Zostera muelleri

A comparison of environmental variables between the Maketū Estuary & seagrass beds within the Tauranga Harbour & Waihi Estuary.

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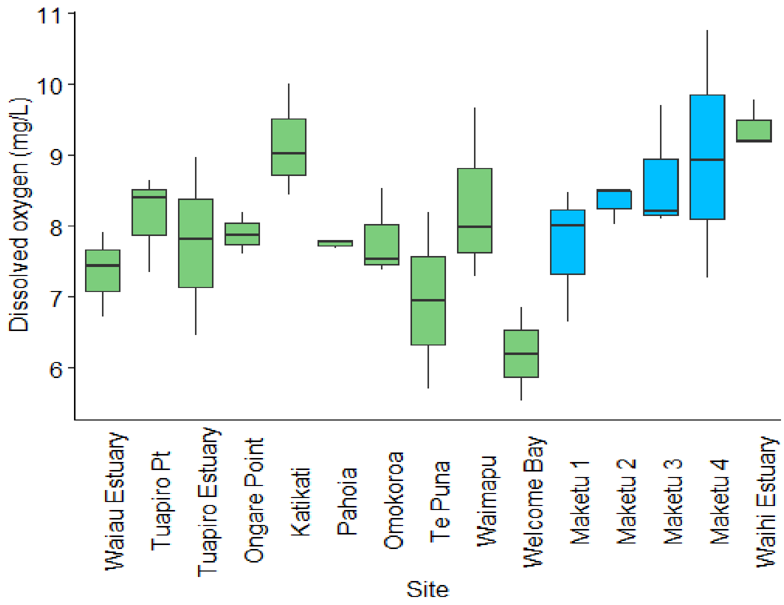
Bay of Plenty Regional Council / Toi Ohomai Institute of Technology



Abstract

Seagrass (*Zostera muelleri*) is in decline within most of its distributed area worldwide and throughout the Bay of Plenty in New Zealand, particularly in Maketu estuary which has had a long term decline since the 50s and the loss of all of the remnant seagrass beds in the last 20 years. For the purpose of gaining insight into potential success of seagrass transplantation and restoration, water quality parameters, sediment characteristics, seagrass coverage, illuminance and temperature data were measured at eleven sites with seagrass (ten within the Tauranga Harbour, one within the Waihī Estuary) and four sites with historic loss within the Maketū Estuary. Maketu estuary sites had significantly higher ammonium levels ($p=.002$), although nitrate, total nitrogen and phosphorous were not higher or sometimes lower compared to areas with seagrass. Eutrophication cannot be clearly identified as a causal agent for seagrass loss from this study. Maketu had significantly higher temperature ($p<.001$) and illuminance ($p<.001$), suggesting that higher temperatures may contribute to seagrass loss. If

so, the recently completed rediversion and greater water flow from the Kaituna river could mitigate the highest summer temperature extremes and seagrass may once again be able to survive in Maketu estuary. There were not significant differences in any other measured variables. Recommendations for a successful seagrass transplantation project are discussed.

Introduction

1.1 Seagrass Ecology

Seagrass (*Zostera muelleri*, formerly known as *Z. capricorni* or *Z. novazelandica*) is New Zealand's only marine angiosperm (flowering plant) (Jacobs, Les & Moody, 2006), often occupying soft sediment habitat typically within the intertidal zone of coastal estuarine & Harbour systems. Seagrass may also inhabit shallow waters near offshore islands such as Slipper Island, throughout New Zealand (Schwarz et al., 2006). *Z. muelleri* brings additional structure to its respective environment, this in turn provides habitat & shelter, for a multitude of marine fauna from invertebrates to juvenile fish, including commercially valuable species such as Snapper (*Pagrus auratus*) (Schwarz et. Al, 2006), as such it supports a high degree of potential biodiversity, particularly in large continuous beds (>1000 m2), (Mills & Berkenbusch, 2009). The physical form of seagrass also results in a reduced flow rate across its cover, this enables fine sediments to settle at a greater rate, reducing re-suspension and subsequently assisting in sorting and substrate stabilisation (Heiss et al., 2000). Growing evidence suggests that seagrass is an invaluable contributor to global carbon storage, due to its ability to sequester large amounts of carbon in the form of plant biomass and organic particles deposited within the seagrass beds (Duarte et al., 2013).

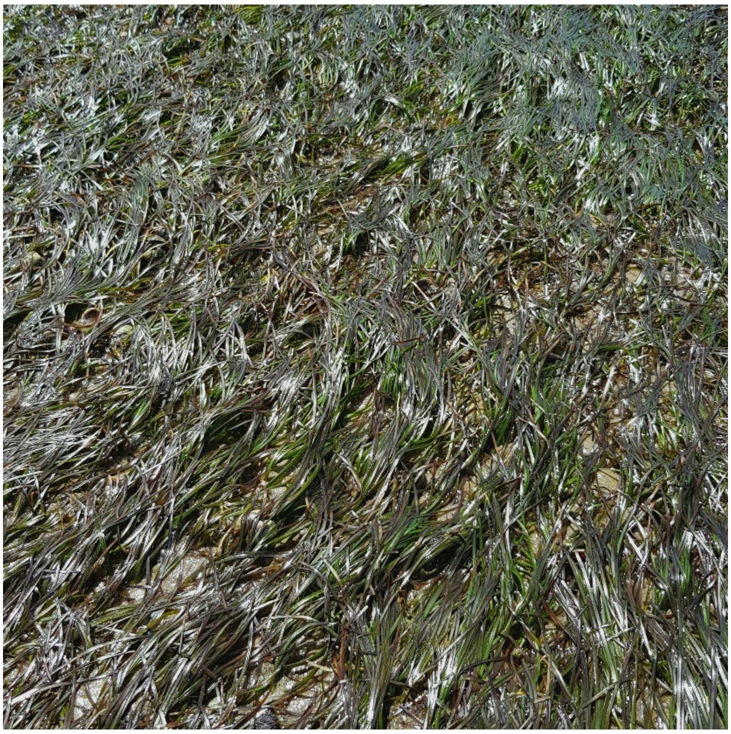


Figure 1. Emerged seagrass (*Zostera muelleri)* bed in Northland's Parengarenga Harbour, NZ. (Ethan Russell, 2020)

1.2 Decline of Seagrass

Seagrass habitats are under threat globally due mostly to a suite of anthropogenic stressors, in New Zealand specifically these stressors are thought to include eutrophication, increased sediment loading, waterfowl grazing, shifts in water temperature and physical disturbance such as dredging and land reclamation (Orth et al., 2006, Roca et al., 2016, Unsworth et al., 2018). The Tauranga Harbour has the majority of seagrass beds within the Bay of Plenty region, 96.4% covering a total of 2,744.9 ha, with the remainder distributed across Ohiwa Harbour & smaller estuaries such as Waihī Estuary (Park, 2016). Tauranga Harbour suffered a large-scale loss between the years of 1959 & 1996 (conceivably due to the 1981 Ruahihi canal failure, which resulted in large volumes of sediments entering the Wairoa river (De La Hyde, 2007), Through that time, 34% of its seagrass beds dissapeared, with the losses primarily taking place in the southern end of the Harbour (Park, 1999). Between 1996 & 2011 this loss was not nearly as dramatic, with a total decline of 6.5%, suggesting the decline has slowed to some degree but not halted (Park, 2016). The trend has been the same within other areas of the Bay of Plenty, with the Waihī Estuary recently declining to a few residual beds & the Maketū Estuary incurring a total loss of seagrass, contributing to the assessment of overall deterioration of the estuary's health (Park, 2018).

1.3 Aims & Hypotheses

Over time the Maketū Estuary has been subject to considerable changes in both its water quality and hydrology, with the primary freshwater inlet, the Kaituna River, diverted directly out to sea in 1956 for the purpose of enhanced land drainage and flood control. Recently large-scale re-diversion work has taken place to attempt to restore 20% of the historical freshwater flow, and as such presents an opportunity to investigate the prospect of seagrass restoration through transplantation to further assist its ecological recovery. Few studies exist detailing the efficacy of seagrass transplantation within New Zealand, however one study performed within the Whangarei Harbour found that survival and growth can be achieved for up to 24 months post-transplant if the site is carefully selected (Matheson et al., 2017, Schwarz et al., 2005). Successful transplantation is likely the fastest means of re-establishing seagrass at sites with historic loss, as flowering (sexual reproduction) is associated with seagrass beds of a high biomass and coverage which don't exist in Waihi or Maketu estuary and have rarely been observed in New Zealand (Dos Santos & Matheson, 2017). Therefore it's thought that rhizomatic growth from transplanted seagrass sods may be the quickest way to re-establish beds into the post-diversion Maketu estuary.

The specific purpose of this study is to identify any statistically significant difference in light, temperature, sediment and water quality variables that may be contributing to seagrass absence in the Maketū Estuary, in comparison to existing seagrass beds in Tauranga Harbour & the Waihī Estuary. Sampling was performed at selected sites across the three tidal estuaries. The data collected from the Maketū Estuary also serves as a baseline prior to the completion of the re-diversion for continued environmental monitoring, and future restorative efforts.

1.3.1 - Null Hypotheses

H_0 - There is no statistically significant difference in water quality (as measured by mean ammoniacal nitrogen, conductivity, dissolved oxygen, turbidity, phosphate/phosphorus, nitrite & nitrate, total nitrogen levels) from collected water samples between sites with seagrass (Tauranga Harbour/Waihī Estuary) and sites with historical seagrass loss within the Maketū Estuary.

H_0 - There is no statistically significant difference in substrate quality (as measured by mean grain size, total recoverable phosphorus, nitrogen and organic carbon levels) from collected sediment samples between sites with seagrass (Tauranga Harbour/Waihī Estuary) and sites with historical seagrass loss within the Maketū Estuary.

H_0 - There is no statistically significant difference in mean light intensity & temperature levels recorded at sites with seagrass (Tauranga Harbour/Waihī Estuary) and sites with historical seagrass loss within the Maketū Estuary.

Methods

2.1 Site Selection

Tauranga Harbour contains many sub-estuaries with varying degrees of water quality, sediment profiles & amounts of tidal flow – due to the high morphological variation within *Zostera muelleri* beds, ten sites were selected, evenly split between both the Northern and Southern end of the Harbour. These sites contain a mixture of both discrete and continuous beds, providing a robust variety of habitat variability. Waihī Estuary at present plays host to two known discrete beds, with the bed located near Pukehina Beach Road selected for ease of monitoring and recording. In order to compare sediment quality, water parameters, and light/thermal conditions relevant to the suitability of seagrass beds four sites were selected within the Maketū Estuary, three of which historically had some seagrass coverage (Figure 2, Maketū 1, 2 & 3). The remaining Maketū Estuary site is located on the southern bank of the main arterial channel (Figure 2, Maketū 4), serving as an approximate parallel to some of the large continuous seagrass beds sites within the Tauranga Harbour, which are situated on the shorelines of wide channels such as those at Tuapiro Point and Omokoroa (Figure 3). All sites sit within the intertidal range for their respective areas, meaning they are covered by water at high tide, and emerged during low tide.

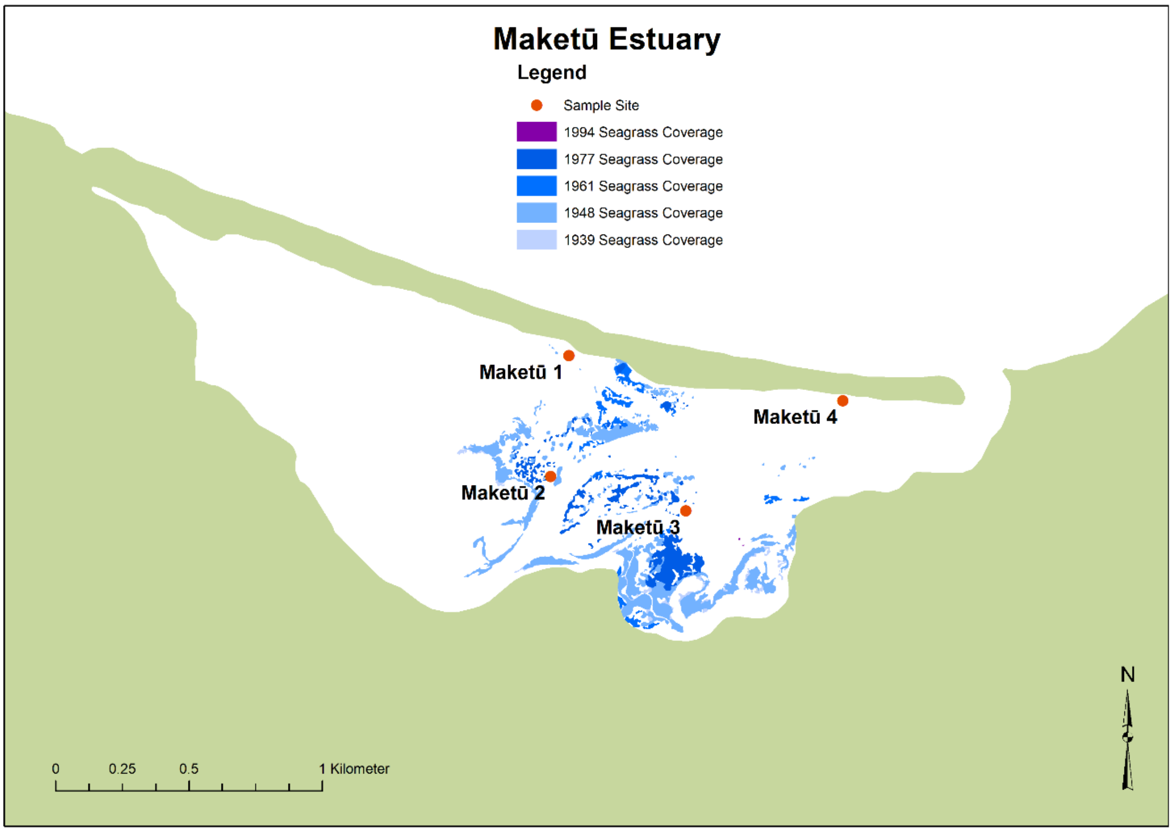


Figure 2. A map of Maketū Estuary showing historical cover and loss of seagrass, sampling sites marked in red. (BOPRC, 2020)

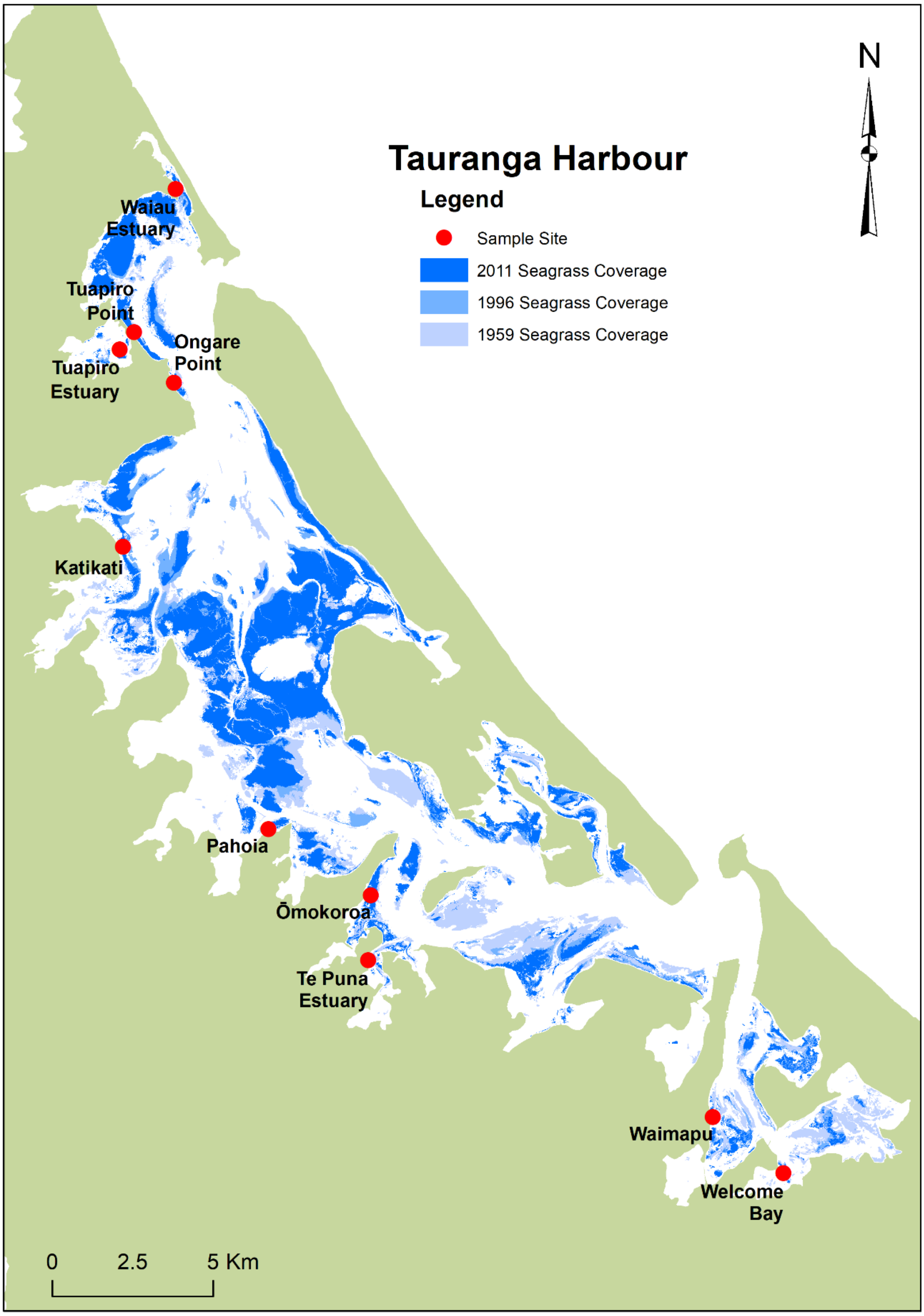


Figure 3. A map of Tauranga Harbour showing historical cover and loss of seagrass, sampling sites marked in red. (BOPRC, 2020)

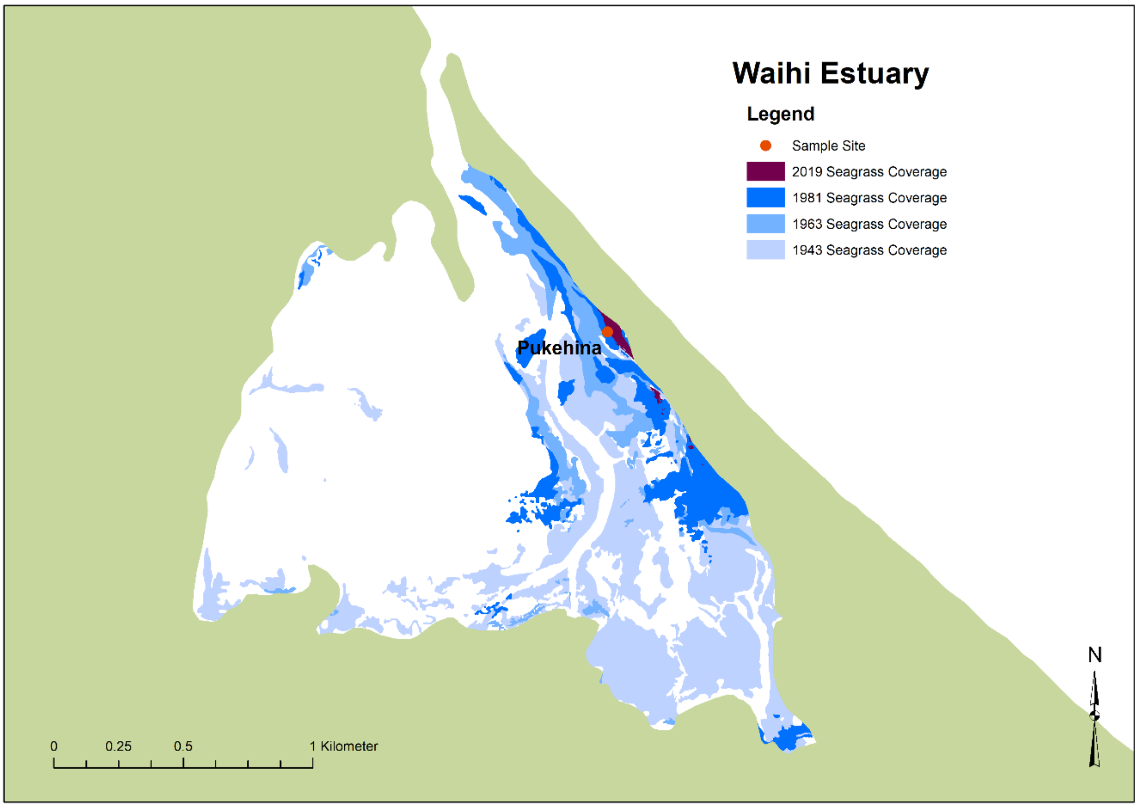


Figure 4. A map of Waihī Estuary showing historical cover and loss of seagrass, sampling site marked in red. (BOPRC, 2020)

2.2 Equipment

2.2.1 - Water Sampling

Water sampling consistently occurred at the nearest channel relative to the seagrass bed, for sites without seagrass it occurred at the nearest channel to the site's GPS co-ordinates with all sampling occurring exclusively on the outgoing tide. Water samples were collected following the protocols of the water quality NEMS (National Environmental Monitoring Standards, draft 2027). Briefly, a 1L sterile sample bottle was used with a telescopic sampling pole was filled with a water sample from ~0.3m below the water's surface. Three samples were collected from each site with 5 sites being sampled per run, runs were based on the site locale (Northern Tauranga Harbour, Southern Tauranga Harbour and Maketū & Waihī Estuary) with overall collection of samples occurring from late November 2019 to early January 2020. Samples were transported on ice and transported to a laboratory within 24 hours of collection. The samples were analysed for dissolved nutrient concentrations (nitrate, ammonium, phosphate), total nutrient concentrations (total nitrogen, total phosphorus), and for turbidity. In addition, prior to water sample collection a handheld probe was deployed ~0.3m below the water's surface to obtain real-time water temperature, conductivity and dissolved oxygen levels (%/mg L).

2.2.2 – Light & Temperature

To obtain data on light intensity and temperature of each site, data loggers (HOBO MX2202) were setup at each site on a metal stake approximately 2-4cm above the substrate surface at a zero-degree angle, in order to best replicate light conditions that seagrass experience. These data loggers were placed at all sites and within bare patches amongst seagrass beds where possible, otherwise they were placed approximately at a comparable mid-tidal position within the immersion zone, but never directly in a channel. The equipment was left once at each site for at least 7 days, with recording taking place at 10-minute intervals.

2.2.3 - Substrate Sampling

Samples were collected using a 50 mL syringe with the end cut off, resulting in a 2cm diameter round core with a depth of 2cm, in line with protocols used by BOPRC in regional Estuary monitoring (Lawton & Conroy, 2019). At each site, 12 cores were haphazardly taken and pooled to create one representative sample of the sediment site. Samples were initially stored on ice, and subsequently frozen until analysis.

Sediment samples were defrosted and dried in an oven at 60°C for 24 hours before sending for grain size analysis (using laser diffraction). The remaining half of the sediment sample was kept cool on ice and sent to a separate laboratory for analysis of sediment total organic carbon (TOC), total nitrogen (TN), and total carbon (TC) values.

2.2.4 - Seagrass Percentage Cover

Using a square 0.25 m^2 quadrat 10 haphazard image samples were taken from each of the 11 seagrass sites, with 3-4 images taken for sites without seagrass. Images were subsequently analysed using Coral Point Count software that assigned 50 random points within the quadrat boundary to determine percentage cover.

2.2.5 Statistical Analysis

Mean differences in variables between sites with seagrass and those without were compared using 2 sample independent t-tests assuming normality, using Excel ver. 1912.

Results

3.1 Seagrass Percentage Cover

3.1.1 Seagrass Quadrat Analysis

The densest seagrass was measured at Ongare Point with 31% coverage. The sparsest seagrass was measured within the Te Puna Estuary at 18.2%. Scatter plot analysis comparing recorded water parameters failed to return an R^2 value greater than 0.5, suggesting that there was no notable trend when correlating % cover of seagrass with recorded water quality variables.

3.1.2 Seagrass Quadrat Images

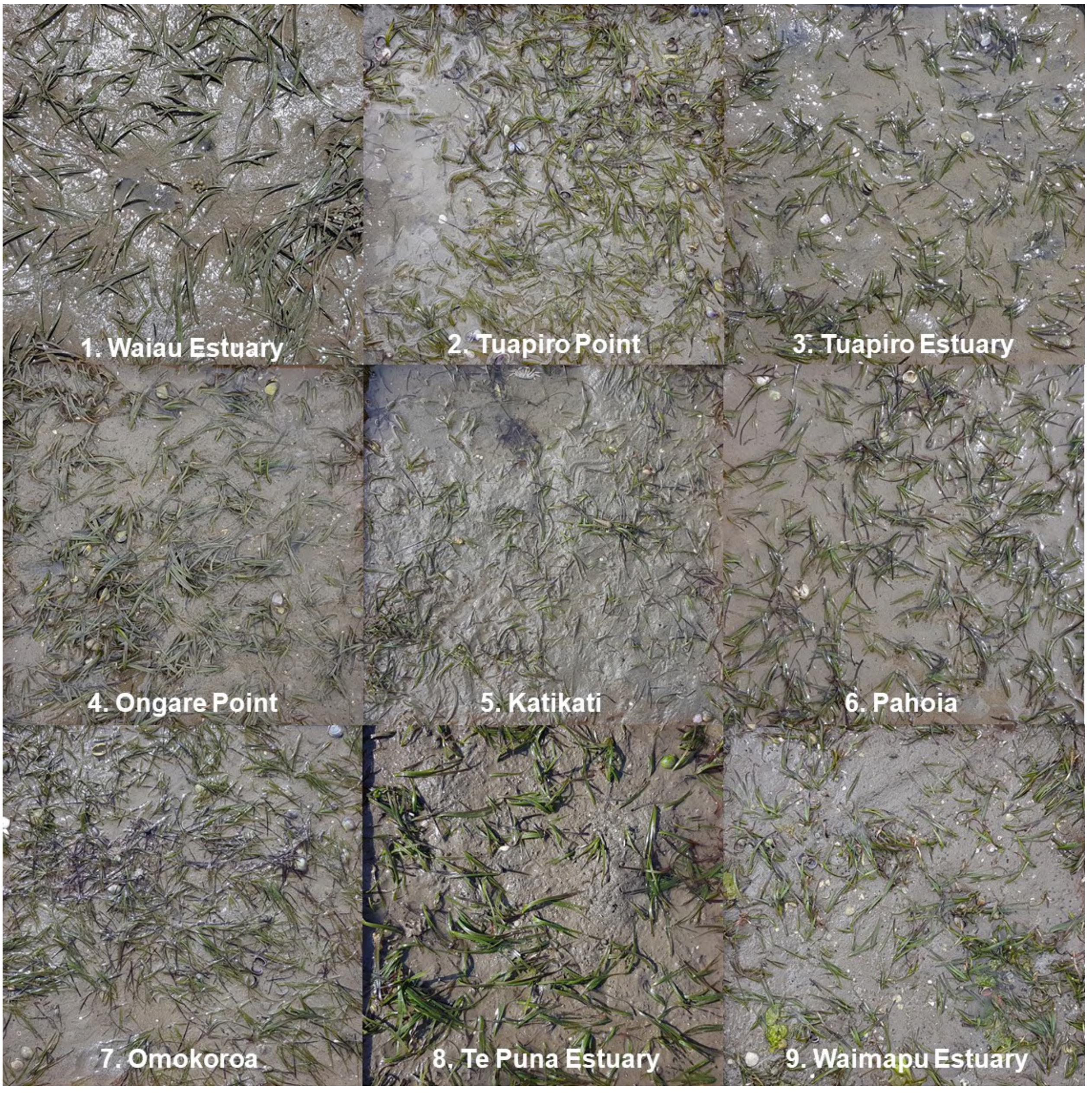


Figure 5. Quadrat images from 9 of the seagrass sampling sites, showing differences in coverage, morphological form and sediment appearance.

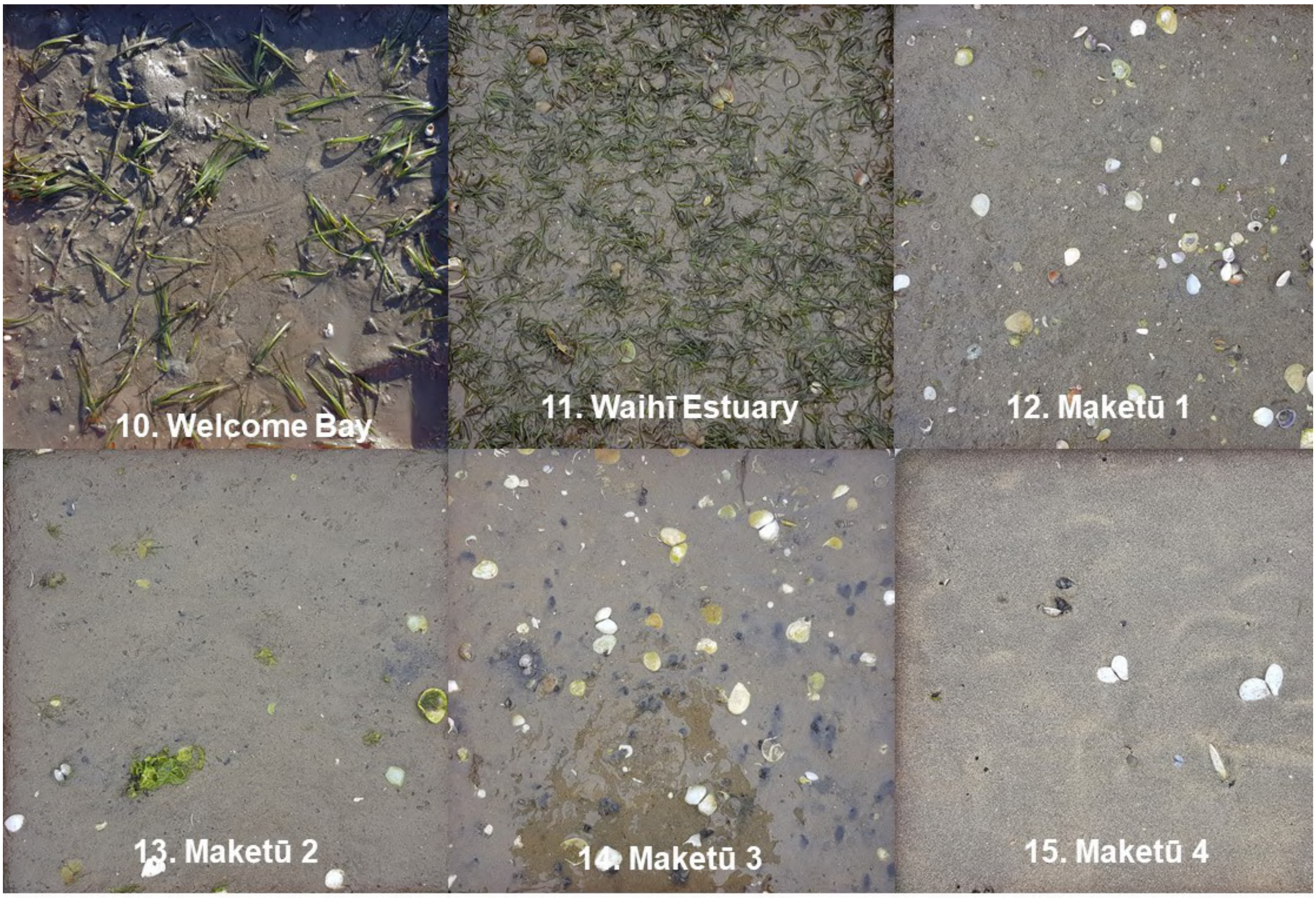


Figure 6. Quadrat images from each of the sampling sites continued, showing differences in coverage, morphology and sediment appearance.

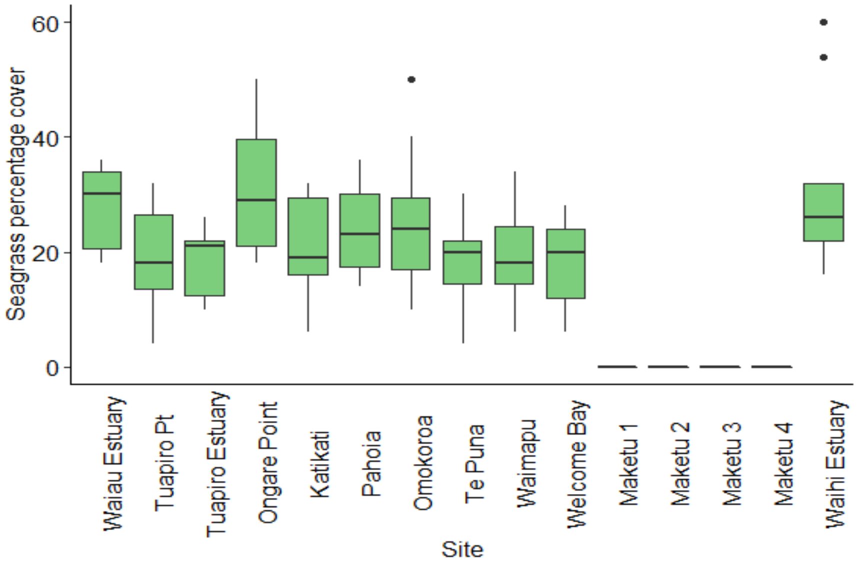


Figure 7. Box plot of seagrass percentage cover from quadrat images from all sites.

3.2 Water Quality

3.2.2 Ammonium

The highest ammonium reading was taken at Maketū and the lowest from Tuapiro Point There was a significantly greater mean concentration of ammonium at sites without seagrass compared to the sites without (p =.002).

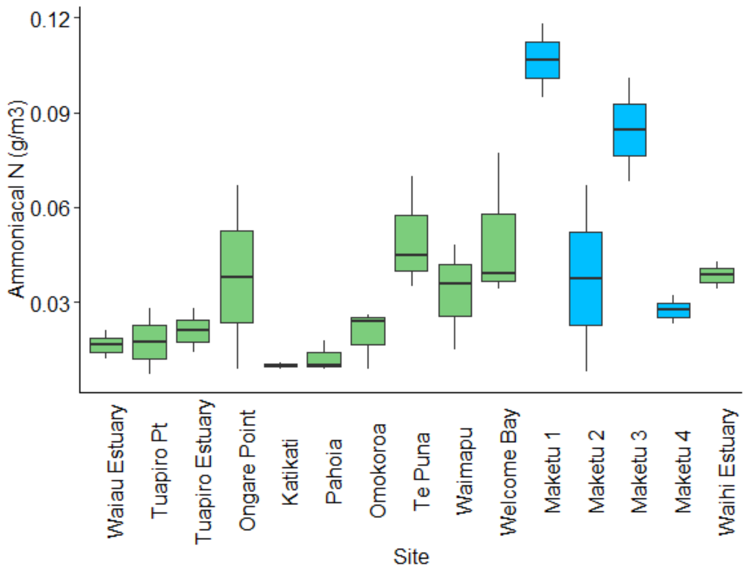


Figure 8. Ammonium content of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.4 Nitrate

The highest nitrate level was measured at Waihī Estuary and several sites including Maketū 4, Omokoroa, Pahoia & Katikati had readings of 0g/m3. There was no significant difference in mean nitrate levels at sites with seagrass and sites without (p=.78).

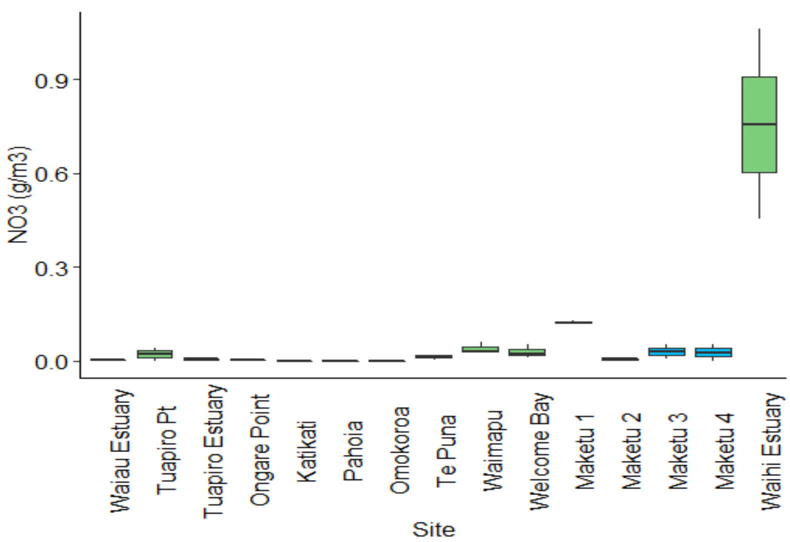


Figure 9. Nitrate content of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.5 Total Nitrogen

The highest total nitrogen reading was recorded at Waihī Estuary and the lowest at Maketū 4 There was no significant difference in mean total nitrogen levels between sites with seagrass and sites without seagrass (p=.54).

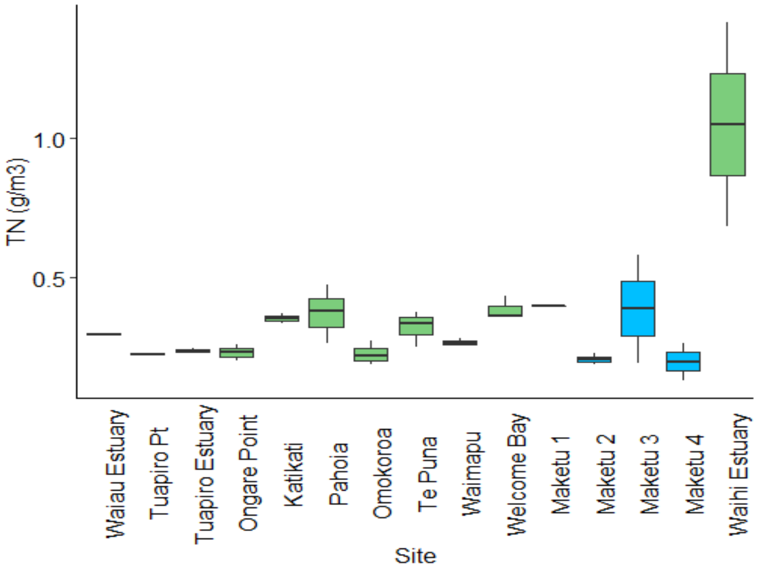


Figure 10. Total nitrogen content of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.6 Dissolved Phosphate

The highest levels of dissolved phosphate were measured at Waihī Estuary and several sites had means of zero. There was no significant difference in mean dissolved phosphate at sites with seagrass compared to sites without seagrass (p=.47).

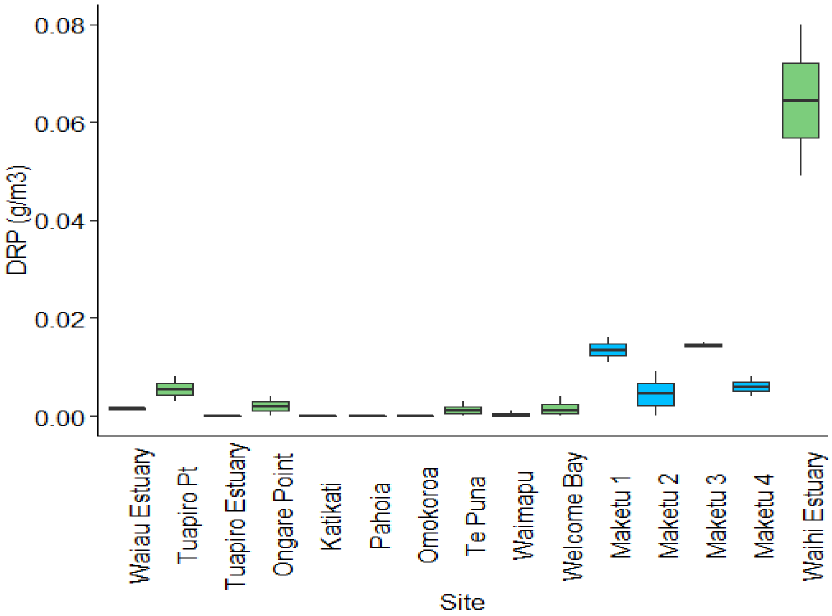


Figure 11. Dissolved reactive phosphate content of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.7 Total Phosphate

The highest levels of total phosphate were measured at Waihī Estuary and the lowest at both Ongare Point and the Waimapu Mean total phosphate levels were not significantly different at sites with seagrass vs. those without (p=.71).

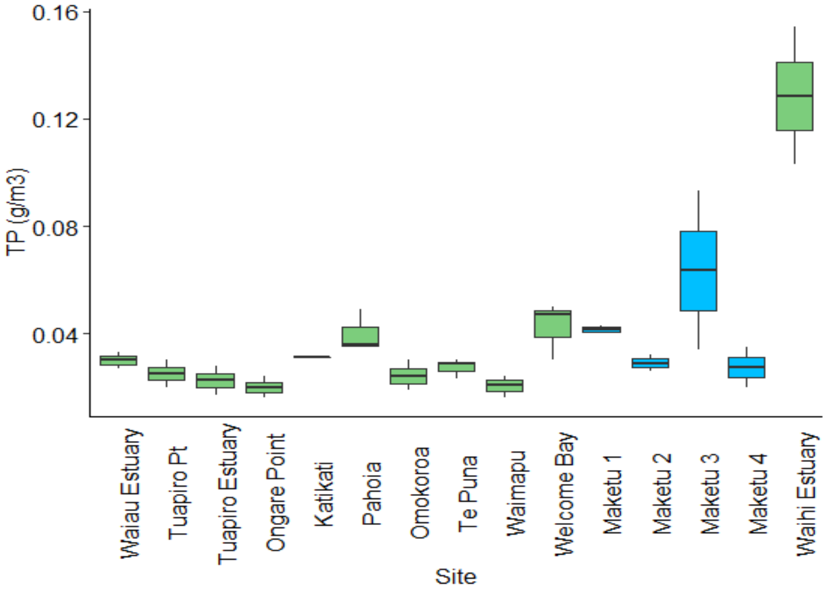


Figure 12. Total phosphate content of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.2 Conductivity

Conductivity readings as a proxy for salinity, were highest at Ongare Point and lowest at Waihī Estuary There was no significant difference in mean conductivity between sites with seagrass and those without (p=.52).

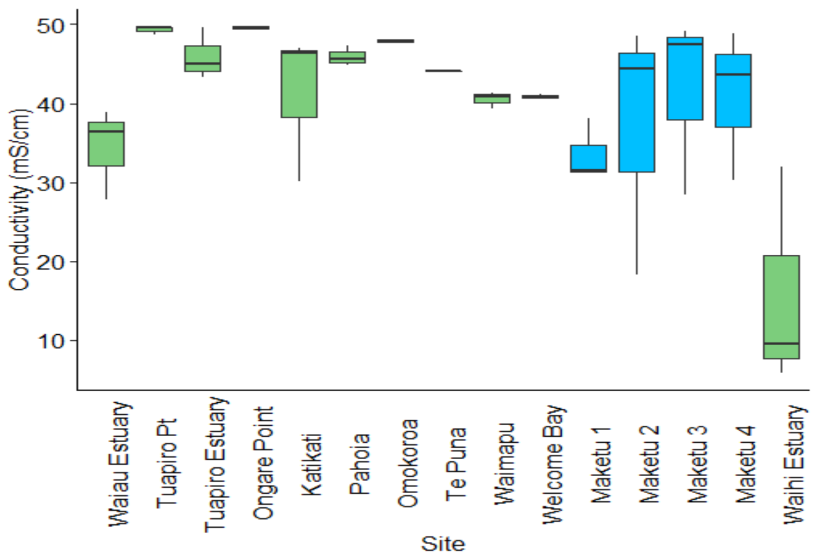


Figure 13. Conductivity readings taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.3 Dissolved Oxygen

The maximum dissolved oxygen reading was measured at Maketū 4 and lowest reading was measured at Welcome Bay. There was no significant difference in mean dissolved oxygen levels at sites with seagrass and sites without (p=.15).

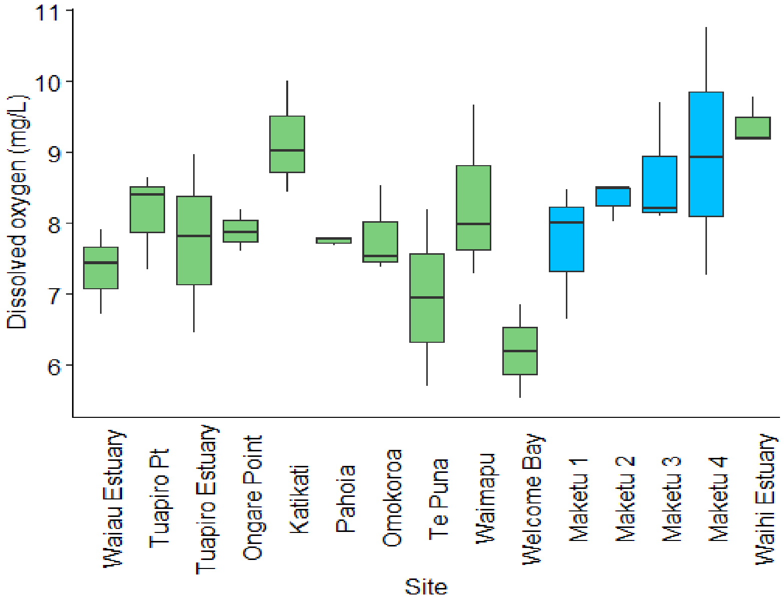


Figure 14. Dissolved oxygen content of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.2.8 Turbidity

The maximum turbidity recording was from the Waihī Estuary and the minimum at Tuapiro Point. No significant difference in mean turbidity was found between sites with seagrass and sites without (p=.12)

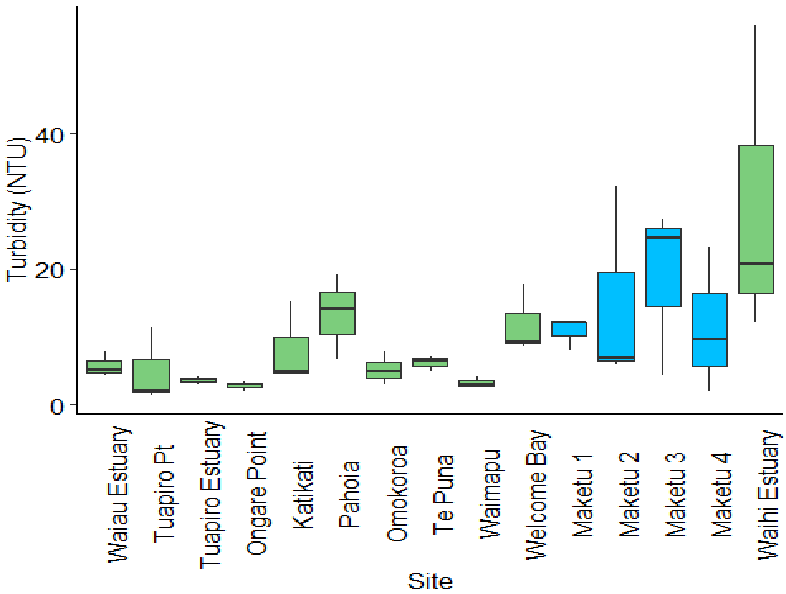


Figure 15. Turbidity levels of water samples taken from all sites. Seagrass sites coloured green and sites without seagrass coloured blue.

3.3 Light & Temperature Data

3.3.1 Illuminance (Lux)

The highest mean illuminance was at Maketū 3 and the lowest at Katikati. There was significantly higher illuminance at sites without seagrass compared to sites with ($p<.001$).

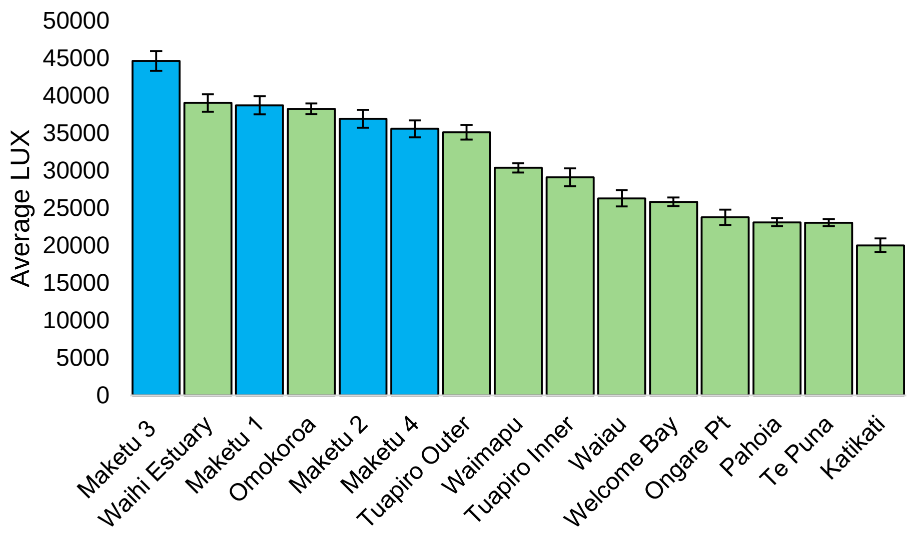


Figure 16. Mean illuminance from data loggers from all sites. Seagrass sites coloured green and sites without seagrass coloured blue. (±SE)

3.3.2 Temperature

The highest mean temperature from all sites was recorded at Tuapiro Point (Outer) with several sites exceeding 40°C. The lowest temperature was recorded at the Waimapu site Sites with seagrass had a significantly higher temperature than those without ($p<.001$).

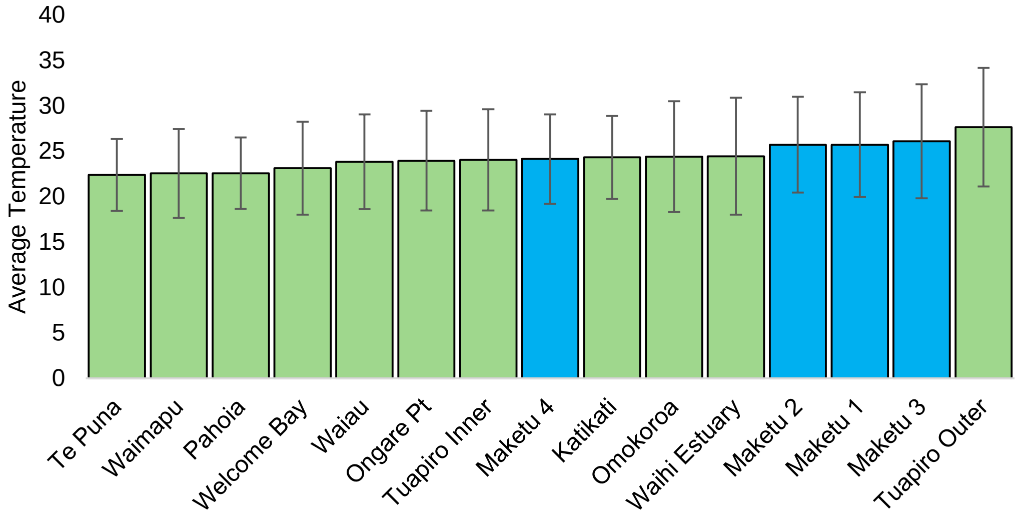


Figure 17. Mean temperature (°C) from data loggers from all sites. Seagrass sites coloured green and sites without seagrass coloured blue. (±SD)

3.4 Substrate Sampling

3.4.1 Grain Size

Grain size was larger at sites without seagrass compared to sites with seagrass, but not significantly so (p=.101).

3.4.2 Substrate Nutrient Analysis

Total organic carbon levels within core samples were higher at sites with seagrass compared to sites without seagrass although not significantly so (p=.12). This is unsurprising considering the root mat of seagrass beds.

There was no trend in total nitrogen content or total recoverable phosphorous between sites with seagrass and sites without (p=.48).

Table 1 : Summary Statistics of data collected at sites within the Tauranga Harbour & Waihi Estuary vs data collected from the Maketu Estuary sites. P values are the result of t-tests run comparing the means of variables between harbours and estuaries with seagrass, to the Maketu Estuary which lacks seagrass.

Parameter	Tauranga Harbour & Waihi Estuary				Maketu Estuary				
	Mean	SD	SE	*n*	Mean	SD	SE	*n*	P Value*
Ammoniacal N (g/m^3)	0.03	0.02	0.00	27	0.06	0.04	0.01	8	**.002**
Conductivity (mS/cm)	41.49	10.72	1.93	31	39.03	10.19	2.94	12	.521
Dissolved Oxygen (g/m^3)	7.97	1.08	0.19	31	8.43	1.06	0.31	12	.145
Dissolved Oxygen Saturation (%)	106.59	15.77	2.83	31	106.86	17.04	4.92	12	.739
Nitrate (g/m^3)	0.07	0.22	0.04	27	0.05	0.05	0.02	8	.786
Total Nitrogen (g/m^3)	0.35	0.24	0.05	27	0.30	0.15	0.05	8	.546
Dissolved Reactive Phosphate (g/m^3)	0.00	0.02	0.00	27	0.01	0.01	0.00	8	.470
Total Phosphate (g/m^3)	0.04	0.03	0.01	27	0.04	0.01	0.02	8	.710
Turbidity (NTU)	8.65	9.96	1.73	33	14.06	10.08	2.91	12	.116
Illuminance (lx)	28489	27640	232.30	14158	38951	31762	610.02	2711	**<.001**
Temperature (°C)	23.58	5.31	0.04	14158	25.43	5.63	0.11	2711	**<.001**
Mud Content (%)	15.00	7.02	2.12	11	8.18	5.02	2.51	4	.101
Total Organic Carbon (g/100g)	0.40	0.14	0.04	11	0.28	0.08	0.04	4	.122
Total Nitrogen (g/100g)	0.04	0.02	0.01	11	0.03	0.01	0.01	4	.475
Total Recoverable Phosphorus (mg/kg)	169.36	68.19	20.56	11	203.25	99.43	49.71	4	.462

* Significant P values are indicated in bold

Note : Data for Ammonical, Nitrate, Total Nitrogen, Dissolved Reactive Phosphate, Total Phosphate are all missing 5 samples. Equipment failure lead to unforeseeable delays in the samples being processed via a laboratory, and as a resultwere not able to be used for this study.

Discussion

The only water quality parameter with a significant difference between sites with seagrass and sites without was ammonium, which was higher at Maketū 1 & 3 (Figure 8). Interestingly, it is also a chemical known to be highly toxic to the seagrass species *Zostera marina* in concentrations upward of 125 µM (Van Katwijk et al., 1997), this implies that it may be an inhibiting factor for potential transplants, however stressor tolerance levels within *Z. muelleri* are not robustly studied, nor is how single stressors may interact with other stressors of seagrass within New Zealand (e.g. sedimentation, grazing). Also, Ammonia is the least persistent state of nitrogen, suggesting that there is a localized source near the Maketu sites. No point source was identified, and a greater post-diversion flow rate from the Kaituna river may dilute this higher concentration bringing Maketu more in line with sites with eelgrass.

Temperature data collected by loggers deployed at the Maketū Estuary showed significant differences when compared to sites with seagrass presence. Maketū Estuary sites sat within the top 50% of all sites for mean temperature. Higher temperatures are potentially a product of the comparative water volume which could be heating at a greater speed and to a greater degree during the summer period. Temperature is thought to be another contributing variable to seagrass health, with trials showing rapid loss of living shoots and leaf mass in *Z. muelleri* occurring at 32°C (York et al., 2013). Certainly in summer they reach those temperatures on the maketu flats. An increase of water flow from the rediversion could potentially keep these areas cooler and could mean a better chance of survival of transplants

Higher illuminance or light levels contribute to higher temperatures and were also higher on average at the Maketū Estuary sites, turbidity or clearer water conditions can be excluded as a factor, as turbidity readings were generally higher than those at Tauranga Harbour seagrass sites (Figure 15

The following data has been sourced from regular monitoring performed by the Bay of Plenty Regional Council, and while no specific sampling from this report has contributed to the data, it provides additional perspective to the sediment loading characteristics of locales which were sampled on or around throughout the duration of this study.

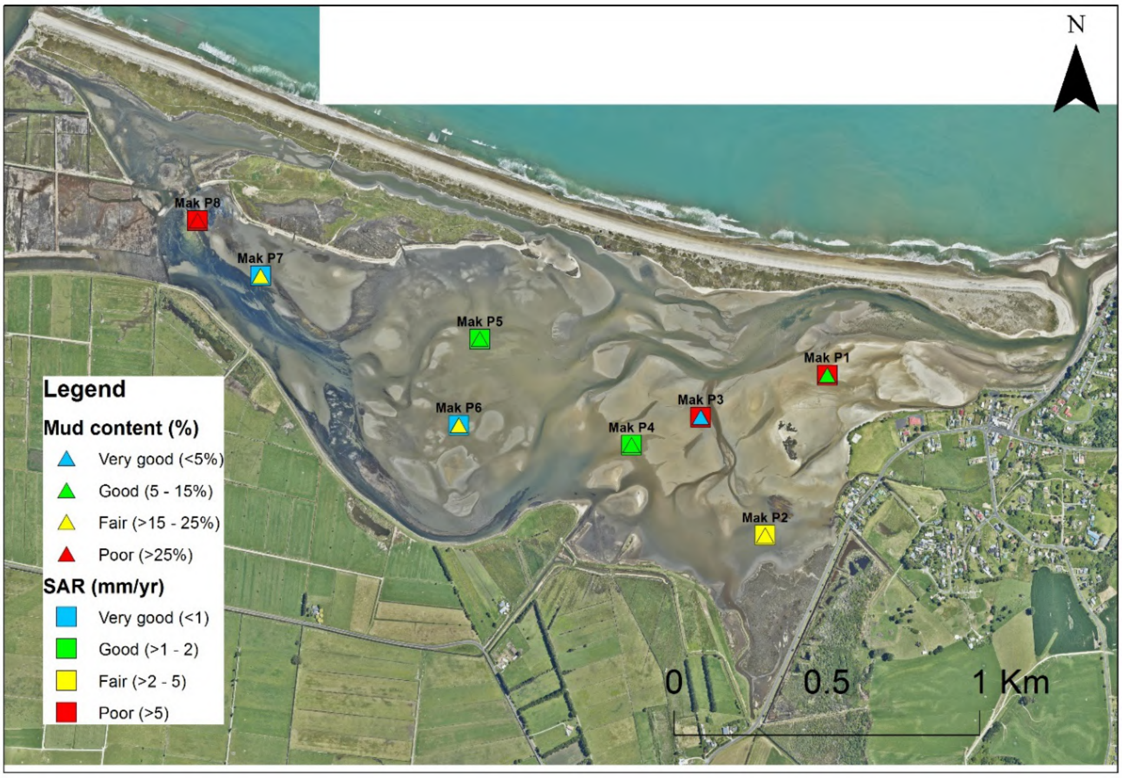


Figure 18. Maketū Estuary with various plate sites and the respective mud content & annual sedimentation rates (BOPRC, 2020)

As visible in the Maketū sedimentation map (Figure 23) "Mak P1" & "Mak P3" or Plate 1 & Plate 3 have a low mud content (5-15%) however have very high deposition rates (These are nearest to sites Maketū 3 & 4 [P3 &P1 respectively]). This is consistent with anecdotal reports from residents, of which report increased levels of sand within the Estuary in recent years. While lacking substantiation, the high sand deposition could be a result of the historically diverted Kaituna river, allowing sediments to be transported from the coast into the estuary and accumulate near the entrance, , this trend may change now that 20% of the historic input flow from the Kaituna River has been restored to the Maketū Estuary. Another interesting point to make is that Tuapiro Point exterior and Omokoroa were the only larger continuous beds sampled on and around, and these sites both had low concentrations of nutrients & low turbidity levels alongside high percentages of sand content, and sat within the upper end of mean light & temperature environment. The specific factors enabling the persistence of large continuous seagrass bed growth aren't acutely understood, however the observed conditions at the Omokoroa & Tuapiro Point seagrass beds provide some insight into the preferential quality of seagrass habitat, as well as location within an estuary – with both beds adjacent to arterial channels of the northern Tauranga Harbour.

Maketū Estuary also exhibited slightly higher mean levels of dissolved reactive phosphate, turbidity and total recoverable phosphorus within the sediment, the sites also had approximately half the mean mud content as seagrass sites within the Tauranga Harbour & Waihī Estuary. This could suggest that although sites within the Maketū Estuary were sandier than most seagrass sites, the typically higher levels of nutrients within the water column and sediment may be above those suitable for seagrass, potentially encroaching toxic levels for the species.

The Waihī Estuary had perhaps the most intriguing results of all sites, having the highest concentration of multiple water column nutrient parameters (nitrite and nitrate, total nitrogen, dissolved reactive phosphorus, total phosphate and turbidity (Figure. 11, 12, 13, 14 & 15) despite supporting two discrete seagrass beds. A potential explanation for this is the noticeably low levels of conductivity recorded during the study period, suggesting that it could either catalyse a higher level of nutrient tolerance or be a result of a more responsive and/or a greater level of genetic fitness (Dos Santos & Matheson, 2017) – as the species is known to increase flower production (Ramage and Schiel, 1998) in lower salinity conditions. Furthermore, the Waihī Estuary seagrass bed is adjacent to the estuary's primary channel, presumably resulting in a large degree of tidal flushing at high tide – and as such could be exposed to differing degrees of water quality on or around the bed throughout the day. The observations from Waihī Estuary suggest proximity to the channel may be a key element supporting seagrass health, as noted with the Omokoroa & Tuapiro Point seagrass beds.

4.1 Recommendations

More samples including control sites within the Tauranga harbour and the Waihi estuary which have had historical seagrass bed losses should be included if this monitoring is to continue. Further data collection should occur at the seagrass beds, under varying rainfall conditions. In addition temporal differences between the sites were not accounted for, perhaps the tidal state could be standardized for collection at each site.

Elevation and intertidal exposure times are also important considerations for seagrass, which likely has a high level of influence on the resulting light and temperature data collected by deployed loggers and will likely vary at each site. Future work should be done to determine which tidal elevation within the intertidal range has the highest suitability for seagrass. Another potential stressor to consider for seagrass transplantation is grazing by black swans (*Cygnus atratus*) (Dos Santos et al., 2013) which were observed whilst sampling within the Maketū Estuary, and as such should be a factor for consideration of any future restoration work. This could be expanded to include other biological stressors such as epiphytic algae, rapidly growing macroalgae species i.e. Sea lettuce (*Ulva lactuca*) & red algae (*Gracilaria chilensis)*, of which were present in large quantities at Maketū 2, and as such may outcompete or shadow any transplanted seagrass. Further monitoring should also seek to assess any changes to the water quality & sediment data collected now that the Kaituna River diversion has 9 of its 12 culverts currently open, which with modified hydrology may bring about new trends in nutrient levels, temperatures and sedimentation rates.

Conclusion

To conclude, the sites sampled at within the Maketū Estuary have very few significant differences between sites with seagrass in the Tauranga Harbour, and in some cases the returned values appear "more suitable", or are in lesser concentrations than they are at sites with seagrass – this is particularly true when compared to Waihī Estuary across the board. The variables that did have a significant difference from those with seagrass were ammonium concentrations, as well as the light and temperature readings. Additionally, parameters like light, temperature and sand content align well with the larger continuous beds within the Tauranga Harbour, specifically Omokoroa and Tuapiro Point exterior beds. The prospect of a transplant appears viable as far as sediment grain size, mud/ sand content & light environment is concerned – with the most concerning factor being temperature spikes, and ammonium concentrations. Both of these are less likely to be mitigated by the greater water flow post-diversion.

The probability of success of a transplantation is uncertain, with the estuary expected to undergo some degree of change to its overall ecological health following the re-diversion. Further monitoring should be carried out to identify any new negative/positive trends in nutrient and/or sediment characteristics at the Maketū Estuary. At the same time, the risk of environmental harm from a small scale seagrass transplant project is considered small, but with potentially great benefits to restoring the Maketu estuary to its former state. Local sourcing has been shown to optimise the prospective success rates (Jones et. Al, 2008).

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