Monthly Variation in Abundance of Different Size Classes of Autotrophs with Relation to Depth

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Introduction

My project is looking at how the abundance of different size classes differ monthly and at different depths. These size classes can vary from < 2 µm to > 20 µm. I am looking at 5 different categories of size classes: < 2 µm, 2-5 µm, 5-10 µm, 10-20 µm, and > 20 µm. I am looking to see how the abundance of each size class changes throughout each month and with depth. Generally, the smaller the organism is, the more abundant it is in the ocean. The spring bloom can also change phytoplankton abundances because of there being more nutrients in the water column.

The site being examined is ALOHA (figure 1). This site is in the open ocean off the coast of Hawaii. Because it is in a tropical location, there is not a clear phytoplankton bloom because of the year-round warm waters. This results in stratification which does not bring up the nutrients that are in the deeper ocean. Since the majority of the surface nutrients are used up, phytoplankton have evolved more than one pigment in order to be able to photosynthesize at lower depths when chlorophyll a runs out. This could mean that the phytoplankton with phycoerythrin are adapted to photosynthesize in deeper waters, so they would be more abundant deeper in the water column. Cyanobacteria such as *Synechococcus* and *Prochloroccus* contain the pigment phycoerythrin. *Synechoccus* is about 1 µm in diameter and *Prochloroccus* ranges from .2-.6 µm in diameter (Olson et al., 1990). This implies that they would be the most abundant out of the 5 size classes, especially in deeper water.

Since the Hawaiian waters are tropical, there is always an abundance of light throughout the year. Some species are adapted to living in this environment with high light, meaning they would be more abundant in the surface waters. This means that they have a high Vmax and half saturation point, so they outcompete the other species that are low light adapted. The low light adapted species have a low Vmax and half saturation point and outcompete the high light adapted species when light is limited (figure 2).

Since light is limited the deeper you go, the low light species will be found in the deeper oceans (figure 3). For example, *Prochlorococcus* is an example of a low light adapted species which means that it should be more abundant in the deeper ocean (Bibby et al., 2003). Agawin et al. (2000) found that picophytoplankton (.2-2 µm) dominate warm, nutrient poor, oligotrophic waters. This is because the smaller cells have a larger surface area to volume ratio which makes them better adapted to low nutrient concentrations. The farther away from the coast you go, the smaller the phytoplankton tend to get. The larger phytoplankton also sink faster, so they would inhabit deeper waters before the smaller phytoplankton.

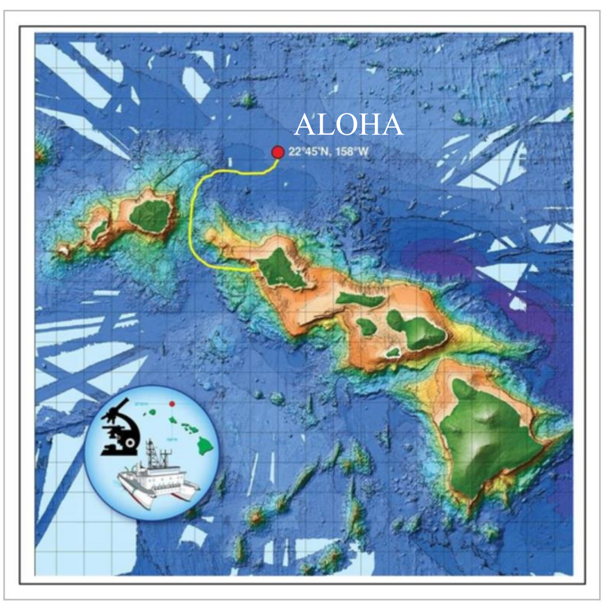

Figure 1. Map of ALOHA site where data was collected, and the route taken to get there (Lui et al., 2015).

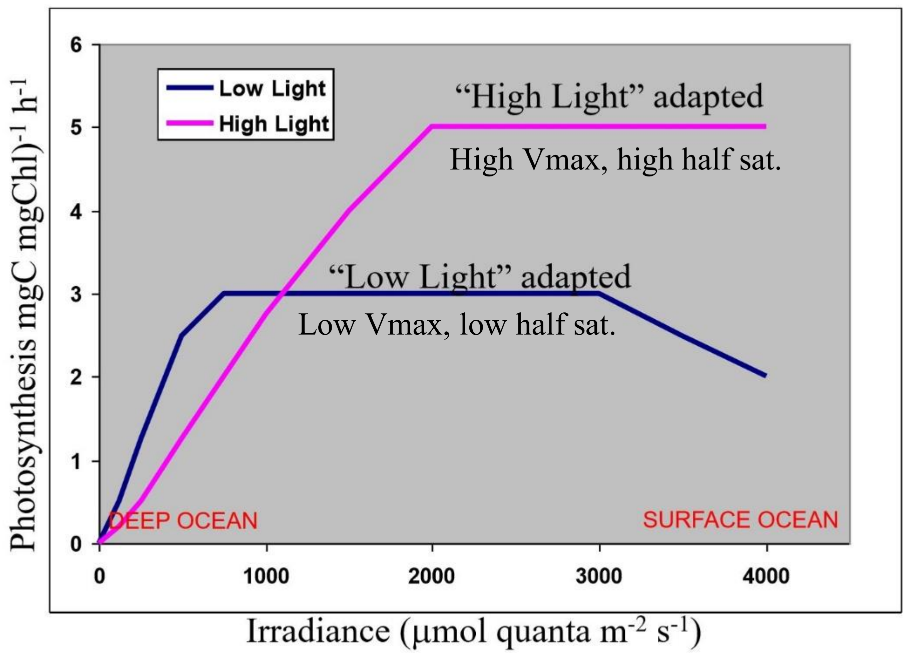

Figure 2. Photosynthesis rates comparing "high light" adapted and "low light" adapted phytoplankton in terms of deep and shallow oceans. This compares the Vmax and half saturation points of each.

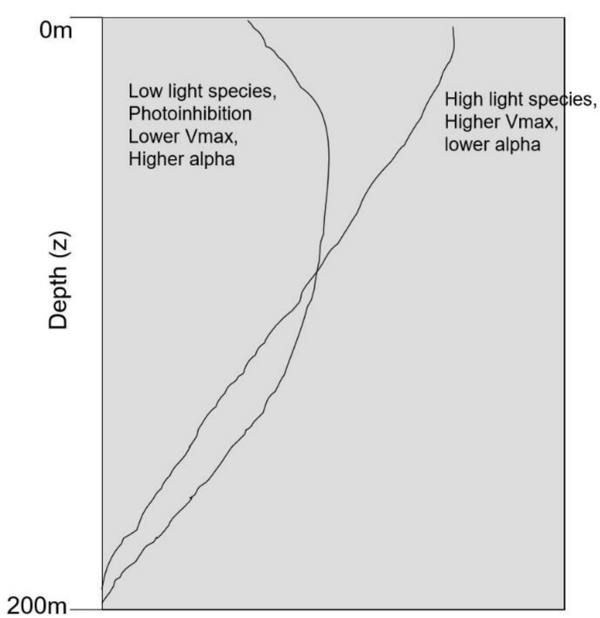

Figure 3. Depth profile showing photosynthesis rates at depth comparing low light adapted species with high light adapted species.

Objective

The purpose of my project was to determine how the abundance of different size classes of autotrophs varies monthly and with depth.

Approach

I am looking at the Hawaii Ocean Time-series (HOT) data, specifically at the ALOHA site (Figure 1). On their website, I went under the “date extraction” tab and picked the “epi-fluorescent” option. Then I selected all the size classes, including the total, under “Autotroph Biomass (by size).” I then selected the year 2006 and extracted the data from 1/01/2006-12/31/2006 with the starting depth 0 m and the ending depth 200 m. I choose 2006 because it was the only year on the HOT site with all the months included. I then turned the .txt file into an excel file to graph the data.

I am looking at how the abundance of size classes vary at depth for each month. I graphed the data by making depth profiles of each size class for each month (figures 4-15). I graphed depth (m) vs size class abundance (µg C/L) for every month. I also made a time series graph by averaging the size classes at each depth (5 m, 25 m, 45 m, 75 m, 100 m, 125 m, 150 m, and 175 m) and graphing time (months) versus abundance (µg C/L) (figure 16). I then made the same graphs for each individual depth (figures 17-24).

Results

Figures 4-15 are depth profiles for the abundance of each of the 5 class size categories for each month. Figure 16 is the average depth time series graph showing time in months versus abundance (µg C/L) of each size class. Figures 17-24 are time series graphs of time in months versus abundance at each individual depth from 5-175 m. For the size class of < 2 µm, the abundance tends to stay close to 0 µg C/L except during the month of January where the abundance stays around .2 and peaks at 45 m with an abundance of .45 µg C/L. The size class > 20 µm tends to be relatively low. It has a peak in July of an abundance of 9.63 µg C/L at 45 m, a peak in October of 11.27 µg C/L at 25 m, and a peak in November of 23.42 µg C/L at 45 m. The size class 10-20 µm tends to be relatively low with some peaks between 75 and 100 m. The size classes 2-5 and 10-20 µm are the most abundant with 2-5 µm being the most abundant throughout most of the year. They tend to have many peaks between 25 and 125 m and tend to go to 0 µg C/L at 175 m.

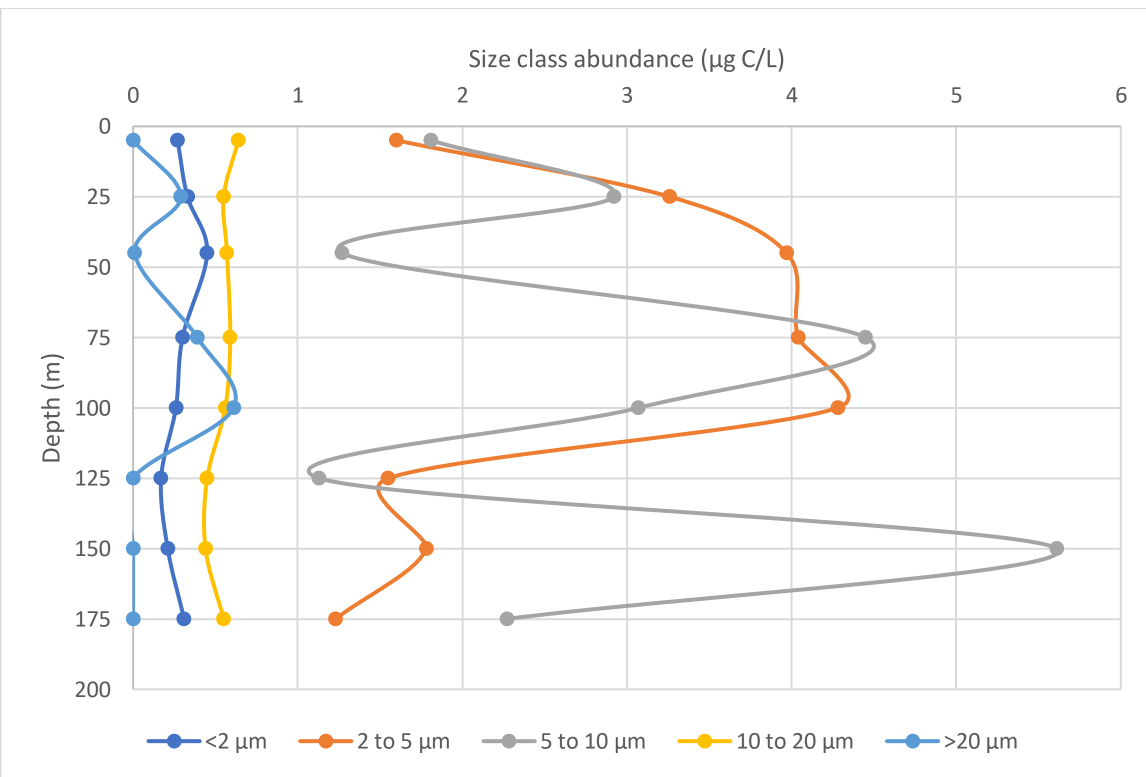

Figure 4. Depth profile for the month of January. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

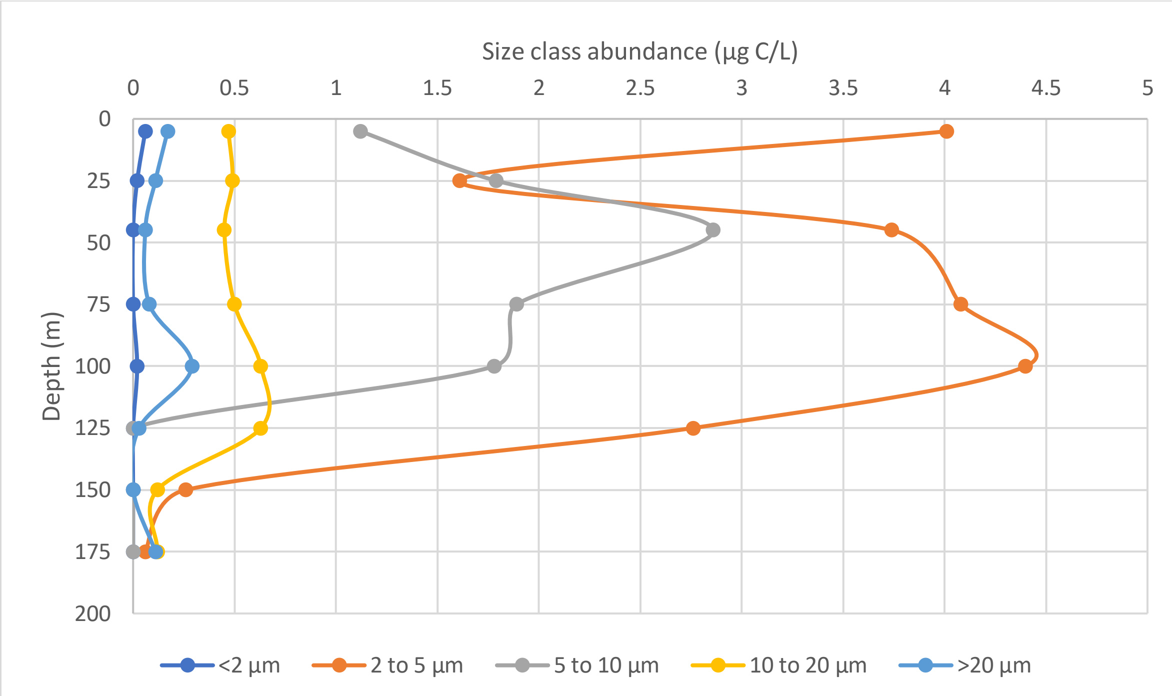

Figure 5. Depth profile for the month of February. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

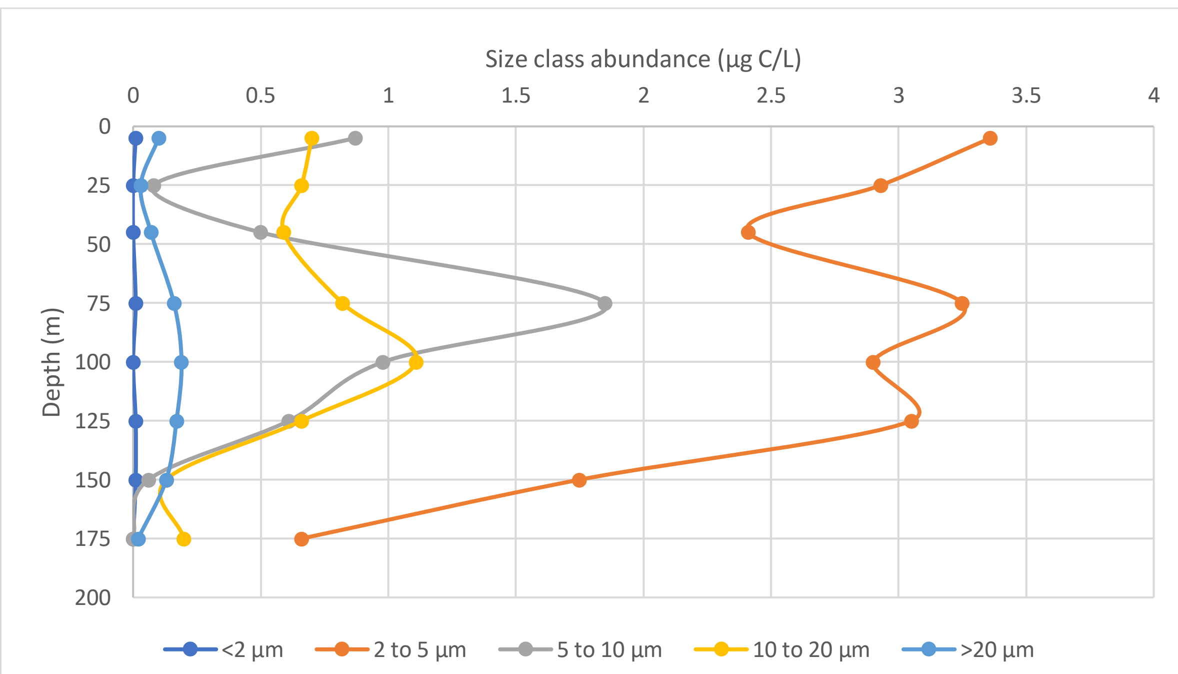

Figure 6. Depth profile for the month of March. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

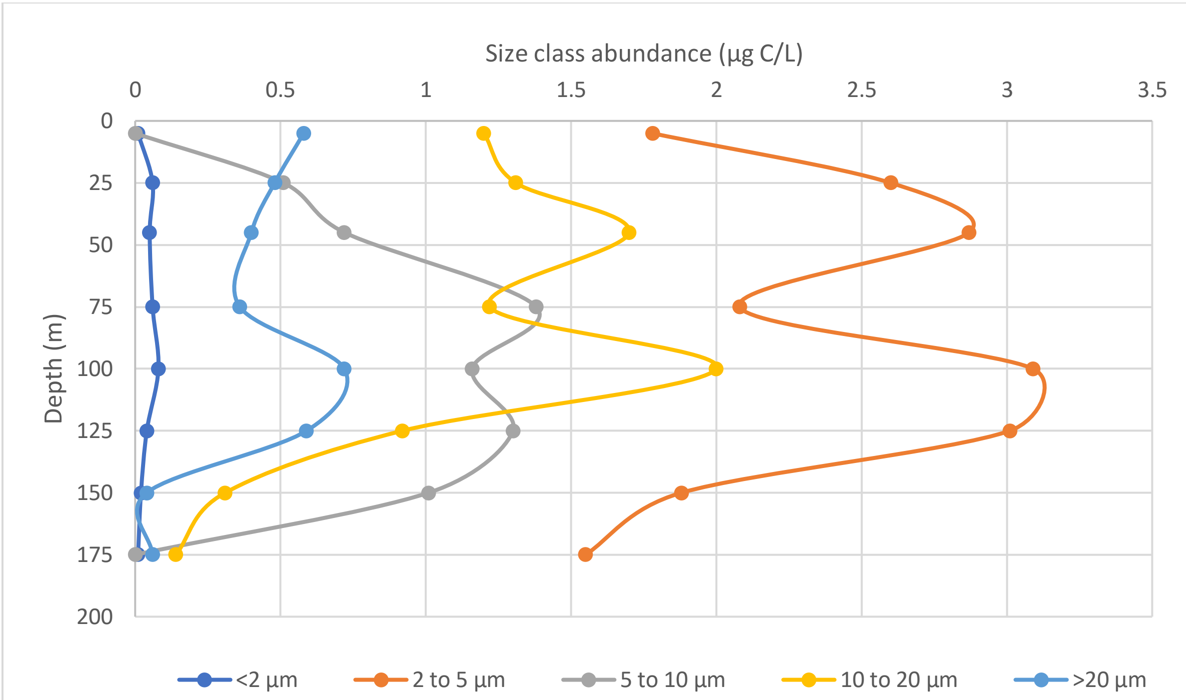

Figure 7. Depth profile for the month of April. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

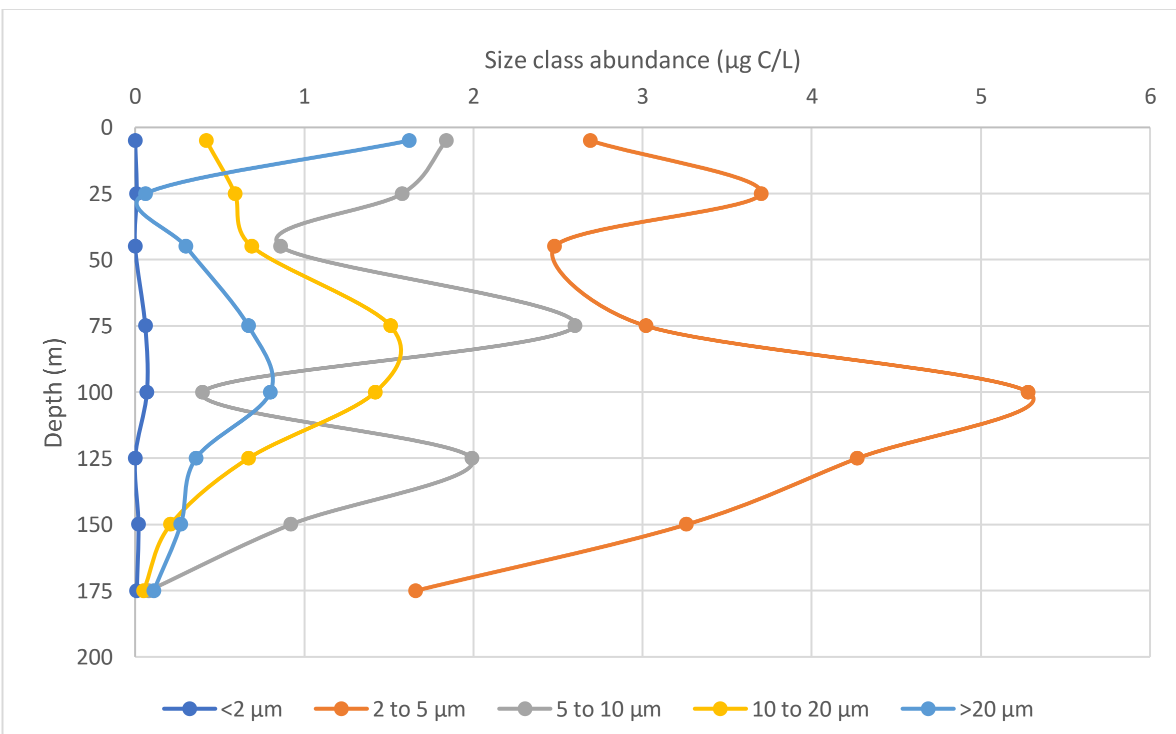

Figure 8. Depth profile for the month of May. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

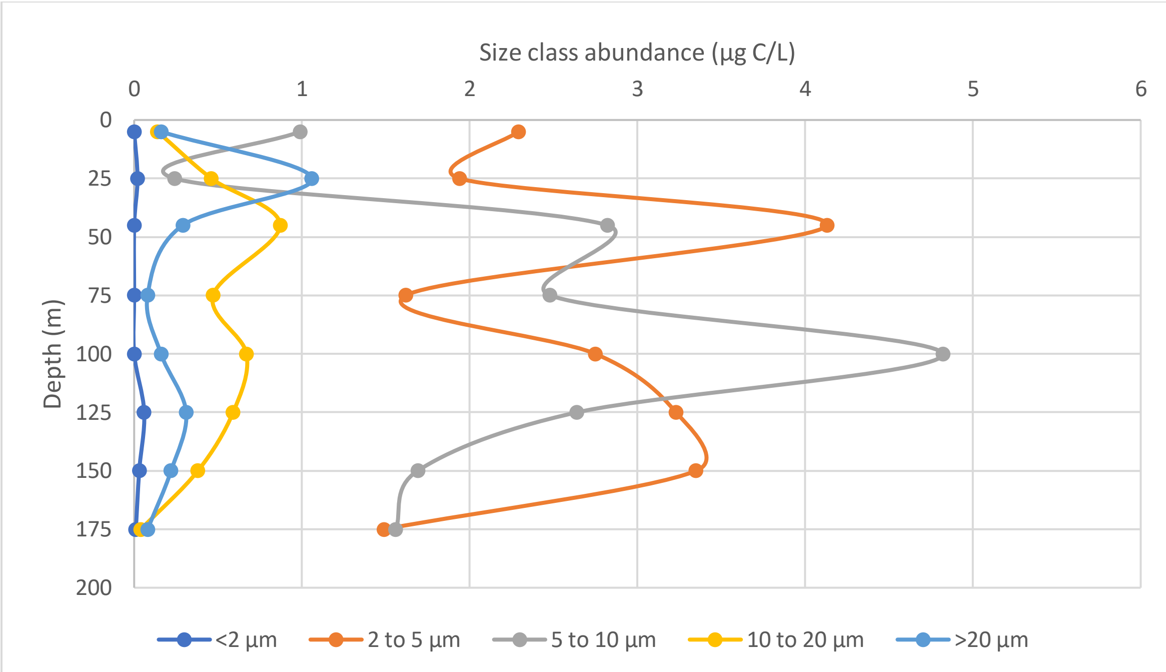

Figure 9. Depth profile for the month of June. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

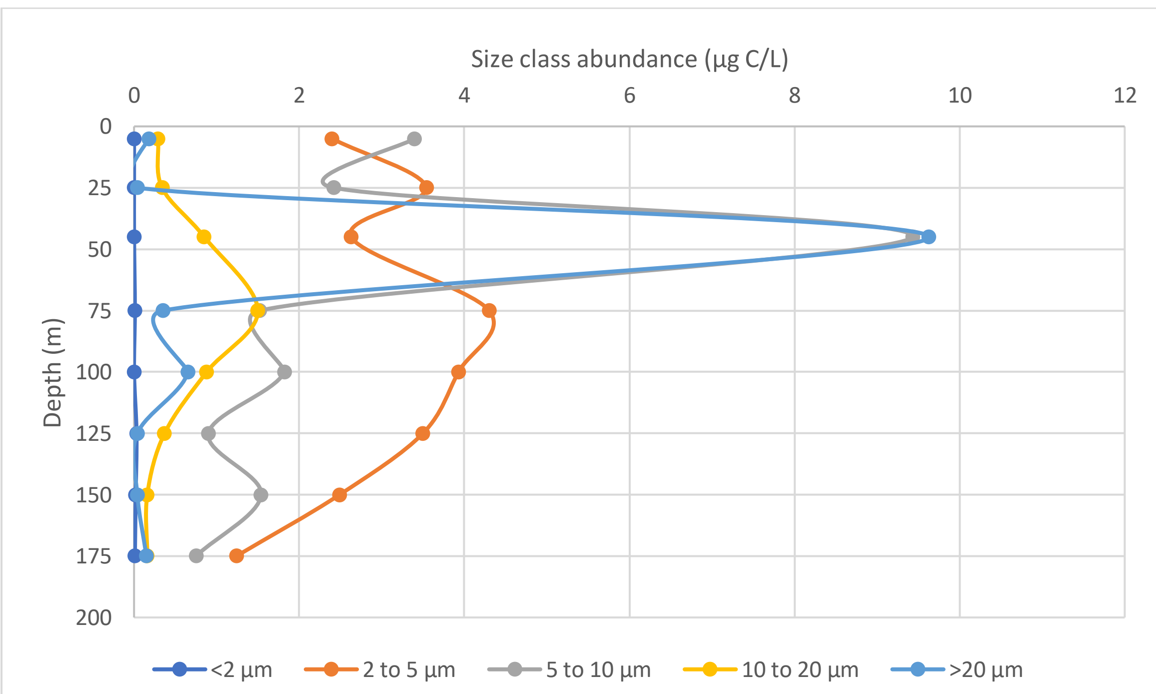

Figure 10. Depth profile for the month of July. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

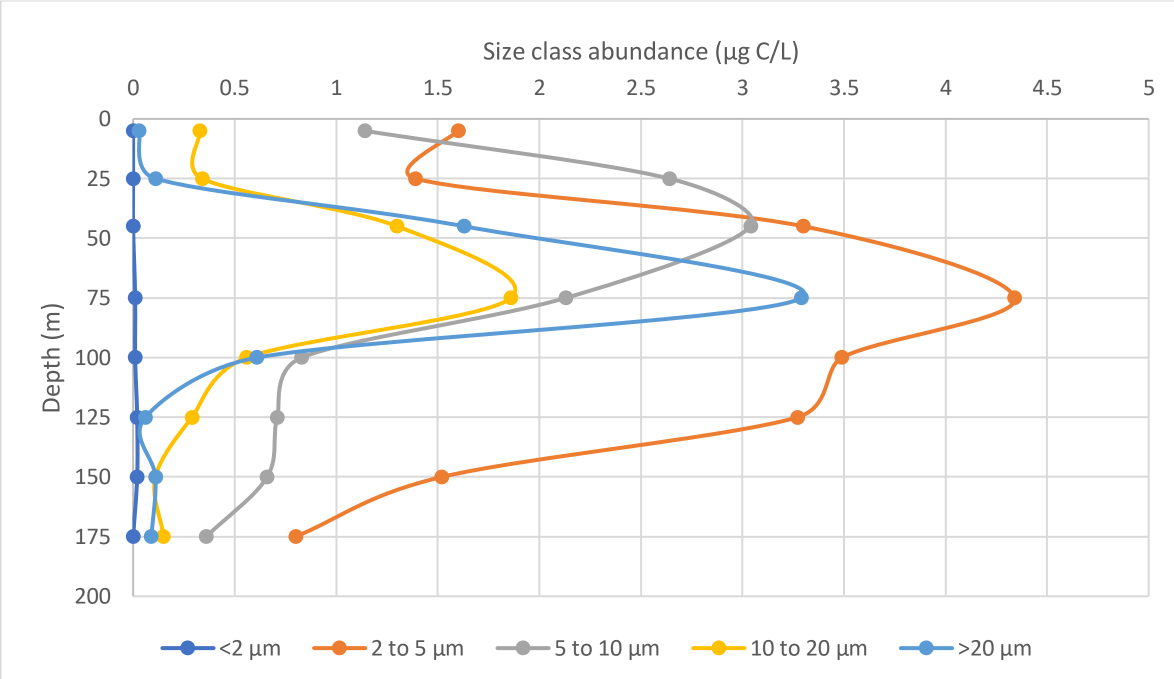

Figure 11. Depth profile for the month of August. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

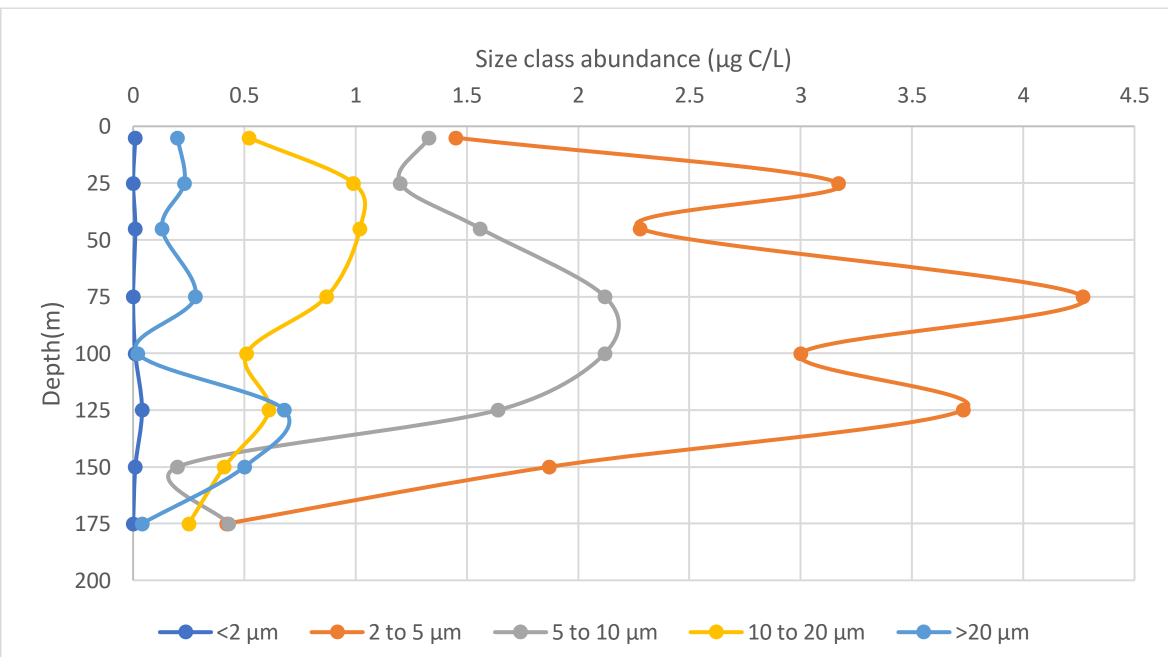

Figure 12. Depth profile for the month of September. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

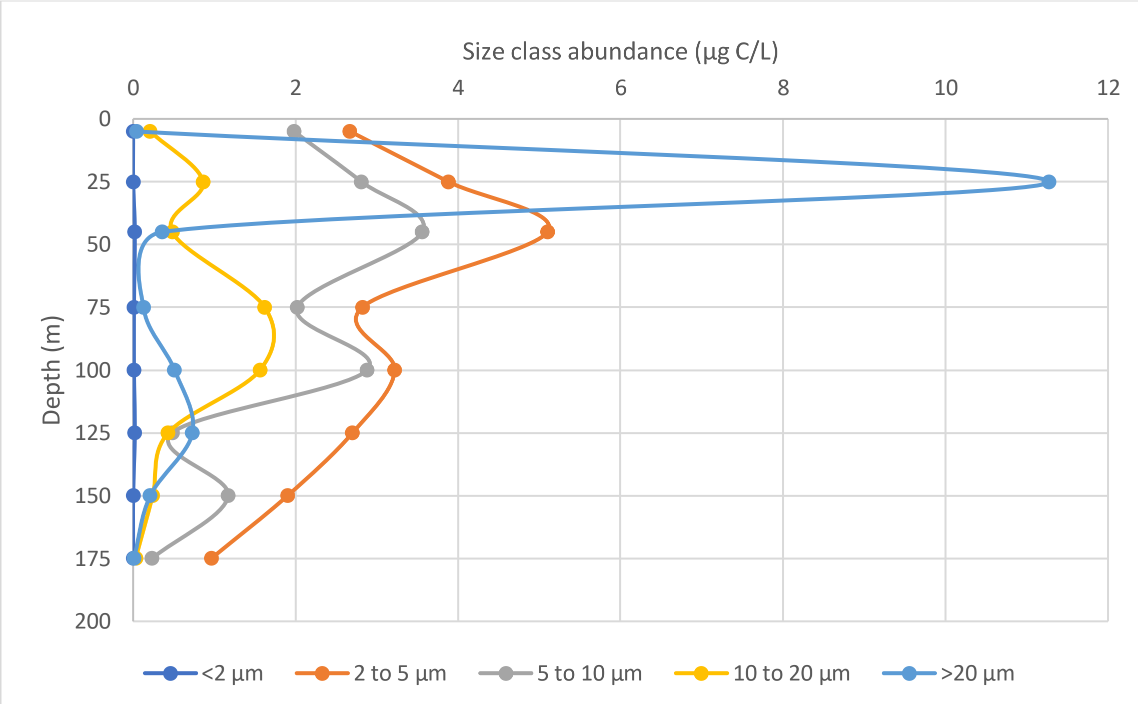

Figure 13. Depth profile for the month of October. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

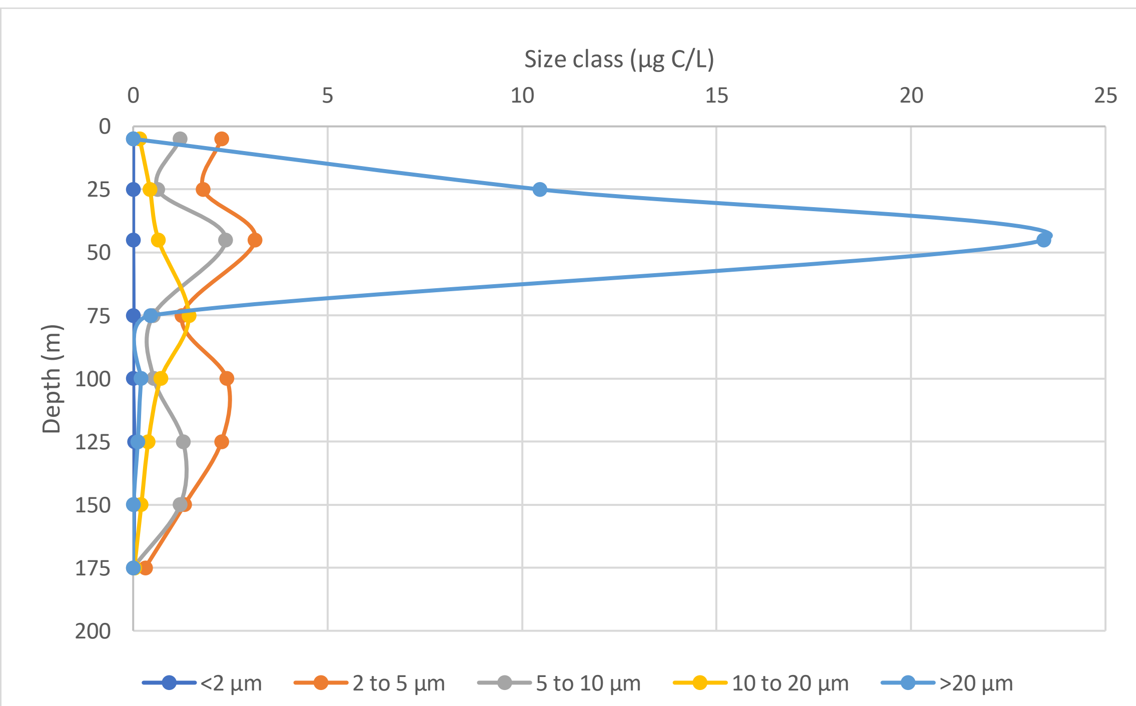

Figure 14. Depth profile for the month of November. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

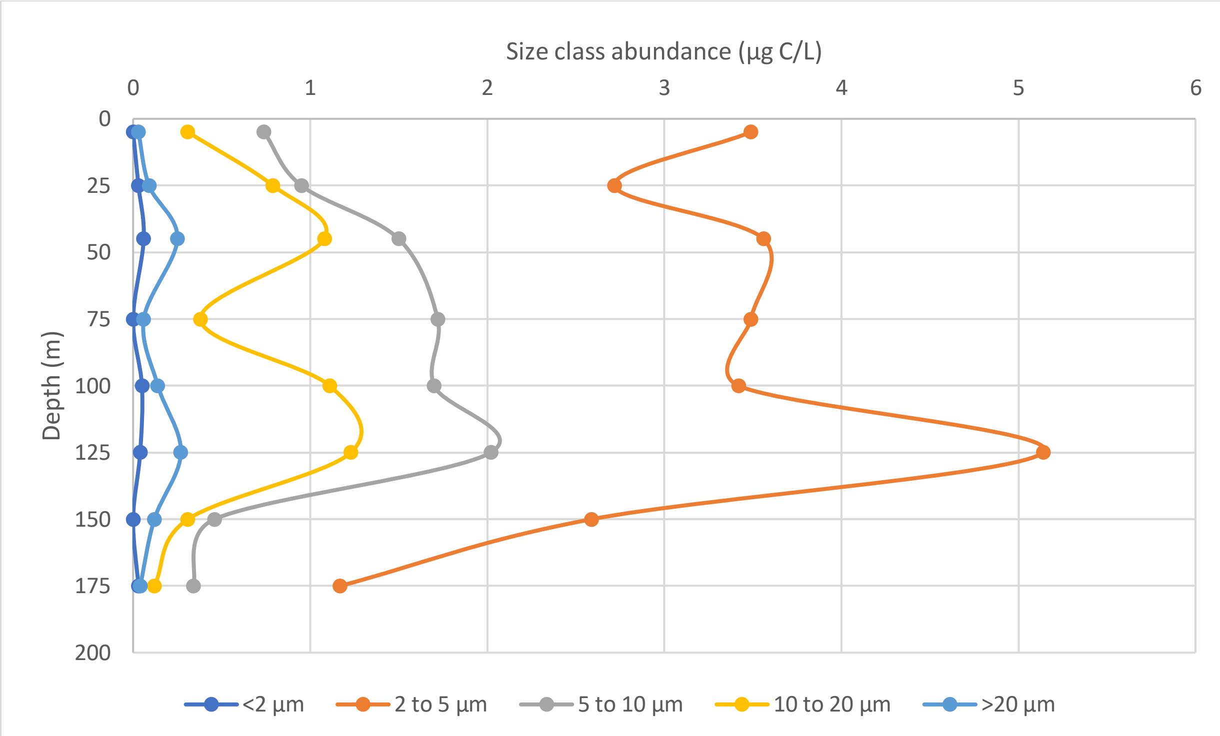

Figure 15. Depth profile for the month of December. Size classes abundances (µg C/L) from 2-20 µm are shown from depths of 5 to 175 meters.

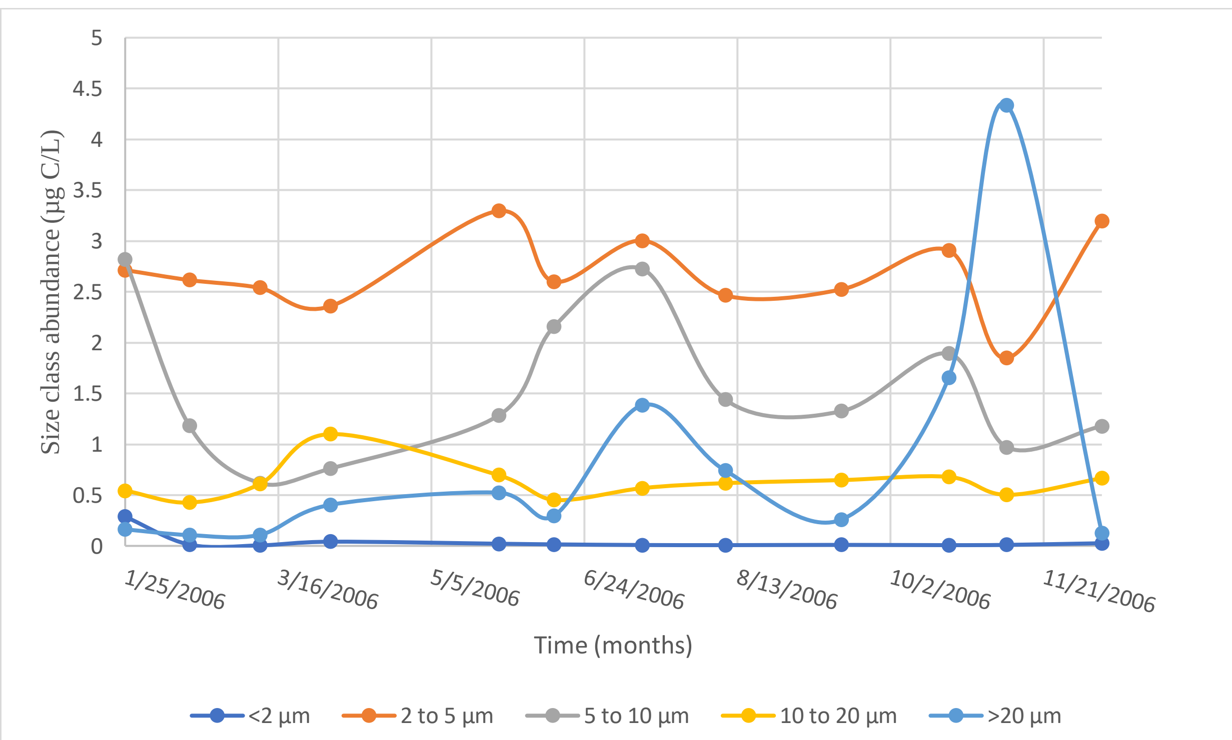

Figure 16. Time series of average size class abundance (µg C/L) for each month. Size classes from 2-20 µm were averaged from every depth (5, 25, 45, 75, 100, 125, 150, and 175 m).

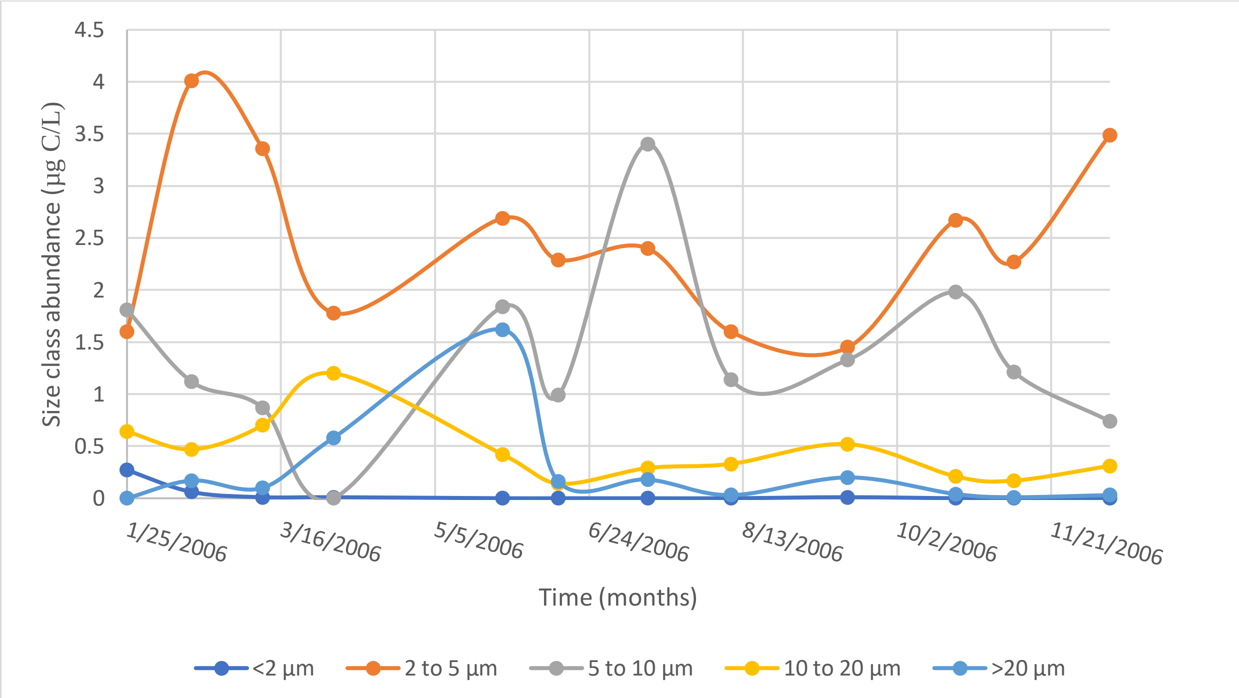

Figure 17. Time series of size class abundance (µg C/L) for each month. Size classes from 2-20 µm were taken from a depth of 5 m.

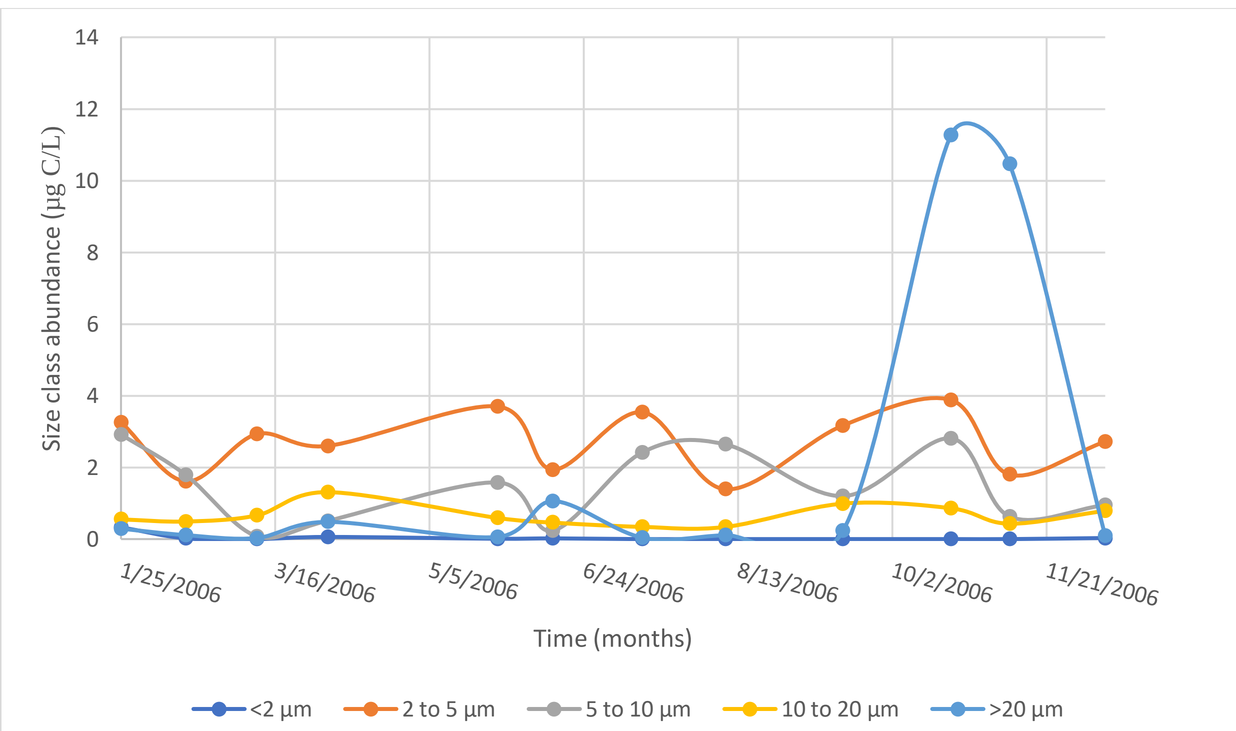

Figure 18. Time series of size class abundance (µg C/L) for each month. Size classes from 2-20 µm were taken from a depth of 25 m.

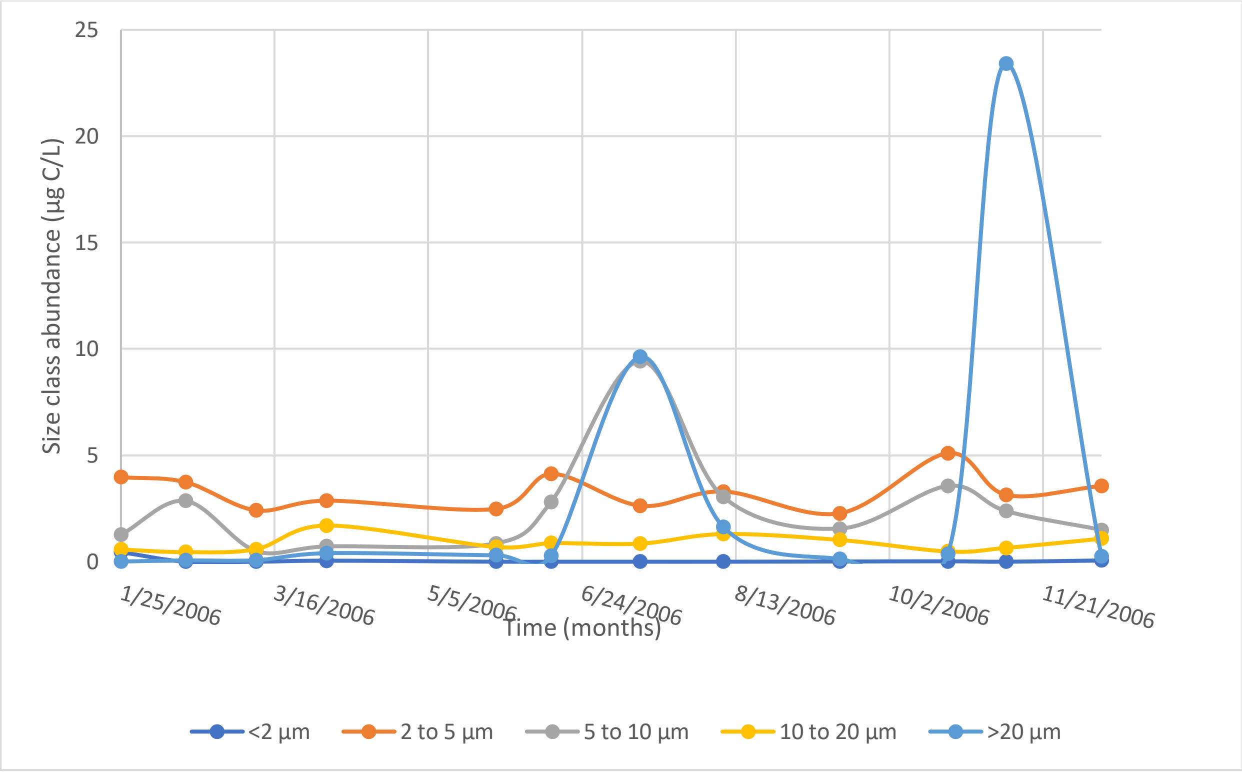

Figure 19. Time series of size class abundance (μg C/L) for each month. Size classes from 2-20 μm were taken from a depth of 45 m.

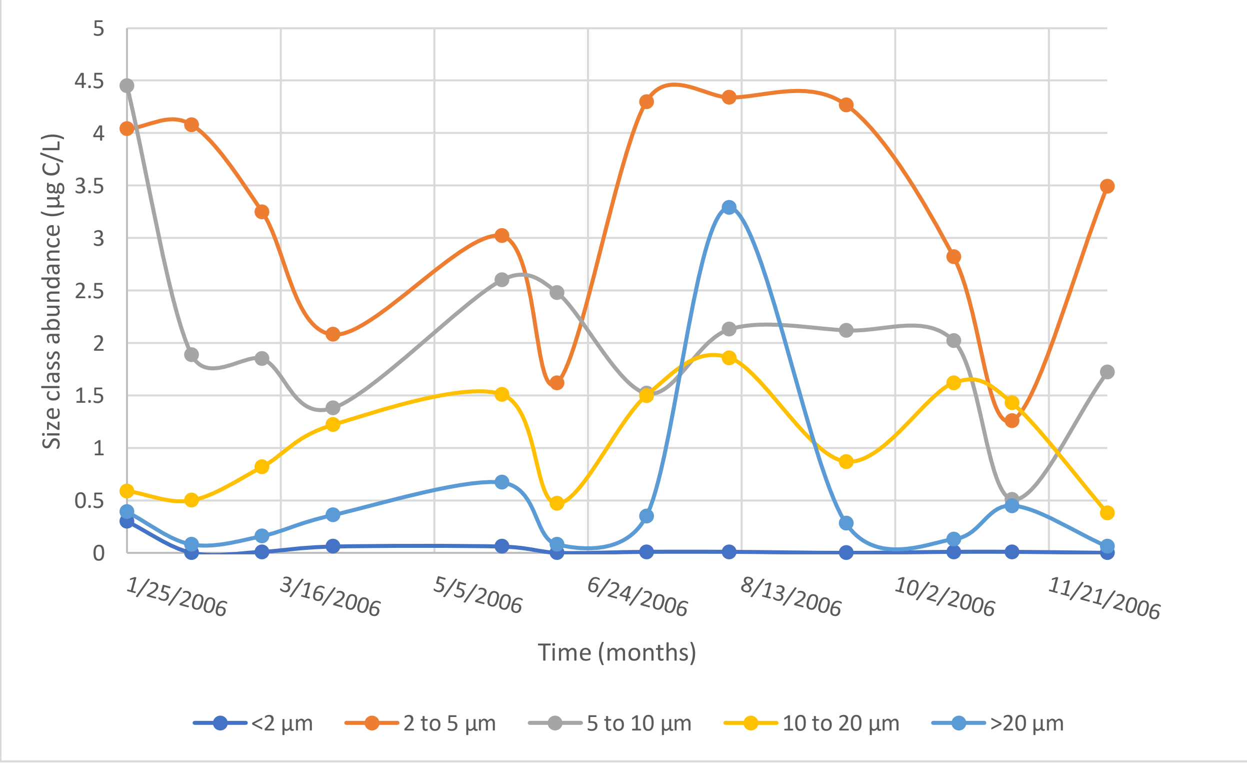

Figure 20. Time series of size class abundance (μg C/L) for each month. Size classes from 2-20 μm were taken from a depth of 75 m.

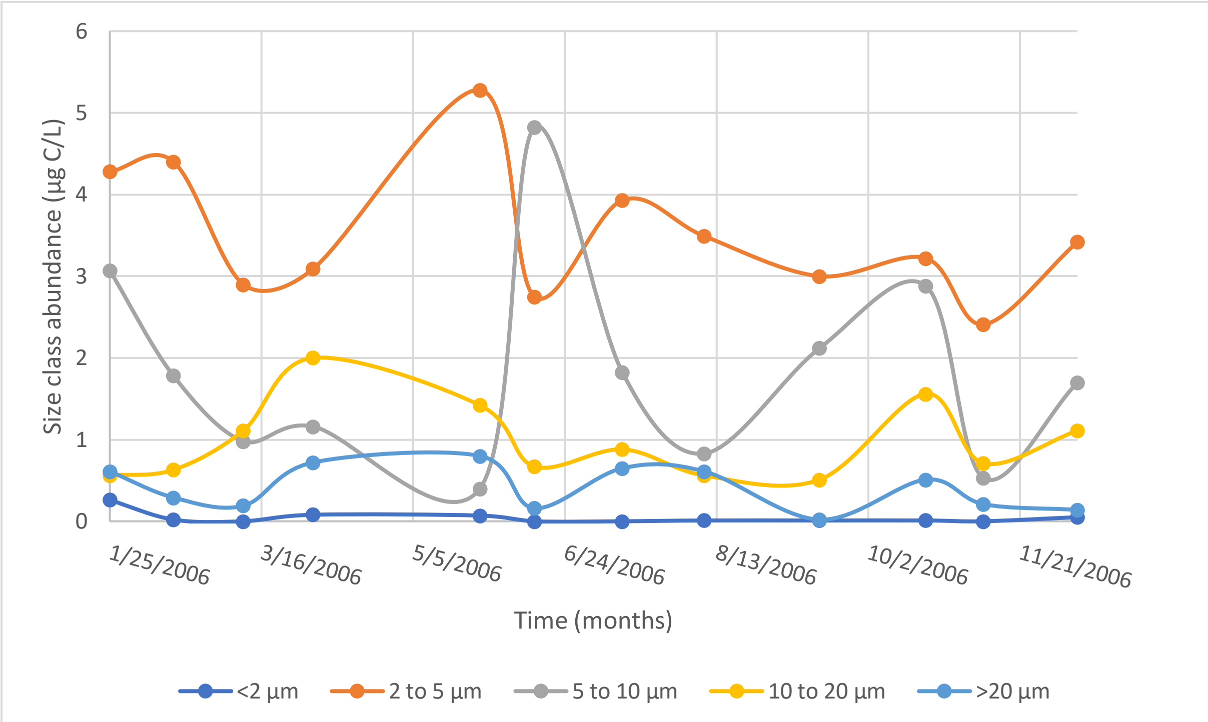

Figure 21. Time series of size class abundance (µg C/L) for each month. Size classes from 2-20 µm were taken from a depth of 100 m.

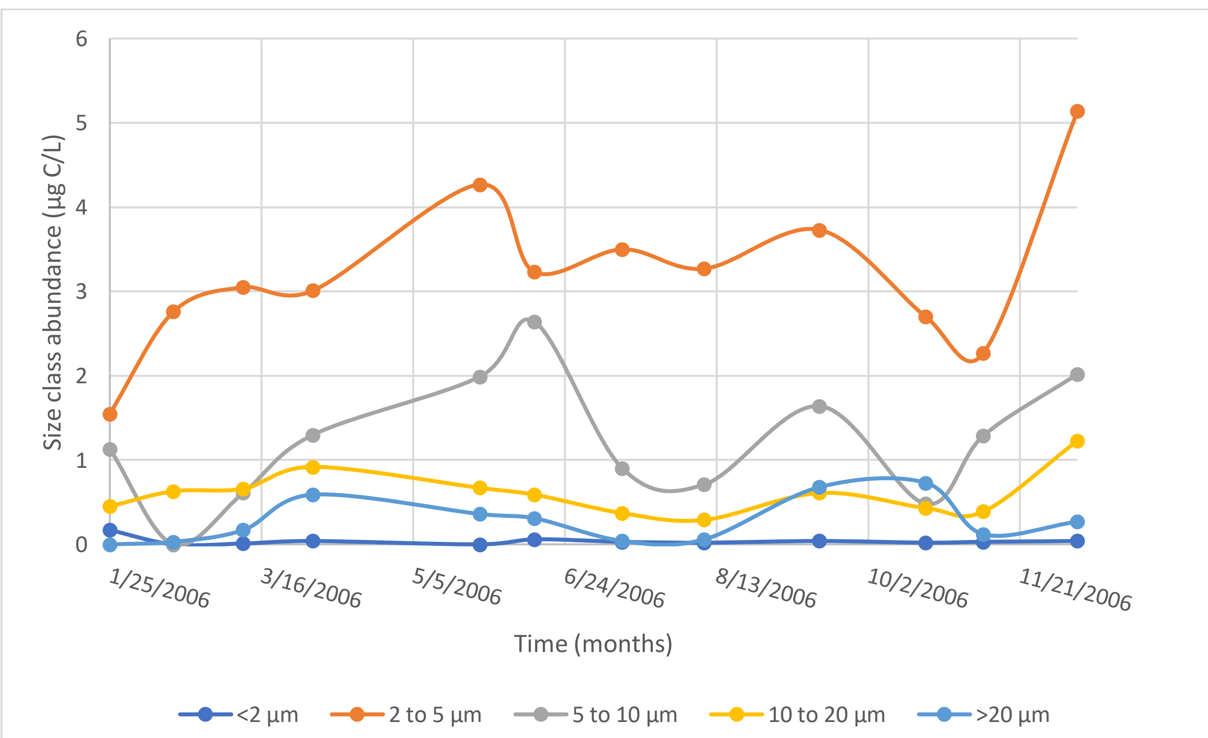

Figure 22. Time series of size class abundance (µg C/L) for each month. Size classes from 2-20 µm were taken from a depth of 125 m.

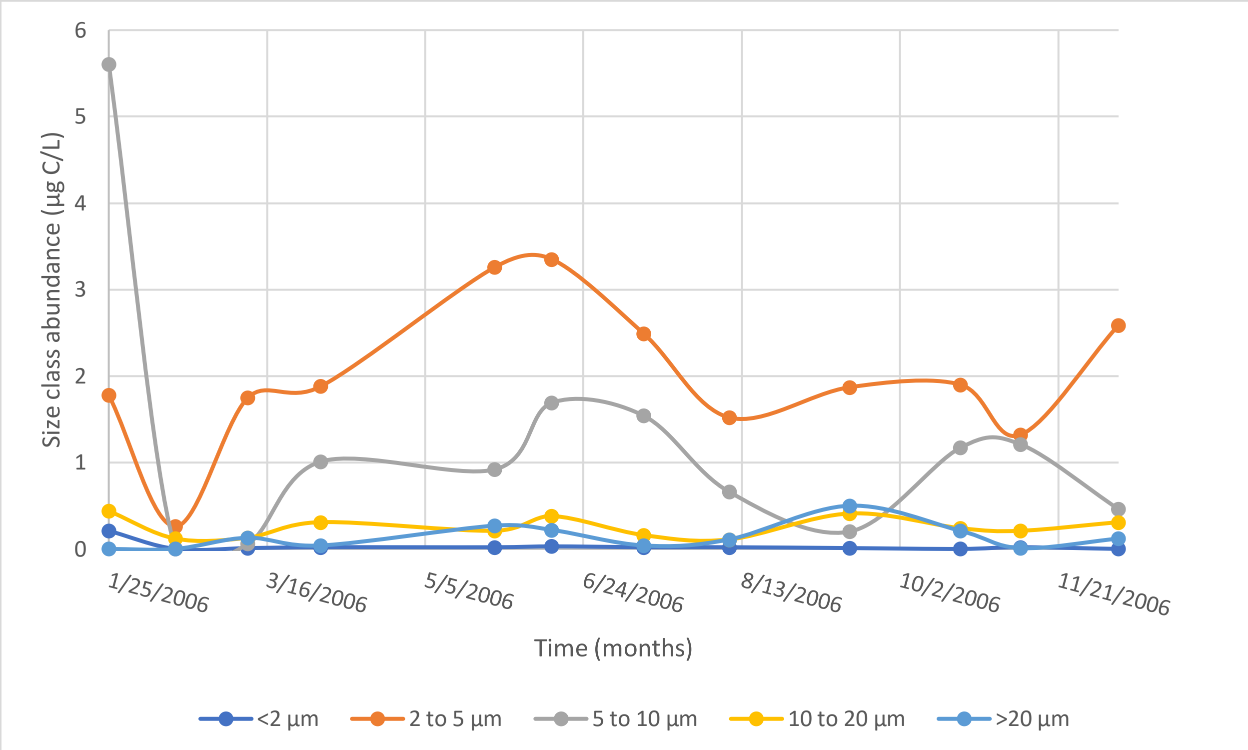

Figure 23. Time series of size class abundance (µg C/L) for each month. Size classes from 2-20 µm were taken from a depth of 150 m.

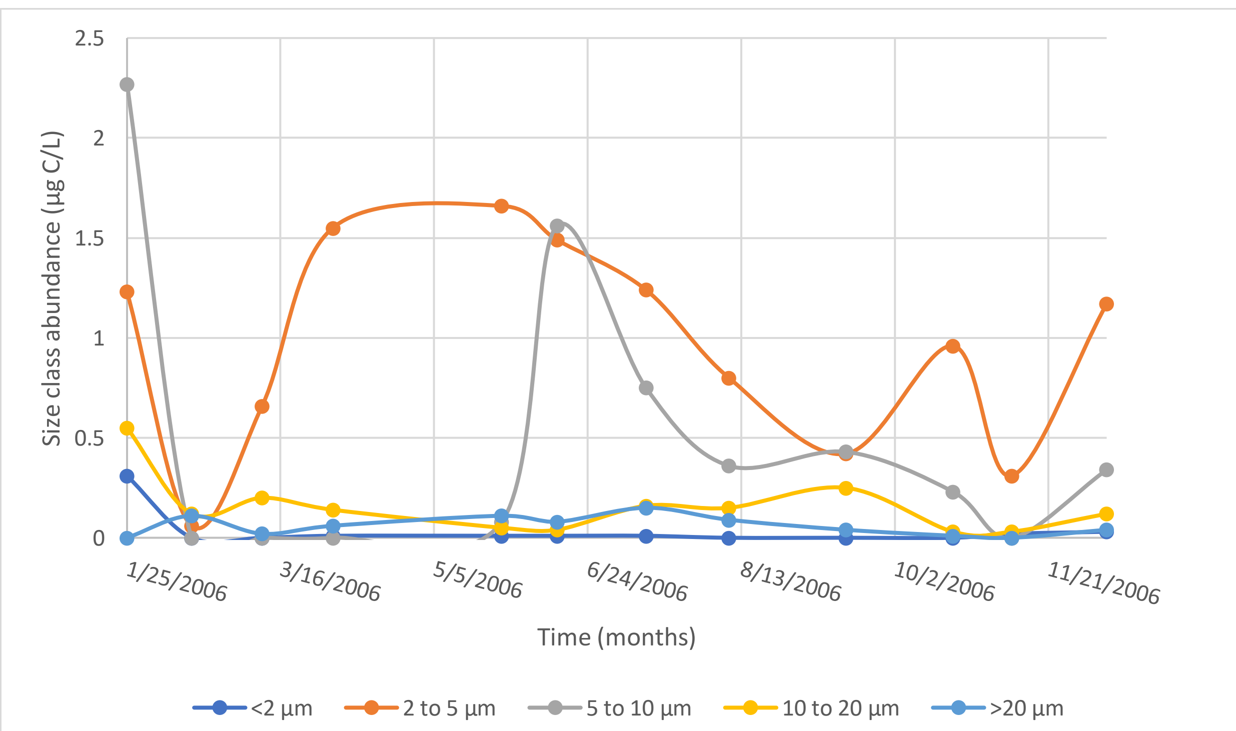

Figure 24. Time series of size class abundance (µg C/L) for each month. Size classes from 2-20 µm were taken from a depth of 175 m.

Discussion

Agawin et al. (2000) looked at picophytoplankton (< 2 µm) and found that they dominate in warm, oligotrophic waters. When looking at my results, picophytoplankton abundance was close to or at 0 for every month. They also mentioned that *Prochlorococcus* may be less efficient at using low nutrient concentrations even though it is small. This could be a reason as to why this size class is at such a low abundance. In addition, the 2-5 µm size class is the most abundant for most months and is the second smallest size class which makes sense because the smaller the organism, the more abundant it is, especially in nutrient poor waters. In addition, the size class of 10-20 µm is always low in abundance at most months because it is larger in size.

Hopcroft and Roff (1990) found that netplankton (> 20 µm) and nanoplankton (2- 20 µm) dominate when there are weaker westerly winds because of the nutrient-rich shelf waters. Hawaii has trade winds which are winds that come from the Northeast direction in the Pacific Ocean. During the months of September and October, these winds are reduced greatly (Van Dorn, 1974). This could be the reason as to why > 20 µm phytoplankton are at the highest abundance in October and November (Figures 13 and 14). In addition, this size class is abundant near the surface (25-45 m) which makes sense because the trade winds blow horizontally and not vertically like that of upwellings They also found that netplankton dominate in areas of high chlorophyll concentrations. At the ALOHA station, chlorophyll concentrations tend to be highest in the fall months which could also account for the high abundance of phytoplankton > 20 µm in October and November. The high chlorophyll concentrations can also cause a bloom in diatoms which may also be why the > 20 µm size class was much higher than any other size class in October and November (Figures 14 and 15) and overall as abundance rarely exceeded 5 µg C/L (Hallegraeff, 1981). In addition, in July of 2006 hurricane Daniel hit the Pacific Ocean near

Hawaii. Hurricanes tend to cause increases in chlorophyll concentrations at the surface because of the cool wakes caused by the hurricanes. This favors larger phytoplankton and could be a reason as to why there was a bloom of > 20 µm phytoplankton in July (Figure 10) (Babin et al., 2004).

Hallegraeff (1981) studied pigment types of nanoplankton (< 15 µm) and diatoms. Nanoplankton are known to thrive in low-nutrient environments and are more abundant than diatoms except when diatoms bloom. Since Hawaii is in the tropic, diatom blooms are less common, meaning nanoplankton will always be dominant. The results show that the 2-5 µm and 5-10 µm size classes are the dominant size classes for most months which are the size of nanoplankton. Since the data only went to 175 m, it is hard to see if pigments played a role as some pigments go deeper than 175 m.

Ciliates are heterotrophic microzooplankton that feed on nanoplankton (Suzuki and Miyabe, 2007). Tanaka and Rassoulzadegan (2002) found that ciliates are most abundant at depths of 5-10 m in January, February, May, August, and October which may be why the 2-5 µm and 5-10 µm size classes have a lower abundance at these depths. Ciliates are also found to be abundant at 175 m which could be another reason why the abundance of these size classes are so low.

Overall, after looking at different data the results were not as surprising as they were before I did research. It is still surprising to me that the size class < 2 µm is the least abundant for all months and mostly at an abundance of 0 µg C/L because the smallest is usually the most abundant. This may be because the data only showed data for depths of up to 175 m. The smaller cyanobacteria such as *Synechococcus* and *Prochloroccus* contain the pigment phycoerythrin which means that they can be found at deep depths, so it is possible that they are more abundant in depths > 175 m. In addition, *Prochloroccus* is better adapted to low light environments so it could be found at depths between 175-200 m, although, it is known to be less efficient at using low nutrient concentrations. I also thought the data would have to do more with pigment types, but I did not find anything that confirmed this. That being said, all size classes have the pigment chlorophyll a which goes to a depth of about 150 m and all the size class abundances are reduced greatly past 125 m and 0 µg C/L at 175 m. Since < 2 µm was never abundant, it may be because of competition with the other size classes so once chlorophyll a reaches its max depth, the deeper pigments may dominate. I was also surprised to learn that the trade winds had an effect on the data. I was able to answer my question for the most part. I think it may be interesting to look at different years because things like hurricanes affected my data, but overall, I was able to understand the trends in my data as well as learn new things that occur in the ocean that can affect these trends.

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