Diatom abundance and community structure in Barkley Sound, Vancouver Island, BC: significant impacts on primary productivity.

Kira Rombeau
May 28, 2010
444 Senior Thesis, Final Draft
College of Oceanography, University of Washington
1503 NE Boat St., Seattle, WA, 98195

Non-technical Summary

Climate change and the ocean's affects on CO_2 in the atmosphere have been recent topics of interest. As more information is obtained about the role of phytoplankton in carbon export, a process commonly known as the biological pump, the importance of these organisms gains better recognition. Little is known about diatom abundance and community structure on the coastal fjords and embayments of Vancouver Island. Large diatoms increase zooplankton abundance, leading to increased carbon export through fecal pellets. Large diatoms also affect carbon flux directly by sinking faster than smaller diatoms, which may remain suspended in the water column. This validates the significant influence of large diatoms in carbon export. The study took place in the Barkley Sound, Vancouver Island, Canada. Chlorophyll *a* concentrations, oxygen concentrations and biogenic silica concentrations were sampled using Niskin bottles attached to a CTD. Phytoplankton community structure was determined by using microscopy for genera identification. The results suggest sampling took place during the early stages of a spring bloom in Trevor Channel and a more stable bloom in Effingham Inlet. There was high phytoplankton biomass and high diatom biomass Effingham Inlet as well as higher primary productivity in Effingham Inlet. The spring bloom was dominated by *Skeletonema*, accounting for over 80% of absolute abundances. High abundances of *Skeletonema* correlated with high primary productivity in Trevor Channel.

Acknowledgements

I would like to thank the School of Oceanography for funding this project. I thank my 443/444 professors; Kathy Newell, Eric D'Asaro, Rick Keil, Bob Morris, and Deb Kelley for their guidance and valuable input. I also would like to thank Colleen Durkin for helping me with my lab methods and her guidance in helping me process and analyze my data. I would like to thank the Armbrust lab for letting me use their facilities for my biogenic silica analysis and Kathy Newell for letting me use her lab for the phytoplankton/diatom counts and for her help in this process. I would like to thank Carly Moreno, who collaborated with me in measuring primary productivity and diatom cell counts and also collected my Effingham Inlet samples. I would like to thank Rachel Emswiler for making the CTD data accessible and Dane Logan for sharing his map of Barkley Sound and Ashley Leung for sharing her data.

Abstract

Sampling took place in Trevor Channel and Effingham Inlet, two regions within Barkley Sound, Vancouver Island, BC between March 20 – March 22, 2010. Stations were sampled for phytoplankton biomass, diatom biomass, phytoplankton community structure and primary productivity, using Niskin bottles attached to a CTD. Samples were taken at 5 meters and the chlorophyll maximum, as determined after evaluating the CTD sensing system data. Average total chlorophyll a values in Trevor Channel ranged from 2.24 ± 0.37 ug/L and 4.06 ± 1.06 ug/L. They were greatest at the outer basin of Effingham Inlet, 11.30 ± 0.69 ug/L, and decreased as stations got closer to the head, 2.30 ± 0.62 ug/L. Biogenic silica concentrations were greatest in Effingham Inlet 4.96 ± 0.54 uM/L - 6.77 ± 0.63 uM/L. Primary productivity was greatest at the outer basin and head of Effingham Inlet. Skeletonema was the dominant diatom genera at all stations in Trevor Channel and Effingham Inlet. Phytoplankton community dynamics were similar to previous studies, finding that *Skeletonema* is dominant during the early spring bloom and higher *Skeletonema* abundances correlate to higher primary productivity. Diatoms were the dominant phytoplankton at each station and were significant contributors to primary productivity. Large diatoms were not abundant and did not significantly

contribute to overall abundance of phytoplankton and therefore did not contribute to primary productivity in Barkley Sound.

Introduction

The issue of global warming has become a major concern in recent years. Anthropogenic CO_2 emissions are the main cause of this problem. About 4 billion tons of anthropogenic CO_2 are emitted into the atmosphere each year, but the amount in the atmosphere only increases by about 2 billion tons (IPCC 2003). This indicates there is another carbon reservoir that is relieving some of the carbon input into the atmosphere reservoir. The world's oceans absorb about half of all total emissions each year. The surface and deep oceans play crucial roles in alleviating this carbon load. Surface water directly absorbs CO_2 from the atmosphere through reactions with existing carbonate ions. The process of carbon transport to the deep oceans is a biological process that involves organisms known as phytoplankton. Phytoplankton live in the euphotic zone, located in the surface oceans, and assimilate CO_2 during photosynthesis. This CO_2 is converted to particulate organic matter (POC). When phytoplankton die, they sink and transport POC to the deep ocean. Most of this carbon is returned to the surface as DIC due to respiration performed by zooplankton, organisms that graze on the phytoplankton. However, some of this organic matter eventually reaches the deep ocean in the form of dead phytoplankton or fecal matter from zooplankton. This process of carbon uptake through phytoplankton production and export of POC to the deep ocean is called the biological pump (Buesseler 1998, Legendre et al. 1996, De La Rocha 2007).

The efficiency of the biological pump has an important impact on carbon uptake. Many factors are known to affect this efficiency; such as primary productivity, particle suspension and degradation, and phytoplankton size (Legendre et al. 1996). Communities dominated by diatoms and large phytoplankton were found be correlated with areas with a stronger coupling of primary production and POC export (Buesseler 1998). Diatoms are responsible for up to 75% of total primary production in coastal waters and can contribute as much as 40% of organic matter exported in to depth (Moriceau et al 2009). The role of phytoplankton biomass, diatom abundance, and diatom size will be closely explored to test the hypothesis that phytoplankton communities with high abundances of large diatoms will correlate with high primary productivity.

The study took place during the 2009/2010 ENSO event. ENSO events provide the opportunity to understand the dynamics of biological communities and how they respond to climatic oscillations and changing ocean physical mechanisms. These mechanisms impact nutrient upwelling and play an important role by regulating bottom-up processes (Harris et al. 2009).

Barkley Sound provides two interesting ecosystems to study phytoplankton biomass, community structure and primary production. Barkley Sound is an open embayment located on the west coast of Vancouver Island, British Columbia, Canada that supports a biologically productive community of organisms, dominated by diatoms (Haigh et al. 1992, Harris el at. 2009, Hay et al. 2003). From late March to September, winds along the west coast of Vancouver Island cause upwelling, resulting in an input of nutrients and high biological productivity in that area (Harris et al. 2009, Thomson 1981). Sampling took place in two areas of Barkley Sound; Effingham Inlet and Trevor Chanel. Effingham Inlet is a fjord located in the northeast corner of Barkley Sound. It is about 15 km long and has an inner and outer basin, accompanied by a sill at each entrance. Trevor Channel is located on the west side of Barkley Sound, between the coast and the Deer Island system. This channel has a direct connection to the open ocean.

The first objective of this study is to measure the autotrophic phytoplankton biomass and estimate diatom abundance in the phytoplankton community. The second objective of this study is to observe how phytoplankton biomass and diatom size change as a function of diatom abundance and location. The third objective is to measure primary production and relate changes in production to diatom size, diatom abundance and sampling location.

Methods

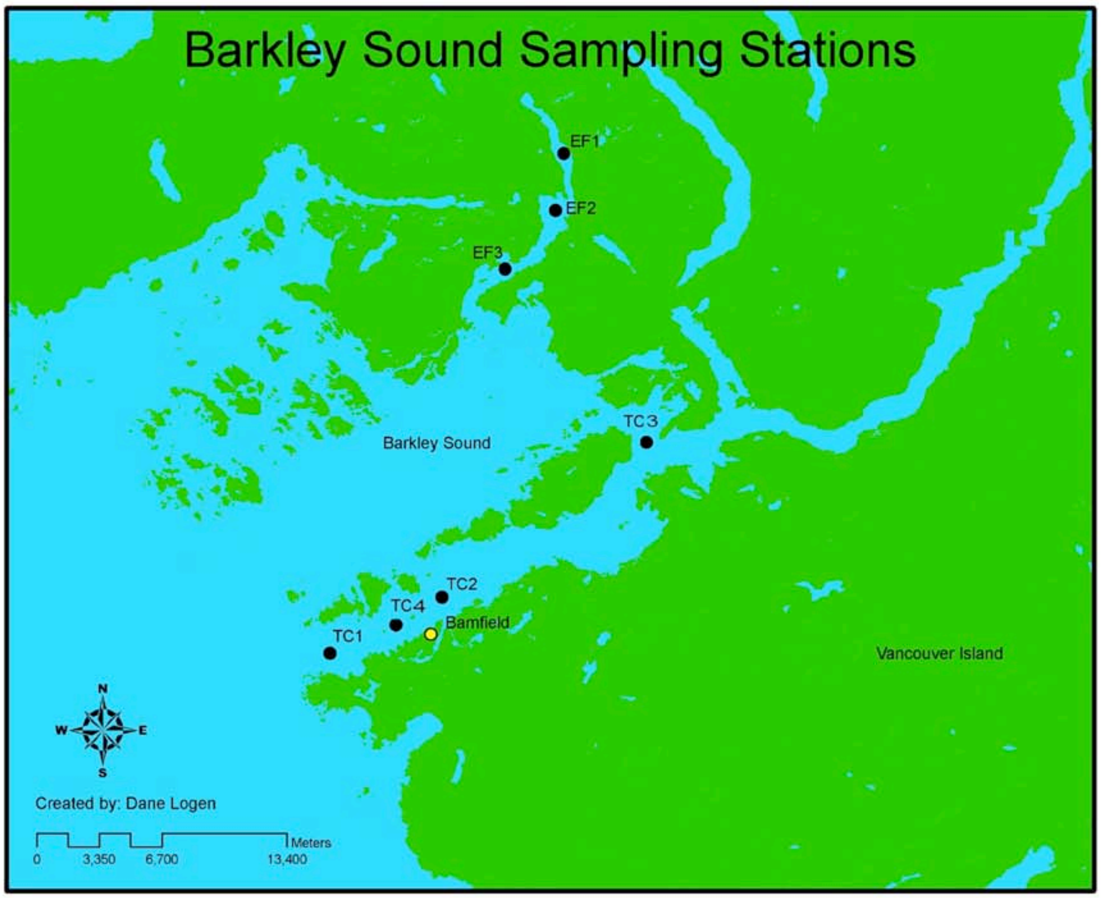


Figure 1: Map of Barkley Sound and stations in Trevor Channel and Effingham Inlet.

Sampling took place aboard the Barkley Star and the Alta, two research vessels contracted from the Bamfield Marine Science Center. Daily sampling cruises departed between March 20 and March

22, 2010. Three stations were sampled in Effingham Inlet and four stations were sampled in Trevor Channel (Figure 1). Stations EF3, EF2, and EF1 represent the stations sampled in Effingham Inlet. Station locations were chosen to compare phytoplankton biomass, diatom abundance and primary productivity in two distinct regions with different environments.

Water samples were collected using two Niskin bottles attached to a CTD and closed at different depths. Samples were collected at 5 meters and the chlorophyll maximum, as determined by analyzing the CTD sensing system data. Chlorophyll a and biogenic silica samples were size fractionated into three size classes; 0.6um – 20um, 20um – 100um, and >100um. Duplicate and triplicate samples were collected when possible.

Phytoplankton Biomass

The water samples were filtered using a stacked filtration rig to separate the size classes in the sample and concentrate the phytoplankton onto polycarbonate filters. The filter paper was placed in a capped plastic test tube with 10 mL acetone. The samples were then placed in a sonicator that emits 3000 watts of acoustic energy, disrupting the cellular membranes so that they can elute into the acetone. The samples were kept on ice and left in the sonicator for 10 minutes. After sonication and lysing of the cells, the samples were placed in a centrifuge and spun in order to ensure that all particulate matter was cleared and a pure sample remained. These samples were individually poured into a cuvette and read by a flourometer to detect chlorophyll fluorescence. Chlorophyll *a* concentrations were calculated using the following formulas:

$$\text{Chl } a = \frac{(F0/Fa\ max) / (F0/Fa\ max-1)*Kx(F0-Fa)}{\text{volume of water filtered (in liters)}}$$

F0/Fa max = 1.989, Kx = 0.11356 (Lorenzen, 1966).

Diatom Abundance

Diatom abundance was measured by sampling biogenic silica concentrations. The water samples were filtered for each size class, placed in a capped plastic test tube and stored in the freezer. Once the samples returned to Seattle, Washington they were analyzed in the Armbrust lab at the University of Washington, according to the methods by Brzezinski and Nelson (1989). A NaOH solution was added to the filtered sample in order to dissolve the diatom frustules and the samples were placed in a hot water bath, after which HCl was added to neutralize the solution. Brzezinski and Nelson (1986) present a method involving various chemical processes, such as the selective formation of beta silicomolybdic acid, extraction into n-butanol, and the reduction to silicomolybdous blue. A colorimetric test produces an absorbance calibration curve that determines silicic acid concentrations indirectly by measuring the intensity of the blue color of the solution. Particulate Si determination was carried out in 3 rounds, due to the large sample load, and a standard curve and blanks were made for each round and used to determine the respective Si concentrations.

Primary Production

Primary production was measured by sampling oxygen concentrations soon after sampling each station and then measuring the oxygen concentration after an incubation period. Water samples for incubation were collected in 0.5 L glass bottles and placed in an outdoor incubator for and incubation period lasting the duration of the research trip. Mesh was used to cover bottles to simulate light levels for different depths. The incubator had surface ocean water circulating through to simulate natural marine water conditions as accurately as possible. Oxygen measurements were taken using the Ocean

Optics oxygen microelectrode. A pad was placed on the inside wall of each bottle before sampling. The microelectrode probe was held next to the pad for one minute to get an accurate oxygen reading. The photosynthesis rate was calculated using the initial oxygen concentrations, final oxygen concentrations and incubation period. A sample bottle with an Ocean Optics temperature probe was used during the oxygen measurement process to calibrate the oxygen sensor and correct for the difference in temperature between the incubator and the lab.

Phytoplankton Community Structure

Phytoplankton community structure was sampled using water from the Niskin bottles, as well as net tows. Surface water samples from a Niskin bottle and preserved using formalin. Once the samples were back at the lab, they were settled in a settling chamber, concentrating 10 mL of seawater down to 1 mL. The diatoms in that sub-sample will be counted and identified to the genera by viewing 1 mL of the sample in a Palmer-Maloney slide under a microscope. The sample was counted along a transect across the middle of the slide under 25x . Phytoplankton community structure will also be sampled using a 20 micron net tow. The purpose of this sampling is to get concentrated samples of phytoplankton to complement the quantitative counting data, for genera identification

Results

Nutrient Concentrations

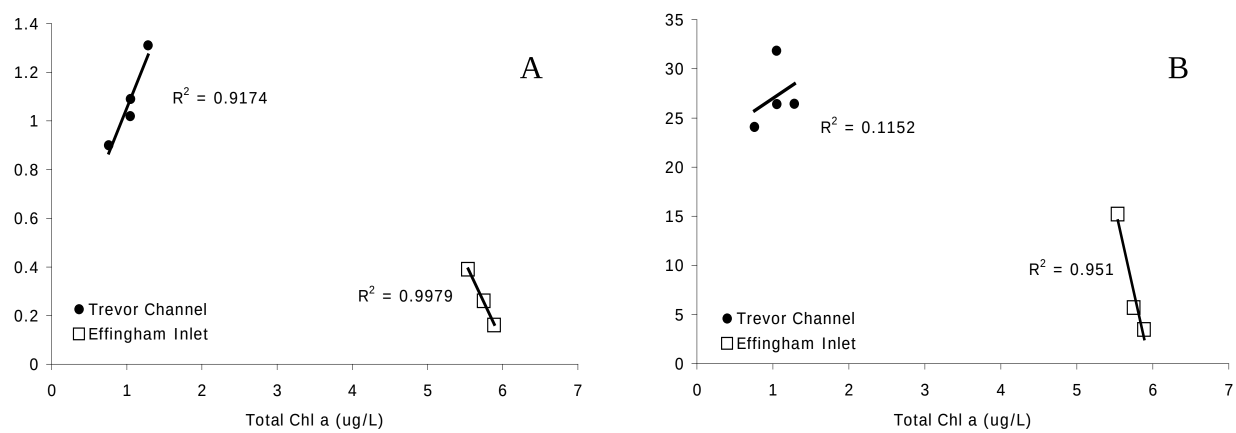
Table 1. Nutrient concentrations in Trevor Channel and Effingham Inlet at the chlorophyll max.

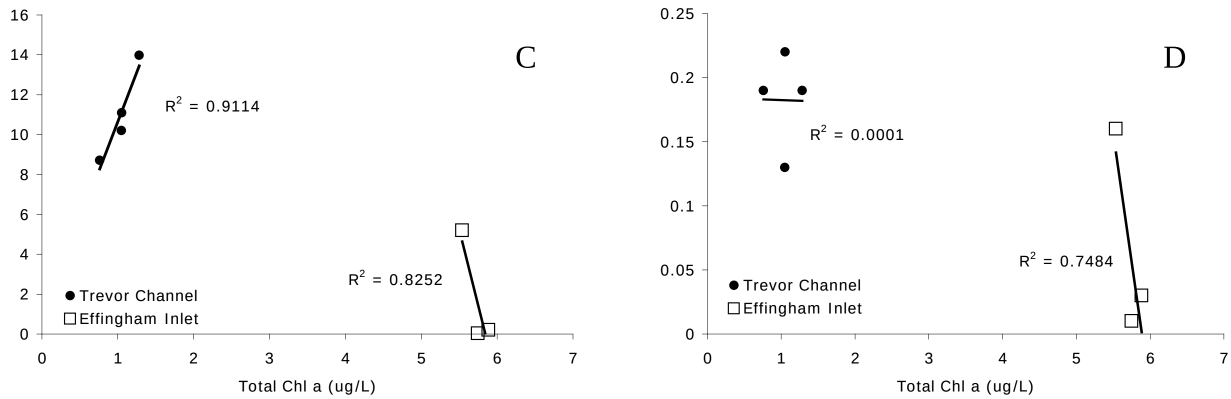
Station	[PO_4]	[$Si(OH)_4$]	[NO_3]	[NO_2]	[NH_4]
TC1	1.31	26.44	13.97	0.19	0.23
TC4	0.90	24.07	8.71	0.19	0.16
TC2	1.02	31.82	10.20	0.13	0.14
TC3	1.09	26.39	11.09	0.22	0.37
EF3	0.74	15.19	5.19	0.16	0.39
EF2	0.04	3.46	0.20	0.03	0.16
EF1	-	-	-	-	-

Table 2. Nutrient concentrations in Trevor Channel and Effingham Inlet at 5 meters.

Station	[PO_4]	[$Si(OH)_4$]	[NO_3]	[NO_2]	[NH_4]
TC1	-	-	-	-	-
TC4	0.94	23.84	9.04	0.19	0.19
TC2	1.12	30.38	11.19	0.16	0.24
TC3	1.33	26.65	13.53	0.24	0.61
EF3	0.16	7.30	0.29	0.03	0.15
EF2	0.04	3.16	0.04	0.02	0.23
EF1	0.14	5.68	0.03	0.01	0.26

Nutrient concentrations were highest in Trevor Channel and lowest in Effingham Inlet (Table 1, Figure 2). Phosphate concentrations were highest at TC1, 1.31 uM, and lowest at EF 2, 0.04 uM. Silicic acid was greatest in Trevor Channel and lower in Effingham Inlet. Nitrate and nitrite concentrations were highest in Trevor Channel and lowest in Effingham Inlet.





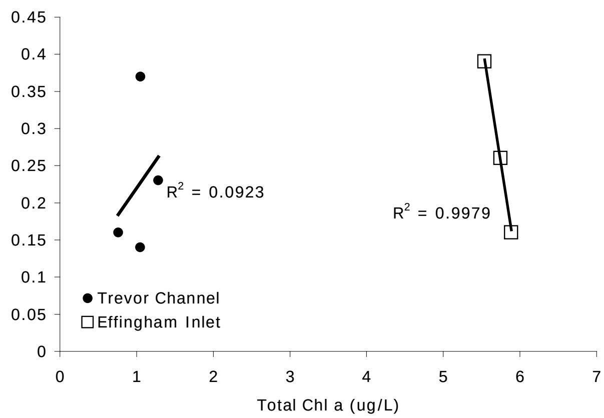
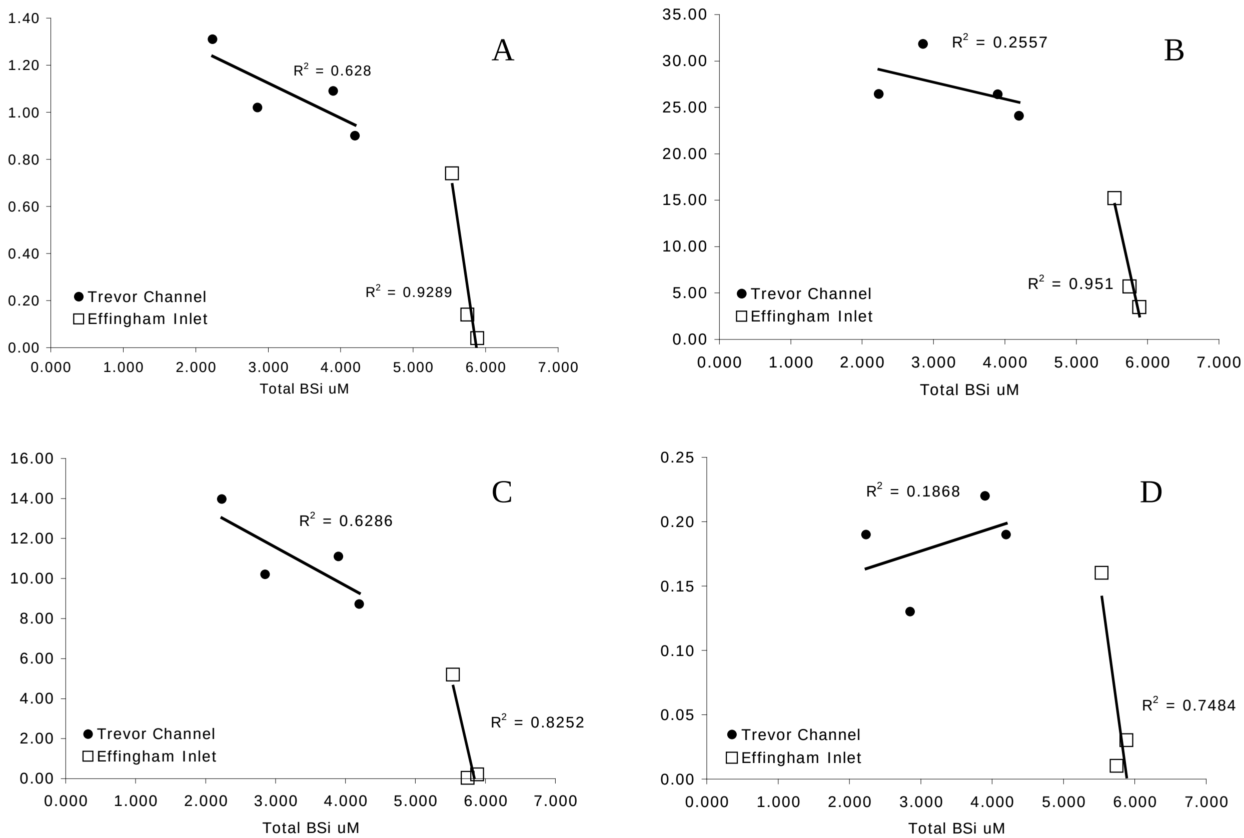


Figure 2. Average chlorophyll a concentrations (ug/L) plotted against nutrient concentrations (uM) for stations in Trevor Channel and Effingham Inlet. Panel A represents phosphate concentrations versus chlorophyll a concentrations. Panel B corresponds to silicic acid, panel C to nitrate, panel D to nitrite and panel E to ammonia concentrations. Samples taken at the chlorophyll max.

Stations in Effingham Inlet followed a general trend for all nutrients measured. As chlorophyll a concentrations increased, nutrient concentrations decreased (Figure 2). This trend had a stronger correlation between chlorophyll a and phosphate, R2 = 0.99, as well as ammonium, R2 = 0.99. Stations in Trevor Channel exhibited a different interaction between chlorophyll a concentrations and nutrient concentrations. As chlorophyll a concentrations increased, phosphate, nitrate, ammonium and silicic acid concentrations increased. There was a strong correlation between chlorophyll a and phosphate, R2 = 0.92, and nitrate, R2 = 0.91.



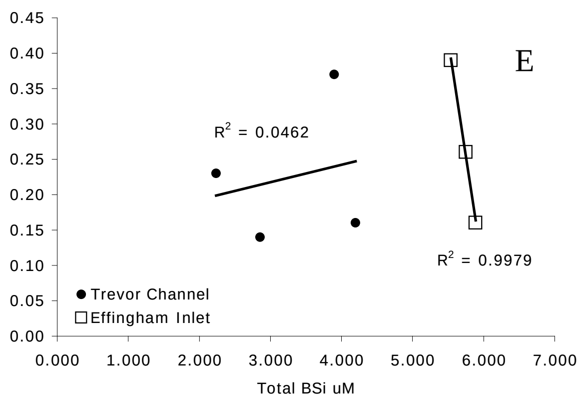


Figure 3. Average biogenic silica concentrations (uM) plotted against nutrient concentrations (uM) for stations in Trevor Channel and Effingham Inlet. Panel A represents phosphate concentrations versus biogenic silica concentrations. Panel B corresponds to silicic acid, panel C to nitrate, panel D to nitrite and panel E to ammonia concentrations.

Samples from Effingham Inlet exhibited a trend where nutrient concentrations decreased as biogenic silica concentrations increased. The strongest correlations between biogenic silica concentrations and nutrient concentrations was silicic acid, R2 = 0.95, and ammonium, R2 = 0.99. Samples from Trevor Channel behaved differently. As biogenic silica concentrations increased, phosphate, silicic acid and nitrate concentrations decreased. Nitrite and ammonium concentrations increased as biogenic silica concentrations increased. The strongest correlation between biogenic silica concentrations and nutrient concentrations was with phosphate, R2 = 0.63, and nitrate, R2 = 0.63.

Chlorophyll Concentrations

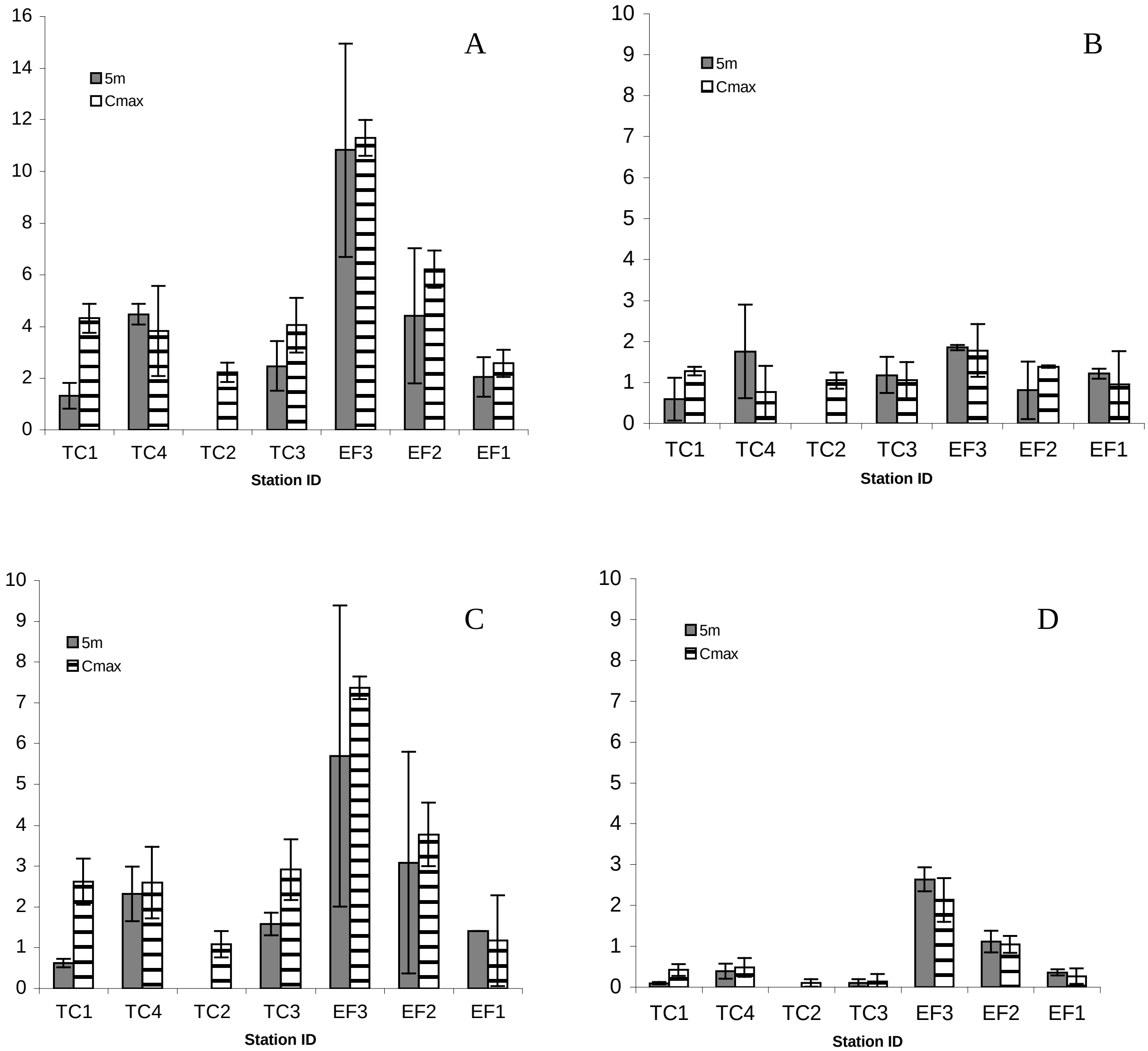


Figure 4. Average chlorophyll a (chl a) concentrations for Trevor Channel and Effingham Inlet, at 5 meters and at the chlorophyll maximum. Panel A is total chlorophyll a concentrations. panel B is the 0.6 – 20 um size class, panel C is the 20 – 100 um size class and panel D is the >100 um size class.

The average total chlorophyll a varied across stations and across depths. The total chl a for stations in Trevor Channel appeared to be lower than total chl a in Effingham Inlet and showed a pattern of decreasing chl a as the distance from the open ocean increased, at chlorophyll maximum (Figure 4). EF3 had the highest total chlorophyll a concentration at 5 meters and at chlorophyll maximum, 10.8 ± 4.12 ug/L and 11.3 ± 2.59 ug/L respectively. TC2 had the lowest total chlorophyll a concentration, 2.23 ± 0.37 ug/L.

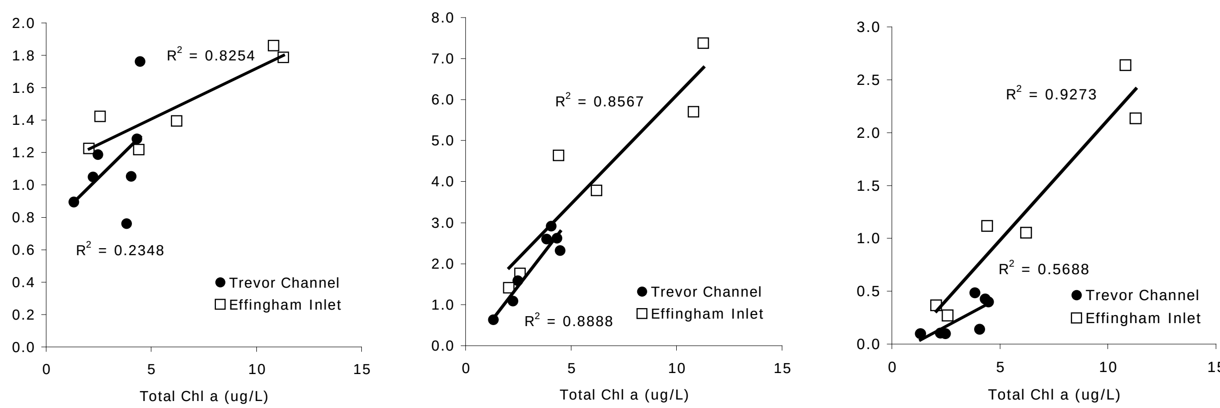


Figure 5. Total chlorophyll a concentrations versus chlorophyll a concentrations in each size class.

The 0.6 - 20 um and 20 - 100 um size classes showed a strong correlation with total chlorophyll a concentrations, $R^2 = 0.83$ and $R^2 = 0.88$, respectively (Figure 5). In Trevor Channel, there was a correlation between the >100 um size class, but it was not as strongly coupled as the other two size classes, $R^2 = 0.57$. The 20 - 100 um and >100 um size classes showed a strong correlation with total chlorophyll a concentrations in Effingham Inlet, $R^2 = 0.86$ and $R^2 = 0.93$, respectively. The 0.6 - 20 um size class did not show a strong correlation with total chlorophyll a concentrations in Effingham Inlet. The 20 – 100 um size class significantly contributed to the total chlorophyll a concentration in Trevor Channel, R2 = 0.89 (Figure 5). All size classes significantly contributed to the total chlorophyll a concentration in Effingham Inlet. The >100 size class showed the strongest correlation, R2 = 0.93.

Biogenic Silica Concentrations

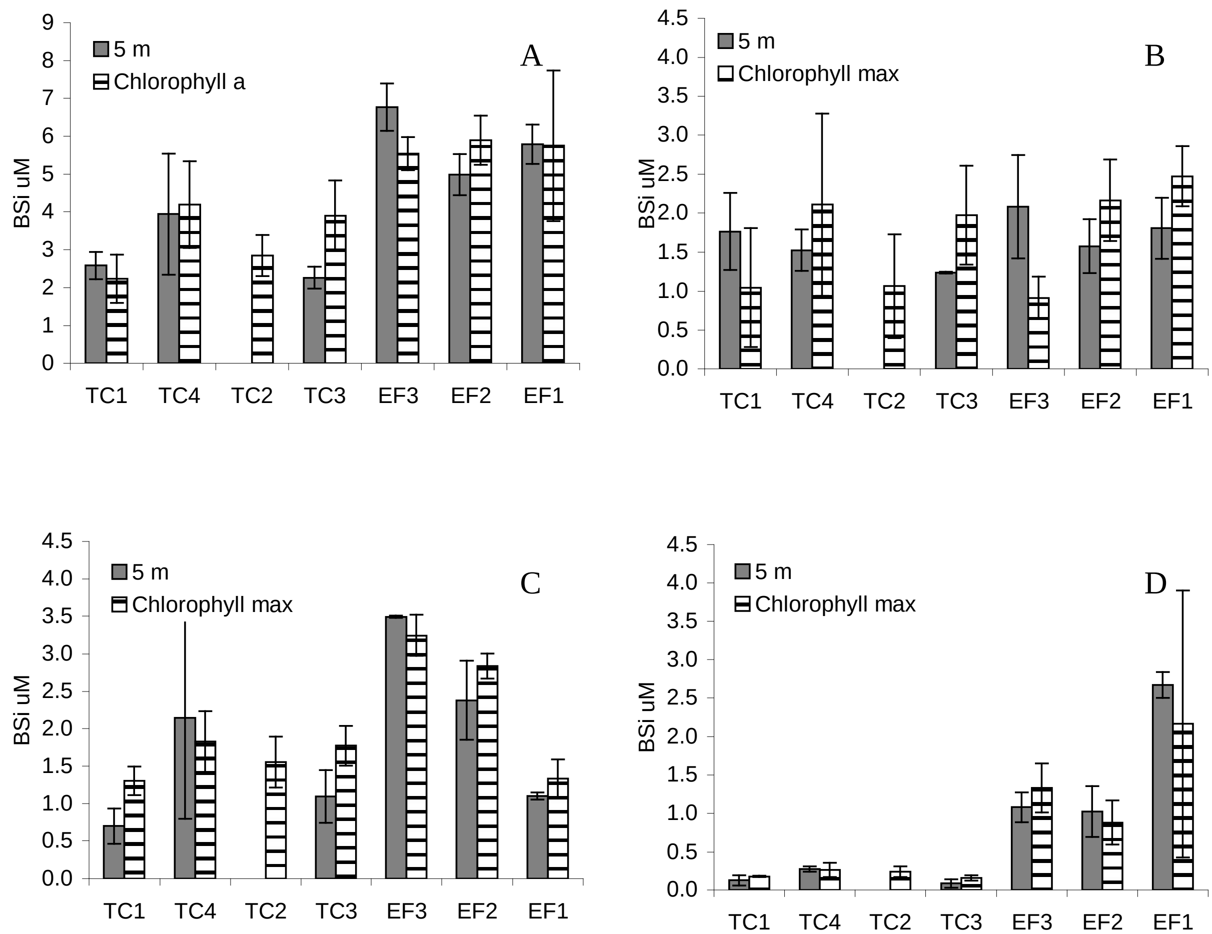


FIGURE 6. Biogenic Silica concentrations for Trevor Channel and Effingham Inlet, at 5 meters and at the chlorophyll maximum. Panel A represents the total biogenic silica concentrations, panel B

represents the 0.6 – 20 um size class, panel C represents the 20 – 100 um size class and panel D represents the >100 um size class.

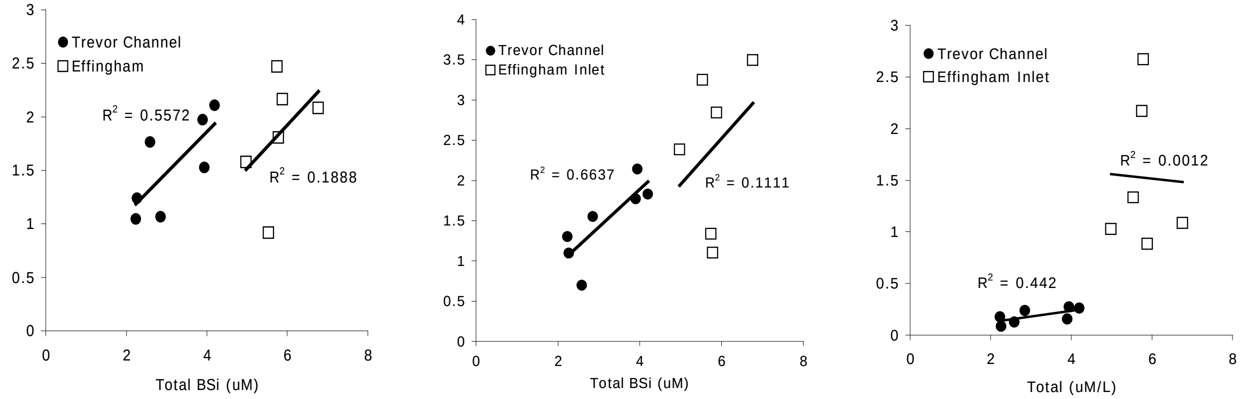


Figure 7. Total biogenic silica and each size class (uM).

There was not a significant correlation between chlorophyll a and biogenic silica concentrations in Barkley Sound, R^2 = 0.30. Biogenic silica concentrations showed a general trend of increased concentrations in Effingham Inlet and lower concentrations in Trevor Channel (Figure 6). Total biogenic silica (BSi) concentration was highest in Effingham Inlet. Station EF2 had the highest concentration values, 5.88 ± 0.65 uM. Trevor Channel had lower BSi concentrations. TC1 and TC2 had the lowest BSi concentrations in Barkley Sound, 2.2 ± 0.63 uM and 2.9 ± 0.54 uM, respectively.

In Effingham Inlet, there was no strong correlation between a size class and the total BSi concentration (Figure 7). The 0.6 - 20 um and 20 - 100 um size classes contributed to total BSi concentrations, R^2 = 0.55 and R^2 = 0.66, respectively. In Trevor Channel, there was a correlation found between each size class and the total BSi concentration. While these correlations weren't as significant, there appeared to be a better correlation between the 20 - 100 um size class BSi values and the total BSi values.

Diatom Community Structure

Table 3. Absolute abundance of diatom taxa found at each station in cells/L.

Phytoplankton Taxa	TC1	TC4	TC2	TC3	EF3	EF2	EF1
Asterionellopsis	8,832	-	26,496	35,328	-	-	-
Bacillaria	-	-	-	-	-	-	552
Basteriastrum	-	444	-	-	47,472	33,120	2,208
Chaetoceros spp	6,216	-	-	20,868	-	-	1,656
Corethron	-	-	-	-	-	-	-
Cylindrotheca	9,936	3,312	4,416	6,624	14,352	5,520	2,208
Ditylum	-	-	-	-	-	1,104	-
Navicula	-	-	-	-	-	-	552
Pleurosigma	1,104	-	1,104	-	-	-	-
Pseudo-nitzchia	7,728	-	24,288	36,432	35,328	19,872	4,416
Rhisozolenia	-	-	-	-	-	1,104	-
Skeletonema	793,776	563,040	441,600	1,451,760	996,912	986,976	607,200
Thalassionema spp.	5,520	1,104	23,184	6,624	32,016	4,416	5,520
Thalassiosira spp.	11,040	19,872	15,456	49,680	23,184	26,496	1,656
Total # genera	8	5	7	7	6	8	9
Total abundances	833,112	567,900	521,088	1,557,636	1,126,080	1,052,112	624,312

Diversity and total abundance varied at each station in Trevor Channel and exhibited a pattern through Effingham Inlet (Table 3, Figure 5). In Trevor Channel, TC1 had 8 genera present, the highest genera diversity, and second highest total abundance (833,112 cells/L). TC3 had the highest total abundance, 1,557, 636 cells/L and 7 genera present. TC4 and TC2 had the lowest cell counts, 567,900 cells/L and 521, 088 cells/L, respectively. Effingham Inlet exhibits a pattern of decreasing cell counts and increasing genera diversity from the entrance to the head of the fjord. *Skeletonema* was the dominant diatom genera at each station ranging from 441,600 – 1,451,760 cells/L (Figure 5). *Thalassionema spp* and *Thalassiosira spp* were the most abundant genera after *Skeletonema*. *Pseudo-nitzchia* was present at every station except TC4, but not at high abundances compared to the overall cell count. Most diatoms viewed during microscopy analysis were between 10 – 60 um. No diatoms above 60 um were observed during microscopy analysis, however, chains of *Skeletonema* easily measured greater than 100 um.

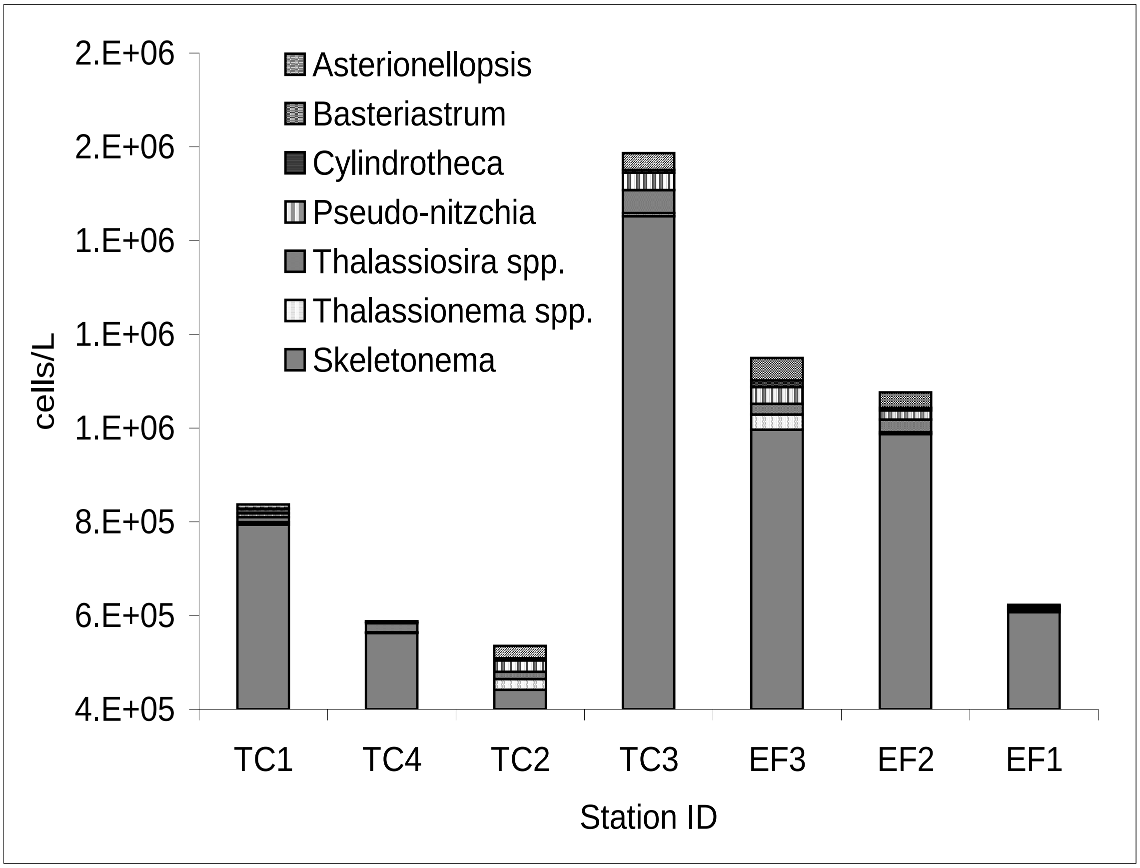


FIGURE 8. Absolute abundance of dominant diatoms at each station.

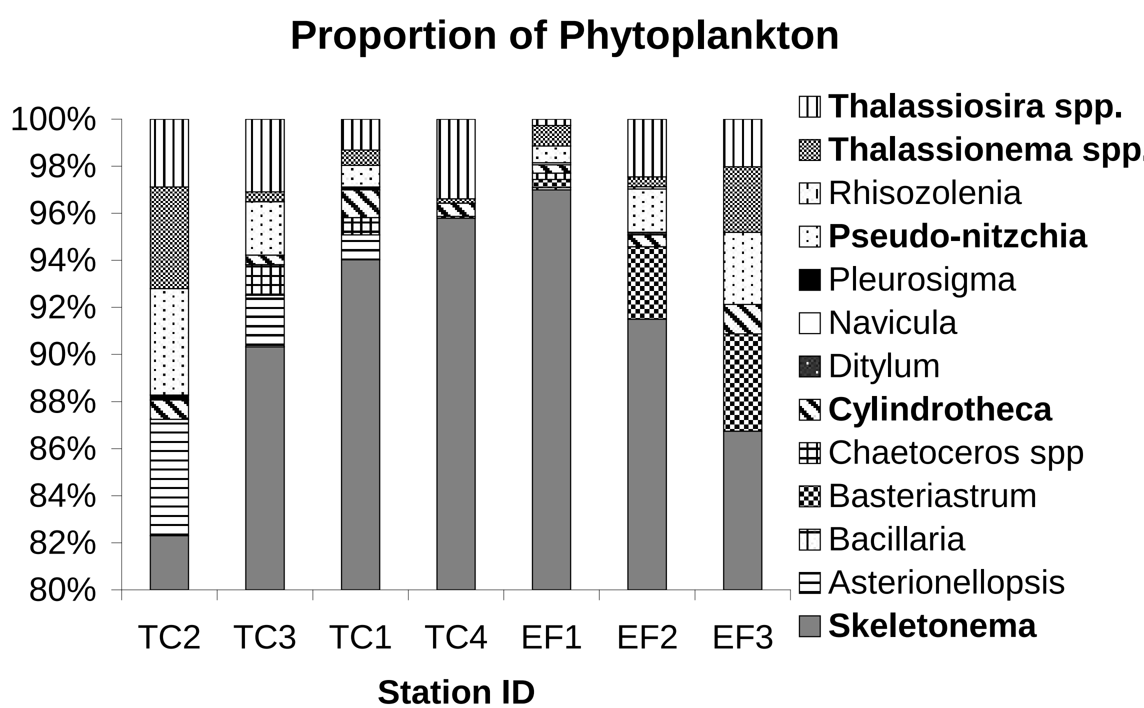


FIGURE 9. Proportion of diatom taxa present at each station. Proportions based on cell/L counts. The bolded names are diatom genera that were found at all stations and abundant in Barkley Sound.

Station TC3 had the highest absolute abundance in Barkley Sound, 1.6 *10^6 cells/L (Figure 9). Trevor Channel had lower total abundance values, compared to Effingham Inlet. The lowest total abundance was found at TC4 and TC2, $5.7 * 10^5$ and $5.2 * 10^5$ cells/L, respectively. *Skeletonema* was the dominant genera, accounting for over 80% of total cell abundance (Figure 9). *Skeletonema* proportions were highest at EF1 and TC4, 97% and 95.5%, respectively. *Thalassiosira spp*, *Thalassionema spp* and *Cylindrotheca* were identified at all stations. *Pseudo-nitzchia* was identified at all stations except TC4. Genera diversity ranged from 5 - 9 genera present. Genera diversity in Effingham was lowest at EF3 and increased as stations were closer to the head of the inlet.

Primary Productivity

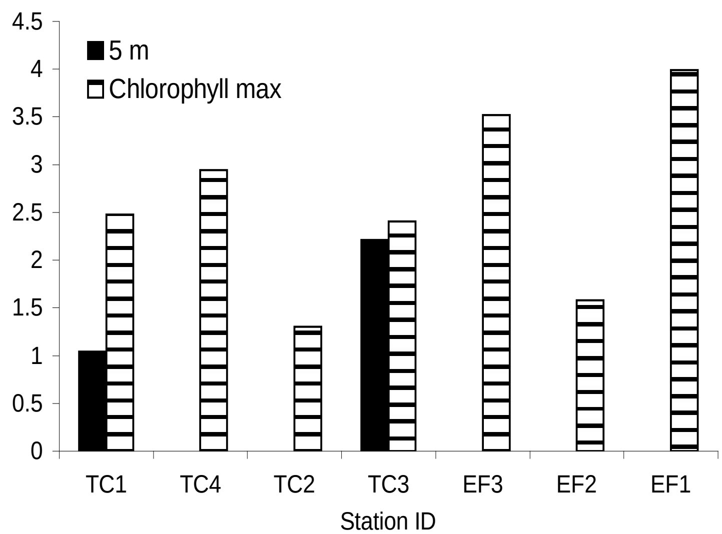


FIGURE 10. Primary production rates in Trevor Channel and Effingham Inlet in mg O_2/L per day. Samples at 5 m were only taken TC1 and TC3 due to bottle/sensor limitations.

Average primary productivity was greater at the chlorophyll max. Average primary productivity in Effingham Inlet was greater than average production rates in Trevor Channel (FIGURE 6). Primary productivity varied in Effingham Inlet. Stations EF1 and EF3 had the highest production rates, 3.99 mg O_2/L per day and 3.52 mg O_2/L per day, respectively. Station EF2 had one of the lowest production rates, 1.58 mg O_2/L per day. Most stations in Trevor Channel had similar primary productivity values, 2.40 – 2.48 mg O_2/L per day. Station TC2 had the lowest production rate, 1.30 mg O_2/L per day.

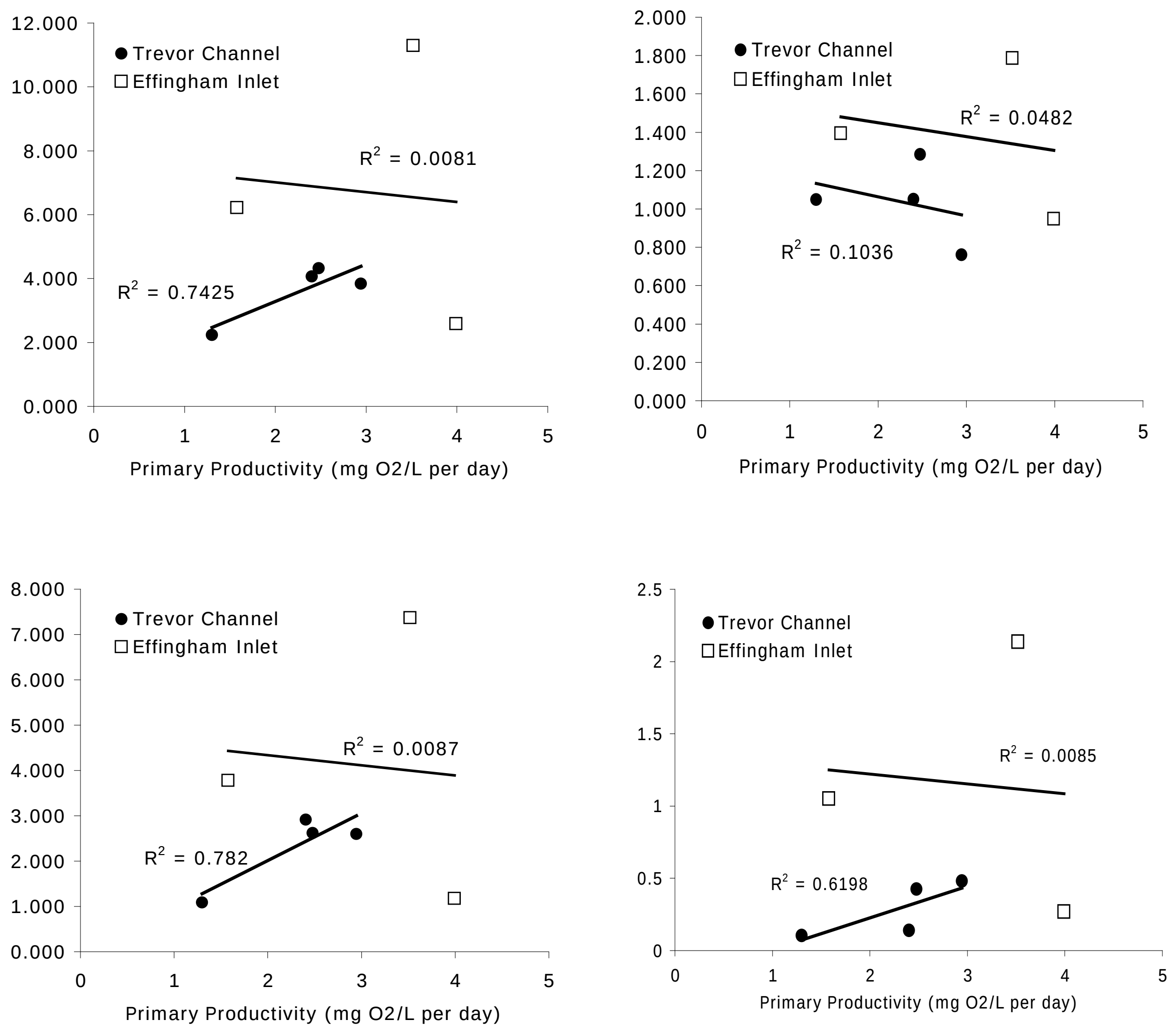


Figure 11. Primary productivity (mg O2/L per day) and chlorophyll a concentrations.

. High total chlorophyll a concentrations were positively correlated with higher primary production in Trevor Channel, $R^2 = 0.74$. The 20 - 100 um and >100 um size classes showed the strongest correlation with primary productivity, $R^2 = 0.78$ and $R^2 = 0.62$, respectively. There were no correlations between chlorophyll a concentrations and primary production rates in Effingham Inlet.

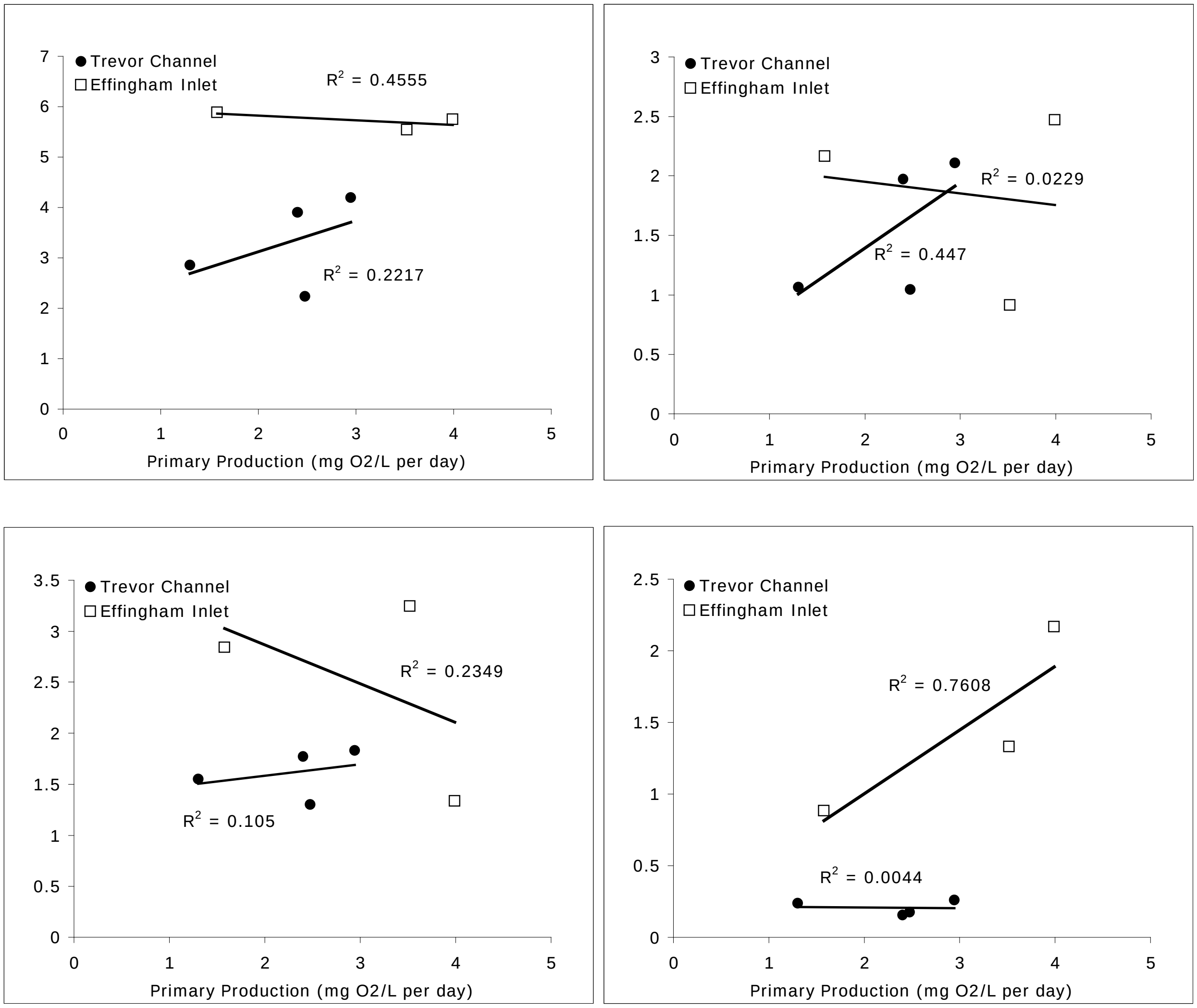


Figure 12. Biogenic silica concentration plotted against primary productivity.

. Effingham Inlet exhibited a better correlation between total BSi and primary production, compared to Trevor Channel. The >100 um size class had a strong positive correlation with primary production, R^2 = 0.76. While there were no significant correlations between size class values and primary production, the 20 - 100 um size class had the best correlation of the three classes, R^2 = 0.45.

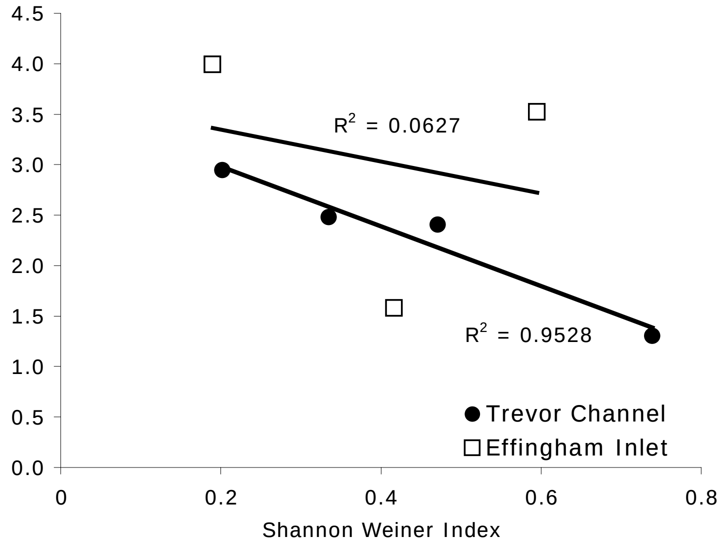
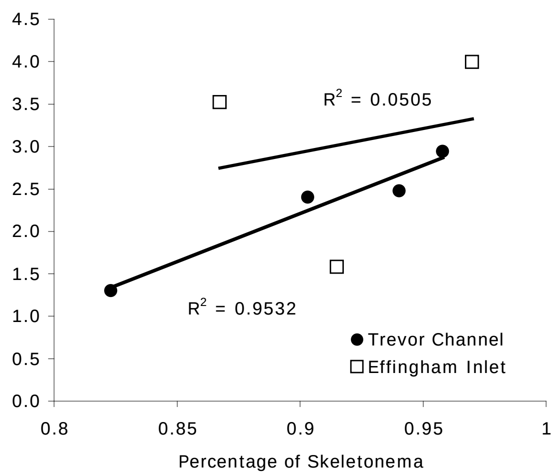
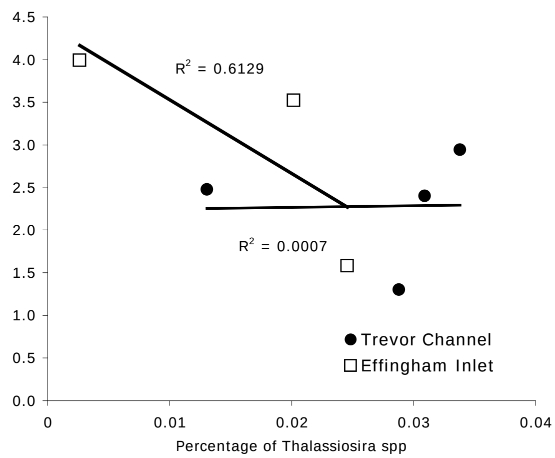


Figure 13. Shannon Weiner Index plotted against primary productivity (mg O2/L per day).





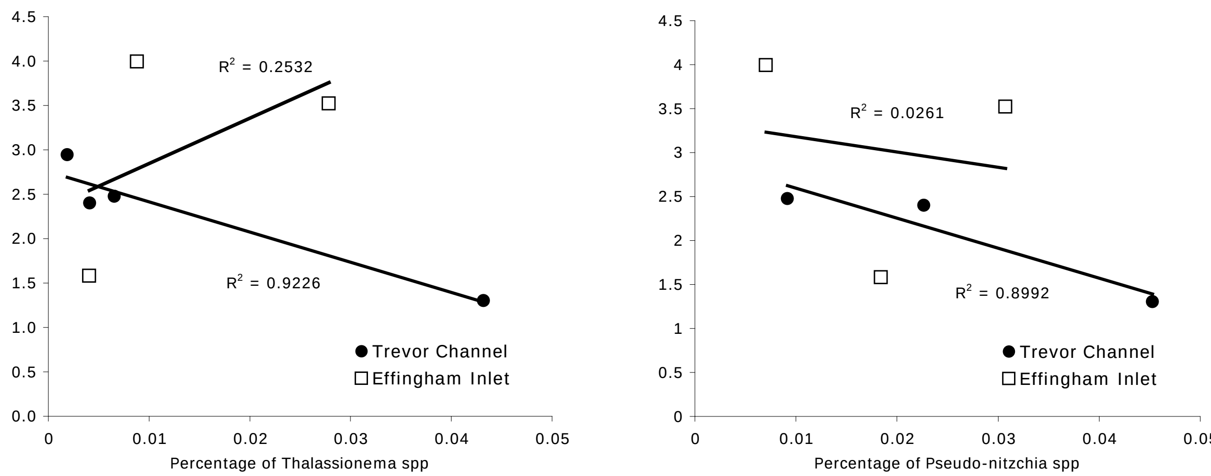


Figure 14. Primary productivity (mg O2/L per day) against the percentage of dominant diatom genera found at each station.

Stations in Trevor Channel exhibited a strong negative correlation between genera diversity and primary production (Figure 13). There was no significant correlation at Effingham Inlet. A positive correlation existed between high proportions of *Skeletonema* and high primary production in Trevor Channel (Figure 14). There was a negative correlation between *Thalassionema spp* and *Pseudo-nitzchia spp* proportions and primary production. There were no significant positive correlations between a dominant genera and primary production in Effingham Inlet. However, there was a negative correlation between *Thalassiosira spp* and primary production, $R^2 = 0.61$.

Discussion

Trevor Channel and Effingham Inlet are regions within Barkley Sound that behave differently. Based on nutrient concentrations and biological data, Effingham Inlet was a more stable system with the main nutrient source located at the mouth of the inlet. High biomass and lower nutrient concentrations in Effingham Inlet suggested that sampling took place during a phytoplankton bloom. The strong negative correlation between biogenic silica and nutrients indicates diatoms are the dominant phytoplankton in this bloom and are taking up the nutrients in Effingham Inlet. Trevor Channel was well mixed, had high nutrient concentrations, and the system was not as stable. The positive correlation between chlorophyll a and nutrients in Trevor Channel indicates that Trevor Channel is a well-mixed system. Higher biomass concentrations were found at stations with greater nutrient concentrations, indicating growth was not limited by nutrients. The negative correlation between biogenic silica and nutrients suggests sampling took place at the early stages of the spring bloom.

Phytoplankton Community Structure

Diatoms were the dominant phytoplankton in Barkley Sound. High diatom cell abundance and low photosynthetic dinoflagellate cell abundance indicates diatoms were the main contributors to chlorophyll a biomass and primary production rates (Leung 2010). Large diatoms were not abundant during the early spring bloom and did not significantly contribute to the >100 um size class. Most of the biomass in the >100 um size class was accounted for by chains of Skeletonema. Diatom abundance showed many similarities with diatom abundance from previous studies. Overall abundance was greatest in Effingham Inlet, specifically in the outer basin and the inner basin. This outcome was expected because previous studies also found high absolute abundance in the inner and outer basins in Effingham Inlet (Hay et al 2003). Previous studies found that Skeletonema was dominant during the spring bloom, along with Thalassiosira (Haigh et al 1992, Hay et al 2003). Diatom abundances in Effingham Inlet are similar to typical spring bloom dynamics in that area (Hay et al 2003).

Chlorophyll a and Biogenic Silica

The correlation between chlorophyll a concentrations and biogenic silica concentrations was not significant. This was unexpected, but a possible explanation is that each diatom genera does not have identical silica concentrations and the same amount of chloroplasts in each cell. The variation among individuals in a species, and especially among genera, would result in a weak correlation between the two data sets. The 0.6 – 20 um size class did not significantly contribute to diatom or phytoplankton biomass in Effingham Inlet. This size class did not significantly contribute to primary production. These results suggest that diatoms in the 0.6 – 20 um size range were not dominant in the bloom. The significant contribution of the 20 – 100 um size class to biomass measurements in Trevor Channel and Barkley Sound suggests that diatoms in this size class were dominating the bloom and driving primary production in Barkley Sound. There was a significant contribution from the >100 um size class to the biomass measurements and primary production, however after microscopy results determined the absence of diatom cells larger than 100 um, it was determined that large chains of Skeletonema contributed to the concentrations in this size class. Diatoms larger than 100 um did not significantly contribute to diatom biomass or primary production in Barkley Sound.

Primary Productivity

Primary productivity was driven by *Skeletonema* in Trevor Channel (Figure #). When Skeletonema are the dominant diatom genera during the spring bloom, there is high primary production (Harris et al 2009, Hay et al 2003). The results are supported by previous studies that found diatoms to be the primary contributors to primary productivity in coastal waters (Moriceau et al 2009). Low diversity correlated with higher production in Barkley Sound, further supporting the suggestion that higher proportions of *Skeletonema* is correlated with higher production. It was not possible to determine whether a particular genera was driving primary production in Effingham Inlet.

The correlation between total biogenic silica and concentrations in the >100 um size class indicate that diatoms are significantly contributing to primary production in Effingham Inlet. *Skeletonema* chains greater than 100 um could be driving primary production.

The primary production values for each station share a similar pattern with the average total biogenic silica concentrations. Diatoms were the dominant phytoplankton in Trevor Channel and the main primary producers at each station in Trevor Channel. The >100 um size class was of particular interest in determining the contribution to primary production. There were similar patterns of chlorophyll a and biogenic silica concentrations when compared to primary production at each station, however, diatoms above 100 um were in such low abundances that they probably did not significantly contribute to primary production in Trevor Channel. Primary production values in Effingham Inlet did not exhibit the same pattern as Trevor Channel stations. Primary Production was highest at the entrance to the inlet in the outer basin and at the head of the inlet. These results exhibit the same pattern as the biogenic silica concentrations, and disagree with the chlorophyll a concentrations and available nutrient concentrations. The larger size fraction for biogenic silica, >100 um, had higher concentrations at the head of Effingham Inlet and this size class significantly contributed to production in Effingham Inlet

Implications

The dominance of *Skeletonema*, a smaller diatom genera, was connected to high primary production. However, further research is necessary to conclude whether the dominance of *Skeletonema* would be in connection with Barkley Sound acting as a CO_2 source or sink. Individual *Skeletonema* cells are small, but because this is a chain-forming diatom, there is a great possibility that chains larger than 100 um can form. Due to the short sampling period, there is not enough information to determine seasonal variations in the dynamic of the phytoplankton community and primary production. In order to collect enough information to determine the effects of ENSO events on the biology in Barkley Sound, the sampling period would need to be over 2 years to adequately sample and compare affects during each event. The results from this study, supported by previous studies on diatoms in coastal waters, indicates that diatoms are dominant in the phytoplankton community and significantly impact nutrients in and primary production in the water column (Harris 2009, Hay et al 2003, Moriceau et al 2009). Future studies need to focus on diatom community dynamics over long term periods and to focus on the role of dominant genera in order to fully understand the importance of diatoms in their ecosystems and the significant role they play on primary production and carbon export.

Conclusion

- Effingham Inlet and Trevor Channel were two regions within Barkley Sound that behaved differently, biologically.
- Sampling took place during the early stages of a spring bloom in Trevor Channel.
- Conditions in Effingham Inlet indicate there was a stable spring bloom.
- Diatoms were the dominant phytoplankton in Barkley Sound.
- *Skeletonema* was the dominant diatom genera at all stations in Barkley Sound.
- *Skeletonema* was the main driver of primary production in Trevor Channel.

REFERENCES

Alves-de-Souza, C., Gonzalez, M.T. and J.L. Iriarte. 2008. Functional groups in marine phytoplankton assemblages dominated by diatoms in fjords of southern Chile. Journal of Plankton Research 30: 1233-1243.

Bianchii A.A., Pino D.R., Perlender H.G.I., Osiroff A.P., Segura V., Lutz V., Clara M.L., Balestrini C.F. and A.R. Piola. 2009. Annual balance and seasonal variability of sea-air CO_2 fluxes in the Patagonia Sea: Their relationship with fronts and chlorophyll distribution. Journal of Geophysical Research- Oceans 114: 1- 11.

Borges, A.V., Delille, B. and M. Frankignoulle. 2005. Budgeting sinks and sources of CO2 in the coastal ocean: Diversity of ecosystems counts. Geophysical Research Letters 32: L14601.

Brzezinski, M.A., and D.M. Nelson. 1986. A solvent extraction method for the colorimetric determination of nanomolar concentrations of silicic acid in seawater. Marine Chemistry 19: 139-151.

Brzezinski, M.A., and D.M. Nelson. 1989. Seasonal changes in the silicon cycle within a Gulf Stream warm-core ring. Deep-Sea Research 36: 1009-1030.

Buesseler, K.O. 1998. The decoupling of production and particulate export in the surface ocean. Glob. Biogeo. Cyc. 12: 297 – 310.

De La Rocha C., and U. Passow. 2007. Factors influencing the sinking of POC and the efficiency of the biological carbon pump. Deep-Sea Res Pt II: Topical Studies in Oceanography 54, Issues 5-7, 639-658

Garcia V.M.T., Garcia C.A.E., Mata M.M., Pollery R.C., Piola A.R., Signorini S.R., McClain C.R. and M.D. Iglesias-Rodriguez. 2008. Environmental factors controlling the phytoplankton blooms at the Patagonia shelf-break in spring. Deep-Sea Research Part 1 – Oceanographic Research Papers 55: 1150 – 1166.

Gonzalez, H.E., Daneri, G., Irarte J.L., Yannicelli B., Menschel E., Barria C., Pantoja S., and L. Lizarraga. 2009. Carbon fluxes within the epipelagic zone of the Humboldt Current System off Chile: The significance of euphausiids and diatoms as key functional groups for the biological pump. Progress in Oceanography 83: 217 – 227.

Haigh, R., Taylor, F.J.R. and T.F. Sutherland. 1992. Phytoplankton ecology of Sechelt Inlet, a fjord system on the British Columbia coast. I. General features of the nano- and microplankton. Mar. Ecol. Prog. Ser. 89: 117 - 134

Harris, S.L., Varela, D.E., Whitney, F.W. and P.J. Harrison. 2009. Nutrient and phytoplankton dynamics off the west coast of Vancouver Island during the 1997/98 ENSO event. Deep-Sea Research II 56: 2487 – 2502.

Hay, M.B., Pienitz, R. and R.E. Thomson. 2003. Distribution of diatom surface sediment assemblages within Effingham Inlet, a temperate fjord on the west coast of Vancouver Island (Canada). Marine Micropaleontology 48: 291 – 320.

IPCC. 2001. Climate Change 2001: The Scientific Basis (edsJ. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden et al.). Cambridge University Press, Cambridge.

Legendre L., and F.. Rassoulzadegan. 1996. Food-web mediated export of biogenic carbonm in oceans: hydrodynamic control. Mar Ecol Prog Ser. 145, 179 – 193.

Leung, Ashley. 2010. Spring time abundance and community composition of dinoflagellates in Barkley Sound, BC. School of Oceanography, University of Washington.

Lorenzen, C. J. 1966. A method for the continuous measurement of in vivo chlorophyll concentration. Deep-Sea Res. 13: 223-227.

Montero, P.G. Daneri, L.A. Cuevas, H.E. Gonzalez, B. Jacod, L. Lizarraga, and E. Menschel. 2007. Productivity cycles in the coastal upwelling area off Concepción: The importance of diatoms and bacterioplankton in the organic carbon flux. Prog in Ocean. 75, Issue 3, 518-530

Moriceau, B., Goutx, M., Guigue, C., Lee, C., Armstrong, R., Duflos, M., Tamburini, C., Charriere, B. and O. Ragueneau. 2009. Si-C interactions during degradation of the diatom *Skeletonema marionoi*. Deep-Sea Research II 56: 1381 – 1395.