.d., para 1). Established from negotiations between the Waiau Working Party and the Electricity Corporation of New Zealand (now Meridian Energy), the trust runs four main restoration projects, one of which is the restoration of the wetlands surrounding the Waiau estuary, which have been impacted by the reduced flow down the Lower Waiau River.

Figure 5. Waiau River and Clifden Bridge, 1906. From personal photograph, Palliser, 2019. Taken from interpretation board sited at Clifden Bridge on the river Waiau, Southland, New Zealand.
As a result of the work done by the Waiau Working Party and because SRC adopted the conditions proposed by the Working Party, there were no submissions against the new consents, which were granted in 1996. Under these consents and conditions, the MPS is allowed to be operational under until 2031, when new consents will have to be applied for (Mark et al., 2001).

![Figure 6. The Waiau today. From Palliser, 2019, personal photograph taken from Clifden Bridge.](image)

A new consent requested by MPS

In 2009 Meridian applied to SRC for a consent for 550 cumecs discharge; the Guardians submitted against this. Two concerns were effects on eel populations and on the Lower Waiau River health. A working group investigating impacts on eels found that the MPS was currently causing the loss of 71% of adult eels trying to migrate back to sea and the increased water take would likely cause a further 6% loss (Guardians annual report 2008).

Despite opposition from the Guardians and the Waiau Working Party, SRC granted the consent for increased discharge, placing conditions that partly but not fully addressed concerns raised. For example, one condition was that a new flushing flow regime for the Lower Waiau was to be developed by the Working Party and other relevant stakeholders. However, a request that a positive flow of 5 cumecs be maintained in the Waiau Arm in front of the Manapouri control structure, to assist eel migration through February until May, was not made a condition; instead a working group was to explore options for mitigating MPS impacts on eel populations. It appears the Guardians accepted these conditions and did not take their submission to the Environment Court (Guardians annual report 2010).

Feedback from meetings of Waiau Working Party

Interviewees 1. and 9. spoke about meetings they had attended of the Waiau working party. In these meetings Meridian presented reports of work done and plans for future operation of the MPS, while scientists presented reports of research done. Interviewee 9. explained that there was a lot of tension at these meetings, that the science was presented in detail but in ways that many would struggle to follow and that there were some instances of the science being challenged by locals, which at least one scientist found difficult to handle. This interviewee didn’t see any instances of local knowledge being listened to and discussed, or of the science being explained clearly in ways that permitted locals to query what may have been missed out or what assumptions had been made during the design of the research.

Interviewee 1. was quite angry about one of the meetings attended as it confirmed to them that local Waiau residents were not being listened to. This was a meeting in 2017 where Meridian were discussing their wish to lower the minimum lake level of
Lake Te Anau by 20 cm and to increase the draw down rate of both lakes when the lakes are at low levels. Regarding this meeting, interviewee 1 angrily said:

“A meeting was held to propose this 20cm² increase and all the big-wigs and scientists came … past data, didymo cases, all this for 3 long hours and all it did was baffled locals as their time run out and cut short the last speaker, they all got up told the crowd they had a plane to catch end of meeting. No time for any explanations or question time it just baffled everyone as to what to do with such a meeting…”

Waiau Rivercare Group

This group was established in 2017 through a public meeting in Tuatapere township. Its purpose is to advocate for the health of the Lower Waiau river. A key focus of the group is its current appeals to the Environment Court on the proposed SRC Southland Water and Land Plan, which is discussed further below. The group wants: “meaningful community involvement in decision-making about the future of the Waiau River” and has been collecting accounts of the changes seen to the Lower Waiau, its estuary and related beaches from long term, local residents (Waiau Rivercare Group Facebook page).

Many MPS impacts on the Lower Waiau were discussed by interviewees and in the Waiau Rivercare Group’s statement for the Environment Court. Residents spoke of the Lower Waiau being used as a spillway for the MPS, with dirty water from the Mararoa being flushed down the Lower Waiau, saying when the Mararoa ran clean, the clean water was always diverted to the lake. Interviewee 6. said: “The only time we get the Mararoa down here it’s in flood, full of dirty water and they don’t want that in the lake”. The Rivercare group’s statement pointed out that the sediment in this dirty water ended up dumped in the river, and the normal low flow rate was not enough to flush it out to sea. This was partly what had changed this once fast-flowing river in a single channel to what is now more like a braided river with a wide flood bank and islands of sediment (ENV, 2018).

Residents discussed sediment issues in relation to the coastal region, explaining how large sandy beaches, gravel spits and dunes in the Bluecliff beach area had all but disappeared, along with the ecosystems they supported. One resident explained that much of the sediment that used to travel down the Lower Waiau is now trapped behind the dam at the control structure, and because the river flow is normally so low, sediment, rocks and gravels don’t reach the sea like they used to. Regarding coastal erosion, interviewee 3. said: “What they don’t accept is that the erosion that is happening is because of the lack of gravel coming down the river” and went on to explain that the large gravel spit that used to protect the coastal area is “getting thinner and thinner and thinner, till the point now where there is lots of areas where it’s completely devoid of gravel and the sea is crashing into the bank and eroding the cliffs and the gravel and the mud banks, everything, yes, total annihilation.”

Several residents spoke of the way the sound of churning rocks crashing against each other used to be a feature of quiet nights along the Waiau. Several also said the massive loss of sand from the beaches occurred after the second tailrace was opened in 2002. The Rivercare statement explained how the Waiau Working Party had signed off the resource consents for the second tailrace, believing scientific reports that said its impacts would be low. However, those reports never investigated possible effects on the beaches (ENV, 2018).

Many interviewees discussed their grief at the loss of these beaches, explaining how people used to go down there at weekends and holidays, fishing for flounders and toheroa (a local shellfish), lighting fires on the beach and spending time in small holiday homes there. Interviewee 4. said: “I think if they had left the Waiau alone, it would’ve still been pristine beach, well, I can remember a time, the toheroa season and two, three, four hundred cars out there, digging, digging for toheroas, now there’s no beach”. Dependent on sand, the toheroa and flounders have reduced massively in numbers and people hardly visit the small rocky shores that remain. Interviewee 7. said:

“The beds were covered in sand, about 10 years ago the sand disappeared, eroded away and down to rock, now mussels grow there. Gravel beaches are gone so the sea has pushed back the lagoon area at the mouth. You could also drive in front

\[5\text{ Referring to the toheroa beds}\]
of the cribs down on the beach, that's gone now too. The road was never replaced once the sand was gone”.

The statement spoke at length about the erosion of the river banks into the river that occurs when the MPS releases high flows into the river, resulting in the loss of farm land and flooding of properties below where the sediment has dumped (ENV, 2018). Interviewee 1. said: “The Waiau is a deep bedded river, no flow means it silts up-no longer has a deep bed-so has now seeped into the surrounding lands and pastures instead of out into the Bay”.

Both the statement and several interviewees spoke of the loss of the town potable water supply, which used to be straight from the Waiau with 95% pristine Alpine waters. Now it came from bores and was often discolored and unpleasant, and as one bore had silted up there were fears regarding security of supply. Interviewee 8 said: “.. have been trying to find a decent bore for the local community to use and drill below the river to find a recharged aquifer. As of yet, nothing has been found.”

Proposed Southland Water and Land Plan

In 2016 SRC notified the public of a proposed new plan covering objectives and rules for the use of land and fresh water in Southland (SRC, n.d.). After receiving submissions and holding a hearing on the plan a ‘decisions version’ of the plan was released (SRC, 2018), which resulted in a significant number of appeals to the Environment Court, including submissions related to MPS. These hearings are still ongoing. The Guardians voiced their objections to the plan and asked the Minister of Conservation to ensure the Department of Conservation appealed in the hearings regarding these objections (Guardians annual report 2018). The Waiau Working Party could not submit against the plan as they have an SRC chairperson (Interviewee 9.). The Waiau Rivercare Group, the Director General of Conservation, Southland Fish and Game Council6 and others are making statements to the court objecting to aspects of the plan related to the MPS (Appeals evidence, 2018). Meridian challenged the right of the Waiau Rivercare Group to be part of the hearings, but the judge deemed them entitled to participate (Decision No. [2018] NZ EnvC218).

The objections related to MPS centre on three parts of the plan. Opposition to Objective 10 (SRC 2018, p.24) focuses on the part which says the structures of the MPS are to be considered as part of the existing environment. Opponents say that if MPS is so considered then its lakes and rivers will never need to be ecologically improved beyond their current values. As the Fish and Game statement (ENVa, 2018, Para, 3) says:

“The taking and use of water for the MPS is consumptive in terms of the Lower Waiau River. Accordingly: 1. Flow rates / flow variability in the Lower Waiau River are highly modified and severely comprised compared to historic levels; and 2. The highly modified flow regime is largely ineffective in flushing the bed of the Lower Waiau River and removing nuisance periphyton.”

Opposition to Rule 52A (SRC, 2018, p.79) objects to the plan saying current activities of the MPS for which consents are held are to be considered controlled activities, calling for these to be discretionary activities instead. If they are controlled activities then SRC will not be able to reduce the MPS water take in the future, when current consents run out, even if reports show environmental degradation if take is not reduced (Guardians annual report 2018).

Opposition to Appendix E (p.145 of the plan), which explains water quality standards, focuses on the part that says that the water quality standards to be given to water bodies will not apply to waters affected by the MPS operation. This would mean council had no obligation to raise the water quality of the water bodies involved in the MPS beyond their current values (Guardians annual report 2018). The Fish and Game statement (ENVa, 2018) objects to this, saying the effects of the MPS need to be measured against natural water quality standards, not standards that have been amended downwards due to the MPS.

The Environment Court Hearings are still ongoing, so the outcomes of these objections are currently uncertain.

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6 A public organisation of people with an interest in hunting and fishing. It has a council elected from this group and has a powerful presence in New Zealand.
DISCUSSION

When the incoming government appointed the Guardians in the early 1970s, public participation in environmental management was in its infancy across the world; the first legislation requiring environmental impact assessments (the U.S. National Environmental Policy Act of 1969) had only recently arrived (Boslaugh, 2016). Inviting a group of environmental activists to design guidelines for MPS operation was unprecedented, certainly in New Zealand but probably globally as well, as can be seen from examples of public participation literature from this period (e.g. Boothe & Seligson, 1979; Derrick, 1974). Establishing the Waiau Working Party in the early 1990s to design the conditions under which the consents for the MPS should operate, was also revolutionary in terms of public participation at the time. Both the Guardians and the Waiau Working Party are examples used by Chapin, Mark, Mitchell and Dickinson (2012) to show how socio-ecological degradation can be transformed into more sustainable pathways by developing stakeholder collaborations. However, this current paper argues that an examination of these two groups over time, through the lens of Environmental Communication literature, shows important limitations in their ability to participate in environmental decision-making.

When the Guardians of the Lakes first began, they were the key governance body for the MPS; however, this changed with the introduction of the RMA 1991, which required MPS to obtain consents from SRC for their activities. From this point, although the Guardians guidelines were still followed and the Guardians still consulted, the consents process under SRC became the key governance tool. This shift changed MPS governance in important ways. The key governing body became SRC rather than a stakeholder group reporting to DOC, yet SRC and the Guardians operate under very different principles. The Guardians operate under the Conservation Act, 1987, which was created to conserve natural and historic resources, and only supports development under special circumstances (DOC, n.d.). However, SRC operates under the RMA, 1991, which supports development as long as it complies with rules and consents in relevant plans (Environment Guide: introduction, n.d.). However, SRC operates under the RMA, 1991, which supports development as long as it complies with rules and consents in relevant plans (Environment Guide: introduction, n.d.). Since the RMA, 1991, although the Guardians and the Working Party remain important advisory bodies for both the MPS and SRC, if MPS submit a proposal to SRC, SRC may agree the proposal even if the Guardians and the Working Party oppose it (as was seen in the consent given for increased MPS water take in 2010, discussed above). In addition, although the Guardians have submitted against certain MPS proposals, the legislation and guidelines they operate under does not give them a clear mandate to submit against consent requests and plan changes, something they are currently trying to change (Guardians annual report, 2018). The Waiau Working Party has not made any submissions against consents or plan changes as this could be considered a conflict of interest because they have a chairperson from SRC (Interview 10.). Therefore, these two groups are limited in their power to effect change. The empowerment, equity and trust discussed by Reed (2008) were clear components of these two groups to begin with, but the formal nature of participatory processes under the RMA has reduced the access, standing and influence these two groups have in MPS management, in ways discussed by Senecah (2004).

Consequently, the Guardians and the Working Party are limited in their ability to oppose requests for MPS operational changes, yet MPS is free to submit proposals to SRC even if the Guardians and/or the Waiau Working Party object. When the Waiau Rivercare Group stated their aim to have “meaningful community involvement in decision-making” (Waiau Rivercare Group Facebook Page, n.d.), they were aware of these limitations and wanted locals impacted by the MPS to have more opportunity to participate in decision-making. In interviews locals reported anger and grief, both because of the changes they have seen to the river and coast and because they feel they have not been listened to. As Phillips (2011), Senecah (2004) and Adger et al. (2005) discuss, such feelings can result in stakeholder resentment, conflict and loss of trust in governing institutions.

A second reason for the formation of the Waiau Rivercare Group originates in the designation of the Lower Waiau as a sacrificial river back when the MPS began (Guardians annual report 1994). Consequently, the guidelines designed by the Guardians did not consider the lower Waiau River, which had no regulatory control
until the conditions imposed by the consents in 1996 (as discussed above). As interviewee 6. said: “Well, when we were fighting to save Manapōuri, we didn’t give a thought to what would happen to the river, you know it wasn’t explained and nobody had enough brains”. Although the minimum flow levels designated in 1996 ensured the lower Waiau would support healthy populations of fish and macroinvertebrates (Jowett and Biggs, 2006), the resulting river was completely different from the river many locals remembered, and according to locals many unaddressed impacts on local communities and ecosystems remain.

Locals are aware that the river cannot be restored to what it was, however they want flow regimes that permit beaches to restore and sediment dumping in the river to reduce (ENV, 2018). Importantly however, such flows would impact severely on MPS power production; thus, MPS submissions called for their activities to be viewed as controlled rather than discretionary to the proposed Water and Land Plan focused on requests for current regimes of flows and water takes to be considered as part of the existing environment, and consents to be viewed as controlled rather than discretionary activities. MPS also tried to have the Rivercare group banned from participating in the Environment Court appeals. However, when SRC incorporated MPS requests into the decisions version of the plan, many appeals to the Environment Court resulted.

Despite laudable beginnings to public participation in environmental management of the MPS, almost fifty years later the Rivercare group voices the frustration and discontent of people who feel their concerns have not been heard and their local environment is being severely degraded. Their statement to the Environment Court and interviewee feedback about meetings of the Waiau Working Party voices these concerns. Feedback about Waiau Working Party meetings indicates that scientists presented their research with little concern that locals may not understand scientific jargon used and that there was scant opportunity for locals to question and deliberate over the value of the research done, what was included and left out when framing the research, and underlying assumptions in the research process. Without good processes that encourage stakeholder deliberation over such issues, any research done is likely to lack social legitimacy (Jasanoff, 2017). This is important because without social legitimacy stakeholders are unlikely to trust research and may continue to oppose decisions based on it (Irwin et al, 2014; Kemmis and McKinney, 2011; Popa et al., 2015). Interviewees also said some scientists were resistant to their knowledge being questioned, this can impede good stakeholder collaboration and problem-solving (Brule, 2010). As Dutta (2011) and Lindenfield (2013) explain, dialogue and deliberation of stakeholders and knowledge holders is important, building trust between stakeholders with different experiences, cultures and understandings.

CONCLUSION

Since 2010 Meridian has proposed several changes to MPS operation that have been opposed by the Guardians and the Working Party. SRC has shown through its response to the 2010 Meridian proposal and to Meridian submissions to the proposed Water and Land Plan that it is willing at times to override opposition from two groups that were set up to advocate for good MPS environmental management. Despite the auspicious beginnings of the Guardians and the Working Party, lower Waiau residents have become so disillusioned about the effectiveness of these two groups that they have set up their own group and entered their own submission to the Environment Court hearings.

While the RMA embraces public participation, the formal processes it uses have limited the power of the Guardians and the Working Party. MPS is still required to comply with the guidelines established many years ago by the Guardians and to conditions set on consents by the Working Party. However, both groups are currently limited in their ability to effectively oppose MPS changes that may negatively affect the environment.

Consequently, it is important to recognise that exemplary public participation may not be a lasting phenomenon. Unless governance institutions understand what is needed for effective participation and fully embrace processes that provide it, good beginnings can be eroded. In this case, where participation has been of historic

7 The Report and Recommendations document and Appendix B (SRC, 2018) illustrates this.
importance and research papers have considered it exemplary, the incremental creep of pressure from the power company on the one hand and increasing bureaucracy of the governance institutions on the other hand have eroded laudable beginnings and resulted in a disenchanted and resentful public.

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New Zealand’s Aluminium Smelter (n.d.). https://www.nzas.co.nz/


ELECTRONIC WASTE MANAGEMENT IN SCHOOLS, INDUSTRIES, AND COMPANIES IN INVERCARGILL, SOUTHLAND

Inessa Endawie and Tapuwa Marapara

ABSTRACT
During the last 20 years, new technologies have continually developed with the latest designs including “smart” functions, which has resulted in many outdated appliances being thrown into landfills without consideration of their impact on the environment. This study investigated how industries, companies, and schools manage e-waste, how much e-waste has been produced per year and what recommendations are needed to be put in action to solve the problem that occurs in Invercargill, New Zealand. E-mail surveys and interviews were carried out during the data collection period to obtain information related to e-waste disposal within a firm. The email survey was completed by seven companies, four schools and two industries, and three interviews were conducted. The findings showed that all respondents from both conducted surveys and interviews are concerned with the possible increase of e-waste. There is also a significant amount of e-waste that is not being recycled and diverted from local landfills. In addition, it was found that there is no management plan available in schools, industries, and companies to control the quantity of e-waste disposed into landfills or for recycling. This study has demonstrated that there are no standard systems of e-waste disposal in schools, companies and industries in Invercargill, indicating that more needs to be done to improve e-waste disposal.

INTRODUCTION
Electronic waste (e-waste) is characterised as an array of electronic devices ranging from large household appliances such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users (Needhidasan, Samuel & Chidambaram, 2014). Valuable resources and rare earth metals can be recovered from dismantling obsolete electronic devices (Jang, 2010).

There were 44.7 million metric tonnes (Mt) of e-waste produced globally in 2016, and it will rise to 52.2 million Mt by 2021 (Baldé et al., 2017). In New Zealand, the government estimate that there are 80,000 tonnes of electrical and electronic waste disposed of into landfills per year and 25% originate from televisions, computers and computer accessories (Gertsakis et al., 2011). The current challenge of dealing with e-waste in New Zealand is the lack of any practical recycling schemes and e-waste collection facilities. Hence, the goal of this study was to determine the amount of e-waste that has been disposed by each school, company and industry in Invercargill, the urban centre of Invercargill (Figure 1).
The aim of this project was to undertake an in-depth analysis of e-waste management in schools, industries and companies to determine the amount of electronic goods disposed by each firm in Invercargill, New Zealand.
METHODS

**Secondary data collection method:**
desktop study to determine current e-waste management and practises in NZ and abroad.

- Various previous study papers were used to compare, evaluate, and combine information that is relevant to the research.

**Quantitative method:**
e-mail surveys

- Used SurveyMonkey to create the survey.
- Contained seven questions (refer to Q1- Q7 under Result section).
- Sent to 10 different companies of which seven responded, 10 schools of which four responded, and 10 industries of which two responded.
- Note: The difference between a company and an industry is that companies are commercial business that aiming to make a profit whereas industry is defined as a brand of manufacture or a large commercial enterprise (Hawke, 2010, para 1-2; Deverson & Kennedy, 2005).

**Qualitative method:**
a semi-structured interview

- The interview questionnaire was set out with ten specific questions.
- A 15-minute telephone interview was conducted in an open-ended manner.
RESULTS

Quantitative data—E-mail surveys:

Q1. Types of electronic devices that have been disposed of by each company, school, and industry.

Overall, the most types of electronic devices that have been disposed by each company and school are screen and monitors whereas, both industries; A and B have disposed lamps and small IT devices the most (Figure 2).

Figure 2. Types of electronic devices that have been disposed by each company, each school, and each industry.
Q2. How much electronic wastes have been disposed per year? In kilograms.

As shown in Figure 3, most respondents have disposed under 100 kg of e-wastes per year. Moreover, 43% of respondents preferred to send their e-waste to a recycling centre; in contrast, 14% returned their damaged gadgets back to the producer (Figure 4).

![The amount of e-wastes that have been disposed annually](image)

- **< 100 kilograms**: 50
- **100-1000 kg**: 32
- **Over 1000 kg**: 11
- **Other (please specify)**: 10

<table>
<thead>
<tr>
<th>&lt; 100 kilograms</th>
<th>100-1000 kg</th>
<th>Over 1000 kg</th>
<th>Other (please specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Schools</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Industries</td>
<td>1</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 3. How much electronic wastes have been disposed per year? In kilograms.

Q3. Methods used to dispose e-waste

Figure 5 and Table 1 shows that most respondents sent their e-waste to local/provided landfills and are interested in recycling e-wastes, respectively. Furthermore, Figure 6 shows that 58% of the respondents have seen an increase in e-waste within their company over the last decade. In addition, 80% stated that there are no e-waste management plans in place or available (Figure 7).

![Methods used to dispose e-waste](image)

- **Send to a recycling centre**: 14%
- **Dump into landfills**: 43%
- **Collect e-waste until the next electronic recycling day (eDay)**: 19%
- **Return damaged electronic device back to the producer**: 24%

Figure 4. Methods used to dispose e-waste.
Q4. Where does your company dispose their e-waste? Locally, internationally or both?

The disposal of e-waste – locally or internationally

```
<table>
<thead>
<tr>
<th>Location of disposal</th>
<th>Locally</th>
<th>Internationally</th>
<th>Both, locally and internationally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Schools</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Industries</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
```

![Figure 5. Where has e-waste been disposed to locally, internationally or both?](image)

Q5. The interest in recycling damaged electronic items instead of dumping into landfills.

Table 1. The interest in recycling damaged electronic items instead of dumping into landfills.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>YES / NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies (A, B, C, D, E, F, G)</td>
<td>YES</td>
</tr>
<tr>
<td>Schools (A, C, D)</td>
<td>YES</td>
</tr>
<tr>
<td>School B</td>
<td>No answer</td>
</tr>
<tr>
<td>Industry A</td>
<td>YES</td>
</tr>
<tr>
<td>Industry B</td>
<td>NO</td>
</tr>
</tbody>
</table>
Q6. Have you seen an increase in e-waste within your company over the last decade?

*Increase of e-waste over the last decade*

- **YES** 58%
- **NO** 25%
- **UNSURE** 17%

*Figure 6. Experienced an increase in e-waste within your company over the last decade.*

Q7. Does your company have its own electronic waste management plan?

*The percentage of e-waste management plans in place*

- **YES** 20%
- **NO** 80%

*Figure 7. The percentage of e-waste management plan in place.*

**Qualitative data- Interviews**

Apart from the conducted e-mail surveys that were completed by seven companies, interviews were also conducted with three other different companies. The three companies interviewed will henceforth be referred to as companies 1, 2, and 3 for confidentiality. It was found that all three companies have disposed screens and monitors and small IT devices, however, company 2 also disposed large equipment and cooling and freezing equipment (Table 2). Both company 1 and company 2 have disposed under 100 kg of e-waste per year, whereas company 3 has disposed between 100 to 1000 kg of e-waste. As for the method of disposal, all companies have disposed their e-wastes by sending to recycling centre, however, company 1 has also discarded its e-wastes to the landfill and returned damaged devices back to the producer (Table 2).

All three companies were interested in recycling e-waste (Table 2). Therefore, each company has its respective method to reduce e-waste; company 1 and company 2 recycled their obsolete devices while company 3 would resell or gift any usable
items. The results also showed that companies 1 and 3 sent their e-waste to local landfill. Company 2 elaborated on their e-waste disposal method which was done through a recycling company that sends their e-waste to overseas countries such as Japan and Australia. This is in line with company’s 2 policy on not sending its e-wastes to a landfill so as to ensure that the e-wastes are properly dealt with.

The Product Stewardship Scheme (PSS) is defined as, ‘when a producer, brand owner, importer, retailer or consumer accepts responsibility for reducing a product’s environmental impact’ (Ministry for the Environment, 2018). It was found that all three companies have not yet implemented this scheme. However, company 2 has applied Product Stewardship Scheme that emphasis on plastic waste rather than e-waste. Company 3 implemented its own manufacture scheme* to deal with e-waste. Only company 2 believed that implementing the PSS would yield benefits. None of the companies interviewed have published any findings with regards to e-waste disposal. Companies 2 and 3 showed concern over the possible increase of e-waste while company 1 believed that its e-waste production would remain constant.

*Note: Information on the types of manufacture scheme used by Company 3 was not obtained.

Table 2. The qualitative data obtained from three companies.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Company 1</th>
<th>Company 2</th>
<th>Company 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Type of e-waste</td>
<td>Screens &amp; monitors, small equipment, and small IT &amp; telecommunication equipment</td>
<td>Screens &amp; monitors, small IT &amp; telecommunication, large equipment, and cooling and freezing equipment</td>
<td>Screens &amp; monitors, and small IT &amp; telecommunication</td>
</tr>
<tr>
<td>2. Amount of disposed e-waste</td>
<td>&lt; 100 kg</td>
<td>&lt; 100 kg</td>
<td>100 kg - 1000kg</td>
</tr>
<tr>
<td>3. Method of disposal</td>
<td>Send to a recycling centre, discard to landfills, and return damage electronic gadgets to the producer</td>
<td>Send to a recycling centre</td>
<td>Send to a recycling centre</td>
</tr>
<tr>
<td>4. Method to reduce e-waste</td>
<td>Recycling and return obsolete electronic gadgets back to the producer</td>
<td>Recycling and use electronic gadgets until the end-of-life</td>
<td>Resell or gift any usable items.</td>
</tr>
<tr>
<td>5. Dispose e-waste at a local or international landfill?</td>
<td>Local</td>
<td>International</td>
<td>Local</td>
</tr>
<tr>
<td>6. Interest in recycling e-waste</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>7. Implementation of Product Stewardship Scheme (PSS)</td>
<td>Not available</td>
<td>Available but for plastic waste</td>
<td>Not available but use manufacture scheme</td>
</tr>
<tr>
<td>8. Benefits of PSS</td>
<td>-</td>
<td>Believed that there would be benefit</td>
<td>-</td>
</tr>
<tr>
<td>9. Provide publications regarding your e-waste disposal</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>10. Possible increase of e-waste in company</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
DISCUSSION

The findings show that screens & monitors and small IT & telecommunication items were the top two types of e-waste that have been disposed. This is because current technology assemblages are made of vulnerable materials; in consequence, devices have a short lifespan (Vats and Singh, 2014; Veit and Bernardes, 2015).

Based on the electronic equipment survey conducted by MFE in 2006, their findings show a lower amount of e-waste compared with the present findings: (i) the usage of screens and monitors has increased from 15% in 2006 (MFE, 2006, p. 20) to 27% (present study), and (ii) small IT and telecommunication equipment increased from 14.3% in 2006 (MFE, 2006) to 24% (present study). Moreover, most companies disposed under 100 kg of e-waste per year because the average weight of current small electronic devices is less than 2 kg, peripheral devices (including printer) weigh around 6 kg and computer weigh about 25 kg (MFE, 2006; Dutta et al., 2017).

Based on the WasteNet Southland Annual Report 2016-2017, there is no data on the quantity of recycled e-waste in Invercargill, but the finding indicated 43% of e-waste are sent to recycling centre. It is also found that there is lack of data on e-waste disposal contained in general municipal waste. Besides, some companies and recyclers export their e-waste to other countries due to the markets for e-waste are largely overseas.

Findings from both conducted surveys and interviews show that all respondents are concerned with the possible increase of e-waste, thus, they are interested in recycling e-waste to lessen pollution.

There is no management plan available to control the quantity of e-waste disposal into landfills or for recycling because respondents were not concerned with their low amount of e-waste and/or they just considered to create one after being approached. Lastly, the biggest barrier to the establishment of a Product Stewardship Scheme for e-waste, is the cost.

CONCLUSION

This study has demonstrated that there are no standard systems of e-waste disposal in schools, companies and industries in Invercargill. This gives an indication that more needs to be done to improve e-waste disposal. All the corporate companies should develop a suitable e-waste policy to tackle the issues of high obsolete rate of e-waste in their firms. There is also a significant amount of e-waste that is not being recycled. There is need to create awareness on environmental management of e-waste among all the stakeholders and request cooperation in the disposal of the same. The result also concludes that e-waste collection and recycling would be a good cause rather than harm to the environment, thereby fostering a sustainable society. In addition, the study has verified that it is difficult to establish a product stewardship scheme for e-waste because it is too expensive and there’s no funding from the government. Therefore, full support from the government and other private institutions would be ideal. The study has also demonstrated that there is a huge gap in research on e-waste recycling in New Zealand. Hence, further studies are required to fill in the knowledge gap and collect and record data in relation to electronic and electrical equipment waste in a more comprehensive manner. This research brings into focus the existing nature of e-waste disposal and hence establishes that more research and development should be encouraged in this area.
REFERENCES


PLANT SURVEY OF EPHEMERAL TINY TURF COMMUNITIES IN THE LONG WHITE LAGOON IN NEW ZEALAND

Gabrielle Wahrlich and Tapuwa Marapara

ABSTRACT
This project was carried out to establish baseline data of the spatial distribution of turf plant communities in the Long White Lagoon (LWL) in Southland. Turf communities form in marginal zones of wetland areas experiencing fluctuating water levels. These turf communities increase biodiversity and contribute to ecosystem functions of wetland areas. The goal was to establish the distribution of turf plant communities to provide recommendations for effective restoration and conservation of the Long White Lagoon. A vegetation survey of the ephemeral zones of lagoon was conducted, and variables that influence the growth of turf species, such as quality of sediments, soil moisture content and environmental pressures, were also quantified. The abundance and presence of turf plants, volumetric soil moisture content and sediment quality were quantified in 50cm by 50cm quadrats along a transect line in three lagoon bodies. The results showed that a majority of the ephemeral species found were native dicotyledonous herbs and exotic grasses. There were some ‘threatened’ and ‘at risk’ species found, including Epilobium angustum, Isolepis basilaris and Eleocharis neozelandica. There were no significant metals found that would affect vegetation growth and all nutrients were in normal plant obtainable ranges. This data was collected mid-winter, and the observed vegetation assemblage is likely to be different in the summer months during the flowering season. Therefore, it is recommended that a further study should be carried out in the summer to gain a better understanding of the ephemeral assemblages present at the site.

INTRODUCTION
Ephemeral or turf environments are unique systems that increase biodiversity within the earth system. They are unique because of the varying seasonal degrees of wetness which influence the vegetation species that grow within them, creating a rare habitat (Johnson & Rogers, 2003, p. 13). Ephemeral wetlands form in shallow depressions without a surface water outlet which means the water levels within the system change seasonally (Johnson & Rogers, 2003, p. 13). Ephemeral or turf wetlands predominantly consist of small structured vegetation assemblages (<3cm), and the flat lying or ground hugging assemblage form interlacing communities which have high tolerance to frequent water availability changes (Johnson & Rogers, 2003, p. 13).
**AIM**

To establish a baseline data via vegetation survey of the ephemeral zones at Long White Lagoon, a privately-owned Queen Elizabeth II covenant* (QEII) property. Variables that influence the growth, distribution and diversity of species in the Lagoon were explored to provide recommendations on effective restoration and conservation for the area.

**METHODOLOGY**

*Study site*

**Long White Lagoon**

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**Ephemeral Survey**

The purpose of this part of the research was to establish the spatial distribution of ephemeral turf plant species. It involved laying out a series of transects, one after the other, from the highest point of the lagoon edge to the water’s edge (water break). The side of the quadrat was placed flat against the edge of the transect line and the species present were recorded. This was repeated every 4 metres switching sides of the transect line down to the water’s edge, allowing for the researcher to record the species present at different levels of water availability or tolerance. This method was continued around the exposed areas of lagoons 1, 2 and 3 (Map 1). The length of the transect depended on the amount of turf exposed between the edge of the lagoon and the water’s edge.

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* A permanent binding agreement on how private land should be sustainably managed. The Queen Elizabeth II National Trust arranges protective covenants with owners over private land.
Measuring Volumetric Water Content (VWC)

The purpose of carrying out this part of the research was to establish the spatial distribution of volumetric soil moisture content, which is an important factor that determines plant distribution. The hydrosense measures the volumetric water content of the soil, as a fraction of total soil volume filled with the soil aqueous solution.

The hydrosense soil moisture probe was used to quantify volumetric moisture content along the transect line, running from the higher lagoon edge to the water edge across a slope gradient. The probe needles (12cm) in length were inserted into the soil for a few seconds to record VWC readings at lagoons 1 and 3 (Map 1).

Sediment sampling

The purpose of carrying out this part of the research was to establish the quality of the sediment (substrate) in the wetland area. Sediment quality influences plant growth and distribution, the quality of water and consequently bio-chemical functions of the lagoon. Twenty-two sediment samples were taken using the Environment Southland standard sediment sampling procedure and then sent to Hills Laboratory in Hamilton within the first 24 hours for analysis. Sediment samples from open water in lagoon 2 were taken via kayak. The sediment samples were tested for a range of metal contaminants such as chromium, copper, lead, mercury, nickel, zinc and cadmium, as well as nutrients: carbon, nitrogen and phosphorus. The grain size of sediment particles was weighed, after being processed through 3 sieves: greater than 2mm (gravels), less than 63um (micrometre) sand, smaller than 36um (fines).

RESULTS

Ephemeral Survey

The results of the quadrat studies are summarised in Figure 1 below. As can be seen, the most common turf species found were exotic grasses and moss Poa annua, Agrostis stolonifera and Bryum capillare. Native dicotyledonous herbs also had a heavy presence such as Hydrocotyle hydrophila, Crassula sinclairii and Limosella lineata. There are two species found in the ephemeral areas that are registered as ‘At Risk – declining’ Epilobium angustum and Eleocharis neozelandica.

Crassula sinclairii was recently on the threatened native plant list but population numbers have increased to a level that is viable for continued reproduction and Mazus arenarium ‘At Risk’ is present at the site but was not recorded while taking the survey. There is a greater number of species found at lagoon 3, including Dicotyledonous Herbs such as Hydrocotyle hydrophila (Figure 10) and native mudworts Limosella lineata and Isolepis aucklandica (Figure 9) were commonly found together closer in quadrats closer to the water body. Lagoon 2 had less diverse vegetation, but most of the species present were native with smaller less dominate exotic grasses pasture grasses like Poa annua and Agrostis stolonifera (Figure 1).
Volumetric Water Content (VMW).

Soil moisture was taken at lagoons 1 and 3; lagoon 2 is the first to fill up with water when the winter rains pick up, covering all soil with standing water and thus making it impractical to record data. There was a gradual increase in water content down each of the transects at lagoon 1 (Figure 2). The areas with VWC recordings between 40 and 55% were covered by Potentilla anserinoids (Figure 6) closer to the outer transects. Saturation of the sediment at or areas with higher VWC showed species that were hydrophilic (water loving species) such as rushes:

**Figure 1. Ephemeral turf species presence at lagoons, 2 & 3**

**Lagoon 1: Soil Moisture**

*Juncus effuses and Juncus pusillus, and single species Hydrocotyle hydrophilia and Limosella lineata in lagoons 1 and 3 (Figures 2 & 3).*
Volumetric soil moisture in lagoon 3 was high overall, with each transect having more than 40% moisture content. A considerable number of the single recorded species such as *Selliera radicas* and *Epilobium angustum* were found at the larger ephemeral areas where there was more variation in water availability, commonly in areas where the VWC lower than 55%.

**Sediments**

The results of the sediment testing are summarised in Figures 4 and 5.

**NUTRIENTS**

Lagoon 1 had a singularly large phosphorus reading compared to lagoons 2 and 3. Sample 3 was taken in an area where there was a high abundance of rushes *Juncus effusus* and a large incursion of neighbouring pasture grass *Poa annua*. Areas from which samples 8 and 21 were derived from had no excessive growth of any species but, areas where sample 21 was taken from, does correlate with a large abundance of *Crassula sinclairii* and population of *Juncus effuses* in and around the water body.

**METALS**

All recorded metals, of all the samples except for sample 3 were in a safe and obtainable range for plant use and uptake. Sample 3 had a slightly higher recording above the usual plant threshold for all metals analysed apart from cadmium which was the only metal for sample 3 that was recorded at a normal obtainable level for plants in that area (Asati et al, 2016, p. 56).
Figure 5. Heavy metal concentrations greater than 1mg/kg dw)

### GRAIN SIZE PROFILE

Lagoon 1 shows a wider range of particle sizes with a higher distribution compared to the other two lagoons. All three lagoons have higher quantities of finer grain soil particles which are optimal for plant root growth and water infiltration (McLean & Kirk, 1968, p. 56). They showed a more diverse populace of species at lagoon 2 and 3 due to the higher percentage of finer sediments that allows for better water filtration, potential root depth and ability for contaminates to bind to the sediment particles (McLean & Kirk, 1968, p. 56).

### DISCUSSION

**Ephemeral Survey and Volumetric Water Content**

The turf species variation down the transects at lagoon 3 could be due to the drought the previous summer that led the lagoon bed to dry out and create some inconsistencies with species diversity, possibly influencing the heavy intrusions of *Poa annua* (Figure 8). There was greater diversity of single species such as *Selliera radicas* (Figure 8) and *Epilobium angustum* at lagoons 1 and 3 due to more intermediate water changes. Lagoon 2 may have lesser diversity due to higher VWC or due to the less available area and damage in the south end caused by compaction and trampling from cattle killing vegetation.
Sediments

Sediment samples 3 and 14 had consistently high concentrations of metals such as zinc, chromium and lead, as well as nutrients such as phosphorus and nitrogen. The higher concentrations found in Sample 3 could be due to the close proximity of the neighbouring paddock from runoff. Sample 14, was taken from the centre of lagoon 2, which could be the accumulative central point (lowest point) for organic matter where nutrient accumulation occurred over time.

CONCLUSIONS AND RECOMMENDATIONS

Long White Lagoon has a few threatened native ephemeral turf species. The ephemeral areas (alternating wetting and drying) have intrusions of exotic grasses and dicot herbs. To prevent continued intrusion of exotic grass, we recommend the creation of a barrier between the fence line and the surrounding paddocks to deter further pasture creeping and seeding from the predicted areas around the lagoon.

Sediment analysis showed that samples 3 and 14 have higher concentrations of nutrients and metals than the other samples taken but are not within toxicity levels for plant uptake. We recommend the addition of a vegetation break or marginal strip to buffer runoff or non-point source pollution that enters the lagoon. The conservation of the area can be optimised by mitigating the human impacts to the site to improve conditions for the turf species present. Furthermore, vegetation surveys for the area need to be carried out in the summer to gain better understanding of the species present during flowering season when more ephemeral sites are exposed.
REFERENCES


Johnson, P. & Rogers, G. (2003), Ephemeral wetlands and their turfs in New Zealand, Science for Conservation 230, Department of Conservation Wellington, New Zealand

TURNING TIDES IN NEW ZEALAND INTERTIDAL RESEARCH: A BASELINE STUDY OF ULVA ISLAND INTERTIDAL ZONES

Rhiannon Warren and Christine Liang

ABSTRACT

Intertidal zones are areas of shoreline that are exposed to both air during low tide and seawater during high tide. These habitats are home to a unique subset of species that are highly indicative of changes in surrounding marine and terrestrial environments. Large areas of New Zealand’s rocky coastlines are lacking in significant ecological datasets, despite the potential for use by researchers and environmental managers. This study quantified intertidal macro-invertebrate species on Ulva Island rocky shorelines, in order to fill ecological data gaps present in the knowledge base of the area. Five intertidal sites were surveyed using a transect-quadrat method. The sites interlapped with the waters of Te Wharawhara marine reserve and the mātaitai area of the surrounding inlet. Across the study sites, a total of 3159 individuals were counted, encompassing 31 different species. Based upon this data, the existence, abundance and distribution of marine macro-invertebrates across high, mid and low tidal shoreline zones were identified. Sites were all found to have high Simpson’s Diversity Index scores (SDI = 0.77-0.90), indicating good ecosystem health. Findings from this research could contribute baseline data for the purposes of aiding future intertidal, terrestrial and marine monitoring and management in the Paterson’s Inlet area, and similar intertidal environments throughout New Zealand.

BACKGROUND

The intertidal/littoral zone – defined by Morton (2004, p. 5) as the area of the seashore that is regularly covered by seawater during high tides and exposed to air during low tides – tends to house species that are uniquely adapted, with strong physiological tolerances towards changing elements. Typically, these communities are slow-moving or sessile, which makes them relatively easy to quantify, and are also susceptible to multiple anthropogenic ecosystem changes, thus making them ideal indicators of environmental changes on surrounding terrestrial areas and in adjoining deeper waters (Smith, 2013, p. 55).

The quantitative baseline survey in this study was undertaken in five intertidal sites on Ulva Island, a sub-island of Stewart Island, situated within an unmodified rocky inlet with a high density of surrounding terrestrial forested land known as Paterson’s Inlet (Wing, 2006, p. 7). The waters of Te Wharawhara marine reserve – three disconnected segments encompassing a 10.75 km² area of Paterson’s Inlet – intersect with several intertidal zones on Ulva Island (Wing, 2006, p. 7). The study sites interlap with waters of the Te Wharawhara Marine Reserve and the rest within the mātaitai reserve (managed by tangata whenua) of Paterson’s Inlet, Southland. These waters are important nursery habitats for valued species of fish, kina, and
bivalve molluscs away from the perils of commercial exploitation. Damaging effects from sedimentation and eutrophication are rare within the waters of the area since the surrounding terrestrial environments of Stewart and Ulva Island have experienced relatively little anthropogenic modification compared to the mainland islands (DOC, 2017). Species that have little tolerance to sedimentation and habitation in sandy areas prone to run-off from the land, now rarely found in many areas of New Zealand, can reside safely within the inlet as a result (DOC, 2017).

These areas therefore hold huge value to environmental managers and researchers alike – yet Ulva Island’s shoreline is merely one of many nationwide examples of an area lacking scientific datasets due to an absence of ecological surveillance (Thrush et al., 2011). The majority of the rocky intertidal shore monitoring done in Southland has been part of the baseline monitoring reports prepared for Environment Southland, commencing in 2011. Under the Resource Management Act 1991, regional councils are required to monitor the health of coastal ecosystems (Stevens & Robertson, 2011). However, all monitoring done by Environment Southland in the region has been limited to ‘representative’ sites on the mainland, despite the extension of Southland Regional Council’s jurisdiction onto Stewart Island.

This study aims to contribute basic baseline data of abundance and diversity of macro-algae and macro-invertebrates for the purposes of aiding future intertidal, terrestrial and marine monitoring and management in the Paterson’s Inlet area. The findings will provide information that can be used to detect and monitor changes when compared with future observational data.

METHODS

Data collection methods and statistical frameworks for this project were based upon standard methodology used by ecologists and regulatory bodies in New Zealand such as the Department of Conservation and Environment Southland, in conjunction with recommendations made by the New Zealand Marine Studies Centre in Dunedin (Smith, 2013).

**Field data collection**

For each of the five study sites on Ulva Island (Figure 1), three transect lines were placed from the Mean High Water Springs (MHWS) mark to the water’s edge at low tide. The lengths of each transect varied depending on the total distance between these two points. Quadrats (0.25m²) were then placed at every 1/11 of each transect line’s length, totalling 11 points on each transect at comparable intervals. Data was collected over three days in the month of July, 2018.

Significant features of each quadrat were recorded such as approximate substrate size and presence of water. Substrate size was recorded simply as either rock, sand, cobble, water, or mixed sizes of the substrate, based upon visual approximations using a ruler. Quadrats were photographed for later visual reference, with a key and 30cm scale.

Contents of each quadrat were observed systematically for macro-algae and macro-invertebrate species: Canopy species within the quadrat were recorded first by percentage coverage, then carefully lifted to record understorey species. Colony forming species, such as barnacles and bryozoans were also counted as percentages. All individual species were tallied, including juveniles. Any unidentifiable species were photographed on a macro-setting and identified using references to at least species level.
Data analysis

Biodiversity statistics were calculated using Simpson’s Diversity Index (SDI), which utilises the following equation, where $D$ equals calculated sample diversity, $n$ equals total number of individuals of each species found in the sample and $N$ equals total number of individuals of all species found in the sample:

$$D = 1 - \frac{\sum n(n-1)}{\sum N(N-1)}$$

The Simpson’s Diversity Index measures the probability that two individuals randomly selected from a dataset will belong to the same category/species, considering species richness and species abundance. The calculated sample diversity ranges between 0-1, where high calculated SDI for a sample should be considered to mean high species richness, whereas low calculated SDI means low species diversity (Simpson, 1949). According to Gamito (2010), in an evaluation of biodiversity indices, Simpson’s Diversity Index is appropriate for an intertidal ecological study. Hence, SDI was used to find biodiversity values for each identified tidal zone across all three transects of each site and again to find the total biodiversity values per site.
Intertidal organisms were recorded as ‘enumerated individuals’, where organisms are counted as individuals as opposed to percentage. Tables were constructed to show the distribution of intertidal organisms from the MHWS mark to the low water mark at each site (See Appendix 1). Transects were divided into three main zones: high-tide, mid-tide and low-tide based upon visual habitat assessment data. These zones were then collated to create a representative picture of species abundance and distribution across all tidal zones per site. From this data, the following could be determined:

- Total number of species per tidal zone per site and total number of individuals per species per tidal zone per site.
- Relative abundance of enumerated individuals per species per tidal zone per site.
- Biodiversity per tidal zone per site calculated by Simpson’s Diversity Index.

RESULTS AND DISCUSSION

The existence, abundance, and distribution of intertidal species were studied at five sites around Ulva Island: West End Beach Site 1, West End Beach Site 2, Boulder Beach Site 3, Sydney Cove Site 4, and West End Beach Site 5 (Figure 1). Physical parameters and substrate were also recorded for each site (Table 1).

A total number of 3159 enumerated individuals were observed across the entire study. There were 31 species in total, with 20 of these species enumerated as individuals due to reasonable densities within the quadrat squares (number of species and individuals across sites available in Appendix 1). The remaining 11 species – one species of barnacle, and all macroalgae algae species save for 1 – were expressed as a percentage. Additionally, macro-algae were expressed in cm² area covered per site.

Table 1. Physical parameters of the five study sites around Ulva Island.

<table>
<thead>
<tr>
<th>Site</th>
<th>Aspect &amp; Location</th>
<th>Substrate</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sheltered, north-facing inlet to the northern side of West End Beach. S46°55.552 E168° 06.879</td>
<td>Rocks ≈25-30cm and sand</td>
<td>≈6°</td>
</tr>
<tr>
<td>2</td>
<td>North-facing rocky section of a predominantly sandy inlet on southern West End Beach. S46°55.620 E168° 06.71</td>
<td>Rocks ≈10-30cm, sandy substrate with solid bedrock in high-tide zone</td>
<td>≈5°</td>
</tr>
<tr>
<td>3</td>
<td>An exposed, west-facing rocky site on the southern side of Boulder Beach. S46°55.892 E168° 07.309</td>
<td>Hard, rugged bedrock littered with rocks ≈10-110cm, allowed for tidal pool regions in mid and high tidal zones</td>
<td>≈10°</td>
</tr>
<tr>
<td>4</td>
<td>A sheltered, north-east facing area at the far eastern end of Sydney Cove Beach. S46°55.827 E168° 08.047</td>
<td>Stacked rocks/boulders ≈20-100cm with multiple crevasses/understories and water intrusion in the low-tide zone.</td>
<td>≈14°</td>
</tr>
<tr>
<td>5</td>
<td>An exposed, north-west facing, rocky outcrop connected to West End Beach. S46°55.552 E168° 06.879</td>
<td>≈10-80cm jagged rocks/boulders, with smaller (=2cm) pebble substrate underlying</td>
<td>≈16°</td>
</tr>
</tbody>
</table>
**Macro-invertebrates: Species abundance**

The relative abundance of macro-invertebrate species varied across each tidal zone (Figure 2). At Site 1, a total of 15 species were identified, with most occurring in the mid and low tidal zones, and fewer in the high-tide zone (Table 2). Site 2 also had a total of 15 species identified, with most in the mid-tide zone and the lowest occurrences being in the high-tide zone (Table 2). Of note here is the high abundance of *Diloma* spp. in all intertidal zones (Figure 2). A total of 14 species were identified at Site 3, again with the fewest species found in the high-tide zone (Table 2). Site 4 had the highest number of observed species of all the sites – a total of 17 – although only three species were present in the high-tide zone (Table 2). Site 5 had the lowest number of observed species across sites – a total of 11 – predominantly found in the low-tide zone, followed by the mid-tide and high-tide zones (Table 2). The lower abundance of species across all sites in the high-tide zone is indicative of stressful conditions in higher regions of shorelines, particularly the risk of desiccation at low-tide periods (Smith, 2013).

![Figure 2. Relative Abundance (RA) of Species Per Tidal Zone (High, Mid, Low) across each site (1-5).](image-url)
Table 2. Number of species across Sites 1-5 for the Low, Mid, and High tidal zones. Zones are colour-coded to show highest number of species (red), intermediate number of species (orange), and lowest number of species (green) per site.

<table>
<thead>
<tr>
<th>Site</th>
<th>High Tide Zone</th>
<th>Mid Tide Zone</th>
<th>Low Tide Zone</th>
<th>Site Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
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<tr>
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<tr>
<td>4</td>
<td>3</td>
<td>14</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

Three species were identified in high abundances in most intertidal zones in almost all sites - *Diloma* spp., *Mytilus edulis* and *A. tenebrosa* (Figure 2). These three could therefore – following confirmation in future studies undertaken in other seasons of the year – be tentatively suggested as potential key species in the Ulva Island intertidal ecosystem. Sudden absences or decreases in abundance of these three species in similar research scenarios could suggest an intertidal regime shift.

Correlations can be drawn from the data which appear to indicate species preferences to particular habitat, such as the absence of *A. tenebrosa* on the sandier shorelines of Site 2, in comparison to the abundance of the anemone on the rockier areas of Sites 4 and 5 (Table 1, Figure 2). This could be due to a variety of trophic, abiotic, or physical factors present at some sites and absent at others.

**Macro-algae: Area covered**

Only two species of macro-algae were noted along Site 1, with a clear presence of *B. arbuscula* in the mid-tide zone, creating a dark "banding" visible to the eye upon shore inspection (Figure 3). Site 2 had five species of macro-algae with encrusting coralline algae *Lithothamnion spp.* covering most area overall (Figure 3). Six species of macro-algae were observed in Site 3, and the site was dominated by seagrasses belonging to the Zostera spp. (Figure 3). Site 4 had four species in total and the most significant abundances of *Lithothamnion spp.* (Figure 3). Five species were noted in Site 5, again with a distinctive mid-shore zonation of *B. arbuscula* (Figure 3). Also of note in Site 5 is the high abundance of the strong calcium-carbonate protected *Lithothamnion spp.* in the low-tide zone (Figure 3). This site experiences strong exposure and wave action (Table 1), which tends to create a noticeable dominance of hardy, sessile species (Smith, 2013; Ballantine, 1961; Airoldi & Hawkins, 2007).

**Diversity trends across sites**

As aforementioned, the relative abundance of individual species was lowest in the high-tide zone across all five sites. This was further supported by SDI diversity scores across tidal zones, with the most biodiverse part of the shoreline being the mid-tidal zone, and the least biodiverse the high-tidal zone (Figure 4A), which is typical as biodiversity tends to decrease due to the influence of stressful conditions in higher regions of shorelines (Smith, 2013). Smith (2013) also notes the increased favourable abiotic conditions in the mid and low tide regions of the shore for macro-invertebrates. Throughout this study, algae were most prevalent in the mid-tide regions, which has also been noted in other studies to coincide with high levels of invertebrate macro-organisms (Alestra, 2014).
Figure 3. Macroalgae Cover (cm²) Per Tidal Zone (High, Mid, Low) across each intertidal site (1-5).

All sites fall in the higher ranges (SDI = 0.77-0.90), indicating high diversity, with Sites 4 & 2 being the least biodiverse, and Site 5 having the highest SDI score (Figure 4B). This is promising, considering the period that this study was conducted is typically the least biodiverse due to lack of proliferation of algae in colder, sunlight-limited months.

Auspiciously, no exotic species were noted at all at any sites, despite 'fair' threats assigned by DOC (2017) from *Undaria pinnatifida* – a subtidal to intertidal preferring pest algae – to Te Wharawhara marine reserve.
Figure 4. A) Intertidal Diversity Scores across Sites 1-5 for low (blue), mid (red), and high (grey) tide zones. B) Total biodiversity scores across Sites 1-5. All sites fall in the higher ranges (0.77-0.90), indicating high diversity.

RECOMMENDATIONS FOR FUTURE MONITORING AND ECOLOGICAL SURVEILLANCE

As stated in the introduction, the ultimate aim of this research is to provide baseline data for the purposes of aiding future monitoring and management efforts of intertidal zones on Ulva Island, and perhaps even in comparable environments across New Zealand’s shorelines. Below are recommendations for possible avenues for future research.
Monitoring change in abundance of key species

Potential key species found in high abundances across most sites were *Diloma* spp. (all tidal zones), as well as *P. elongates, B. linea* and *A. tenebrosa* (high and mid tide zones), and *M. galloprovincialis* and *M. edulis* (low tide zones). It would be pertinent to determine through further baseline data collection the change in abundances in different seasons, temperatures and tidal times. The low-rare species observed that did not dominate the shoreline or any particular tidal zone, may have been due to intolerances such as abiotic conditions associated with the high tide zone, or pressure from predation and spatial competitions, as noted as being relevant to intertidal regions by Tomanek & Helmuth (2002). The limited scope of this study did not allow to take such factors into consideration.

*Lithothamnion spp. as a bioindicator for environmental degradation*

Encrusting coralline algae such as the pink variety noted in large areas such as in the mid-tidal zone of Site 2, holds promise as an indicator species of environmental degradation. Species of coralline algae are regarded as good indicators of health in intertidal and deeper water ecosystems. These algae are slow-growing and subject to environmental changes such as raised acidity since their outer shells are comprised of calcium carbonate, which is dissolved in acidic water (Law et al., 2018; Payton et al., 2002, p. 6). Therefore, in future research and environmental management of the area, the potential of *Lithothamnion* spp. as an indicator should be considered, especially given the growing risk ocean acidification related to the climate crisis.

Pink coralline paint occurred in all tidal zones of Site 4, and in high area of low and mid-tide zones – as this site links with the waters of Te Wharawhara Ulva Island marine reserve, the importance of this species as an easily-monitored indicator for ocean acidification is notable to environmental managers of the marine reserve (Law et al., 2018). An easily accessible, budget-friendly monitoring programme that is also non-destructive (via fixed quadrat monitoring as per Hartnoll & Hawkins (1980, p. 484)), could be valuable to environmental managers. Absence or bleaching may represent significant deeper water issues that may threaten the integrity of the reserve (Law et al., 2018).

Investigating the effect of the marine reserve on intertidal biodiversity

Site 4 was the only site to coincide with the waters of Te Wharawhara marine reserve, therefore data collected is not significant enough to determine the influence of the marine reserve status upon its intertidal regions. A more thorough analysis of rocky shores in the reserve area would be required to confidently confirm apparent lower biodiversity levels at Site 4 despite deeper water protection, as it may be a result of the randomised site-selection and transect-location methods used.

Impact of macroalgal cover on biodiversity of grazing species

The lack of a significant population of macroalgae in sites such as Site 1 (the only species observed being *B. arbuscula* and *Lithothamnion* spp., predominantly in the mid-tide, Figure 3) appears to have had an effect on biodiversity observed, as the number of grazing species increases where macro-algae was observed. This reflects the findings of reviewed literature by Alestra (2014), who notes the importance of macro-algal cover for biodiversity: if this study had encompassed other seasons, biodiversity values are likely to have risen due to increased photosynthesis and growth. Therefore, further research is highly recommended to gather alternative seasonal data in order to see the impact upon biodiversity and abundances of particular species.
CONCLUSIONS

A range of intertidal marine species were observed on sites in Ulva Island in the area between the Mean High Water Springs mark to the edge of the water at low tide, and correlations between particular species and basic habitat characteristics such as shoreline slope were noted. Sites were all found to have high diversity scores based upon the Simpson’s Index, indicating good ecosystem health. Generally, the mid-tidal and low-tidal zones were more diverse and densely populated than high-tidal zones. The high abundance and presence of particular species such as Lithothamnion spp. in specific shoreline zones may be useful for determining keystone or ‘forecasting’ species of intertidal Ulva Island and its surrounding deeper water ecosystem, which may be useful for future researchers and managers of the island and Te Wharawhara marine reserve. It would be beneficial for larger-scale additional data collection to be carried out in the same and additional shorelines, particularly in alternative seasons. Further recommendations were also made to contribute to future research and data collection for environmental managers, based upon post-data collection/analysis reflections, with suggestions of notable species that could be valuable indicators of ecosystem stability.

The pristine intertidal area of Ulva Island and similar areas of New Zealand should not be underestimated by future environmental planners, managers or researchers. The methods of monitoring such areas are not only budget-friendly in comparison to many other methods, but also indicate the health of surrounding terrestrial and marine environments. Given the scientific predictions of a minimum 1.5°C global warming over the next two decades and the related increasing ocean acidification levels with the potential to affect marine species – including commercial species such as mussels and paua – environments such as intertidal regions of our coastlines should be monitored more heavily than they are currently. Their susceptibility and the insight they can give us via research into major global and national issues should be seriously considered.
REFERENCES


APPENDIX 1 TABLES OF SPECIES, INDIVIDUALS AND BIODIVERSITY FOR SITES 1-5

Appendix Table A1. Site 1 Individuals, Species and Biodiversity

<table>
<thead>
<tr>
<th>Site 1</th>
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<tr>
<td>Number of individuals</td>
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<td>287</td>
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<tr>
<td>SDI</td>
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<td>0.86</td>
<td>0.84</td>
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Appendix Table A2. Site 2 Species, Individuals and Biodiversity

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<td>12</td>
<td>15</td>
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<tr>
<td>Number of individuals</td>
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<td>328</td>
<td>269</td>
<td>761</td>
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<tr>
<td>SDI</td>
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<td>0.84</td>
<td>0.82</td>
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Appendix Table A3. Site 3 Species, Individuals and Biodiversity

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<td>Number of individuals</td>
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<td>SDI</td>
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<td>0.83</td>
<td>0.79</td>
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Appendix Table A4. Site 4 Species, Individuals and Biodiversity

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<tr>
<td>Number of species</td>
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<tr>
<td>Number of individuals</td>
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<td>SDI</td>
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<td>0.78</td>
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Appendix Table A5. Site 5 Species, Individuals and Biodiversity

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<th>Site 5</th>
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<td>SDI</td>
<td>0.73</td>
<td>0.8</td>
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</table>
AN ECOLOGICAL AND HYDRO-CHEMICAL BASELINE ASSESSMENT OF LONG WHITE LAGOON

Ainsley Adams¹ and Tapuwa Marapara¹

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ABSTRACT

Wetlands are among the world’s most diverse and productive ecosystems supporting a wide variety of flora and fauna often harbouring rare and endangered species (Futter, 2008). They are often referred to as “earth’s kidneys” as they are known to filter toxins and contaminants from water. New Zealand’s wetlands are home to one third of all native fish species. Despite their importance, New Zealand’s wetlands have been historically drained and destroyed to reclaim land for development and agriculture leading to the decline of over 90% of the country’s wetland. Wetlands that remain face many modern-day threats from catchment land use changes and introduced species. Legislation in New Zealand highlights the importance of protecting wetlands since 74% are under 10 hectares in size and are small remnants found on private land surrounded by developed land. Successful restoration and protection of wetlands requires characterisation of their components and processes that drive functions. This study was carried out to establish the ecological and hydro-chemical baseline data of the Long White Lagoon to highlight the health of the ecosystem for guiding restoration, management and future monitoring. Assessments on sediment, water quality, vegetation assemblage, and fish species were carried out. Results showed that sediments were comprised of mainly sand, and some silt particles, and the concentration of nitrogen and phosphorus exceeded threshold limits set out in the Australian and New Zealand Environment Conservation Councils (ANZECC). Water quality results showed that the Long White Lagoon is in a hypertrophic state of extreme degradation. The vegetation mapping results showed that there are diverse native wetland vegetation assemblages present within the Long White Lagoon property. The native vegetation assemblages present, make the Long White Lagoon a significant pocket of biodiversity within a heavily monocultural area and an important remnant of the southland coastal habitat. The fish survey showed that there was only one fish species present in the lagoon, identified as Gobiomorphous cotidians (Common bully), which was unexpected given the lagoon’s lack of connectivity.
BACKGROUND

The Southland region of New Zealand has seen the loss of wetlands primarily for agricultural development with only 10.8% of wetlands remaining (Ewans, 2014). One of the last small series of coastal wetland systems located between Invercargill and Riverton in Southland, New Zealand is known as Long White Lagoon (Figure 1). Long White Lagoon consists of a series of semi-ephemeral freshwater lakes which have been historically modified and drained for agricultural land reclamation (Moss, 2018). The importance of New Zealand’s wetland ecosystems has only been recognized as a recent development and, restoration of these systems has been driven by government organisations, private conservation and environmentalist groups (Futter, 2008).

Before individuals and groups can carry out successful restoration, management and monitoring programs in a wetland, baseline information is required regarding the status of various components that drive ecosystem functioning. In the case of Long White Lagoon, there was scarce information on the state of the wetland, with only a few studies on water fowl populations undertaken (Atkinson, 2008; Schallenburg & Kelly, 2012). It was within the interest of the landowner to understand the ecological, hydrological and chemical state of the wetland prior to managing it.

Ecological and hydro-chemical baseline studies in an area give insight into the initial environmental status and/or characterisation of an ecosystem (Marapara, 2016).
AIM AND OBJECTIVES

The aim for this study was to carry out ecological and hydro-chemical baseline assessments at Long White Lagoon to provide data that gives a snapshot of the health and integrity of the ecosystem, to guide restoration, management and future monitoring.

Specifically, the objectives were;

1. To quantify texture and quality of sediments from various locations in submerged and dried ephemeral areas of the lagoon bed;
2. To assess water quality of all water bodies, present at the time of sampling;
3. To map terrestrial vegetation assemblage;
4. To carry out fish surveys using trapping and netting in the main water body of the lagoon;
5. To analyse and discuss the results in regard to recommendations for future monitoring and management at Long White Lagoon.

METHODOLOGY

Study Site

Map 1 Aerial view of Long White Lagoon
Long White Lagoon is located near the river mouth of the Waimatuku River and is the last small series of coastal lagoons and lakes situated along the coast between Invercargill and Riverton in the Southland region of the South Island of New Zealand.

**Sediment sampling**

Sediment samples were collected using a sediment coring method at 22 sites (Figure 2) and analysed by Hill Laboratories for grain size profile, heavy metals and nutrient concentrations.

![Figure 2 A sediment sample collected using a corer (left) before it is placed into an airtight container (right).](image)

**Water quality Sampling**

Water quality samples were collected at 6 sites from a kayak (Figure 3) and analysed by Hill Laboratories for nutrients (N,P), fecal coliform, chlorophyll a, turbidity, electrical conductivity, pH, dissolved oxygen and salinity.

![Figure 3, Kayaking the water sample in the bucket back to shore, (Photo by Keryn Roberts, 2018).](image)
Fish surveys

Fish surveying was carried out on two occasions with the use of fyke nets and minnow traps set overnight to catch fish (Figure 4). The fish were retrieved from the nets the following morning, identified, measured and released back into the lagoon.

Figure 4, Setting of fyke net using kayak in the lagoon,
VEGETATION MAPPING

Vegetation mapping was carried out by identifying and describing standing vegetation at a 50m interval around the Long White Lagoon property. Dominant vegetation types were mapped around the property.

RESULTS AND DISCUSSION

Sediment

The results from sediment analyses showed that the sediment grain size profile in the lagoon was comprised primarily of sand and then silt sized particles. According to Turnbull and Alibone (2003) Long White Lagoon is found in a part of the "Southland Plains" which are underlain with quaternary gravels of alluvial and marine origin. Alluvial sediments are derived from the Oreti River and the smaller grain size profile seen in Long White Lagoon is a combination of these alluvial sediments and aeolian material creating sand dunes that trend diagonally across the lagoon complex (Turnbull and Alibone, 2003).

The heavy metal concentrations found in the sediments were all at safe levels and were within threshold limits set out in the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (2001) and the Australian and New Zealand Environment Conservation Councils (ANZECC) Interim sediment quality guidelines (2000). The nitrogen and phosphorous levels were all high in the sediment samples. The levels seen in Long White Lagoon correlate directly with the levels found in the water samples taken, showing high concentrations. This was also seen in a study carried out in the Bukit Merah Reservoir in Malaysia with the sediment nutrient loads directly correlating with the water quality at different sites of the reservoir (Talib et al., 2016).

Nitrogen (Total, Sediment)

Figure 6 Nitrogen concentration in sediment
**Water quality**

All the water sampling results returned with very high fecal coliform count (Figure 8) with every sample exceeding the national standards for drinking water limits of 1 CFU/100ml and the Ministry for the Environment’s national standards for recreational use of 550CFU/100ml (Carbon & Poutasi, 2003). There could be a few point sources for the high fecal coliform counts in the lagoon complex as noted while carrying out data collection on site. There is a large population of waterfowl living at the Long White Lagoon, including swans, ducks and high numbers of Canadian geese. Waterfowl have very high e-coli levels in their feces compared with warm blooded mammals and they have a very fast metabolism, which results in frequent excrement (Fleming & Fraser, 2001). Run-off from neighboring dairy farms could have also contributed to this concentration. A large proportion of the water in the lagoon is recharged via run-off from neighboring properties, all of which are intensively used for dairy farming. This run-off could also be a contributing factor to the high fecal coliform counts in the lagoons waters. Another potential point source of pollution observed, is the direct excretion of fecal matter by an intrusion of cows into the largest permanent water body. This is a direct source of fecal coliforms into the water as the cows were in the property for some time and this could have contributed to the high levels recorded.

**Figure 7 Phosphorus concentration in sediment**

**Figure 8 Fecal coliform counts in water samples**
The total nitrogen was high with all samples massively exceeding the National Policy Statement for Freshwater Management (2014) bottom line limit for nitrogen levels of 0.8g/m³ by over six times on average (Figure 9). Phosphorous results in the lagoons water were also all very high at each site (Figure 10). All readings exceeded the National Policy Statement for Freshwater Management (2014) low threshold limit for phosphorous levels of 0.05g/m³ by at least six times. Long White Lagoon’s catchment is almost all dairy and sheep farming and the Lagoon is at the very bottom of this catchment, so it is plausible that the water quality has been severely impacted with high nutrient levels. This nutrient loading is common in Southlands shallow coastal lakes and Long White Lagoon follows this trend. Another factor that could be contributing to the loading of nutrients is the lack of flushing ability the lagoon complex possesses.

**Total Nitrogen Levels**

![Total Nitrogen Levels](image)

Figure 9 Total Nitrogen (TN) in water samples

**Phosphorous Levels in Long White Lagoon**

![Phosphorous Levels in Long White Lagoon](image)

Figure 10 Phosphorus in water samples
Chlorophyll in all samples exceed the National Policy Statement for Freshwater Management (2014) bottom line limit for chlorophyll a concentration of 0.06g/m³ (Figure 11). This exceedance in the bottom line levels indicates that there is an algal bloom present at the lagoon. This algal bloom that is preset is directly correlated to the high nutrients found in the water. Because these water samples were carried out in May which is a cooler month in Southland it is predicted that this algal bloom would be much larger over the summer months. A study by Toporowska et al (2010) on phytoplankton levels in a lake in Poland showed the direct correlation between phytoplankton abundance and seasons, with phytoplankton exhibiting a larger presence during summer and less of a presence during winter.

**Chlorophyll a levels**

![Chlorophyll a levels](image)

The conductivity results were all very high in all waters of Long White Lagoon indicating high levels of dissolved ions exceeding The National Institute of Water and Atmospheric Research’s (NIWA) (2018) "very poor" level of 400mS/cm (Table 1). The dissolved oxygen levels are unexpectedly very good in the lagoon even though all other results indicate toward poor levels such as from the algal bloom (Table 1). The turbidity readings at Long White Lagoon are all high readings exceeding NIWA’s indicators of freshwater habitat health indicating very turbid water with a visual clarity of 35cm or less. The pH at all sites were slightly alkaline in nature (Table 1). NIWA’s indicators of freshwater habitat health state that a pH between 8 and 9 is a moderately high pH which usually signifies intensive photosynthetic activity either from periphyton, phytoplankton or macrophytes. This correlates with the high chlorophyll A levels, indicating a high presence of phytoplankton.

![Figure 11 Concentration of Chlorophyll A](image)
### Table 1 Water quality parameters in the Long White Lagoon

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Conductivity (Field) (uS/cm)</th>
<th>Conductivity (Lab) (uS/cm)</th>
<th>Dissolved Oxygen Saturation (%)</th>
<th>Dissolved Oxygen mg/L</th>
<th>Salinity (Field) ppt</th>
<th>Turbidity (Lab FNU)</th>
<th>Water Temperature (Field degC)</th>
<th>pH (Lab Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long White Lagoon_4</td>
<td>544.60</td>
<td>566.00</td>
<td>126.10</td>
<td>14.55</td>
<td>0.26</td>
<td>49.00</td>
<td>9.20</td>
<td>7.80</td>
</tr>
<tr>
<td>Long White Lagoon_8</td>
<td>615.00</td>
<td>619.00</td>
<td>105.70</td>
<td>12.12</td>
<td>0.30</td>
<td>84.00</td>
<td>9.50</td>
<td>8.10</td>
</tr>
<tr>
<td>Long White Lagoon_10</td>
<td>592.00</td>
<td>619.00</td>
<td>106.30</td>
<td>12.16</td>
<td>0.29</td>
<td>81.00</td>
<td>9.60</td>
<td>8.30</td>
</tr>
<tr>
<td>Long White Lagoon_14</td>
<td>585.50</td>
<td>619.00</td>
<td>101.40</td>
<td>11.55</td>
<td>0.28</td>
<td>85.00</td>
<td>9.80</td>
<td>8.20</td>
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<td>Long White Lagoon_18</td>
<td>576.90</td>
<td>622.00</td>
<td>104.80</td>
<td>11.75</td>
<td>0.28w</td>
<td>92.00</td>
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<tr>
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<td>569.70</td>
<td>622.00</td>
<td>120.20</td>
<td>13.60</td>
<td>0.28</td>
<td>82.00</td>
<td>10.20</td>
<td>8.10</td>
</tr>
</tbody>
</table>

Analysis of all water quality results shows that the Long White Lagoon waters are in a hypertrophic state of extreme degradation. The degraded water quality is most likely a result of four main factors including, the large water fowl population present in the lagoon, runoff and groundwater discharge from an almost entirely agricultural land use catchment, intrusion of cattle into the lagoons waters, and the nature of the lagoon system with its lack of flushing ability.

**Fish survey**

The fish survey showed that there was only one fish species present in the lagoon waters which was Gobiomorphous cotidianus or common bully (Figure 12). A total of 46 common bully were caught (Table 2). This was unexpected due to the lagoon’s lack of connectivity. Common bullies are an endemic species of fish adding biodiversity and conservational value to Long White Lagoon. It also shows that common bullies are active and breeding during the winter months, of which there is a lack of knowledge around seasonal activity such as this. Common bullies are primarily diadromous but can persist in closed systems if there is ample food and a suitable temperature range such as within a marine environment (Closs et al., 2003). It was noted that most common bully caught in Long White Lagoon were ripe with eggs or had dark mating colorations, which indicates that the population are successfully breeding in the lagoon system.

*Figure 12, Common bully caught at the lagoon*
Table 2 Total fish caught in each net or trap during fishing survey 1

<table>
<thead>
<tr>
<th>Fyke Net or Minnow Trap</th>
<th>Fish Species</th>
<th>Total Number Caught</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnow trap 1</td>
<td>Gobiomorphus cotidianus</td>
<td>4</td>
</tr>
<tr>
<td>Minnow Trap 2</td>
<td>Gobiomorphus cotidianus</td>
<td>1</td>
</tr>
<tr>
<td>Minnow Trap 3</td>
<td>Gobiomorphus cotidianus</td>
<td>14</td>
</tr>
<tr>
<td>Minnow Trap 4</td>
<td>Gobiomorphus cotidianus</td>
<td>8</td>
</tr>
<tr>
<td>Fyke Net 1</td>
<td>Gobiomorphus cotidianus</td>
<td>14</td>
</tr>
<tr>
<td>Fyke net 2</td>
<td>Gobiomorphus cotidianus</td>
<td>3</td>
</tr>
<tr>
<td>Fyke Net 3</td>
<td>Gobiomorphus cotidianus</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>46</strong></td>
</tr>
</tbody>
</table>

Vegetation assemblage

The vegetation mapping results showed that there are diverse native wetland vegetation assemblages present within the Long White Lagoon (Figure 13). The native vegetation assemblages present make the Long White Lagoon a significant pocket of biodiversity within a heavily monocultural area and an important remnant of the Southland coastal habitat. The large notable vegetation assemblage, denoted by a yellow polygon on the vegetation map (Figure 13), is a great example of the beginning of a succession sere, as cabbage trees, pittosporums and broadleaves are starting to grow above the predominant canopy of mature flax. This new canopy will eventually shade out the flax as it continues to grow, causing it to die back and change the ecosystem from a flax dominated assemblage to a broadleaf wetland forest (Clarkson & Peters, 2012). There are many significant patches of native wetland vegetation present in the Long White Lagoon with Phorium tenax dominated assemblages to Carex secta dominated, providing a good habitat for wetland fauna including fish as there is a lot of overhang into the water bodies. These assemblages are very fragmented in distribution being separated by pastoral grassland. The vegetation is confined within the property boundary as the surrounding property is all in pastoral grass and agricultural crop. This means that there is restricted wildlife passage between habitats, which is known as a wildlife corridor. The closest area would be the Waimatuku River mouth estuary which is about 100 meters away and separated by pasture paddocks and crop. The largest and most diverse vegetation assemblage found at the lagoon is in one of the wettest areas. The plant species here are comparable with Environment Southland’s Wetland Planting Guide (n.d) for species recommended for planting that thrive better in wetter areas such as Phorium tenax and Carex secta.

CONCLUSION

Long White Lagoon is an important habitat for flora and fauna as noted in this research. This study provides baseline data to aid in the future management and monitoring of the lagoon. Sediment grain size profile is made up of predominantly sand size particles. There are safe levels of a range of heavy metals and there is a high accumulation of nutrients bound to the sediments. Long White Lagoon waters are in a hypertrophic an algal bloom which is a result of very high levels of nutrients and fecal coliform levels. The lagoon has now been shown to be an important habitat for Common bullies or Gobiomorphous cotidianus. The vegetation mapping results showed that there are diverse native wetland vegetation assemblages present. The native vegetation assemblages present make the Long White Lagoon a significant pocket of biodiversity within a heavily monocultural area and an important remnant of the Southland coastal habitat.
Predominantly Coprosma propinqua (80%), Phormium tenax (10%), floor dominated by long exotic pastural grasses (10%).

Predominantly an exotic Nightshade vine known as bittersweet (Solanum dulcamara) (90%), Jointed Wire rush (Apodasmia similis) (10%).

Predominantly Phormium tenax (70%), Coprosma propinqua (15%), Purei found on the edges of the vegetation bordering the water (Carex Secta) (10%), Cordyline australis (5%).

Predominantly Libertia peregrinans (90%), Exotic pastural grasses and thistles (10%).

Sparse juvenile Jointed Wire rush (Apodasmia similis) Large notable individual Cabbage trees or Flax

Predominantly Phormium tenax (60%), Coprosma propinqua (10%), Griselinia littoralis (5%), Pittosporum tenuifolium (5%), Cordyline australis (10%).

Purei found on the edges of the vegetation bordering the water (Carex Secta) (10%). Significant area of regenerating wetland vegetation with succesion starting to occur of kapuka, pittosporum and cabbage tree growing above the mature flax which will create a new canopy.
RECOMMENDATIONS

It is recommended that further monitoring be carried forward using the results of this research as a baseline and that a management plan is devised to improve water quality. Continuous water monitoring during different seasons would capture temporal variation of water quality, especially when the lagoons dry out partially to show change in pollutant concentration over time.

Recommended management strategies would be to maintain the fencing at the very east of the largest lagoon where cows have intruded into as they have most likely contributed to deterioration of the water quality and have done extensive damage to the vegetation assemblage found here from eating and trampling plants. Replanting of native vegetation in areas where clear runoff is occurring from the neighboring dairy cow paddocks would be ideal. There are a few visually notable areas such as drainage channels in the dip of small hills that accumulate runoff and channel it down through short pastoral grass straight into the lagoon water body. Replanting various native trees in these areas can reduce sediments, excess nutrients and fecal coliforms from entering the lagoon body.

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