

Relative Abundance and Distribution of Phytoplankton in Glacier Bay, Alaska

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Abstract

Phytoplankton are the primary producers within coastal temperate and polar waters, yet little is known about their distribution, make-up, or abundance in the coastal fjords of the Alaskan Panhandle. Glacier Bay National Park, Alaska is a fjord system that is recognized for its productivity and diversity of marine wildlife. The objective of this investigation was to characterize the composition of the phytoplankton community and how it geographically changed within Glacier Bay. Net tows were taken March 19- March 22, 2008, as part of the School of Oceanography senior thesis cruise aboard the *R/V Thomas G. Thompson*. Phytoplankton species composition was analyzed in surface water samples along a transect spanning across hydrological regions of the Bay which included: near the Grand Pacific glacier toes, the Western Arm, the main Basin, and near a major sill at the entrance to the sound and inside the Icy Straits. In situ temperature, chlorophyll concentrations and salinity measurements were obtained using a Conductivity, Temperature, and Depth (CTD) instrument on board the *R/V Thomas G. Thompson* to characterize environmental conditions. Relative cell abundance and composition were measured using standard microscopy methods. Statistical results showed that differences in salinity, temperature, and nutrients did not structure the phytoplankton community. Relative phytoplankton composi-

tion, abundance and distribution within the bay was not statistically different, but statistically differed in populations found near the mouth of the bay, and outside the bay.

Introduction

The characterization of phytoplankton communities has become important in understanding the functionality of ecosystems (Ariyadej et al. 2004, Cermeño 2008). This is especially of interest in attempting to understand the dynamics of biological and chemical fluxes, uptake of CO₂ in the oceans, and the impact of this process on global change. In recent decades, there has been increased interest in processes that are influenced by phytoplankton communities in high latitudes, such as the nitrogen cycle, nutrient ratios, and carbon sinks. As high latitudes are experiencing drastic reduction in ice extent and influx of fresh water from ice melt, changes in dominant species might noticeably affect biogeochemical cycles.

Phytoplankton blooms are annual phenomenon that occur around the world. The taxonomic composition, abundance, and distribution of phytoplankton can influence the intensity of a bloom and are characterized by yearly successions that differ depending on the latitude that the bloom is occurring (Fleming et al., 2006). In higher latitudes, blooms have been of particular interest due to the importance and role of diatoms, a taxonomic group of phytoplankton, and how they influence environmental change in biogeochemical cycles (Fleming et al.,

2006).

Diatoms are one of the most prominent phytoplankton species in respect to abundance and photosynthetic capabilities within coastal waters and provide about twenty five percent of global net productivity (Lalli et al., 1997). Growth rates of diatoms are very high, and can increase in abundance by several orders of magnitude under favorable conditions (Rynearson 2003). Consequently, diatom blooms often compose more than ninety percent of phytoplankton biomass during blooms (Rynearson 2003). Diatoms and other dominating phytoplankton constitute a fundamental link in aquatic food webs and contribute significantly to the biogeochemical fluxes and cycles within the ecosystem (Lalli et al., 1997; Miller 2004). As a result, phytoplankton, specifically diatoms, remain a subject of increased interest with respect to global warming and the effects of carbon dioxide (CO₂) emissions in the atmosphere (Miller 2004).

Diatoms are crucial in the sequestration and burial of atmospheric carbon. Diatom shells are primarily composed of silica (SiO₂) and are negatively buoyant (Horner 2002). Due to this negative buoyancy, when the diatoms die in the oceans, they typically sink to watery graves on the seafloor, taking carbon out of the surface waters and locking it into sediments below (Melillo 2003). The organic materials within the diatom cells contribute significantly to the soft tissue pump within the ocean ecosystem and the global carbon cycle.

The sequestration of CO₂ burial from diatom derived organic material is dependent on environmental conditions (Cupp 1943). Specific environmental conditions support the growth and abundance of diatoms, which sustain the derivation of organic materials (Cupp 1943). As environmental conditions change, so does the diatom community and abundance. Marine species of diatoms are either pelagic or littoral and are found near surface waters (Cupp 1943). Diatoms can live in fresh, salt, and brackish

water (Cupp 1943). Most diatoms live as single cells or as chains of cells, and are generally found planktonic, however, some live colonially within different substrates (Lalli et al., 1997). Salinity gradients pose a challenge to the osmoregulation of phytoplankton species, consequently only a few osmo-tolerant species are found in brackish environments (Cupp 1943).

Glacier Bay is a young fjord in Southeast Alaska that has experienced rapid deglaciation for the last 225 years and can serve as a model for Alaskan fjords subjected to climate warming (Etherington et al., 2007). It is a marine fjord that is composed of ice fields, rivers, streams, and is approximately sixty five miles long and two to ten miles wide (Etherington et al., 2007). The dynamics of the Glacier Bay watershed significantly impacts the planktonic community throughout most of the year. Large fluxes of freshwater enter both the East and West arms and the center of Glacier Bay either as ice melt, or river water. The resulting brackish water in the center of Glacier Bay is then mixed and carried into the Icy Strait (Etherington et al., 2007). The interplay of terrestrial, littoral and marine processes and high shore to volume ratio often results in fjords being highly productive marine environments (Melillo 2003). Fjords are therefore important for near shore and shelf productivity because they provide important habitats for breeding, nursing, and feeding for many marine organisms (Etherington et al., 2007).

A study in 1993 by Etherington et al. (2007) showed that Glacier Bay exhibits exceptionally long and undefined spring blooms that range from early March to late October. Previously measured chlorophyll-a concentrations were highly variable both temporally and spatially (Etherington et al., 2007). Day length, euphotic depth, and water column stratification all contribute significantly to the influence of chlorophyll-a concentrations (Etherington et al., 2007). During the spring bloom, the lower bay had the lowest average chlorophyll-a con-

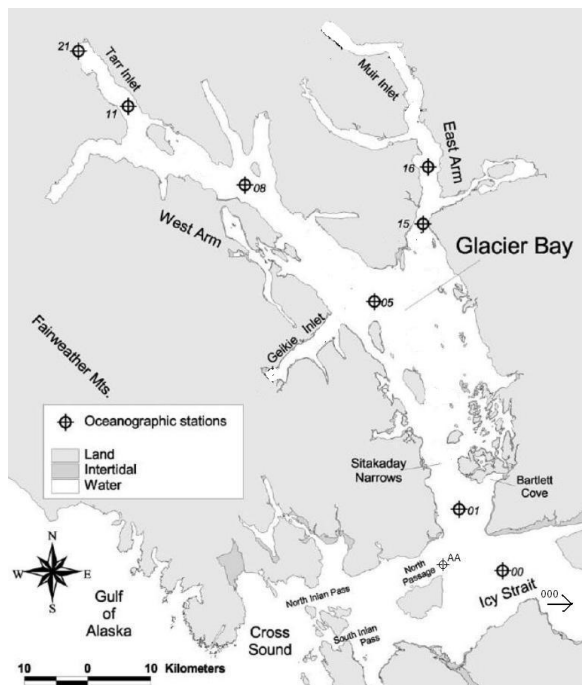


Figure 1: Modified Glacier Bay map from Etherington et al. (2007) showing all sampled stations.

centrations, while the East arm had high concentrations, and the West arm had maximum concentrations (Etherington et al., 2007). Non-linear models indicated that the highest concentrations of chlorophyll were found in the intermediate stratification levels (Etherington et al., 2007). This analysis provides a framework for examining the relative diatom abundances, compositions and distributions in Glacier Bay.

Despite the importance of phytoplankton species in Alaska’s coastal environments, little is known about the living phytoplankton community in Glacier Bay, Alaska, a vivid example of a rapidly changing environment.

The objective of this study was to determine the relative abundance and distribution of the phytoplankton community in Glacier Bay. Specifically, it was expected that relative abundances would change progressively throughout the Bay in relation to environmental variables.

Methods

Glacier Bay was divided up into four geographical regions based on hydrographic features: the Outer Bay, Main Basin, West Arm, and East Arm. Within each of these regions, ten samples were taken. The Outer Bay, stations 000, 00, and AA; Main Basin at 01 and 05; West Arm at 08, 11, and 21; in the East Arm at 15, and 16 (Tables 1, Fig. 1). With the exception of the two stations AA and 000, all stations follow those outlined from Etherington et al., 2007.

At each of the ten stations, a twenty-five micron mesh net was towed horizontally within the first three meters of the surface. Due to low biomass, nets were towed until a discoloration of the water sample indicated a visual concentration. Approximate volume of water sampled ranged between 600- 900L. Concentrated net tows resulted in 100mL samples, which were processed following the procedures outlined by Horner 2002. Once samples had been collected, they were viewed under a microscope for qualitative assessment. Within 48 hours of sampling, each sample was fixed with formalin for a final concentration of eight percent formaldehyde and stored for transportation.

Nutrient samples were taken from Niskin bottles on a twenty four rosette/CTD package from a depth of three meters at stations AA, 000, 01, 05, 11, 15, and 21. The nutrient samples were analyzed by Kathy Kroglund’s lab at the University of Washington. Procedures for nutrient analysis followed those outlined in UNESCO (1994).

In the laboratory, all phytoplankton cells were counted and identified to species using a Zeiss Standard 16 phase microscope with 25x objective for a final magnification of 250x. A total of 0.1mL of each sample was placed into a Palmer-Maloney counting slide and allowed to settle for 15-30 minutes. Using swaths along the counting slide, each sample was counted until a total of 400 phytoplankton cells were recorded (Horner 2002).

Phaeocystis concentrations were assessed in

Station	Date	Time (GMT)	Latitude	Longitude
Outer Bay				
000	3/22/08	03:20:29	N 58 12.6957 to N 58 12.7095	W 135 20.5376 to W 135 20.6044
00	3/18/08	13:30:14	N 58 19.6314 to N 58 19.6431	W 135 52.3394 to W 135 52.3833
AA	3/21/08	16:06:47	N 58 17.7174 to N 58 17.7156	W 136 14.9274 to W 136 14.9272
Main Basin				
01	3/22/08	23:05:06	N 58 24.7749 to N 58 24.7728	W 135 59.5734 to W 135 59.5734
05	3/19/08	11:06:07	N 58 40.6929 to N 58 40.6936	W 136 17.0150 to W 136 17.0224
Western Arm				
08	3/21/08	09:56:30	N 58 51.9175 to N 58 51.9177	W 136 35.5137 to W 136 35.5128
11	3/19/08	23:56:13	N 58 58.0421 to N 58 58.0413	W 136 54.5167 to W 136 54.5181
21	3/19/08	21:33:34	N 59 02.8385 to N 59 02.8385	W 137 03.3507 to W 137 03.3506
Eastern Arm				
15	3/22/08	06:05:09	N 58 48.8810 to N 58 48.8928	W 136 06.1374 to W 136 06.1172
16	3/22/08	04:06:32	N 58 53.7711 to N 58 53.7729	W 136 05.4549 to W 136 05.4555

Table 1: All ten stations where samples were taken, the date and time they were taken, and the exact location.

four categories of percent coverage of a counting slide: zero to twenty five percent; twenty five to fifty percent; fifty to seventy five percent; seventy five to one hundred percent. Each respectively ranked one through four.

Diatom cell concentrations, Phaeocystis categorical data, and environmental data (nutrients, temperature, and salinity) were used for statistical analysis using the statistical cluster analysis package, PRIMER.

Results

Throughout Glacier Bay, in situ fluorescence readings of chlorophyll-a were low and ranged between zero and eight micro-grams per liter (Fig. 2). Salinity varied very little and ranged between thirty and thirty-one Practical Salinity Units (PSU) (Fig. 3). Temperatures from surface waters of three meters depth, ranged within a degree increment from 2.8 to 3.9 °C (Fig. 4). Nutrient concentrations were found to be statistically insignificant between stations AA, 000, 01, 05, 11, 15, and 21 (Fig. 5).

Phaeocystis was present at all but station 16 and 000 and typically visually dominated

the phytoplankton community. Diatoms were second to dominate relative taxonomic composition at all geographical regions. Within the Main Basin, abundant species, defined as contributing with equal or more than ten percent composition to the overall abundance were *Chaetoceros decipiens* (21.5%), and *Chaetoceros socialis* (33.6%) (Table 2, Fig. 6). In the West arm, abundant species included *Chaetoceros decipiens* (18.3%), *Coscinodiscus oculus-iridis* (30.2%), *Protoperdinium* (14.3%), *Thalassiosira nordenskiöldii* (10.58%), and *Thalassiosira pacifica* (13.8%) (Table 3, Fig. 6). In the East arm, abundant diatoms consisted of *Chaetoceros debilis* (39.7%), *Chaetoceros decipiens* (22.6%), and *Thalassiosira pacifica* (19.1%) (Table 4, Fig. 6). Outside of the bay the abundant species was *Chaetoceros socialis* (43.2%) (Table 5, Fig. 6).

Discussion

This paper provides the first record of relative phytoplankton abundance and distribution within Glacier Bay, Alaska. It represents one of the few studies of phytoplankton community

composition in Southeast Alaska. This analysis provides a framework for future studies examining phytoplankton abundance, composition, and distribution.

Over the four days samples were taken, Glacier Bay and surrounding waters were found to have three statistically distinct diatom communities that do not necessarily reflect the geographical regions of Glacier Bay. These three communities fall into areas of: Inside Glacier Bay, inside and out of the mouth of Glacier Bay, and the Icy Strait (Fig. 7, 8).

Phytoplankton blooms are regulated by temperature, nutrients, salinity, and grazers (Horner 1969). Temperature differences between each station were minimal, and changed only about a degree Celsius. Nutrient concentrations were found to be statistically insignificant from each other. Throughout the entirety of Glacier Bay, salinity did not change or differ by more than two PSU. According to C. Ekblad (Oceanography 444), the concentrations of grazers were extremely low. All of these environmental factors inconsequentially varied and all were disregarded as contribution for influence on the phytoplankton abundance. Other factors that contribute to phytoplankton abundances that were not considered were currents, advection, sources such as runoff, and the relationship between light and mixed layer depth.

Etherington et al.'s ten year study averaged phytoplankton blooms and found them occurring during March; however, variation in the pattern of spring blooms within Alaskan waters isn't uncommon. Because of considerably low in situ fluorescence readings and very low phytoplankton cell concentrations, it was concluded that in mid-March 2008, a spring phytoplankton bloom was not present. This was also corroborated by very low grazer abundances (Ekblad pers com). These findings support that Alaska has been characterized with having inconsistent plankton blooms (Horner 1969). Other studies by Horner et al. (1982), and Laws et al. (1982), showed that Alaskan phytoplankton

blooms more predictably occur in mid April to early May. Arctic studies by Horner (1969), have shown that Eastern Canada and Western Greenland have late blooms that tend to occur in the summers.

The phytoplankton community composition found in Glacier Bay wasn't uncommon for Alaskan waters. Arctic and sub-Arctic waters are initially dominated by *Phaeocystis* before or during blooms, followed by *Chaetoceros*, *Thalassiosira*, and *Asterionella* (Horner 1969). Within Alaskan waters, Horner et al. (1982), and Laws et al. (1988), found that *Chaetoceros*, *Cylindrotheca* and *Thalassiosira* were dominating diatoms. In Northern Atlantic and Europe, Horner (1969) also found that the phytoplankton community was heavily dominated by *Chaetoceros* and *Thalassiosira*. The *Chaetoceros* community was generally dominated by species *socialis* and *Thalassiosira* was commonly dominated by species *nordenskioldii* (Horner 1969). *Dictyocha* and *Phaeocystis* were both dominating plankton within Eastern Canada and Western Greenland (Horner 1969). With the exception of *Dictyocha*, all of the species found to be dominant in Arctic and sub-Arctic waters were also found to be also dominant within or just outside of Glacier Bay, Alaska (Tables 2-5, Fig. 7, 8).

Conclusion

Glacier Bay is a complex fjord that represents an estuarine system with three statistically significant phytoplankton communities that can be identified as inside the Bay, the mouth of the Bay, and outside the Bay. Although this study provides a description of the relative phytoplankton abundance and distribution in Southeast Alaska, it only provides the first source of information for Glacier Bay during the winter to spring transition. This study recognizes and emphasizes the spatial complexity and importance of diatom and *Phaeocystis* species for Glacier Bay prior to phytoplankton bloom conditions

Genera	Station 05	Station 01	<u>Total for the Main Basin</u>	
Diatom				
Centric				
Actinoptychus				
<i>Chaetoceros anastomosans</i>		28	28	3.50%
<i>Chaetoceros concavicornis</i>		2	2	0.25%
<i>Chaetoceros danicus</i>	1	1	2	0.25%
<i>Chaetoceros debilis</i>	50	15	65	8.13%
<i>Chaetoceros decipiens</i>	158	14	172	21.50%
<i>Chaetoceros radicans</i>				
<i>Chaetoceros socialis</i>	12	257	269	33.63%
<i>Chaetoceros vanheurckii</i>	79		79	9.88%
<i>Coscinodiscus centralis</i>		1	1	0.13%
<i>Coscinodiscus oculus-iridis</i>	8	1	9	1.13%
Dactyliosolen				
Rhizosolenia		1	1	0.13%
Skeletonema		4	4	0.50%
Stephanopyxis				
Thalassionema		4	4	0.50%
<i>Thalassiosira aestivalis</i>		19	19	2.38%
<i>Thalassiosira anguste</i>				
<i>Thalassiosira eccentrica</i>		15	15	1.88%
<i>Thalassiosira nordenskioldii</i>	44	12	56	7.00%
<i>Thalassiosira pacifica</i>	47	9	56	7.00%
Pennate				
Cylindrotheca		2	2	0.25%
Pseudo-nitzschia	1	15	16	2.00%
Dinoflagellate				
Protoperidinium				
Silicoflagellate				
Dictyocha				
TOTAL	400	400	800	100.00%
Prymnesiophyte				
Phaeocystis	3	2	2.5	

Table 2: Phaeocystis was dominant in this geographical region of Glacier Bay. Concentrations were assessed in four categories of percent coverage of a counting slide: zero to twenty five percent; twenty five to fifty percent; fifty to seventy five percent; seventy five to one hundred percent. Each respectively ranked one through four.

Genera	Station 11	Station 08	Station 21	<u>Total for the Western Arm</u>	
Diatom					
Centric					
Actinoptychus	1	4		5	0.42%
Chaetoceros <i>anastomosans</i>					
Chaetoceros <i>conconvicornis</i>		31	27	58	4.83%
Chaetoceros <i>danicus</i>					
Chaetoceros <i>debilis</i>	18	17	15	50	4.17%
Chaetoceros <i>decipiens</i>	95	125		220	18.33%
Chaetoceros <i>radicans</i>		8		8	0.67%
Chaetoceros <i>socialis</i>					
Chaetoceros <i>vanheurckii</i>					
Coscinodiscus <i>centralis</i>					
Coscinodiscus <i>oculus-iridis</i>	24	165	173	362	30.17%
Dactyliosolen					
Rhizosolenia					
Skeletonema			12	12	1.00%
Stephanopyxis					
Thalassionema					
Thalassiosira <i>aestivalis</i>					
Thalassiosira <i>anguste</i>					
Thalassiosira <i>eccentrica</i>		1		1	0.08%
Thalassiosira <i>nordenskioldii</i>	66	21	40	127	10.58%
Thalassiosira <i>pacifica</i>	62	28	76	166	13.83%
Pennate					
Cylindrotheca			12	12	1.00%
Pseudo-nitzschia			7	7	0.58%
Dinoflagellate					
Protoperidinium	134		38	172	14.33%
Silicoflagellate					
Dictyocha					
TOTAL	400	400	400	1200	100.00%
Prymnesiophyte					
Phaeocystis	3	2	2	3.5	

Table 3: Phaeocystis was dominant in this geographical region of Glacier Bay. Concentrations were assessed in four categories of percent coverage of a counting slide: zero to twenty five percent; twenty five to fifty percent; fifty to seventy five percent; seventy five to one hundred percent. Each respectively ranked one through four.

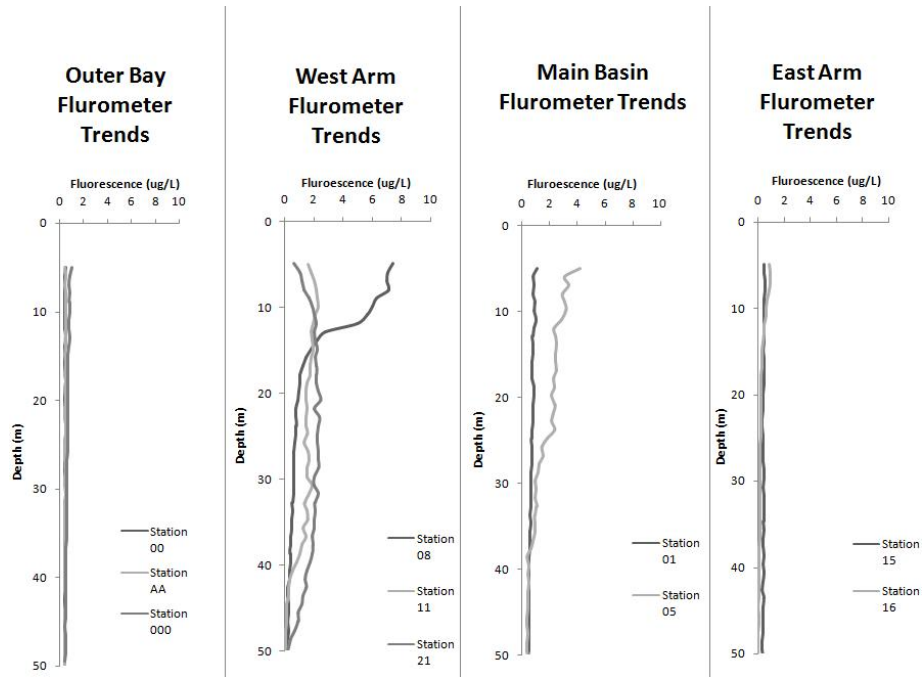


Figure 2: Fluorometer trends within 50 feet of the surface in Glacier Bay. Fluorometer readings range between zero and eight $\mu\text{g/L}$ in all regions.

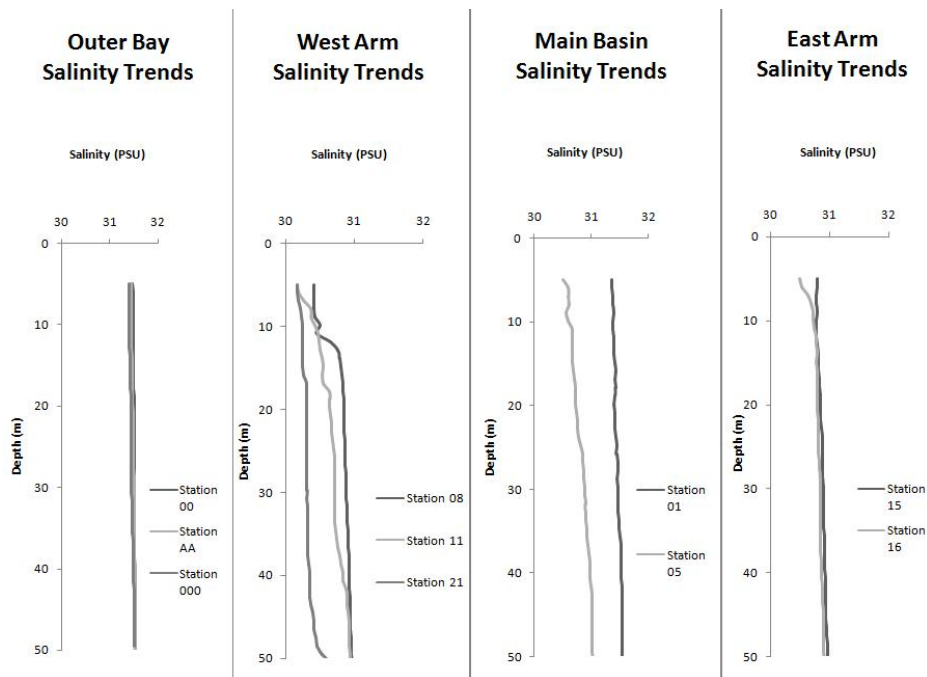


Figure 3: Salinity trends within 50 feet of the surface in Glacier Bay. Salinity readings ranged between thirty and thirty-two PSU.

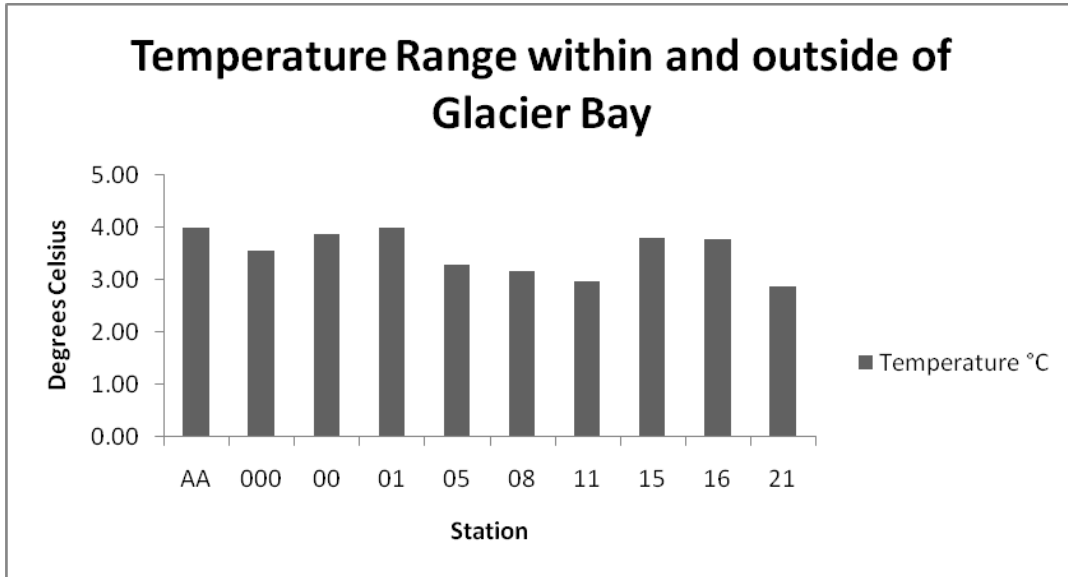


Figure 4: In situ surface water temperatures in Glacier Bay. Temperatures ranged between 2.8 and 3.9°C.

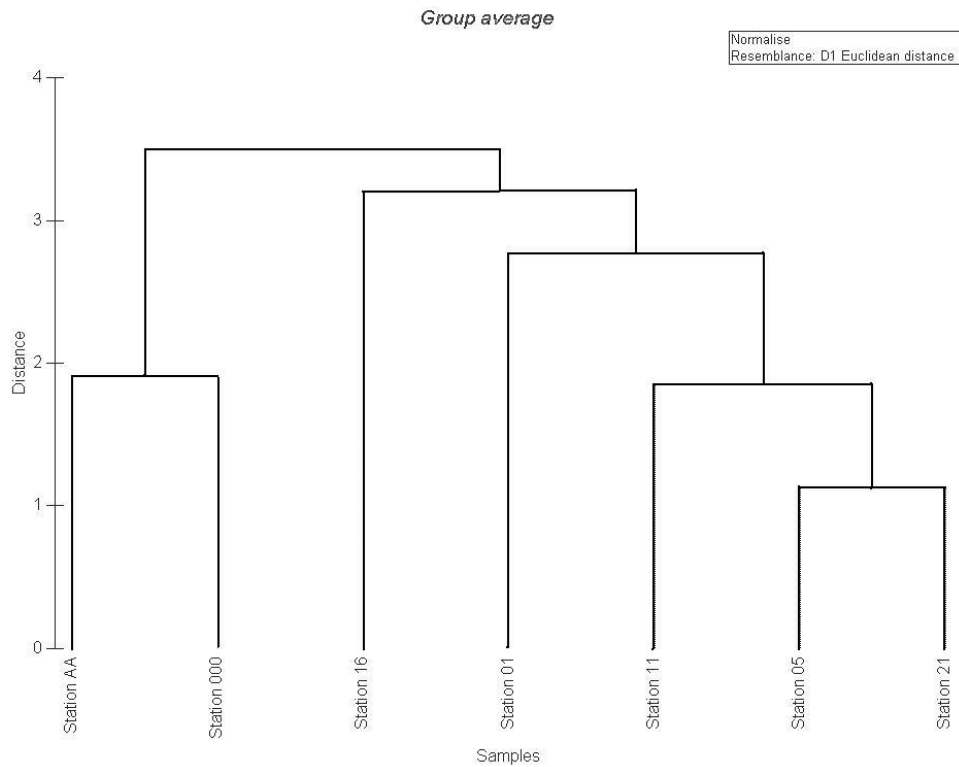


Figure 5: Cluster analysis of nutrients. Light solid lines show statistical insignificance. This shows that there isn't a statistical difference in nutrients between any of the given stations.

Genera	Station 15	Station 16	<u>Total for the Eastern Arm</u>	
Diatom				
Centric				
Actinoptychus				
Chaetoceros <i>anastomosans</i>				
Chaetoceros <i>conccavicornis</i>	9		9	1.13%
Chaetoceros <i>danicus</i>				
Chaetoceros <i>debilis</i>	123	194	317	39.63%
Chaetoceros <i>decipiens</i>	123	58	181	22.63%
Chaetoceros <i>radicans</i>		17	17	2.13%
Chaetoceros <i>socialis</i>				
Chaetoceros <i>vanheurckii</i>				
Coccinodiscus <i>centralis</i>				
Coccinodiscus <i>oculus-iridis</i>	4		4	0.50%
Dactyliosolen				
Rhizosolenia				
Skeletonema		42	42	5.25%
Stephanopyxis				
Thalassionema				
Thalassiosira <i>aestivalis</i>				
Thalassiosira <i>anguste</i>				
Thalassiosira <i>eccentrica</i>	1		1	0.13%
Thalassiosira <i>nordenskioldii</i>	14	53	67	8.38%
Thalassiosira <i>pacifica</i>	126	27	153	19.13%
Pennate				
Cylindrotheca				
Pseudo-nitzschia		9	9	1.13%
Dinoflagellate				
Protoperdinium			0	0.00%
Silicoflagellate				
Dictyocha				
TOTAL	400	400	800	100.00%
Prymnesiophyte				
Phaeocystis	1	0	1	

Table 4: Phaeocystis was dominant at station 15. Concentrations were assessed in four categories of percent coverage of a counting slide: zero to twenty five percent; twenty five to fifty percent; fifty to seventy five percent; seventy five to one hundred percent. Each respectively ranked one through four.

that are not reflected in the patterns of growth limiting variables such as temperature, salinity or nutrient concentrations. Further studies are necessary to determine a more thorough analysis

of what environmental factors are responsible for the three statistically distinct phytoplankton communities in Glacier Bay.

Genera	Station AA	Station 00	Station 000	Total for the Outer Bay	
Diatom					
Centric					
Actinoptychus	3		50	53	4.42%
Chaetoceros <i>anastomosans</i>					
Chaetoceros <i>conconcavicornis</i>	13			13	1.08%
Chaetoceros <i>danicus</i>	65			65	5.42%
Chaetoceros <i>debilis</i>	81			81	6.75%
Chaetoceros <i>decipiens</i>			6	6	0.50%
Chaetoceros <i>radicans</i>					
Chaetoceros <i>socialis</i>	154	364		518	43.17%
Chaetoceros <i>vanheurckii</i>	12			12	1.00%
Coscinodiscus <i>centralis</i>			74	74	6.17%
Coscinodiscus <i>oculus-iridis</i>	10		139	149	12.42%
Dactyliosolen			7	7	0.58%
Rhizosolenia				0	0.00%
Skeletonema			71	71	5.92%
Stephanopyxis					
Thalassionema			6	6	0.50%
Thalassiosira <i>aestivalis</i>					
Thalassiosira <i>anguste</i>	8			8	0.67%
Thalassiosira <i>eccentrica</i>	11	4	17	32	2.67%
Thalassiosira <i>nordenskioldii</i>			10	10	0.83%
Thalassiosira <i>pacifica</i>	39	28	2	69	5.75%
Pennate					
Cylindrotheca			11	11	0.92%
Pseudo-nitzschia	4	4		8	0.67%
Dinoflagellate					
Protoperidinium			5	5	0.42%
Silicoflagellate					
Dictyocha			2	2	0.17%
TOTAL	400	400	400	1200	100.00%
Prymnesiophyte					
Phaeocystis	1	1	0	1	

Table 5: Phaeocystis was dominant at stations AA and 00. Concentrations were assessed in four categories of percent coverage of a counting slide: zero to twenty five percent; twenty five to fifty percent; fifty to seventy five percent; seventy five to one hundred percent. Each respectively ranked one through four.

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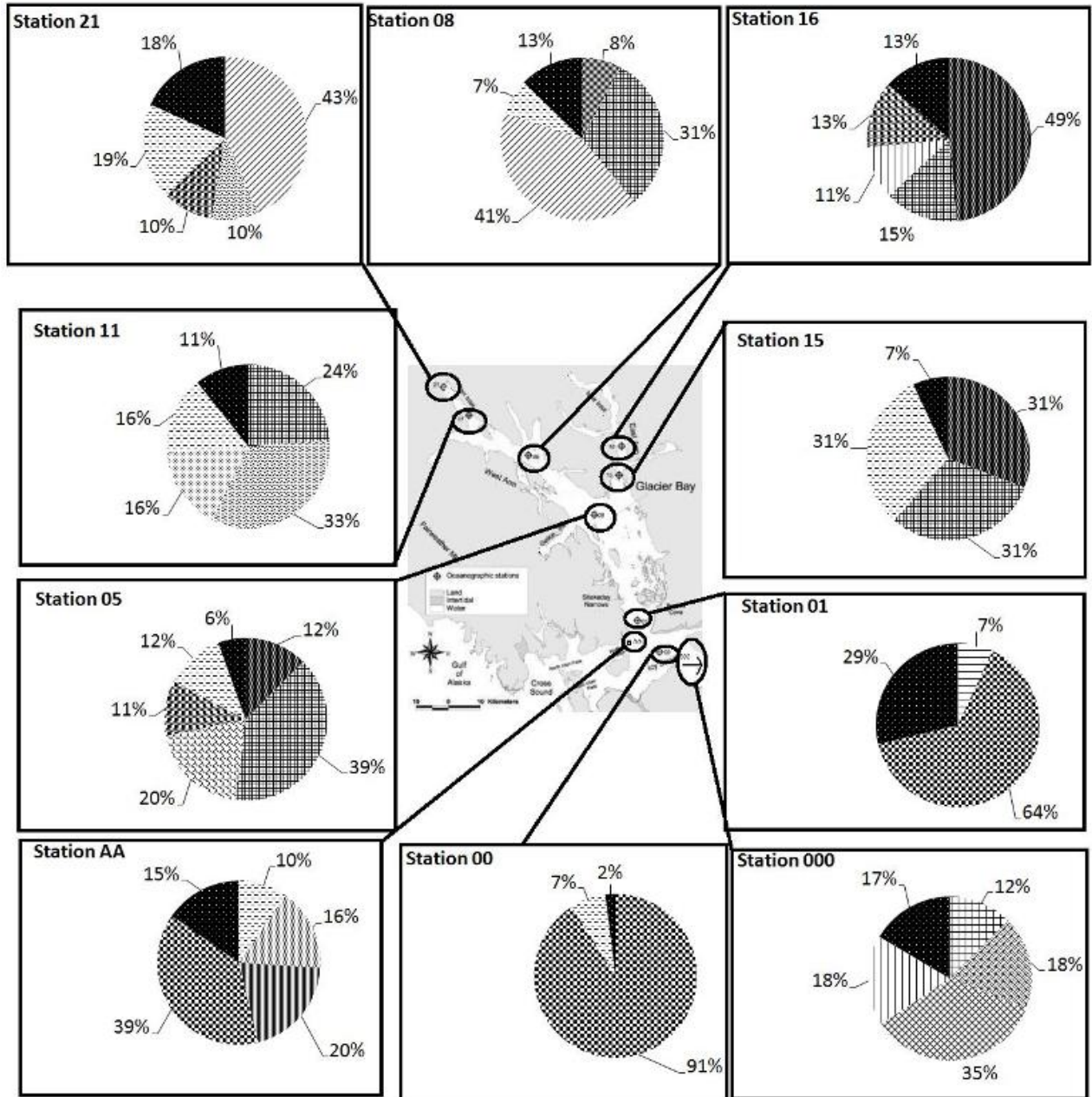


Figure 6: A summary of phytoplankton findings within Glacier Bay, using pie charts to indicate the percent composition of species indicated and color coding to show similarity of sixty-five percent.

Thompson, the University of Washington senior project faculty, and the senior students whom all worked together to accomplish this great capstone. I'd like to personally thank Dr. Rita Horner for her advice and interest in this study; Ms. Kathy Newell for being an excellent mentor

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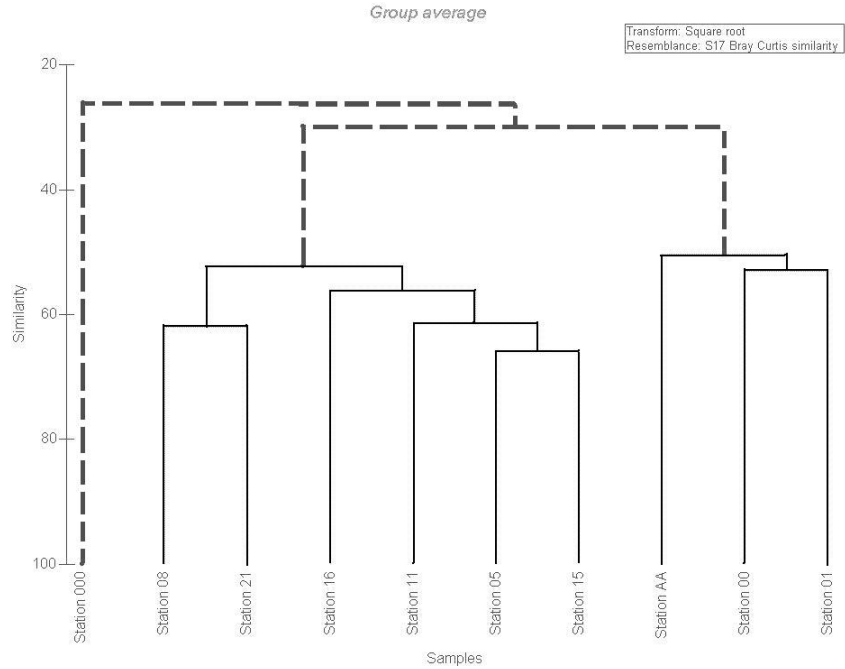


Figure 7: Cluster analysis of species composition at all stations. Light solid lines show statistical insignificance; Bold, dashed black lines show statistical significance. This shows that there are three statistically significant regions of diatom communities.

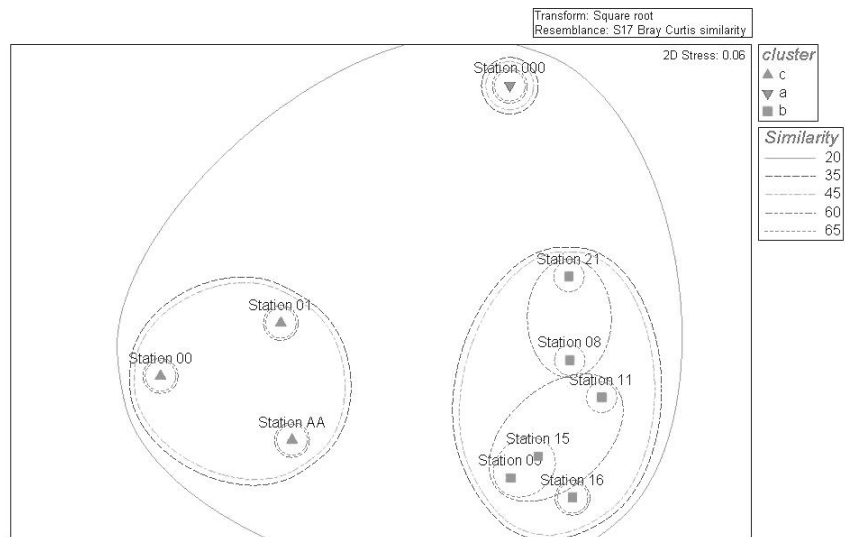


Figure 8: Cluster analysis of phytoplankton species in Glacier Bay. As legend shows, there is a similarity of sixty-five percent between stations that are closely circled. This shows three distinct clusters of phytoplankton communities within Glacier Bay.

they offered.

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