

Clayoquot Sound Harmful Algal Blooms Investigation of Sydney Inlet – 2019

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Abstract:	In 2014 and 2019, an unusually warm patch of water in the North Pacific called the ‘Blob’, came ashore in early Fall of both years. Researchers were interested to see if this warm water intruded into Sydney Inlet of Clayoquot Sound, which is located off the west coast of Vancouver Island an important source of food and income for the neighboring communities. If these warm waters intruded into the Sound, this could in-turn create favorable conditions for harmful algal blooms (HABs) to form, specifically the phytoplankton <i>Alexandrium</i> known to be present in this region. As a result, University of Washington Tacoma (UWT) faculty and students measured water properties and collected water samples for nutrient analysis for Clayoquot Sound for those years. Choropleth maps were created to compare relative concentrations of key nutrients used by phytoplankton, and contoured profile plots were used to determine if oceanic conditions were favorable for HABs to develop. Overall, researchers found that the ‘Blob’ intruded into the waters of Sydney Inlet, causing an average temperature increase of 1°C within the water body, as well as a decrease in nitrate and phosphate concentrations and an increase in fluorescence. This data suggested an increase in favorable conditions for <i>Alexandrium</i> corresponding to the years where the ‘Blob’ was present. This leads to the need for additional monitoring of shellfish beds within the area during these warm water anomalies.
Key Words:	<i>Alexandrium</i> , paralytic shellfish poisoning, CTD, The Blob, nutrients, Surfer plots, choropleth
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This analysis is part of a larger project known as the Clayoquot Sound Harmful Algal Bloom Project that has been ongoing since 2000. Dr. Cheryl Greengrove and Julie Masura have been leading several research teams yearly to study this area to include undergraduates, graduates, middle & high school students, and research scientists. This work began with partnership with Dr. Richard Keil from [UW Oceanography](#) and has since led to additional partnerships including the Dr. Laura Loucks of the [Clayoquot Sound Biosphere Trust](#) and the [Raincoast Education Society](#) to name a couple. Please contact Cheryl Greengrove at cgreen@uw.edu or Julie Masura at jmasura@uw.edu with any questions concerning this work.

Introduction

Statement of Problem

In the summers of 2014 and 2019, University of Washington Tacoma (UWT) faculty and students collected CTD (conductivity, temperature, and depth) and nutrient data for Clayoquot Sound on the west coast of Vancouver Island, British Columbia. These years were considered especially interesting as a phenomenon called the ‘Blob’, which was an unusually warm patch of water in the North Pacific, came ashore in early Fall of both years. Researchers were interested to know if those warm waters also intruded into the inlets of Clayoquot Sound at that time, potentially effecting the local ecosystem. This research is important because Clayoquot Sound is not only a protected biosphere, but also a major source of food and income for the neighboring areas, and an important part of the cultural aspects for the neighboring tribes. The dinoflagellate *Alexandrium*, is responsible for paralytic shellfish poisoning (PSP) and has been present in Clayoquot Sound for some time. The hypothesis was, because *Alexandrium* prefers to grow in warmer waters, one of the potential effects of the ‘Blob’ may be that the number of days that favor *Alexandrium* growth will increase. Should this occur, this could lead to longer shellfish bed closures and other issues which would be detrimental to the neighboring communities.

Purpose of Study

Clayoquot Sound is a beautiful biosphere reserve, home to many animals, whales, and ancient cedar trees, as well as large swaths of temperate rainforest. Not only is this place extremely important from an ecological perspective, it is a large and important part of the lives and traditions of many First Nations peoples and the cities populated around it (Baer *et al.* 2020).

In 2000 this location was declared a biosphere reserve to spare it from industrial logging. Since then, Clayoquot Sound has become an experiment for environmental sustainability. As a result, the community has invested many resources and efforts in keeping the place clean, while harnessing the traditional knowledge from the local tribes to preserve this place as much as possible. Because this is a biosphere reserve, much of the local income and food comes from tourism and living off the resources that the land can provide. Some of these activities include shellfish farming, kayaking courses, hiking, whale watching, and fishing (UNESCO 2015).

In this study, temperature, salinity, transmissivity, fluorescence, dissolved oxygen, and density of the water, as well as nutrient data were analyzed for each inlet within Clayoquot Sound for the years 2014 and 2019. The water properties were measured using an instrument called a CTD, while the nutrient data was determined by taking discreet water samples. This was done to determine if conditions were similar to those in 2014 due to the latest occurrence of unusually warm waters within the area. Because much of the food and income for populations surrounding Clayoquot Sound comes from the water, any changes brought by the ‘Blob’ through oceanic conditions or nutrients within the water could have a massive effect on the community and the ecosystem. Additionally, the nutrient and CTD data were analyzed to determine if these recurring conditions brought about by the ‘Blob’ were favorable for *Alexandrium* growth. Conditions that promote *Alexandrium* growth are, highly stratified, nutrient rich, warm waters that occur for long periods of time (CDC 2020). Should the conditions be determined favorable for *Alexandrium*, this would help determine a pattern that could be used for early detection and public policies to help keep people safe by implementing additional monitoring at shellfish beds within the area during other instances of the ‘Blob’ in the future.

Review of Literature

Since the summer of 2000, students and faculty of the UWT have collected data from the waters of Clayoquot Sound. Clayoquot Sound, much like other sounds off the southwestern coast of Vancouver Island, was made from a glacially carved interconnected fjord. Clayoquot Sound can be characterized by deep, narrow basins with sills surrounded by mountainous topography and freshwater rivers feeding into its inlets, with a temperate rainforest climate. Because of this unique environment, Clayoquot Sound is considered a protected biosphere and is home to many indigenous peoples as well as small fishing and logging communities that rely heavily on the waterways for food and income (UNESCO 2015).

Sydney Inlet, which is at the northern most point of the Sound, is a glacially carved fjord that is bisected by Stewart Inlet. This inlet is known for high salinity due to its low freshwater inputs, low precipitation, and high vertical mixing. Sydney Inlet also has limited nutrient flushing during ebb tides. This section of Clayoquot Sound is also extremely preserved compared to some of the other inlets, with only one research cabin in the area (Leckman 2014).

Through the course of this investigation, CTD profiles of temperature, salinity, density, dissolved oxygen, fluorescence, and transmissivity, as well as discrete water samples for nutrients and phytoplankton have been monitored at multiple stations, locations where data is collected, within each inlet of Clayoquot Sound. Because of the bathymetry of the inlets within Clayoquot Sound, it takes a long time for water from outside of the inlets to integrate into the waters within the inlets. This is largely due to the many sills and deep fjords. Because of this, it is interesting to look at changes in the oceanographic conditions of these areas over time. For instance, a research study done by G. L. Pickard in 1963 showed that the average temperatures

for Sydney Inlet ranged between 10.8 to 9.2 °C, and the average salinity was about 25 to 31.2 parts per thousand. As expected, these numbers are still relatively close to the ones found in later years.

Because these inlets do not mix with neighboring waterbodies as readily as other locations, and because Clayoquot Sound is an important source of food and income to the neighboring communities, any changes in that area would be extremely important to document and monitor to ensure the well-being of the local populations. This is why the data for 2014 and 2019 were considered especially interesting to researchers, as a phenomenon called the ‘Blob’ came ashore in early Fall of both years. The ‘Blob’ was an unusually warm patch of water in the North Pacific, and researchers were interested to know if those warm waters intruded into the inlets of Clayoquot Sound at that time, as well as some of the potential effects that phenomenon may have had on the local ecosystem.

The dinoflagellate *Alexandrium*, is responsible for paralytic shellfish poisoning (PSP) and has been present in Clayoquot Sound for some time. The hypothesis of this research study is, because *Alexandrium* prefers to grow in warmer waters, one of the potential effects of the ‘Blob’ may be that the number of days that favor *Alexandrium* growth will increase. Should this occur, this could lead to longer shellfish bed closures which would be detrimental to the neighboring communities. According to a 2020 news article by Nicola Jones of *Hakai Magazine*, some of the glacially fed fjords in British Columbia have warmed up to six times faster than the rest of the ocean since the 1950s. This was believed to be the result of the “Blob” and has had detrimental effects on the local salmon populations, as well as on zooplankton communities and many other marine animals.

In addition to the data highlighted in this study, it should be noted that Simone Alin, an oceanographer at NOAA's Pacific Marine Environmental Laboratory in Seattle found many other anomalies both in Puget Sound and outwards through the Strait of Juan de Fuca besides the "Blob" which may have harmful effects and warrant further research as well (Wagner 2020). Some of these anomalies included high CO₂ levels, low pH levels, and low aragonite saturation.

Methods

Sampling:

For the summers of 2014 and 2019, UWT faculty and students collected CTD and nutrient data for various locations within Clayoquot Sound on the west coast of Vancouver Island. Sampling took place at various stations within each inlet of Clayoquot Sound (Figure 1). The CTD collected information on temperature, salinity, density, dissolved oxygen, fluorescence, and transmissivity (Figure 2a). A CTD, a multifunctional instrument with many sensors, can be used to find much information about a certain waterbody. On the bottom of the instrument was a temperature sensor, a pressure sensor, and a conductivity sensor. The conductivity sensor was used to determine salinity, which when coupled with temperature and pressure was used to calculate the density of the water. The instrument also contained a transmissometer which used a beam of light and a sensor to determine the amount of solids (presumably phytoplankton) in the water. Additionally, the CTD was equipped with a fluorometer which determined how much chlorophyll-a was in the water, indicative of phytoplankton. The CTD also contained an oxygen sensor to determine the concentration of dissolved oxygen. Transmissivity is known as the percentage of visibility within the water. This

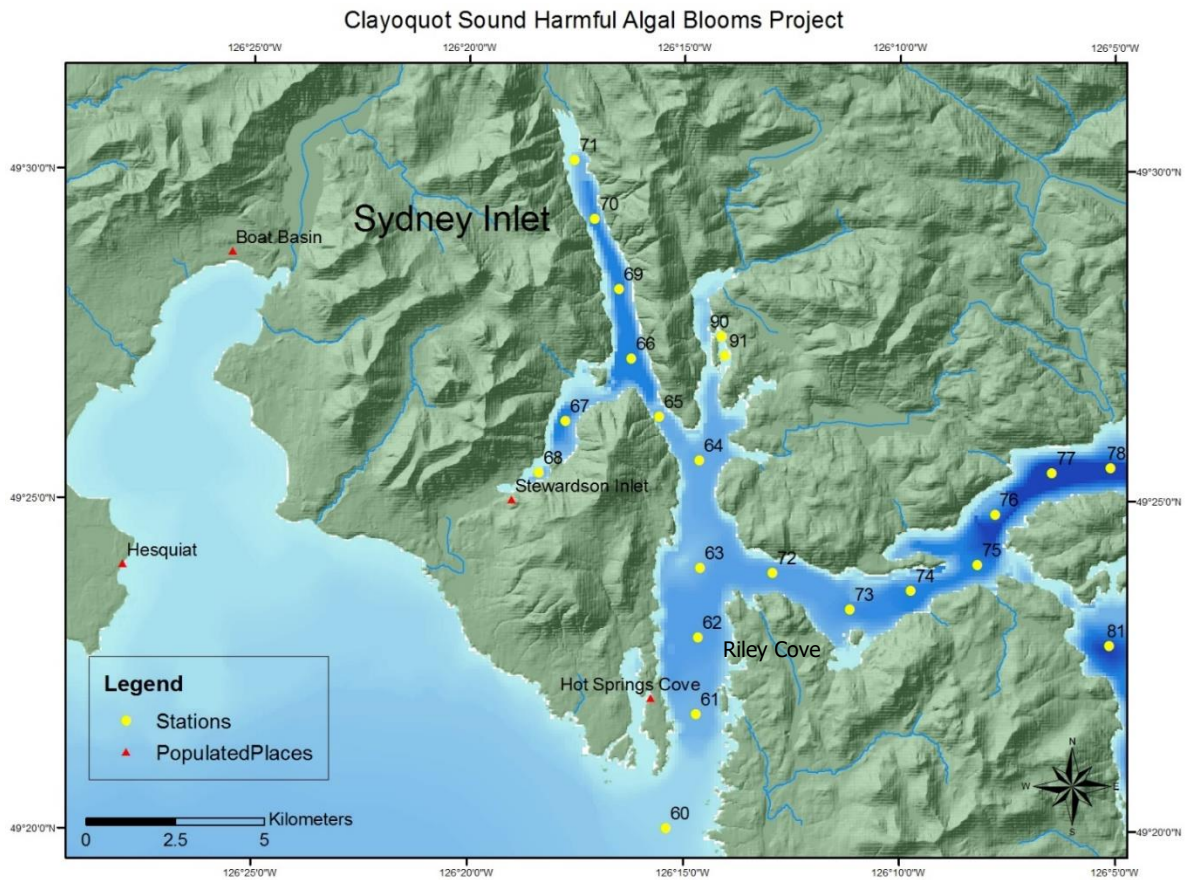


Figure 1: Map of Sydney Inlet, one of the many inlets within of Clayoquot Sound. Includes sampling stations within the area as well as any notable populated places nearby. The sampling stations for Sydney were 63, 64, 65, 66, 69, 70, & 71.

is measured using a transmissometer which uses a beam of light and a sensor to determine how much stuff (presumably phytoplankton) is in the water.

Additionally, discrete samples were taken by dipping a bottle vertically into the water to a desired depth, and then closing the bottle at that depth to capture the water sample (Figure 2b). These discrete samples were then frozen and sent to the lab at UW Seattle where they were analyzed for nutrient levels. Information about the location of the stations was also noted such as any geographic features, what the weather was like, and any notable factors within the area such as logging activity (Figure 3).

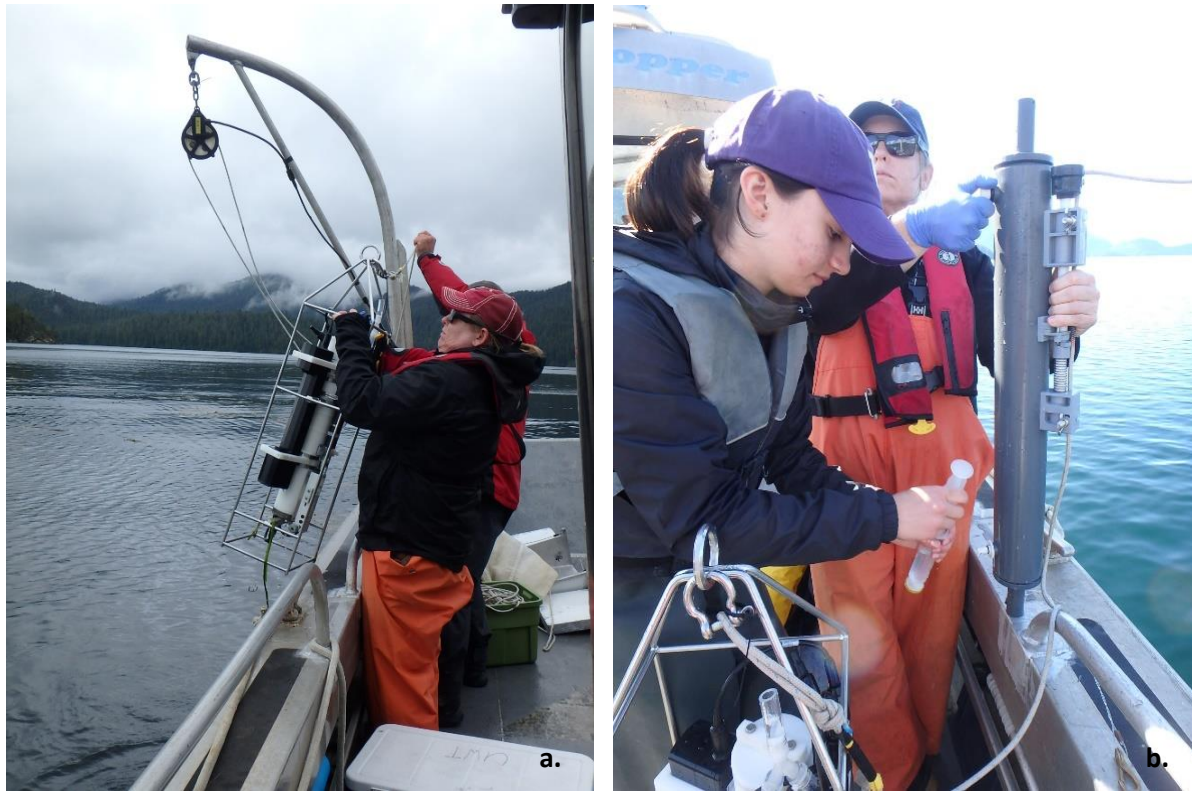


Figure 3: a. Image of CTD apparatus used in 2019 and b. sampling apparatus used to obtain discreet water samples using vertical bottle with spigots (Photographs by M. Baer).

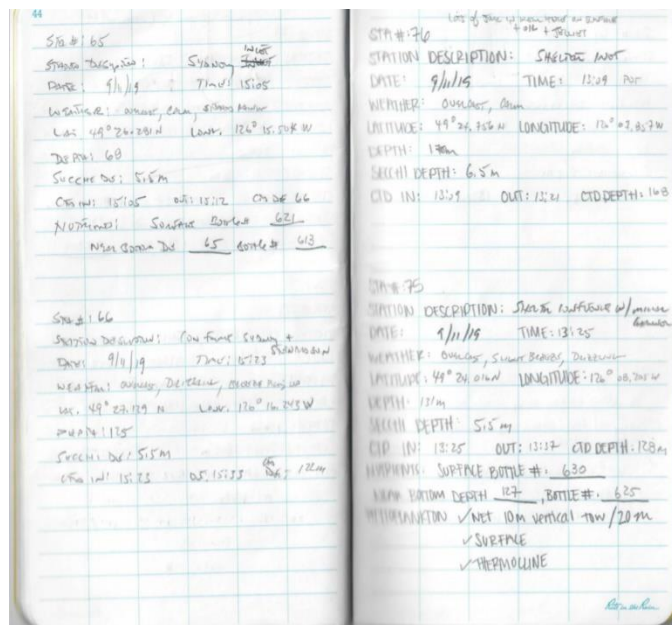


Figure 2: Image of field notebook taken in 2019 for Sydney and Shelter Inlets to illustrate the conditions

Instrumentation:

The data recorded by the CTD was processed to show a vertical profile of the properties measured and was then stored within the apparatus until it was hooked to a laptop where the data could then be read and analyzed. The CTD data was downloaded & exported into a spreadsheet, while the nutrient samples were sent to the UW oceanography lab for analysis.

Data Analysis:

The frozen discreet samples were analyzed for nutrients at the UW Oceanography Marine Chemistry Lab. To prepare the sample for analysis, the water was filtered and frozen for storage. The sample was then placed into a cleaned cylinder and analyzed by a special apparatus in the lab. The nutrient concentrations for this experiment were calculated using either a Technicon AAII system, or Seal Analytical AA3 apparatus (UWSO 2020).

The nutrient data was separated into surface and bottom data for analysis. Microsoft Excel was used to determine the five number summaries for the monitored nutrients. Box and whisker plots were created to see any possible trends within that data, as well as to determine how to correctly plot any outliers. ArcGIS was used to create choropleth maps which visually showed the concentrations for surface and bottom nutrients at each location. This also made it easier to compare the 2019 data to the data collected from 2014.

Additionally, CTD profiles were created for all properties using Excel. The information from the CTD was extracted from .cnv files and compiled into one master file in Excel, which was then used to draw profile plots of all the data based off depth and station. Surfer plots were created to show a contoured vertical profile for the length of the fjord. Surfer 15 was used to

show differences of the CTD data from a more visual perspective. These plots were also useful for comparing the data between 2019 and 2014.

Results

For this study, the sampling stations of Sydney Inlet began at station 63 on the seaward side of Sydney Inlet, at the confluence with Shelter Inlet, then ranged north past Stewart Inlet up to the head of Sydney at station 71 (Figure 1). The meteorological data and tidal data for the sampling dates were graphed using Excel. The meteorological data was taken from a weather station located by Tofino Airport (CDECC 2019) while tidal patterns for the week surrounding the sampling dates for 2014 and 2019 were taken from Riley Cove's Tidal Data (Mobile Geographics 2019). This data included temperature, pressure, wind direction, and wind speed, as well as tides. On September 11, 2019, the sampling day, temperature had a slightly lower range than that of the 2014 sampling date, with a high of 17°C for 2019 and a high of 22°C for 2014 (Figure 4 & Leckman 2020). The air pressure was relatively the same, with 101.5 to 101.75 kPa for 2019 and 101.3 to 101.6 kPa for 2014 (Figure 5 & Leckman 2020). Wind speeds ranged slightly higher in 2019, with a range of 0 to 21 km/hr, while the 2014 sampling date showed a range of 0 to 17 km/hr (Figure 6 & Leckman 2020). Wind direction (Figure 7 & Leckman 2020) and tidal data (Figure 8 & Leckman 2020) showed slightly different patterns for 2019 and 2014.

The box and whisker plots of the nutrient concentrations for 2019 seemed to show an overall trend in which the level of nutrients at the bottom of Sydney Inlet were more concentrated than at the surface (Figure 9). For the PO₄ surface data, there was a small box with one outlier at 1.09 µM, the data appeared to be slightly left skewed. For the PO₄ bottom data, the box was also small, with one outlier as well at 7.07 µM. This data appeared to have a slightly

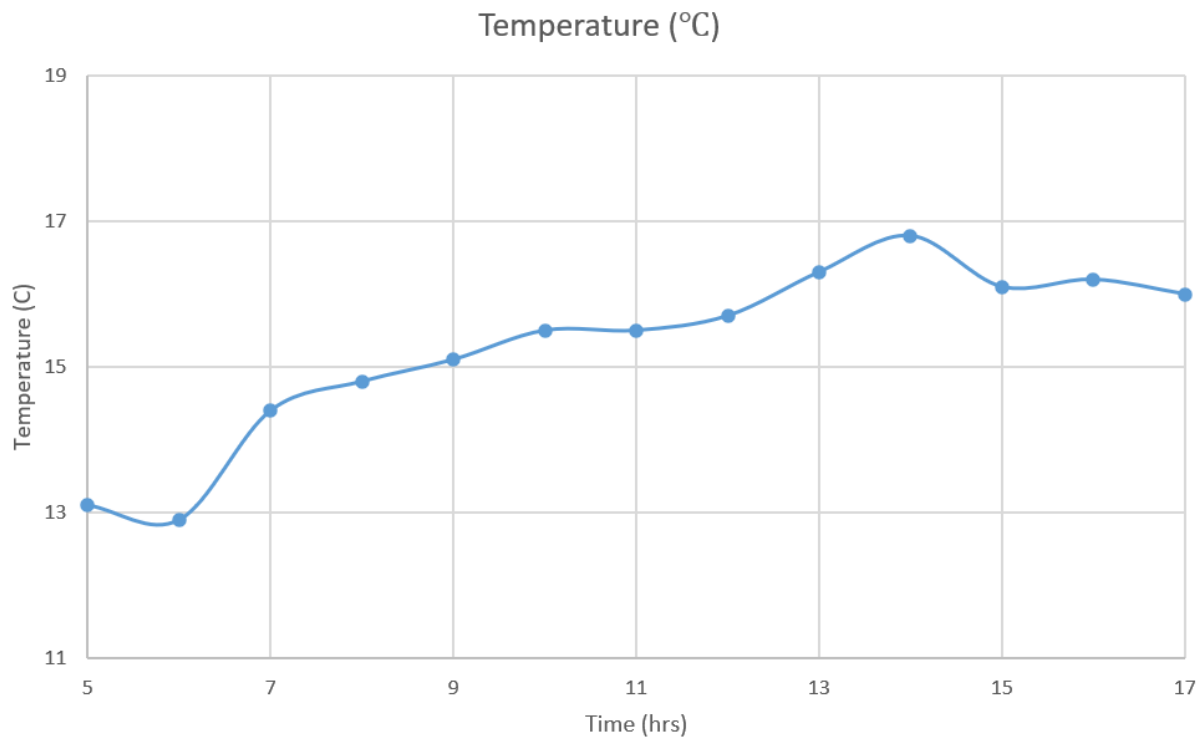


Figure 5: Chart showing the temperature for 9-11-19 taken from the Tofino Airport. (Source: CDECC 2019)

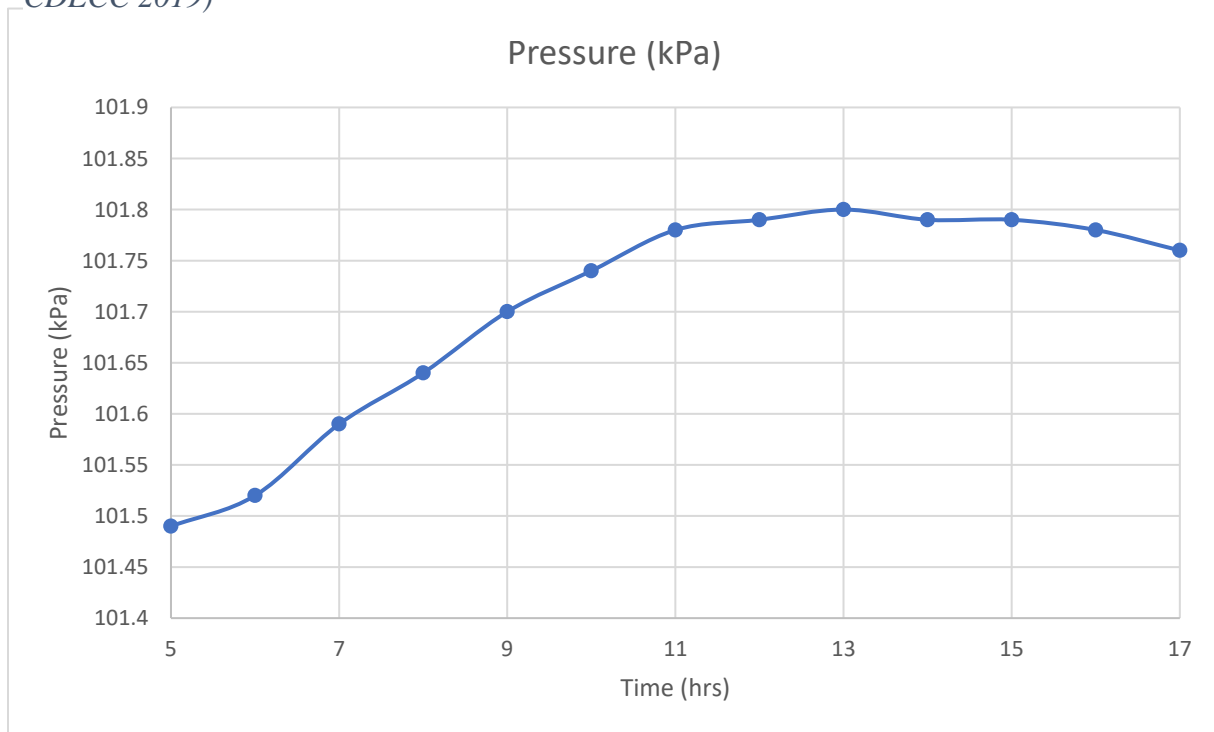


Figure 4: Chart showing the air pressure for 9-11-19 taken from the Tofino Airport. (Source: CDECC 2019)

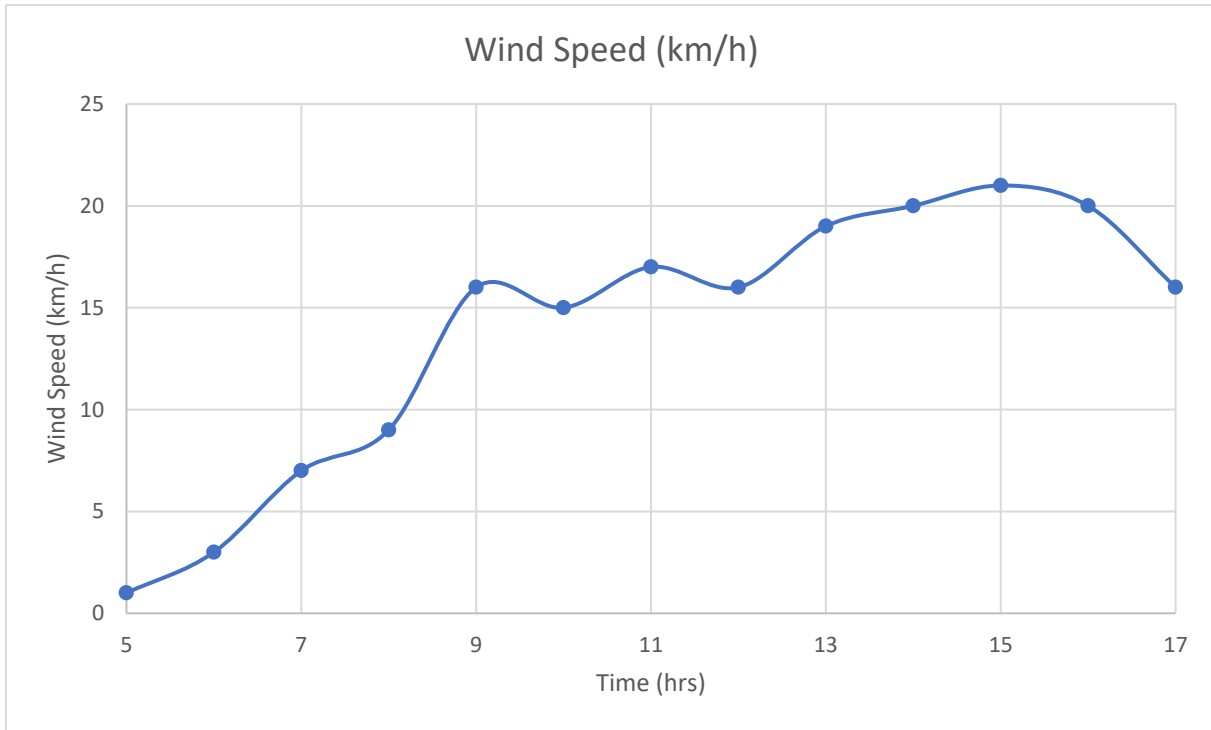


Figure 7: Chart showing the wind speeds over time for 9-11-19 taken from the Tofino Airport. (Source: CDECC 2019)

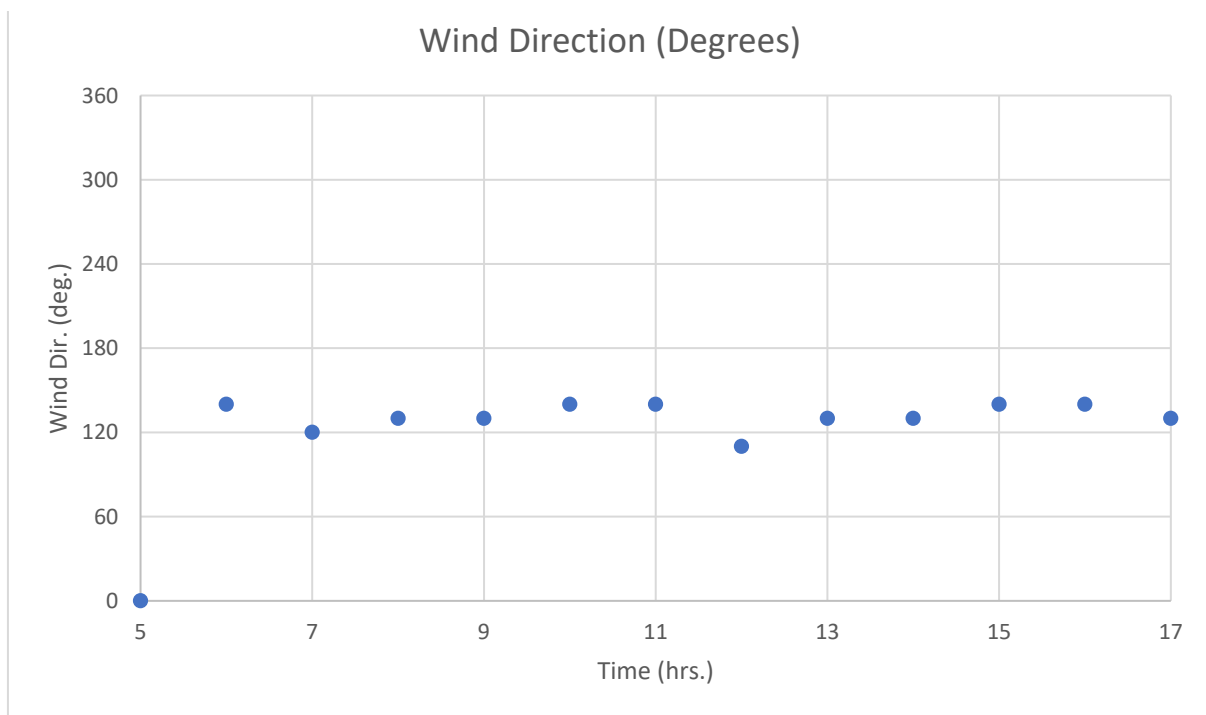


Figure 6: Chart showing the wind direction over time for 9-11-19 taken from the Tofino Airport. (Source: CDECC 2019)

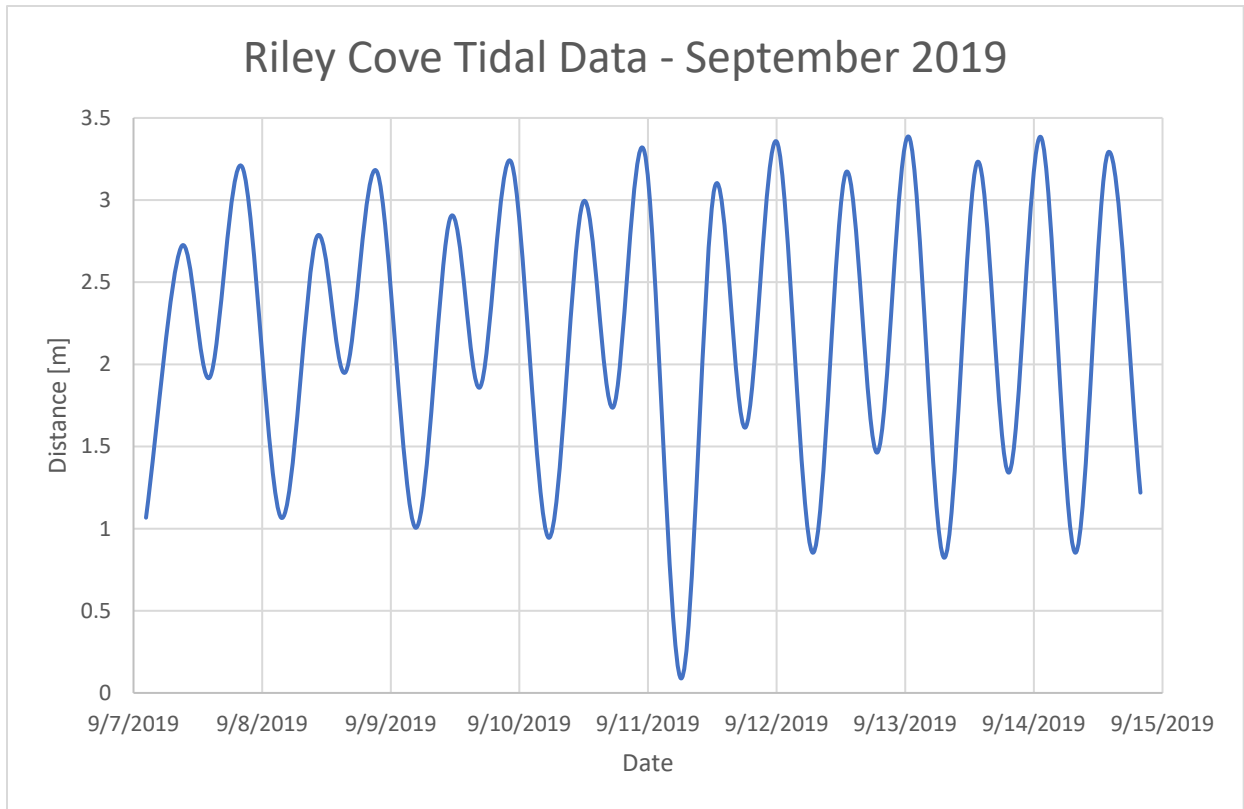


Figure 8: Tidal chart for the week surrounding the sampling date for Sydney Inlet of 9-11-19 taken from Riley Cove Tidal Data. (Mobile Geographics 2019)

more normal distribution. For the SiOH_4 surface data there was a larger box that was also higher than the other data points with no overlap. This box had normal distribution. For the SiOH_4 bottom data, there was a large box that was again, occurring in higher levels than the other nutrients with a distribution skewed to the left. For the NO_3 surface data, there was a medium sized box with two outliers at $3.95 \mu\text{M}$ and $4.63 \mu\text{M}$, and slightly left skewed distribution. For NO_3 bottom data, there were no outliers and left skewed distribution. For NO_2 surface data, there was a box smaller and slightly lower than PO_4 with one outlier at $0.35 \mu\text{M}$ and slightly left skewed distribution. For the bottom NO_2 data there was no outlier and somewhat normal distribution. For NH_4 there was a medium box smaller than that of NO_3 with two outliers at 1.89

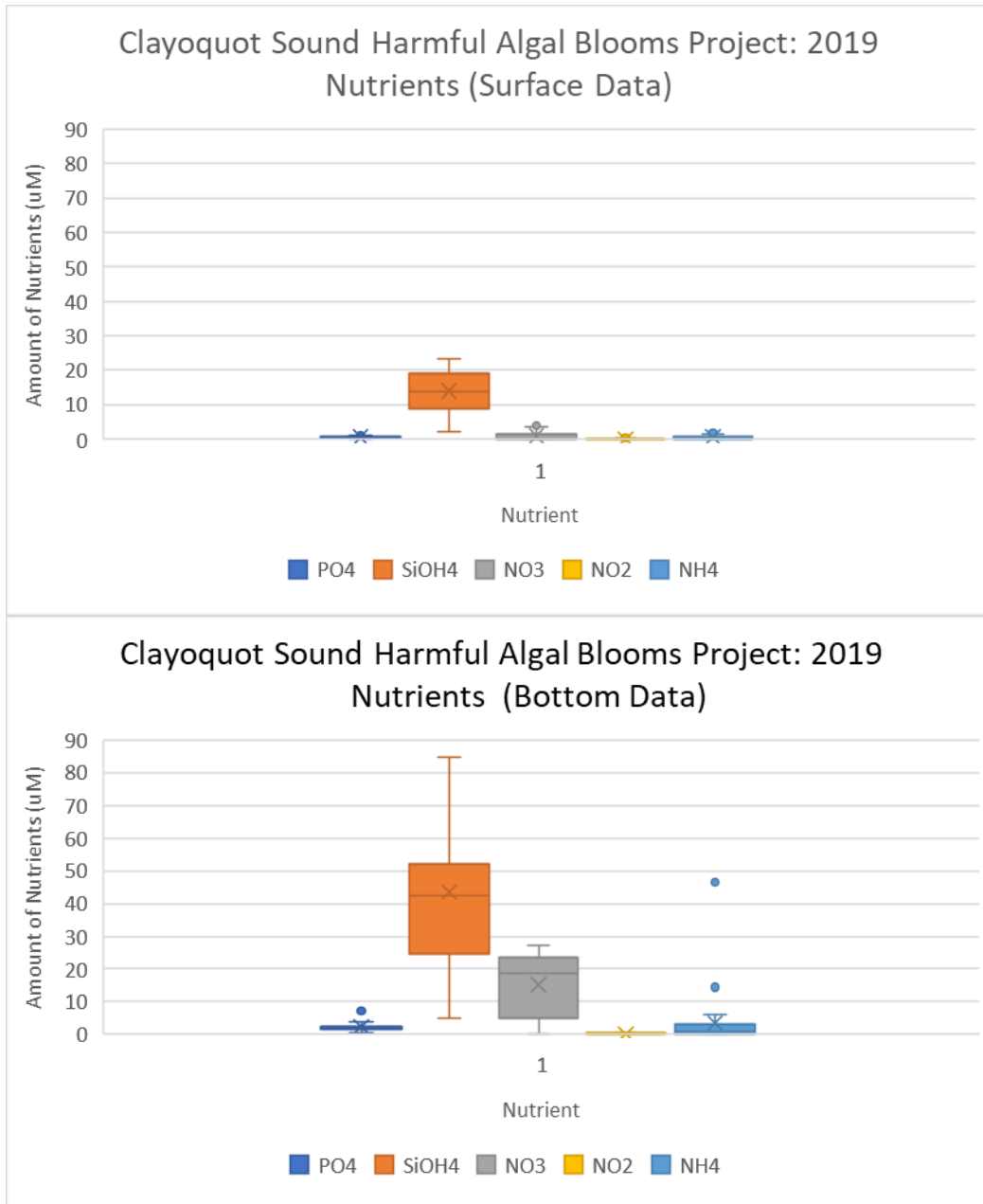


Figure 9: Image showing a scaled comparison of the box and whisker plots for surface (Top) and bottom (Bottom) nutrient data for the 2019 Sydney Inlet data.

μM and $3.07 \mu\text{M}$ with a right skewed distribution. For the bottom data, there was right skewed distribution as well and two outliers at $14.4 \mu\text{M}$ and $46.6 \mu\text{M}$.

Five number summaries were created to inform the data range needed to create choropleth maps (Tables 1 & 2). The choropleth maps show relative concentrations of nutrients at each station, represented by changes in size and shade of the dots. For those maps, surface nutrients were compared side by side with bottom level nutrients for each station, and these trends were compared between the years 2019 and 2014 for any notable differences (Figures 10 – 12). The nutrients being monitored for each station were nitrates, phosphates, and silicates. These maps show there were some differences between concentrations of nutrients on the surface and bottom of the water body.

Table 1. Five-number summary for the surface nutrient data within Sydney Inlet for summer of 2019.

Surface	PO ₄	SiOH ₄	NO ₃	NO ₂	NH ₄
Q0 (minimum)	0.03	2.02	0.01	0	0
Q1	0.33	9.44	0.03	0.02	0
Q2 (median)	0.53	13.94	0.05	0.02	0.09
Q3	0.59	18.28	0.7	0.1	0.63
Q4 (maximum)	1.26	23.35	4.72	0.37	3.07
Mode	0.58	13.63	0.03	0.02	0

Table 2. Five-number summary for the bottom nutrient data within Sydney Inlet for the summer of 2019.

Bottom	PO ₄	SiOH ₄	NO ₃	NO ₂	NH ₄
Q0 (minimum)	0.61	5.14	0	0.01	0
Q1	1.535	25.37	5.39	0.095	0
Q2 (median)	2.23	42.57	18.58	0.16	0.75
Q3	2.49	51.485	23.46	0.38	3.055
Q4 (maximum)	7.07	84.62	27.16	0.56	46.6
Mode	#N/A	#N/A	#N/A	0.15	0

Table 3. Five-number summary for the CTD data within Sydney Inlet for Summer of 2019.

	Pressure	Temperature	Conductivity	DO Voltage	Fluorescence	Transmissivity	DO	Salinity	Potential Temperature	Density	Density	Depth
	db	°C	cms/cm	SBEoxV	mg/m ³	%	ml/l	PSU	°C	kg/m ³ sigma-t	kg/m ³ sigma-theta	m
Q0	2	9.4472	35.19295	0.6035	0.4771	76.3307	0.2827	29.6852	9.4332	21.2887	21.2888	1.983
Q1	24	10.2285	35.50505	1.3428	0.5095	92.16105	2.30905	31.70135	10.2206	23.82975	23.8304	23.797
Q2	47	11.7192	36.69339	1.731	0.5603	95.7807	3.2708	31.994	11.7131	24.3308	24.3318	46.6
Q3	71	13.10665	37.66955	2.1743	1.07745	97.0871	4.33105	32.2099	13.10345	24.7134	24.7148	70.392
Q4	131	17.6522	39.6693	3.1428	9.3504	98.1031	6.5225	32.5415	17.6519	25.1199	25.1218	129.86
Mode	2	12.9553	#N/A	1.3621	0.5009	97.5998	3.7553	32.0753	9.46	24.3373	24.4509	1.983

The CTD data for each station was also analyzed using Microsoft Excel and Surfer plots. Five number summaries were created for the CTD data using Excel (Table 3), as well as profile plots to show trends for each condition varying with depth at every station. These profile plots included temperature, salinity, density, dissolved oxygen, fluorescence, and transmissivity (Figures 13, 15, 17, 19, 21, 23). In addition to the profile plots, Surfer 15 was used to illustrate the shape of the fjord in relation to the CTD data for each sampling station (Figures 14, 16, 18, 20, 22). These contour plots were also used to compare any trends or changes in the data with the samples taken in 2014. Much like the Excel plots, the Surfer plots included profiles for temperature, salinity, density, dissolved oxygen, fluorescence, and transmissivity. Overall, there were similar trends in temperature, density, and dissolved oxygen in relation to depth, showing a decrease in values with increasing depth.

Discussion

While the box and whisker plots were useful in determining overall trends for the data and general surface and bottom trends for nutrients concentrations, the choropleth maps are more useful in showing trends for each individual station. For the 2019 data, the amount of nitrates on the surface of most of the sampling locations was less concentrated than the amount of nitrates at the bottom of the water body (Figure 10a). Station 63 which is shallower than some of the other stations and located closest to the mouth of the inlet, showed a lower concentration of nitrates at the bottom of the water body than the other stations. Because lower nitrate concentrations indicate that organisms such as phytoplankton used up those nutrients, it was possible that these lower numbers were due to the fact that because station 63 is shallower, more sunlight penetrated to the bottom of the water body allowing for more plant and animal life to consume these nutrients. Compared to 2014, many stations in 2019 had less nitrates in the water in general, with the exception of surface nitrates for station 75 (Figure 10).

For the phosphate maps, concentrations seemed to increase with depth further north, however they were roughly equal for top and bottom concentrations further south (Figure 11a). The bottom value for station 69, one of the deepest stations, had the highest concentration of phosphates. In addition to nitrates, phosphates are also important nutrients for phytoplankton, meaning stations depleted of this nutrient may have more activity than those with a buildup of nutrients. It would therefore make sense that there would be a larger buildup of phosphates in deeper areas where there is little sunlight which is needed for these organism's survival, such as station 69. Compared to 2014, the 2019 data showed lower concentrations of phosphates for the bottom data (Figure 11).

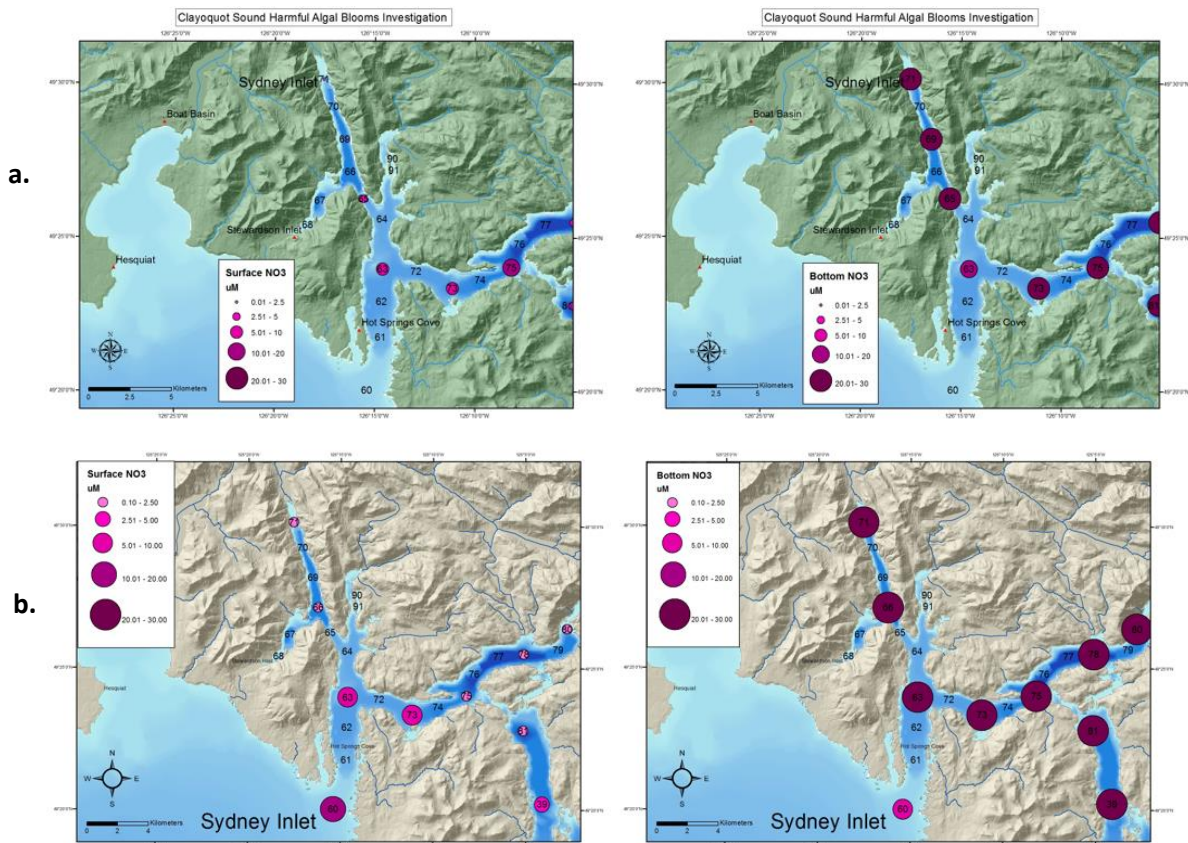


Figure 10: Choropleth maps showing the relative abundances of NO_3 in μM on the surface (left) and bottom (right) of waterways within Sydney Inlet from multiple locations. 10a. Summer 2019 and 10b. Summer 2014 (Leckman 2014).

For the silicate maps, the concentrations of silicate seemed to be slightly higher at the bottom of the water body when compared to surface concentrations (Figure 12a). The exception would be station 71 located far north in the inlet, which had slightly more surface silicate than bottom levels. Diatoms use silicate in their shells and require this nutrient for survival. Because they are only productive at the surface, areas that presented higher levels of silicate would have less diatoms present, since the silicate was not being used up. The concentrations of silicate for the surface readings were also generally the same, whereas the bottom readings had more variation in 2019. Compared to the 2014 results, there were similar trends for top and bottom

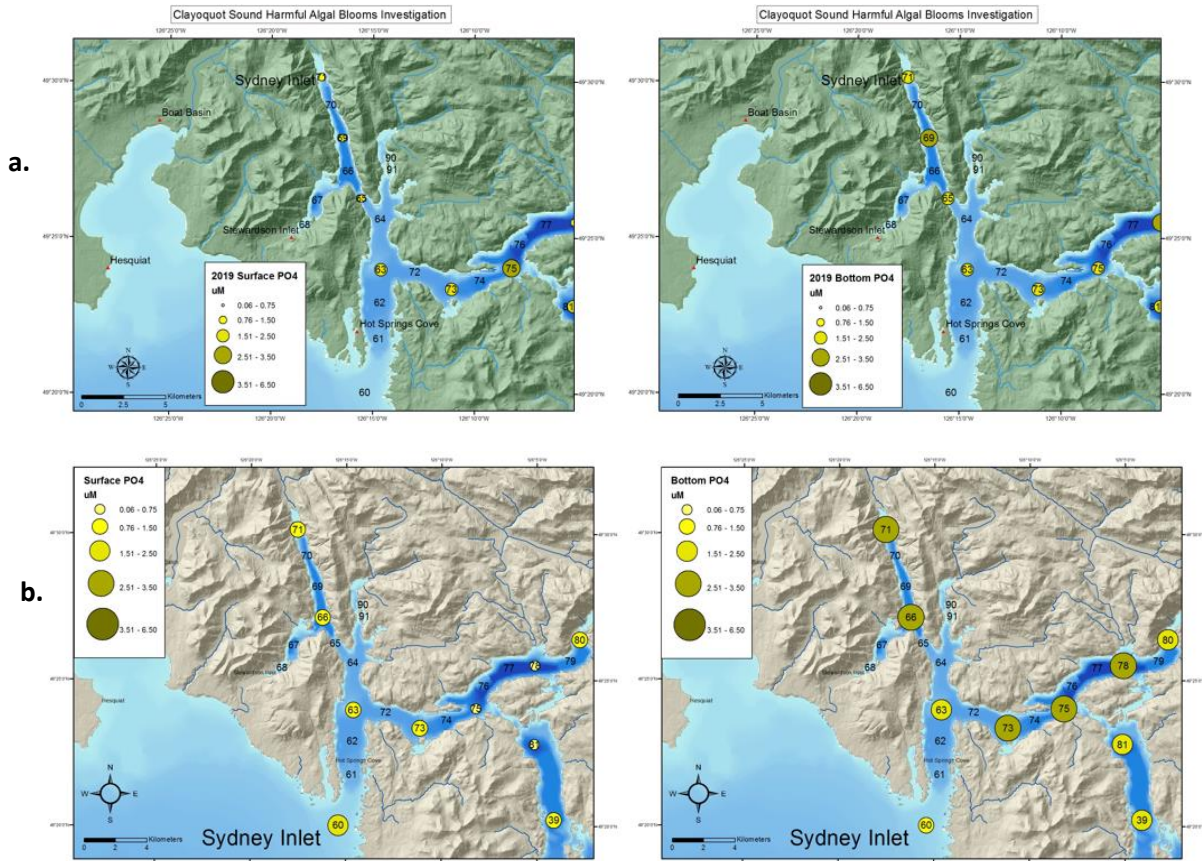


Figure 11: Choropleth maps showing the relative abundances of PO4 in μM on the surface (left) and bottom (right) of waterways within Sydney Inlet from multiple locations. 11a. Summer 2019 and 11b. Summer 2014 (Leckman 2014).

concentrations, however in 2014, there was more surface variation while the bottom levels were more uniform (Figure 12).

In addition to nutrient data, CTD data was expressed using charts in Excel, as well as Surfer plots. For the temperature data, the general trend according to the profile plot shows an decrease in temperature with a increase in depth. For station 63 between 2.975m and 12.89m of depth, there was a rapid temperature change indicating the thermocline (Figure 13). In addition to this, the Surfer plot of temperature highlighted that, while in both years, temperature seems to decrease with depth, there appeared to be a little less mixing towards the bottom of the fjord in

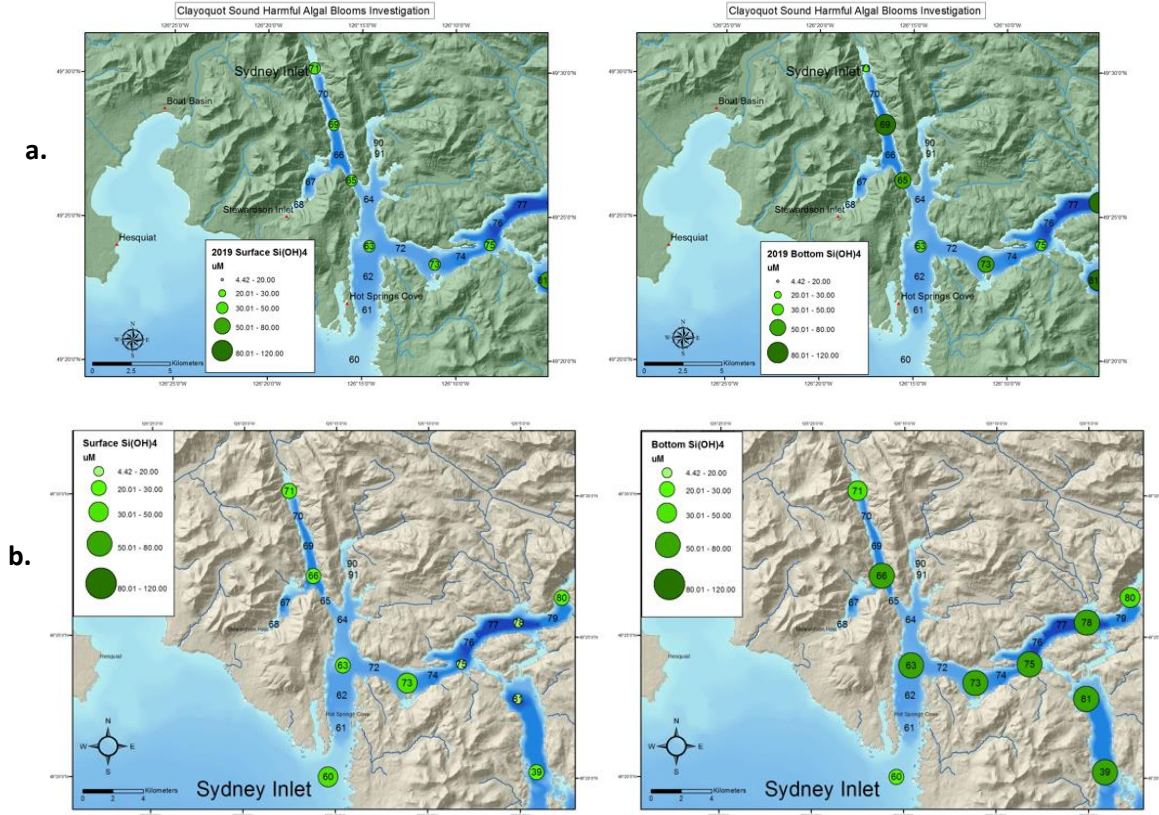


Figure 12: Choropleth maps showing the relative abundances of Si(OH)_4 in μM on the surface (left) and bottom (right) of waterways within Sydney Inlet from multiple locations. Figure 12a. Summer 2019 and Figure 12b. Summer 2014 (Leckman 2014).

2019 than in 2014. Additionally, the temperatures in 2019 were on average 1°C higher than in 2014 (Figure 14).

For the profile of salinity, the levels appeared to start off relatively similar on the surface, and then increase with depth. Station 70 appeared to have slightly higher levels of salinity around 76m of depth, most likely due to older water and the limited mixing in this deeper section of the fjord (Figure 15). According to the Surfer plots for salinity, in both 2019 and 2014, Sydney Inlet was extremely salty. 2019 showed slightly saltier levels with increasing depth, while 2014 had less variation. Stations 66 to 71 appeared to have the least salinity for both years, while stations

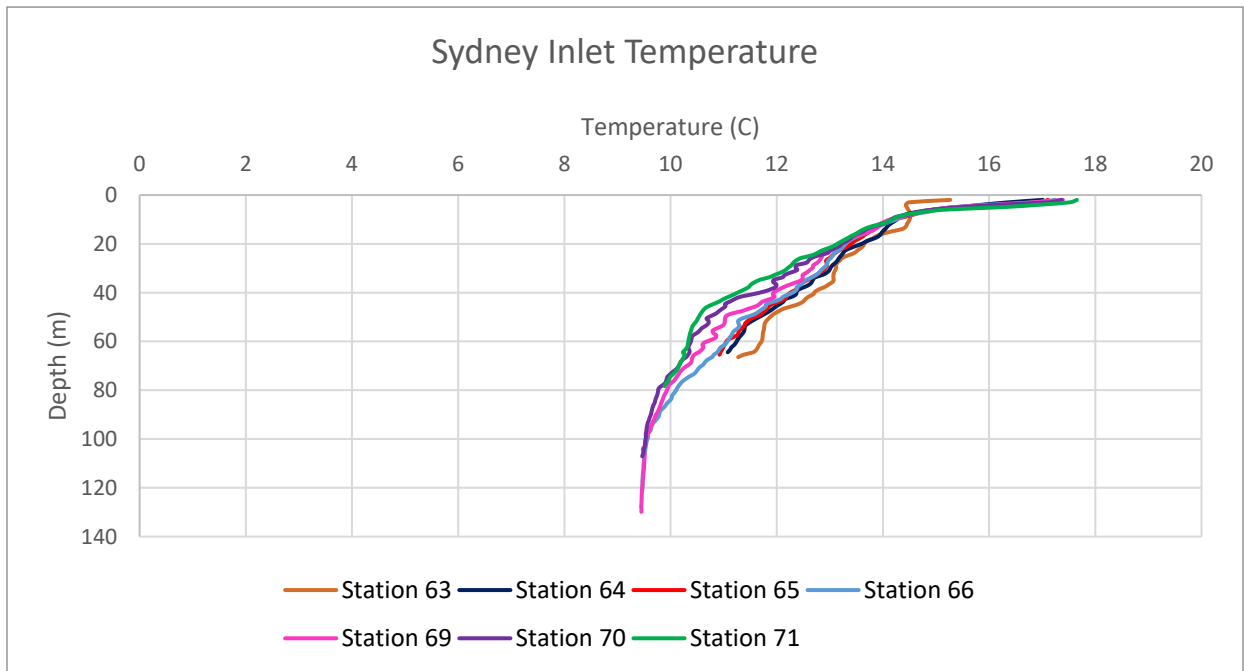


Figure 13: Chart showing the temperature profiles over various depths for each station within Sydney Inlet during summer of 2019.

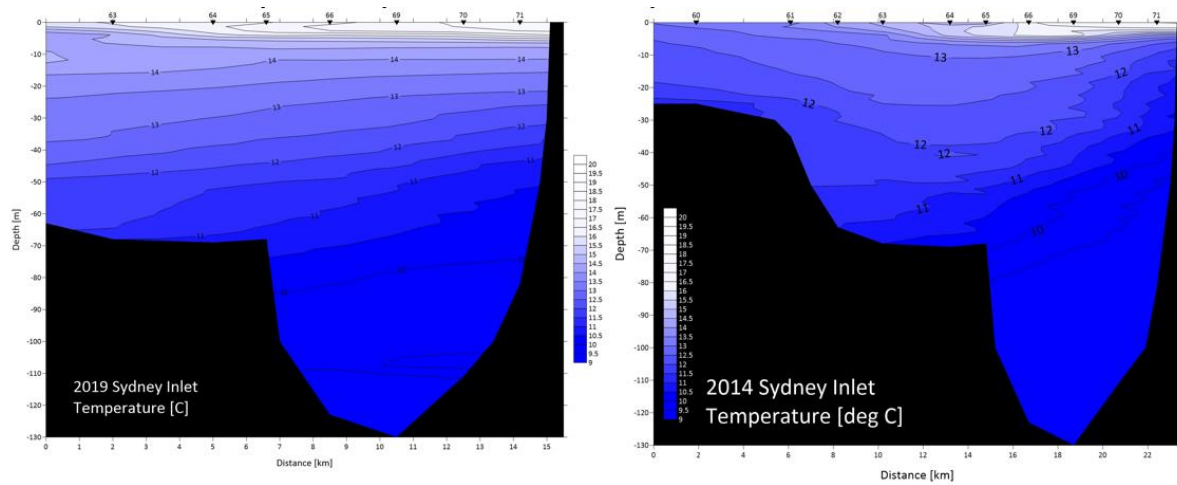


Figure 14: Surfer plots showing the relative temperatures for each station sampled at Sydney Inlet during the summers of 2019 (left) and 2014 (right), corresponding to depth and cumulative distance from each station. (Leckman 2014)

64 to 66 appeared to have slightly lower salinity levels in the year 2019 compared to 2014 (Figure 16).

The values from the density profiles were relatively similar, showing an increase in density with an increase in depth. Station 63 appeared to have higher densities at the surface than the other stations (Figure 17). For the Surfer plot of the density data, there appeared to be a slightly lower surface density, and higher bottom density for the year 2019. There also appeared to be more variation in densities for the year 2019 than in 2014, which may suggest less mixing (Figure 18).

For the profile of the dissolved oxygen data, concentrations of O₂ appear to decrease with increasing depth. Station 63 seemed to show higher levels of oxygen than the other stations (Figure 19). The Surfer plots for dissolved oxygen showed similar trends, however they also illustrated that, while the bottom of the fjord is hypoxic in both 2019 and 2014, the bottom of the fjord in the year 2019 seemed to have more of a hypoxic area than in 2014 (Figure 20).

For the profile of the fluorescence data, there appears to be low levels of fluorescence until less than or equal to 20m of depth, when the readings begin to spike. This spike is known as the chlorophyll max, which is generally located just below the thermocline where phytoplankton can be found in higher numbers due to less predators and the presence of sunlight. Station 63 was an exception to this, as its fluorescence readings were higher than all the stations throughout the water column (Figure 21). Because fluorescence can be an indicator of phytoplankton, and because instances of higher dissolved oxygen seemed to correlate with those higher levels of fluorescence, this would suggest that photosynthetic phytoplankton were present in the areas with higher fluorescence and dissolved oxygen. According to the Surfer plots for fluorescence, for both 2014 and 2019 fluorescence only existed near the surface of the water body. However,

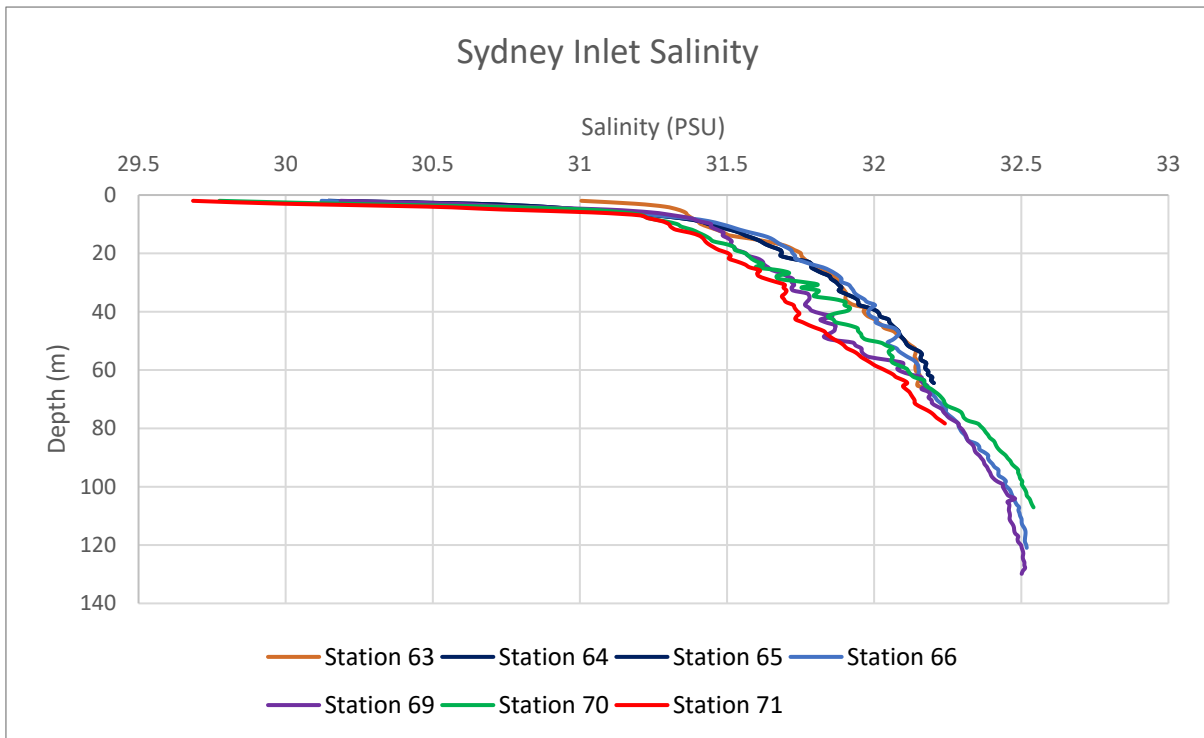


Figure 15: Chart showing the salinity profiles over various depths for each station within Sydney Inlet during summer of 2019.

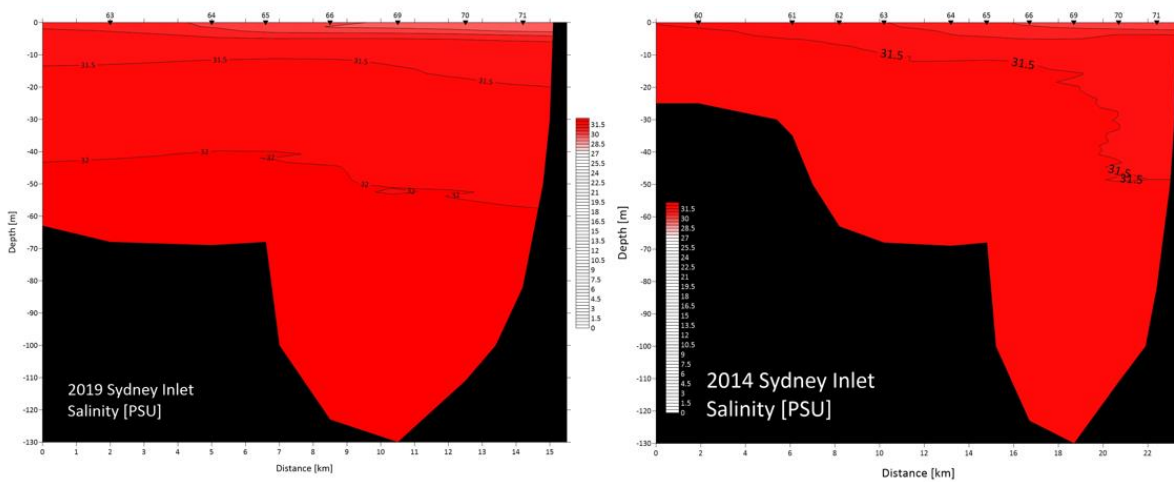


Figure 16: Surfer plots showing the relative salinity levels for each station sampled at Sydney Inlet during the summers of 2019 (left) and 2014 (right), corresponding to depth and cumulative distance from each station. (Leckman 2014)

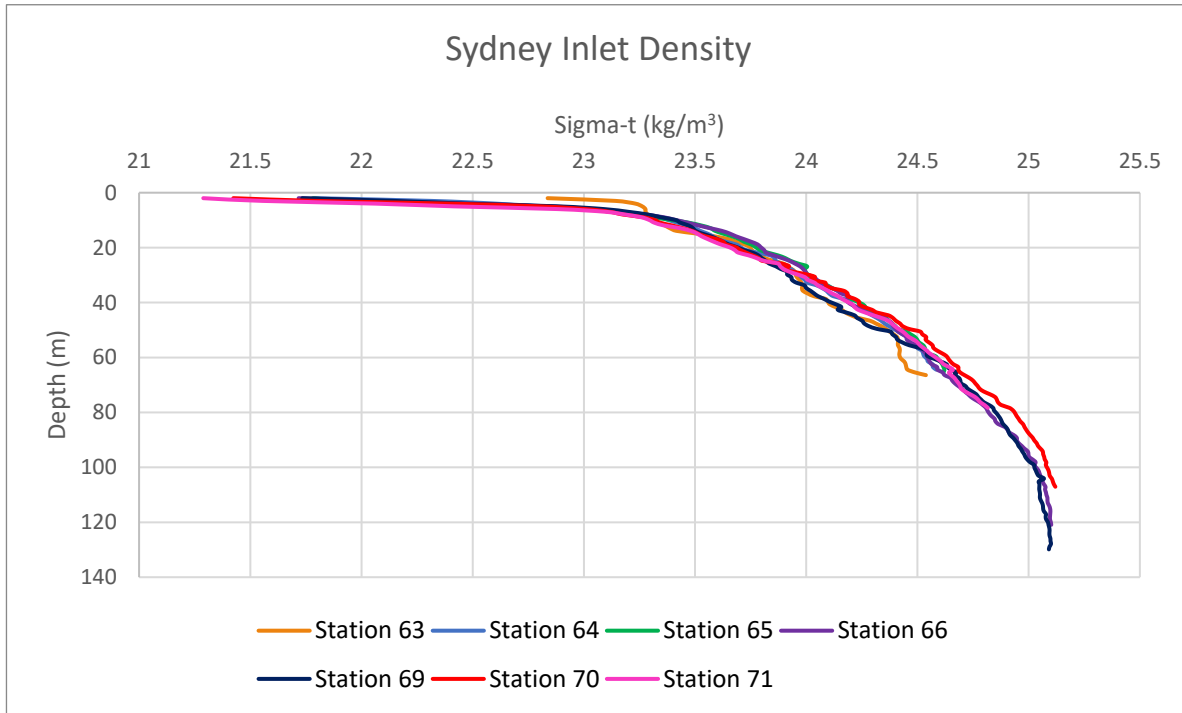


Figure 18: Chart showing the density profiles over various depths for each station within Sydney Inlet during summer of 2019.

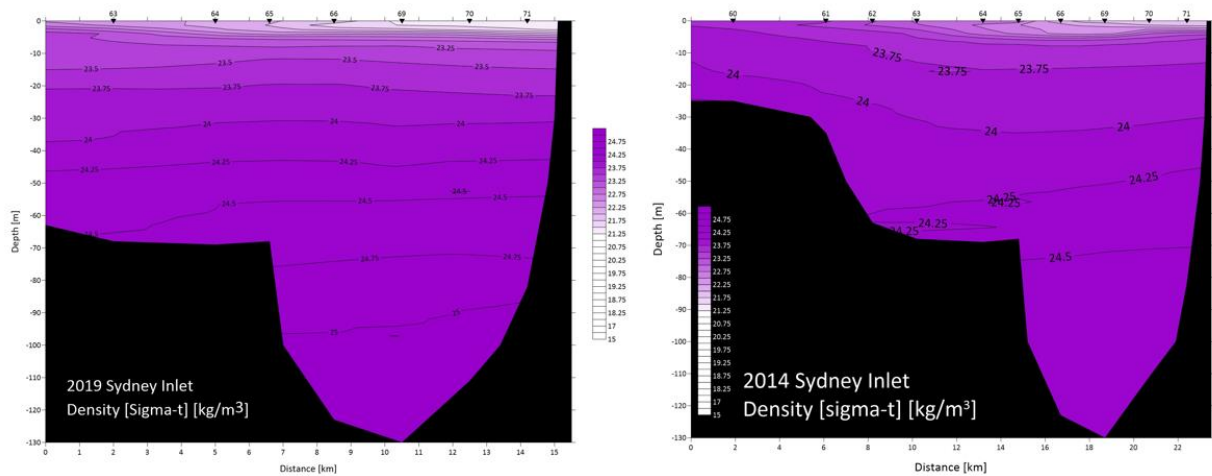


Figure 17: Surfer plots showing the relative densities for each station sampled at Sydney Inlet during the summers of 2019 (left) and 2014 (right), corresponding to depth and cumulative distance from each station. (Leckman 2014)

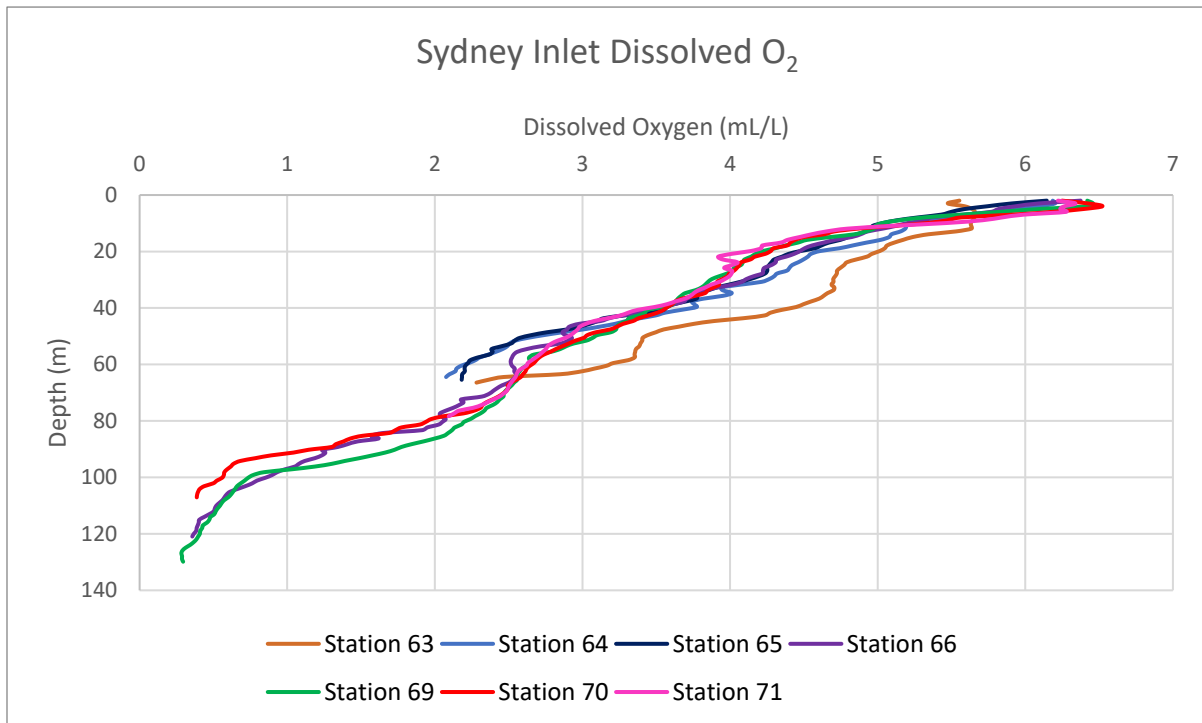


Figure 20: Chart showing the dissolved oxygen profiles over various depths for each station within Sydney Inlet during summer of 2019.

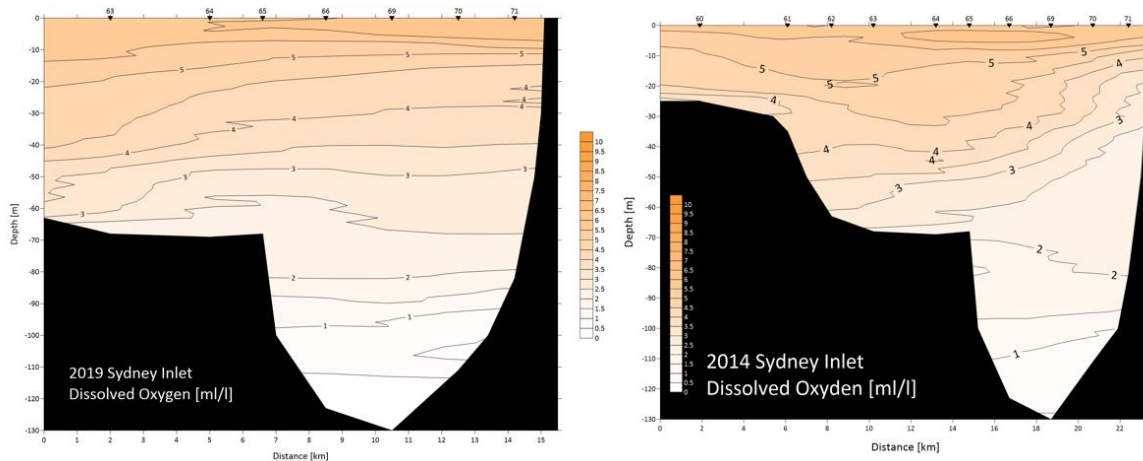


Figure 19: Surfer plots showing the relative amounts of dissolved oxygen for each station sampled at Sydney Inlet during the summers of 2019 (left) and 2014 (right), corresponding to depth and cumulative distance from each station. (Leckman 2014)

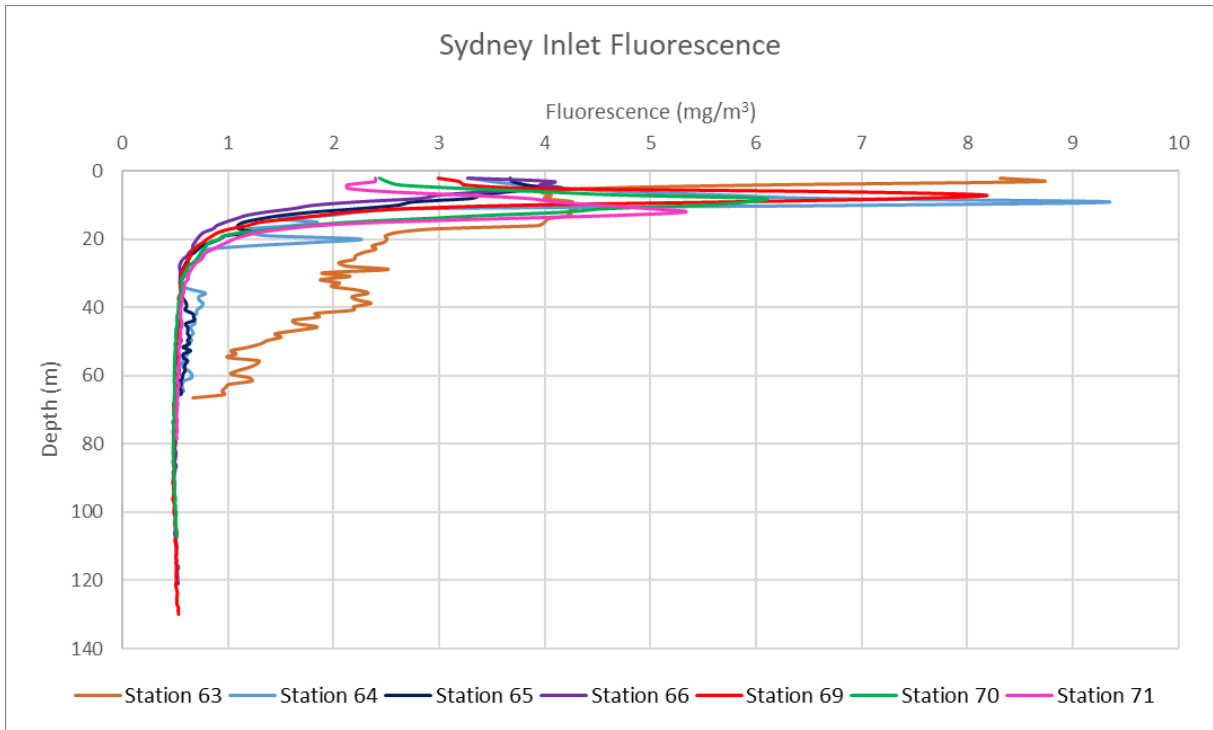


Figure 22: Chart showing the fluorescence profiles over various depths for each station within Sydney Inlet during summer of 2019.

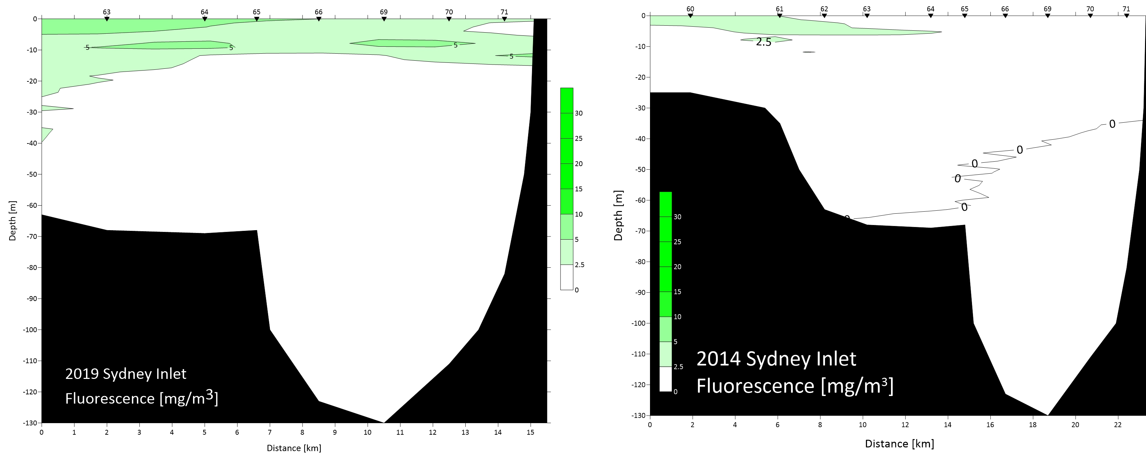


Figure 21: Surfer plots showing the fluorescence for each station sampled at Sydney Inlet during the summers of 2019 (left) and 2014 (right), corresponding to depth and cumulative distance from each station. (Leckman 2014)

there was a significant increase in locations and in the general amount of fluorescence for the year 2019, as compared to the year 2014 (Figure 22).

For the profile of the transmissivity data, all the stations seemed to be between 80 and 100%. Station 63 appeared to have the lowest transmissivity numbers of the group (Figure 23). Because station 63 had higher levels of fluorescence, this would suggest that there were phytoplankton present inhibiting some of the light transmission. According to the Surfer plots of transmissivity, there appears to be lower levels of transmissivity towards the surface of the water in both years, with a decrease in transmissivity between stations 66 and 71 for the year of 2019 on the surface of the water. Transmissivity in both years seemed to get higher with increasing depth (Figure 24).

Overall, in 2019 there was increase in fluorescence and a decrease in surface transmissivity which would suggest an increase in productivity. 2019 also had less nitrates and phosphates for the bottom data which would suggest a potential increase in phytoplankton and other organisms that can consume those nutrients. In 2019 the temperature throughout was 1°C higher than in 2014, suggesting that these waters have gotten warmer as well. Additionally, the waters appeared to be more stratified, with less mixing. Because of these changes between 2019 and 2014, the data would suggest the 'Blob' did intrude into the waters of Sydney Inlet for the year 2019.

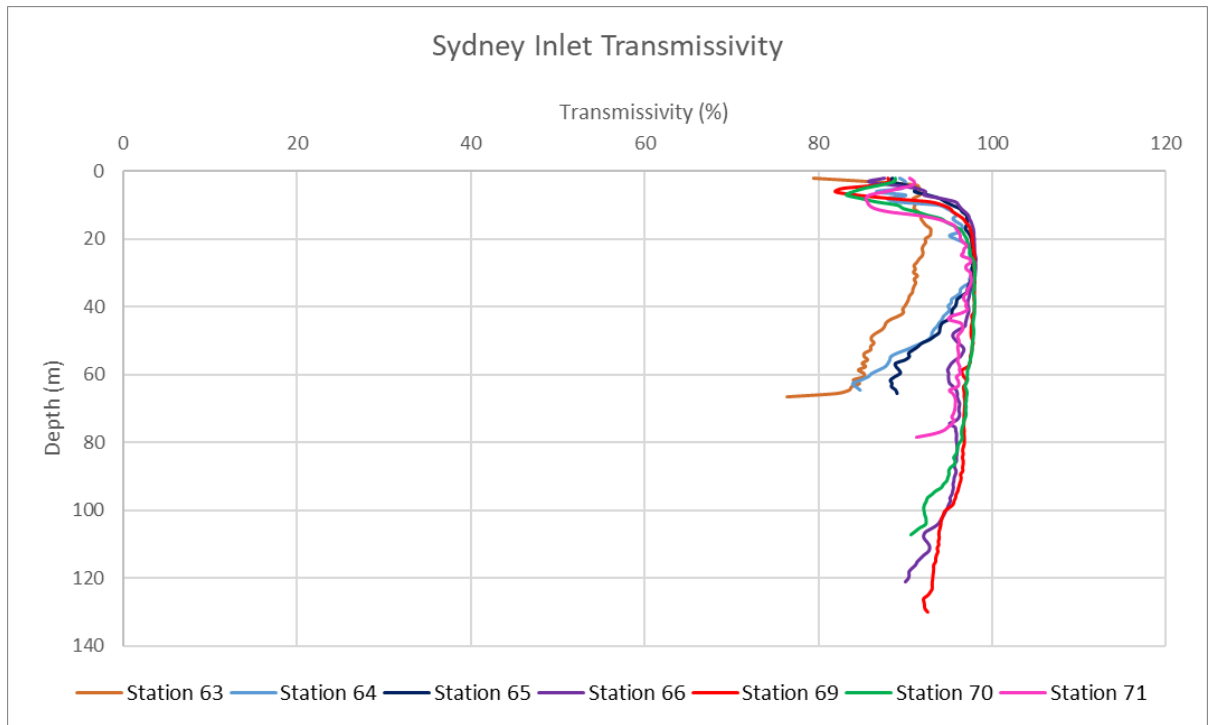


Figure 23: Chart showing the transmissivity profiles over various depths for each station within Sydney Inlet during summer of 2019.

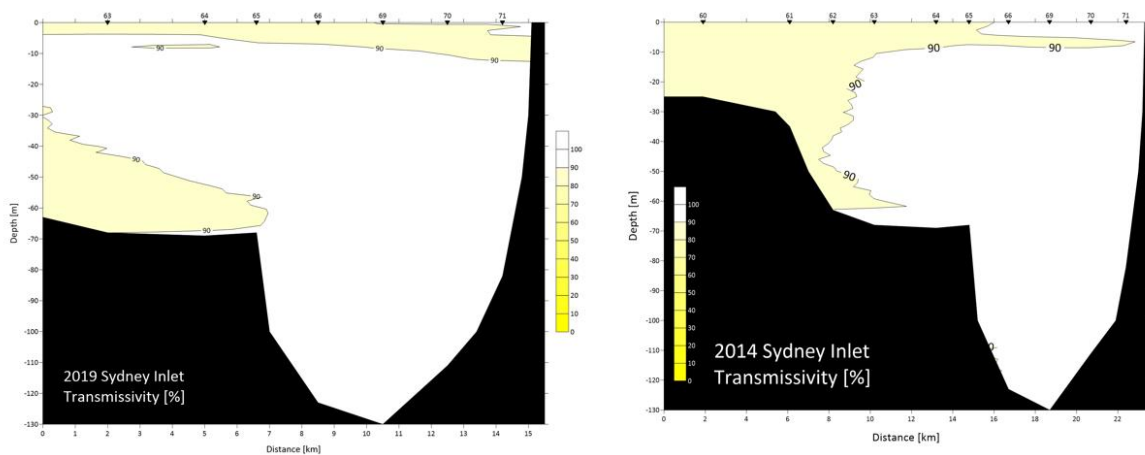


Figure 24: Surfer plots showing the level of transmissivity for each station sampled at Sydney Inlet during the summers of 2019 (left) and 2014 (right), corresponding to depth and cumulative distance from each station. (Leckman 2014)

Conclusion

In this study, the CTD and nutrient data for Sydney Inlet was analyzed for the years 2014 and 2019 for stations 63-71. The temperatures in 2019 were on average 1°C higher than in 2014 which would suggest that the warmer waters from the ‘Blob’ may have intruded into the waters of Sydney Inlet. Furthermore, there was a significant increase in locations and in the general amount of fluorescence for the year 2019, as compared to the year 2014. Overall, it was found that the nutrient concentrations for 2019 seemed to show an overall trend in which the level of nutrients at the bottom of Sydney Inlet were more concentrated than at the surface, this trend was similar to that of 2014. This would make sense, as the organisms that consume these nutrients generally require sunlight to survive, and therefore would not be found in some of the deeper areas within the inlet, allowing for some of the nutrients to settle towards the bottom of the water body. Additionally, it was found that many stations in 2019 had less nitrates in the water in general apart from the surface nitrates for station 75. Compared to 2014, the 2019 data showed lower concentrations of phosphates for the bottom data. It was also found that in 2014 there was more surface variation for silicates while the bottom levels were more uniform. The 2019 data seemed to suggest the presence of solids in the water, with higher bottom densities and more variation than in 2014. The readings for dissolved oxygen, density, and temperature showed relatively different trends towards the surface of the water at station 63. This was most likely due to a freshwater input nearby, and because station 63 is at the confluence between Sydney and Shelter Inlets. Station 70 appeared to have slightly higher levels of salinity than the other stations, which makes sense as this water would most likely be older due to limited mixing in this deeper section of the fjord. Because fluorescence can be indicator of phytoplankton, and because instances of higher dissolved oxygen seemed to correlate with those higher levels of

fluorescence, this would suggest that photosynthetic phytoplankton were present in the areas with higher fluorescence and dissolved oxygen.

In sum, the warm waters from the 'Blob' most likely did intrude into the waters of Sydney Inlet, causing an average increase of 1°C within the water body, as well as a decrease in nitrate and phosphate concentrations and an increase in fluorescence. This data would suggest an increase in phytoplankton, and an increase in favorable conditions for *Alexandrium* as well. This data therefore supports the hypothesis that, because *Alexandrium* prefers to grow in warmer waters, one of the potential effects of the 'Blob' may be that the number of days that favor *Alexandrium* growth would increase. In the future, it would be interesting to look at concentrations of *Alexandrium* cysts within the sediments at each location over multiple years to track its migration.

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Appendix

Data files are located here -

X: GIS/SCIData/Clayoquot/201909_clayoquot/tesc_495_summer_2020/clayoquot_2019/sydney