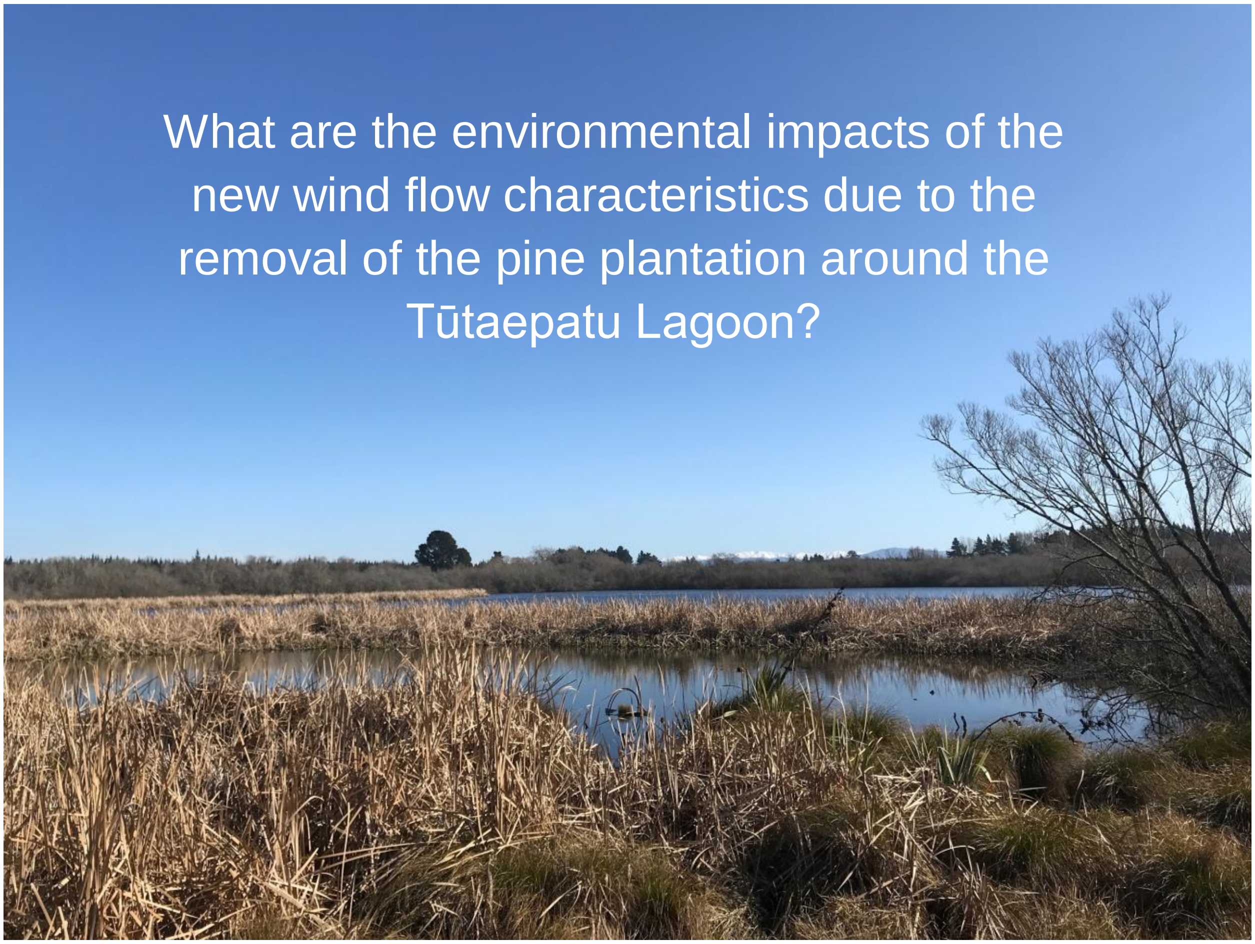
What are the environmental impacts of the new wind flow characteristics due to the removal of the pine plantation around the Tūtaepatu Lagoon?



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Te Kōhaka o Tūhaitara Trust

Contents

Executive summary

- Te Kōhaka o Tūhaitara Trust, located at Woodend Beach, Canterbury, had a report completed in 2017 regarding the possible impacts on Tūtaepatu Lagoon due to the pine forest removal that was about to take place. Since this pine harvest has occurred, the Trust are now concerned about what impacts are actually being observed and how severe they are.

- The research question is: *What are the environmental impacts of the new wind flow characteristics due to the removal of the pine plantation around Tūtaepatu Lagoon?*

- The methods for this report included sampling the climatic conditions of the area, using weather stations that were located on both the eastern and western sides of the lagoon. Water sampling was also undertaken to give salinity and depth profiles, as well as a turbidity sensor being installed at the western edge of the lagoon to measure the potential impact from the increase in exposure.

- The results for this project suggest that there has been little salt spray transported into the lagoon, despite the increase in the strength of the easterly winds since the removal occurred. The results also show that there are areas of the lagoon, such as the centre and the west, that have slightly higher sediment content which is potentially caused by the increased exposure after the trees have been removed, while also providing a baseline data record.

- Future research for this project would include a longer range of data collection, such as one year, to allow for more seasonal trends to be observed. Other research could also include investigating the tolerance of the plant species to the new wind and salt levels, post-harvest. Furthermore, an investigation of the biota found in the lagoon and their tolerance to the greater exposure would be of cultural and environmental interest.

1. Introduction

The Tūhaitara Coastal Park Reserve is located to the north east of Christchurch at Woodend Beach. The Reserve covers an area of 575 hectares of land, extending 10.5km along the coast, where the majority of which is dedicated to pine plantations (Te Kōhaka o Tūhaitara Trust, 2017). However, a large portion of these pines have now been harvested leaving the land bare. Other areas of the Reserve are occupied by native plantings and freshwater systems, such as the Tūtaepatu Lagoon. These native plantings are now a large focus of the Reserve with a regeneration programme being implemented.

This area and the Tūtaepatu Lagoon hold great cultural and historic value with its links to being the burial site for the founder of the Kaiapoi Pā, Tūrakautahi, as well as being an area that provided a plentiful source of food for the Ngāi Tahu tribe in early settlement (Christchurch City Libraries, n.d). These aspects of the environment have been greatly valued and treasured by locals for many years. With the removal of the pine plantation surrounding the lagoon, there may be an increase in the salinity and sediment levels in the lagoon, as well as changes to the native species found at the lagoon. To address these issues, this has led to the research question of:

What are the environmental impacts of the new wind flow characteristics due to the removal of the pine plantation around the Tūtaepatu Lagoon?

The main aim of this research project was to investigate the potential changes to the wind profile of the area since the pines have been harvested, and compare the results to those that were found from the 2017 research project (Morgan et al, 2017). This included investigating any wind speed and wind direction profile changes. Additionally, we aimed to investigate the potential environmental impacts of these wind profile changes on the lagoon by looking at salinity, sediment and turbidity measures of the lagoon. Another aim of this research project was to investigate whether the pine removal resulted in overall positive or negative impacts for the lagoon.

This research project begins with a literature review of the local climate characteristics, as well as a history of the area. This history was inclusive of both cultural history and historic events that may have shaped the area. Methodologies are then highlighted, which includes both field and lab based methods. Following this section is the results and discussion, where the findings are analysed and discussed in terms of the previously mentioned aims. Lastly, the research leads to conclusions being made and any limitations being highlighted. Future research needs are also made clear at this point.

2. Literature Review

This report includes a variety of research methods and approaches that have been inspired by literature relating to the stated aims of the project. The literature review is inclusive of the local climate conditions (McGann, 1983; Macara, 2016), Aeolian effects in coastal settings (Hesp, 1999; Hesp et al, 2005; Guevara, Silva and Lithgow, 2019), native vegetation and shelterbelt effects in coastal areas (Choi, Kim and Jung, 2013). Notably there is limited research on the effects of wind on coastal lagoons in New Zealand and studies on wind-blown sediment in this country have largely only progressed in the last 20-25 years (McGowan, 1996; McGowan and Sturman, 1997).

2.1 Local History

In an article by Reid et al (2016), the importance of the idea of Maori people, and specifically Ngāi Tahu people, feeling connected to their environment and the people is discussed. In terms of the Tūtaepatu Lagoon, this is very important as historically it provides a very significant place for people to gather and cherish the former Kaiapoi Founder, as well as gather food. Moving forward it is important to keep these culture values in mind when making decisions, such as the native regeneration scheme.

2.2 Wind Flow

Predominant winds around Christchurch alter depending on the season, with summer and winter being north-easterly and south westerly respectively (McGann, 1983; Macara, 2016). North-easterlies are more persistent, blow for longer periods of time and are influenced by the sea breeze from Pegasus Bay (Macara, 2016). Calmer winds are more persistent than stronger winds with topography and ocean heating processes around Christchurch causing winds change (McGann, 1983; Macara, 2016), a feature of the coastal location. (McGann, 1983, Macara, 2016). NIWA's climate report for Canterbury (Macara, 2016), details more recent data collection and climate profiles. This technical report with information on temperature, rainfall, wind, solar radiation including historical weather events and intra-regional comparisons is a useful reference point. The nearest weather station at Rangiora indicates an average of 10 – 10.9 km/hr for the months of August and September (Macara, 2016) while historically summer wind speed has averaged 15- 20 km/hr (McGann, 1983) which equates to $9.7mS^{-1}$ – $11.1mS^{-1}$.

2.3 Shelterbelts and effect on the lagoon

At Tūtaepatu lagoon, the forestry block was a wind momentum sink (Kilaka, 2015), which inhibited aeolian transport. Shelterbelts influence wind by reducing speed (Wang et al, 2001) and deflecting airflow above the tree line (Gardiner et al. 2006). At Tūtaepatu lagoon the forestry block was the wind momentum sink (Kilaka, 2015), which inhibited the basic transport model assumptions for sediment in a coastal environment mentioned by Hesp (Hesp, 1999). These were 1. The wind field being even and constant, topography being flat, horizontal and unobstructed, 2. That the sediment is sand and is not sticky, wet or fouled 3. The transportation of salt is in sync with the localized wind pattern. The Tūtaepatu Lagoon has formed during prograding of the Pegasus Bay area (Blake, 1968) where sediment was transported by rivers and as loess. Now set well back from the ocean, these formation processes have reduced in recent decades (Tonkin and Taylor, 2015), however the seasonal change in wind direction experienced in Canterbury is noted.

2.4 Vegetation

Vegetation shelters the soil surface from the erosive force of wind by reducing momentum of that wind at height (Wolfe and Nickling, 1993). As Te kōhaka o Tūhaitara Trust is undertaking extensive replanting, so it is important that this is completed in a timely manner to avoid unwanted sediment movement.

White and Owers (2010) states that strategic removal and biological control can be used to reduce the biomass of weeds and also have minimal damage on native vegetation. Therefore, allowing native species to re-establish and improve resilience against further re-infestation - a long term example being the Hinewai Nature Reserve on Banks Peninsula. This further relates to a study by Kim, Choi & Jung, (2014) where they stated that coastal forestry can cause the infestation of invasive species. So we can infer that the forestry harvest has reduced introduced species and allows the native reintroduced species to thrive. Additionally, some exotic forest has already been replanted, leading to retention of soil.

3. Methodology

This project involved site visits and installation of equipment at Tūtaepatu lagoon located at Woodend Beach, 27 km north of central Christchurch, Canterbury. The data collection procedure involved measuring wind speed and direction, air temperature, lagoon turbidity and depth, water conductivity. Water samples for sediment in the water column we collected, as well as downloading of long term monitoring data via a permanently installed weather station. The assessments were conducted over a 28 - 40 day period between August and September 2019. Data was then graphed and interpreted for trends and anomalies with wind roses produced to visual wind trends both on a long term and short term (single season) basis.

3.1 Site Selection

Two sites were chosen: Site 1 was the existing automatic weather station (AWS 1) that has been continually recording from March 2017 until September. This is located at the Tūtaepatu Lagoon viewing platform on the eastern edge of the lagoon and is marked as (1) (43º19’34.57”S, 172º42’22.40”E).

Site 2 was located on the western boundary of the lagoon in a clearing at location (43°19’31”S, 172°41’57”E) at an elevation of 10 m a.s.l. This location was selected for an AWS to allow comparison of wind/climate effects across the lagoon with wind/climate effects arriving at the eastern side of the lagoon. The AWS was removed at the conclusion of monitoring for this project. Marked as (2).

Figure 1: Location of AWS 1 & 2

3.2 Equipment

Automatic weather station 1 (AWS 1) comprised a Campbell CR23x datalogger, Vector cup anemometer and wind vane, two Li-cor Pyranometers. REBS net radiometer and two Vaisala HMP50 temp/RH sensors (one at low and one at high). Automatic weather station 2 (AWS 2) comprised a Campbell CR310 datalogger, Vector cup anemometer and wind vane, Campbell 107 air temperature sensor which was added at the second site visit.

The Lagoon itself was also inspected by conducting transects of the lagoon using a water conductivity, temperature and depth sensor (model RBR XR-620) aboard a kayak. A Campbell CR310 datalogger and OBS300 turbidity sensor was installed on a waratah for approximately 28 days and was positioned in approximately 0.9m of water on the far western side of the lagoon but in a location exposed to wind from the east (*probe*). This turbidity sensor was a model RBR XR-620 and battery powered. Transect locations and locations of water samples were recorded using a Garmin Etrex Legend® GPS at each sample location. A map was created of all sample points as seen in figure 3.

The effect of turbidity was inspected in relation to potential disturbance from an altered wind regime.

Figure 2: AWS 1

3.3 Site visits

The first site visit was carried out on Thursday 15th of August 2019. AWS 1 located at the Tūtaepatu Lagoon viewing platform was visited first to download data that had been recording for 14 months while forestry logging was carried out. AWS 2, which was a 5 meter structure, was installed at the selected site on the western side of the lagoon. This was done with the assistance of UC geography department technicians.

A second site visit involving field work took place on Tuesday 27th of August. During this period a temperature sensor was added to AWS 2, depth/temperature and conductivity measurements were taken in the lagoon using a kayak, a turbidity sensor was installed on the western edge and water samples taken at specific locations to give a varied representation of the sediment in the water column and allow for comparison with the probe results. 6 samples were taken and locations marked with the Garmin Etrex GPS plotter. Water samples were in 750mL jars and labelled according to the position set by the GPS tracker. This was conducted using bow a row boat and with permission from Tūhaitara Trust Ranger Greg Byrne.

Figure 3: Tūtaepatu Lagoon waypoints showing transects conducted using a kayak and depth probe

AWS = Automatic Weather Station
GPS = Global Positioning System

3.4 Analysis of water samples

Water sampling analysis took place in the University of Canterbury Geography laboratory
The six water samples had been taken from various locations of Tutaepatu lagoon with an emphasis on obtaining a distributed representation. Locations were marked using the Garmin GPS tracking device which was also used to take depth analysis. Site 6 was of most interest as this was a very sheltered location on the eastern edge and least exposed to north easterly or easterly winds.

Volume of collection jars were measured using a Marienfeld graduated cylinder (1000 mls) and recorded in table 1 along with results. GF/A 55mm filter paper circles were used and each clean paper was first weighed using a Sartious LA2000P scales then placed upon a conical flask

Figure 4: Removing sediment from water sample in Geography laboratory using vacuum pump

attached to a permanently installed vacuum pump. An additional flask was placed over the top and clamp applied to prevent spillage. Sample water was stirred to ensure adequate filtering of particulates then poured through the conical flasks. Once all the liquid has passed through, the filter paper was removed, placed in a petri dish with lid applied and placed in a CONTHERM Thermotec 2000 oven for approximately 72 hours. This process was repeated for all 6 samples.

4. Results

4.1 Wind speed and direction

The wind speeds shown in figure 5 are taken from the eastern AWS 1 (figure 1), which has been installed since March 2017 and was still present for the duration of this project. There is a period of data missing in 2018 from 19th February until 5th May. This is likely from a memory override in the weather station data logger. We used AWS 1 because AWS 2 was only installed for this project and does not show wind data from before forestry. The graph is also marked in red showing 2 different stages of forestry, stage one from 14/07/18 until 05/05/18 and stage 2 from 13/05/19 until 30/08/19.

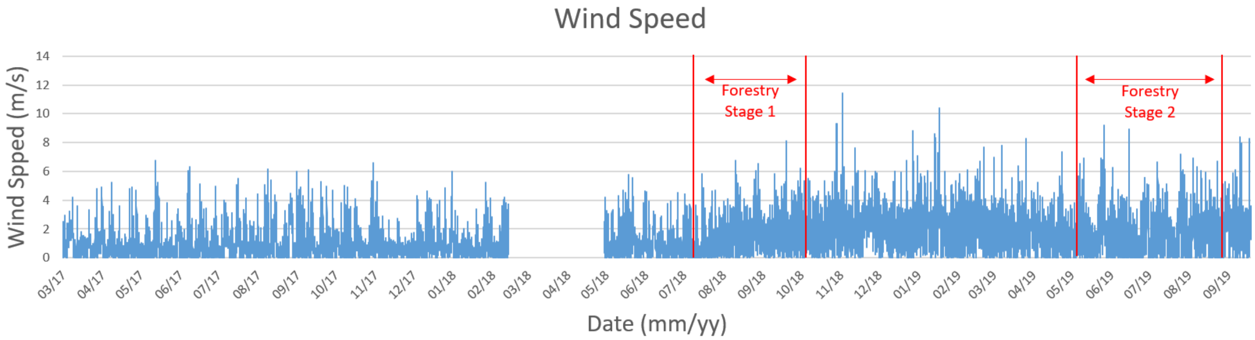

Figure 5: Wind speed over time at AWS 1 from March 2017 until September 2019

Figure 5 shows the wind speed but the wind direction is also a key component when analysing the wind trends. Figures 6, 7 and 8 are wind roses that show both the wind direction and speeds across 2017 to 2019, from 05/05/19 until 24/09/19, as this is the only time period with data for all three years due to the missing data in 2018, and not having a full year's worth for 2017 and 2019. Once again, the data in these plots was taken from AWS 1 for the same reason as in figure 5. It has only been one year since forestry, so the results are limited in regards to the long term effects of forestry however this is an indication of the immediate effects and there are changes present between 2017 (figure 6) and 2019 (figure 8).

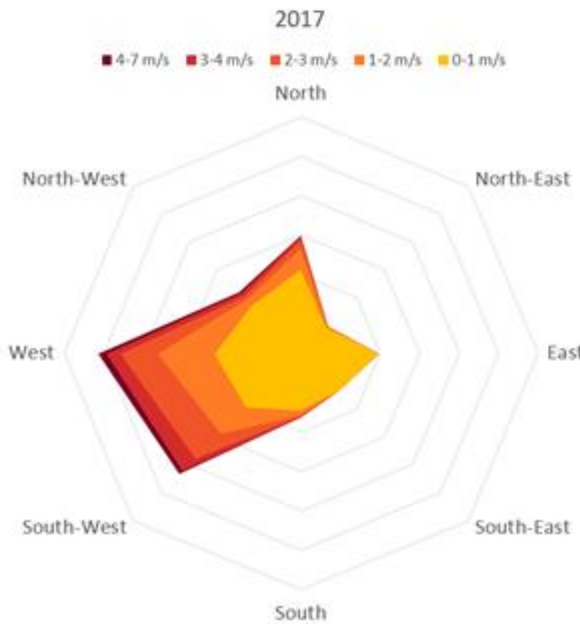

Figure 6: Wind rose for AWS 1 from 05/05/17-24/09/17

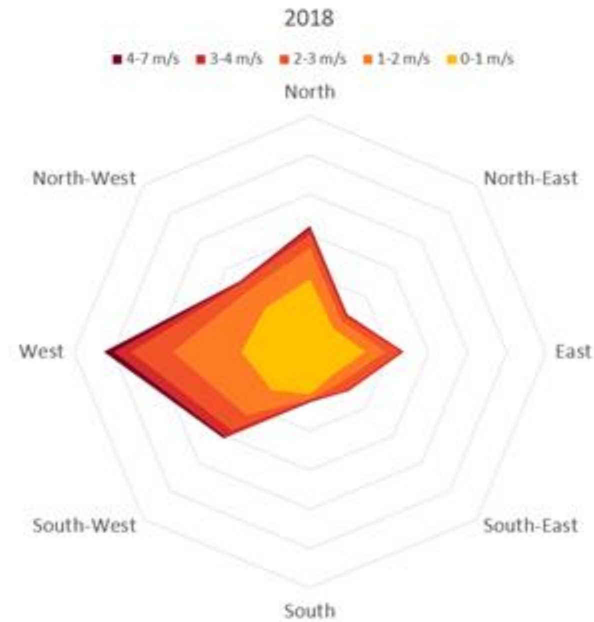

Figure 7: Wind rose for AWS 1 from 05/05/18-24/09/18

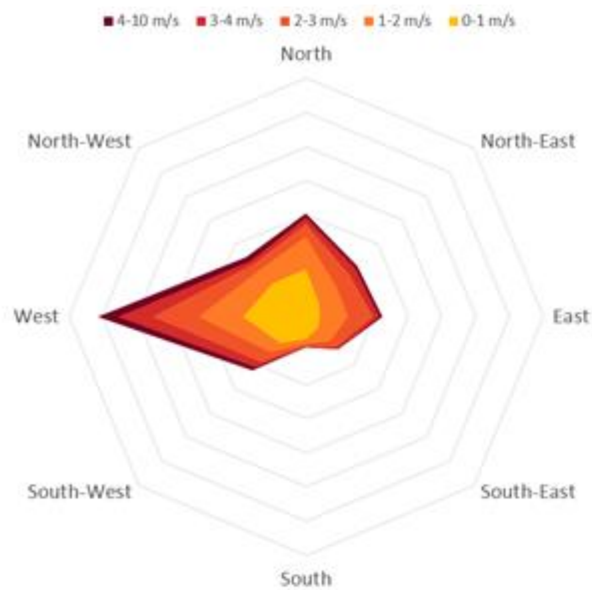

Figure 8: Wind rose for AWS 1 from 05/05/19-24/09/19

As mentioned in the methodology, the idea behind putting in AWS 2 on the Western side of the lagoon was to be able to compare data from each side of the lagoon. Figure 9 shows wind data collected from AWS 2 from the period of time it was up from 15/08/19 until 24/09/19 September. Figure 10 shows data from the Eastern station over the same time period.

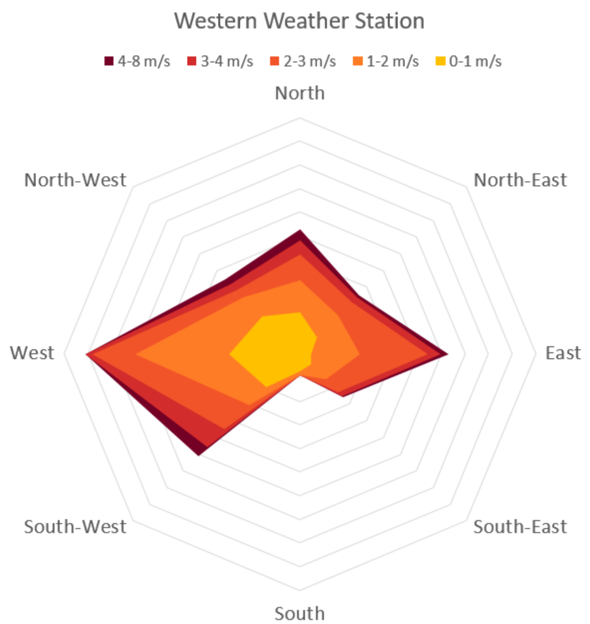

Figure 9: Wind rose for AWS 2 from 15/08/19-24/09/19

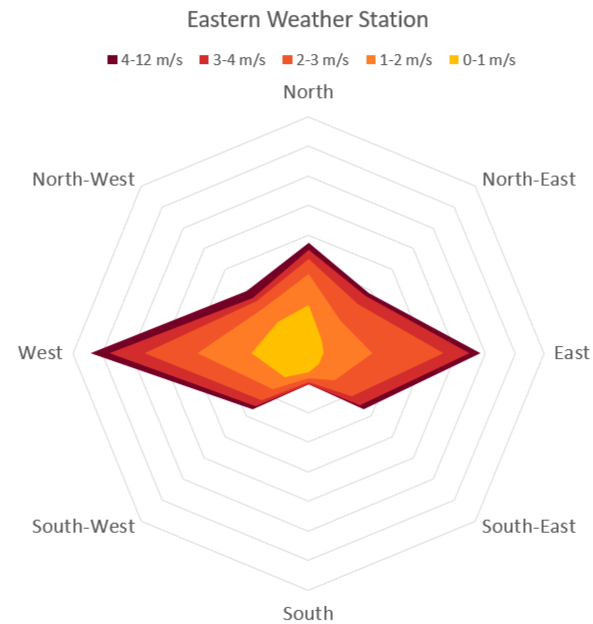

Figure 10: Wind rose for AWS 1 from 15/08/19-24/09/19

Using these wind roses, we can compare the wind speed and direction between sites, the same way as between years in figures 6, 7 and 8. Once again, the data is limited as AWS 2 was only present for 40 days over the course of this study but comparisons can still be made.

4.2 Water Turbidity

Another of the main focuses, analysed in this study was water turbidity. Figure 11 shows the average turbidity within the lagoon over time. Each measurement shows the average turbidity since the last measurement, taken every 10 minutes between the second site visit on 27/08/19 until the third site visit on 24/09/19. The turbidity is recorded in Nephelometric Turbidity Units, or NTU.

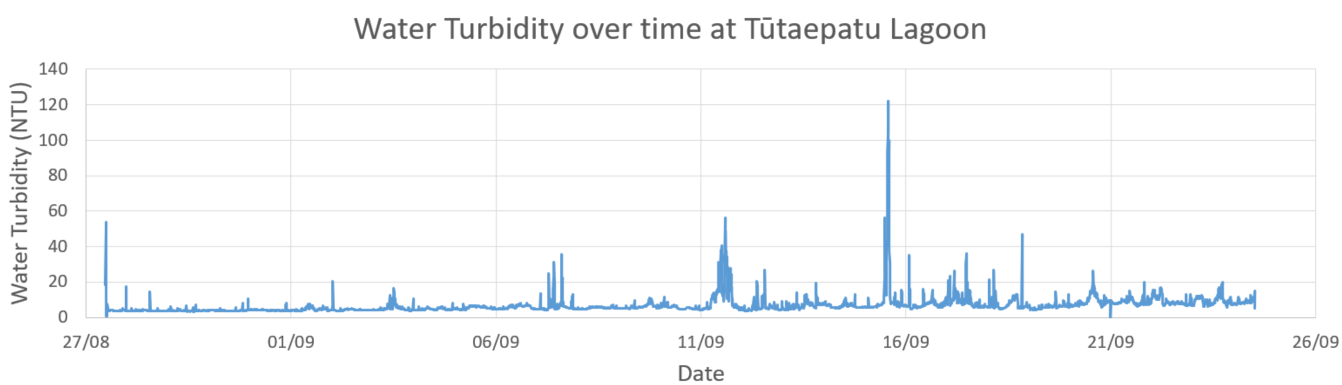

Figure 11: Water turbidity over time at the turbidity sensor site from 27/08/19-24/09/19

The location of the turbidity sensor was within the lagoon, on the western side as stated in the methodology. The turbidity sensor site is shown in figure 13 under sediment content, which is the next section of results obtained. Figure 12 shows correlation between turbidity and wind speed.

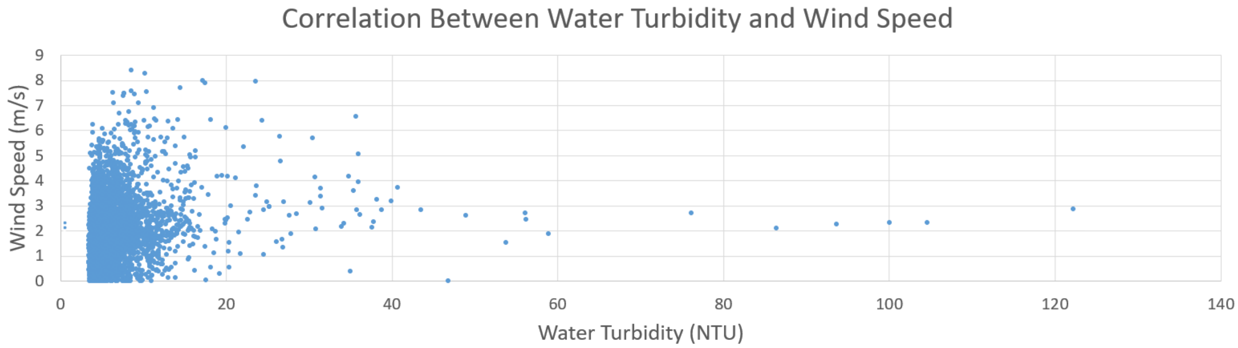

Figure 12: Scatter plot showing correlation between turbidity and wind speed at the turbidity probe site from 27/08/19-24/09/19

4.3 Sediment content

The results obtained from the sediment in the water samples is shown in table 1. The rightmost column is of most interest, as it shows the concentration of sediment per 100 mL. To obtain the sediment weight per 100mL values, the sediment weight in the second column was divided by the volume of water in the third column, as 100mL values (e.g. for site 1 sediment weight per 100mL is 7/6.1 = 1.15g/100mL)

Table 1: Sediment content data obtained from water samples and lab testing by g/100mL

Sample	**Sediment Weight (Difference between pre and post) (g)**	**Water Sample Volume (mL)**	**Sediment Weight per 100mL (g/100mL)**
1 (West - Probe Location)	7	610	1.15
2 (South)	2	650	0.31
3 (Central)	6	720	0.83
4 (North)	3	720	0.41
5 (Central-East)	3	730	0.41
6 (East)	4	720	0.56

Figure 13: Sediment content water sample sites at Tūtaepatu Lagoon

4.4 Salinity

When looking at the aeolian processes around the lagoon, salinity is important because we can use it as a measure to see how much airborne salt is transported into the lagoon after the removal of the trees between the ocean and itself. The salinity values found in the lagoon are shown below in table 2. The salinity was measured in Practical Salinity Units, or PSU.

Table 2: Salinity values taken from Tūtaepatu Lagoon	
Maximum value	0.371
Minimum value	0.009
Range	0.362
Average	0.223

There were technical difficulties with the device measuring salinity, meaning there was only recordings from 27/08/19 until 03/09/19. However, due to the low variation it can be assumed that even if the equipment worked properly for the full time there would not be too much change. The low variation allows for this average value to be an accurate representation of the salinity content in the lagoon.

4.5 Data Averages

Table 3 below shows data averages from all sampling. As these recorded on the same device as salinity, therefore there is only a short time period of data. Similar assumptions were made for these as stated with salinity, due to low variance, their averages are highly representative of all records.

Table 3: Data averages for relevant information collected at Tūtaepatu Lagoon	
Category	**Average**
Eastern Station Wind Speed (m/s)	1.67
Western Station Wind Speed (m/s)	1.94
Turbidity (NTU)	6.79
Sediment Content (g/100mL)	0.61
Salinity (PSU)	0.23
Water Temperature (°C)	10.33
Conductivity (mS/cm)	0.34
Water Depth (m)	0.62

5. Discussion

5.1 Wind speed and direction

Looking at figure 5, there is a clear increase in the average wind speeds from when forestry began occurring, with a number of bigger spikes also occurring across 2018 and 2019. Many of the bigger spikes occurred over late 2018 and early 2019, however it is hard to compare these across years as there is only certain seasons with data for all 3 years and there is only one year's worth of data since stage one of forestry. The period of missing data does not affect the data significantly as there doesn't appear to be any clear change in the trend from the start of the gap until the end of it. Stage two of forestry shows no clear change in wind speed trends. This is mainly because most of the forestry had already occurred and instead a lot of log removal happened in this period.

The yearly wind roses shown in figures 6, 7 and 8 have similar wind trends, however there were greater maximum winds in 2019, up to 12m/s with 2017 and 2018 only reaching 7m/s. During the 2017 period, there were no Easterlies recorded above 2m/s, however in 2019, there were 1000 Easterlies records above 2m/s, almost half of all Easterlies from that period. 2017 had 4344 recordings of South-Westerlies compared to 2240 in 2019, with 2018 sitting in between with just over 3098. 2018 did have some higher wind speed occurrences over 8m/s (figure 5), however they fall outside the time periods used for these wind roses.

Comparing wind speed and direction from each side of the lagoon in figures 9 and 10 immediately shows higher frequency of South-Westerlies at the Western weather station. A likely cause for this is due to the Eastern weather station's positioning, where it is reasonably sheltered from the South-Westerlies from willow around the lagoon, whereas the Western station was at a higher elevation, with no significant shelter. South-Westerlies are expected to be more frequent as it is one of the predominant winds in Christchurch, especially in the Northern areas *(McGann, 1983)*. The wind speeds at the eastern weather station tend to be higher, with a similar overall trend in wind direction across both sites. Winds at the Eastern station reached up to 12m/s, whereas the Western station didn't reach higher than 8m/s. The only records that exceed 7m/s at the western station were North and North-Westerlies, and only 6 records exceeding 10m/s, which were North-Westerlies.

5.2 Water Turbidity

The turbidity data has one main concern, in figure 11 there is a significant in turbidity on the 15th of September, where the average turbidity reached over 120NTU. Potential causes for this were investigated, such as seismic events, rainfall or human interaction, but there were no significant records of either of those first two options and as it was a Sunday there was no one working at the lagoon. According to the recording device specifications (Downing, 2008), obstruction on the infrared lens can scatter records and this is believed to be the most likely cause for this anomaly from algae in the lagoon. This is backed up by field observations on the 3rd trip, where larger amount of algae was noticed in the lagoon compared to the first two trips. This may be due to seasonal change, with the weather warming as it was getting closer to summer.

Apart from that occurrence, the turbidity stayed similar across data collection, apart from a few smaller spikes, likely also caused by algae or rainfall events. The high turbidity at the start of the time frame is likely due to human interaction while installing the sensor. Figure 12, showing correlation between turbidity and wind speed, shows no noticeable trend between these two variables, as many of the higher turbidity readings have the same wind speeds as the large concentration of lower turbidity values. Because there is no correlation, wind does not cause turbidity within the lagoon.

5.3 Sediment content

As seen in table 1, sample 1 at the sensor site has the highest sediment content at 1.15 grams per 100 mL. This is significantly higher than the other sites, but could be because the sample was taken straight after installing the turbidity sensor, where human interaction may have caused more stirring and mixing of sediment off the bottom of the lagoon, which is reflected by high turbidity readings at the time of installation in figure 11. The second highest sediment content is from sample 3 in the centre of the lagoon, the least sheltered area. This suggests that exposure may cause more sediment content in that area from aeolian interactions. The rest of the samples were very similar, ranging between 0.31 and 0.56 grams per 100 mL, showing that the sheltered areas tend to have less sediment content. Sample 5 was one of the central samples, but still had a lower sediment content, however for a central site it was still reasonably far east.

5.4 Salinity

The average salinity was 0.223 (table 2), which converts almost equally to 230 parts per million (PPM), another salinity measurement. This is very low, as anything below 1,000 PPM is considered fresh water (James, 2017). For more context, drinking water should be below 600PPM (James, 2017), and the lagoon water is well below that. As stated in the results, the average value is representative of all the recordings. This leads to the conclusion that there is no significant amount of aeolian transport of airborne salt being transported into the lagoon even after forestry occured.

5.5 Data Averages

Table 3 is a helpful summary of the relevant data collected during the research process. The low salinity value is backed up by a low conductivity value, as conductivity and salinity generally have a positive relationship, meaning low salinity often means low conductivity. The average turbidity is slightly higher than parameters, however this value could have been skewed due to the algae interference scattering some of the readings. Overall, there was an abundance of data collected and analysed, which allowed for key findings to be formed.

6. Conclusions and limitations

6.1 Key findings

The results produced allowed for key findings to be made. Firstly, there were stronger easterly winds in the years of 2018 and 2019 compared to 2017 in the permanent weather station that resides on the eastern side of the lagoon. Secondly, there was found to be a low salt content in the lagoon. From this we can infer that the forestry harvest hasn't led to high levels of salt content being transported from aeolian processes and as a result there has been no severe environmental impact within the lagoon. Thirdly, there was no correlation between wind speed and turbidity. Lastly, it is assumed that the spike in the turbidity data is likely due to algae, not wind processes, however it inconclusive whether the forestry harvest has had an effect on the turbidity.

6.2 Limitations and future needs

The limitations of our research were the small amount of time we had to gather data to make a reasonable conclusion. Therefore, we can't account for seasonal changes as temperature data was only taken over the winter months. Some of our equipment in the field also failed like the temperature sensor failing in weather station 2 which could mean other parts of our data were inaccurate.

Some future needs for this research would be having a longer amount of time to collect data to account for these seasonal trends. We also would need more means of data collection to then get a better understanding of the environmental effects caused by the forestry harvest. As well as some investigation into vegetation types and their responses to potential environmental impacts could also be helpful.

6.3 Regeneration planting

The future for Tūhaitara coastal park will be the regeneration of native plantings. Te Kōhaka o Tūhaitara Trust have adopted a concept plan for regeneration of lands in the Tūhaitara Coastal Park. The plan promotes coastal protection, environmental stewardship and recreation opportunities. More specifically, coastal protection planting, carbon sequestration forests and riparian planting.

The goal proposed for the restoration of the Tūtaepatu Lagoon explicitly is to create a lagoon with indigenous vegetation that supports mahinga kai and spiritual values. The lagoon supports a diverse range of indigenous biota including wetland and swamp plants, fish like inaka, tuna, kowaro and birds like kotuku bittern, kotare kōrimako and ruru (Te Kōhaka o Tūhaitara Trust, 2019). As part of the restoration project of the Tūtaepatu Lagoon, 30,000 natives have been planted over the past 5 years. As well as the control female grey willow and old beard and the eradication of over 800 animal pests. The Te Kōhaka o Tūhaitara Trust has a rehabilitation plan for the indigenous coastal ecosystem which supports a range of native flora and fauna species and provides sustainable mahinga kai. This is a plan that will span over 200 years (Te Kōhaka o Tūhaitara Trust, 2019).

7. Acknowledgements

We would like to thank Greg Byrnes and Te Kōhaka o Tūhaitara Trust for being our community partner in this project. A big thank you to our tutor, Daisuke who has been a huge help in figuring out our research direction, as well as his guidance when conducting and analysing our data. Next we would like to thank Justin Harrison and Nick Key, the Department Technicians for their great help in our data collection in the field. This research project wouldn't have been possible without their expertise. We would also like to thank Simon Kingham and Jillian Frater for giving us the opportunity to conduct this research which has been invaluable in our learning.

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