Factors affecting plankton type dominance in Monterey Bay

Alaina Smith, University of Hawaiʻi at Mānoa

Mentors: Monique Messié

Summer 2016

Keywords: plankton, dominance, Monterey Bay, bio-physical variability

ABSTRACT

This project was birthed out of the idea that there could be a way to use the physical features of Monterey Bay to predict when and where the different types of plankton will dominate. However, it did not turn out into that same exact project. While I still looked at physical features of the Bay it was not really about location in the Bay or time of year, because these did not seem to have any effect. What did seem to have an effect was stratification, and wind turbulence. It seems as though diatoms prefer little stratification, whereas autotrophic dinoflagellates prefer stratification, and that dinoflagellates prefer little wind turbulence while diatoms have a wide range of wind turbulences it can withstand and dominate during. This project also opened up the idea that the Dorado AUV should do more surveys without focusing so much on the Autumn months, because the Summer and Spring months are just as important to plankton.

Introduction

Plankton are an important component to any aquatic ecosystem, especially to one as lucrative in diversity as Monterey Bay. That is why understanding the community relationships between the dominating plankton types is important, especially when one type is the main cause for harmful algae blooms. There has been talk of a trade-off in time between diatoms and dinoflagellates in the Bay, seemingly to the shift in favorable resources. That idea is what sparked the whole project. I wanted to see if there was a way to predict when and where these different types of plankton will dominate. It turned in to deriving other types of physical factors in the Bay, that were more then just measured variables, and the derived data seemed to have more of an affect on plankton dominance.

The three types of plankton that will be talked about today are diatoms, autotrophic dinoflagellates, and heterotrophic dinoflagellates. The values for these plankton types are not actual biomass counts, but proxy values. These proxy values were derived from the relationship between fluorescence and bioluminescence.

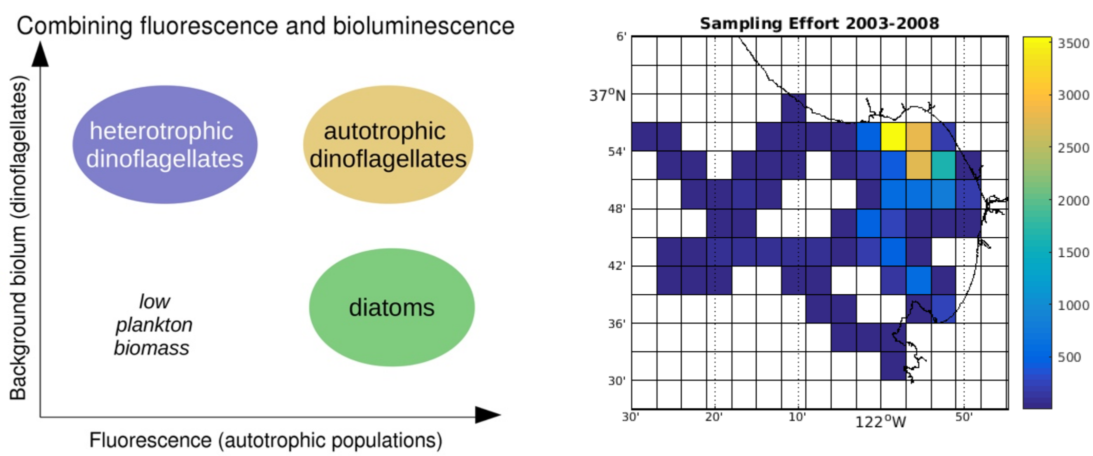

Figure 1. a) Plankton type relative to fluorescence and biolumiescence measurements. (Figure by Monique Messié). b) The sampling effort for the location in the bay, showing how many profiles were taken within each bin of a latitude and longitude range.

What separates dinoflagellates and diatoms in the bioluminescence measurements (Figure 1). When it is high, that is likely attributed to dinoflagellates and if it is low then this would be diatoms. However, what separates heterotrophic from autotrophic is fluorescence. One of the big caveats of this project is the sampling effort. This project's sampling effort was related to the location in the Bay the data was taken (Figure 1b.) and the time of year that the data was taken (Figure 2). The time of year the data was taken is especially important because the Autumn months are not the only months that are important to plankton. The Spring time is also an important bloom period for diatoms and heterotrophic dinoflagellates have been shown to capitalize on the increase in diatoms by grazing on them (Tiselius & Kuylenstierna 1996).

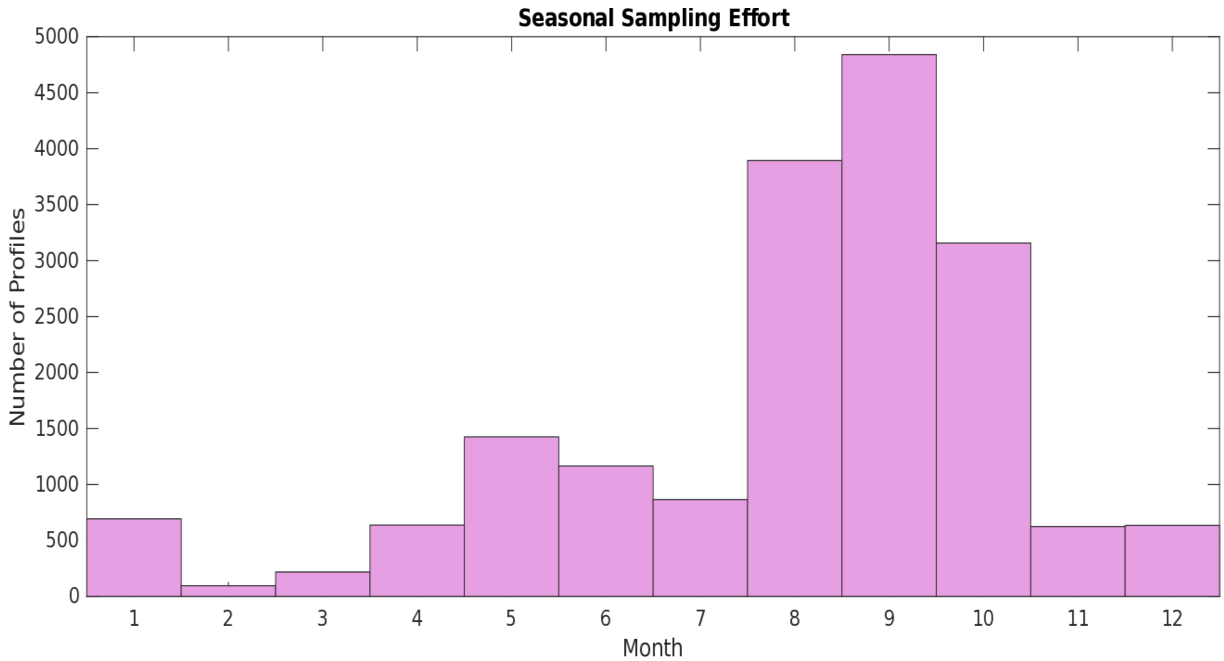

Figure 2. Seasonal sampling effort showing the time of year the profiles were collected.

This paper will be exploring whether or not physical factors of Monterey Bay can be used to determine when or where three different plankton types will dominate in Monterey Bay.

Methods

The measured data, temperature, time, depth, fluorescence, background bioluminescence, oxygen, and nitrate, from the Dorado AUV dataset for the time period of January 1, 2003 to December 31, 2008 was downloaded in MatLab. Since the depth, oxygen, and nitrate were measured using different sensors, they had to be interpolated to all have values for the same times. The second dataset for the proxy values, which were derived using the measured bioluminescence and fluorescence from the Dorado AUV, was downloaded into MatLab, giving me values for the three plankton types, profile numbers, and latitude and longitude. The profile number is literally the number given to each profile in each day and this just allows me to separate out the profiles based on their start and end time. After figuring out where each profiles starts and ends, I found the temperature, depth, fluorescence, bioluminescence, oxygen, and nitrate values for each of the profiles. I then calculated the minimum depths of each of the profiles, to make sure that the profiles were reaching the surface and then found the depths in each profiles at which 80% of the data for each plankton type was above.

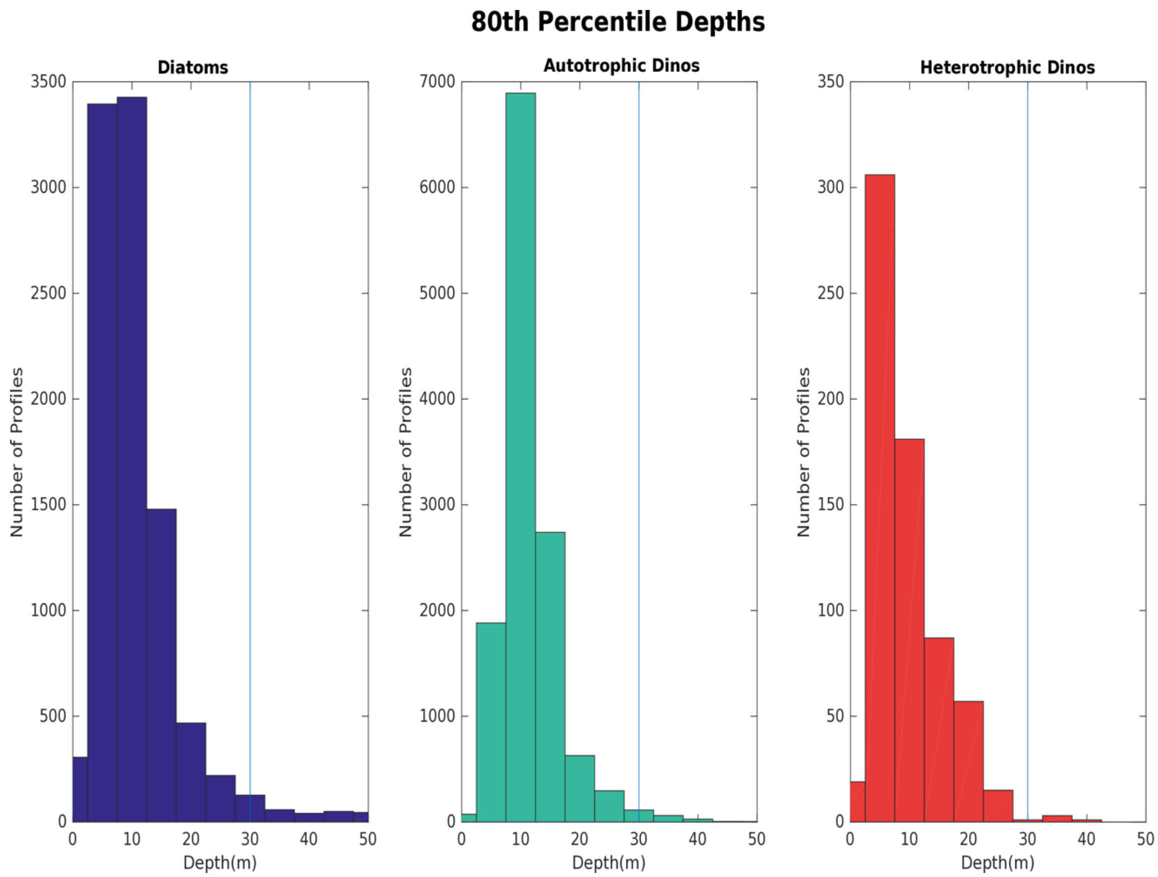

Figure 3. Depths at which 80 percent of the data for each of the plankton types is above, with the line showng the depth I chose to average over.

This value was determined to be 30 meters (Figure 3). For only the profiles that had minimum depths above 5 meters, I took the means for oxygen, nitrate, the plankton types, bioluminescence, fluorescence, and latitude and longitude, in the upper 30 meters. So now each profile has one number for each of the variables that represents what those conditions were at the time that profile was taken.

In addition to the measured or proxy variables, I also derived some physical factors, sea surface temperature, thermocline depth, and stratification. Sea surface temperature was derived by taking the mean of the temperature data between 2 meters and 5 meters. Thermocline depth was derived by finding the depth at which there is a 0.8 °C difference in temperature from the temperature at the surface. I defined stratification as the temperature difference between 20 meters and 5 meters. So first, the temperature had to be interpolated to make sure there was a value exactly at 5 meters and 20 meters, and then the temperature at 20 meters was subtracted from the temperature at 5 meters. Three more physical variables were decided to be added and these are upwelling, bathymetry, and wind turbulence. The bathymetry data was able to be directly downloaded and the interpolated into the latitude and longitude being used for the other variables. The other two variables come from M1 wind data.

Upwelling is found by using the equation: $Ektrans = \frac{stressparallel}{rho*f}$ where $stressparallel$ is the wind stress parallel to shore based off of wind speed, rho is a variable equal to the density of water (1025 $\frac{kg}{m^3}$), $f = 2\Omega \sin latitude$ (where latitude is equal to the latitude of M1 which is 36.7470 N). Finally, for each day a value for Ektrans is given, which is then turned into the upwelling variable by finding the mean of Ektrans every 4 days with a 3 day lag, so the data for Ektrans every seven days would be subtracted from the data every 3 days. This is due to the idea that plankton would not be effected by upwelling every day, it would take a much longer time scale of upwelling to created whole community effects. After upwelling, wind turbulence was calculated by simply cubing the wind speed.

After all of the variables were calculated, I established plankton type dominance in each of the profiles. To do this I compared the each of the plankton type's means. If the mean of the diatoms was greater than 1.1 times the mean of autotrophic dinoflagellates, greater than 1.1 times the mean of the hetertrophic dinoflagellates and the mean fluorescence for that profile was greater than a set calibration number representing low biomass, then that profile was diatom dominated. Therefore, the profiles could be classified as either being dominated by one of the plankton types, having low biomass, or having no dominance (Figure 4)

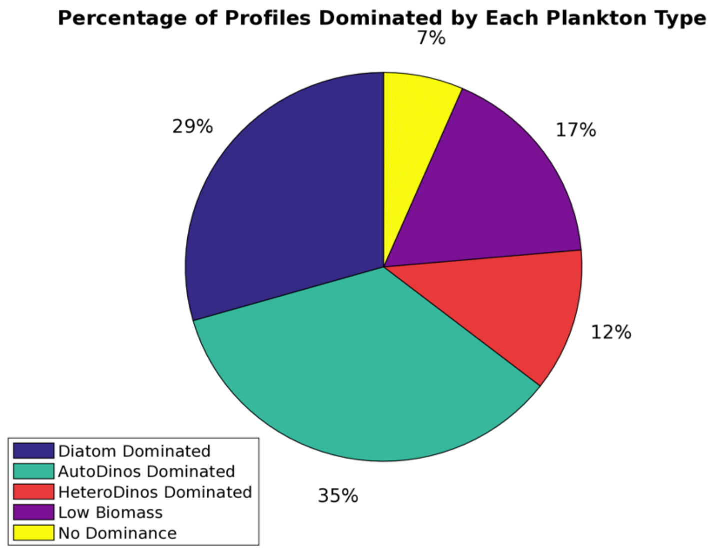

Figure 4. Pie chart showing the percentage of profiles classified by each field.

I could do this for all three plankton types and for all the profiles and then each of the variables could be separated based on which profile was dominated by which plankton type.

Results

Stratification

First, it was found that there were more profiles dominated by diatoms compared to the other plankton types when there was no stratification, and there were more profiles dominated by autotrophic dinoflagellates when there was stratification.

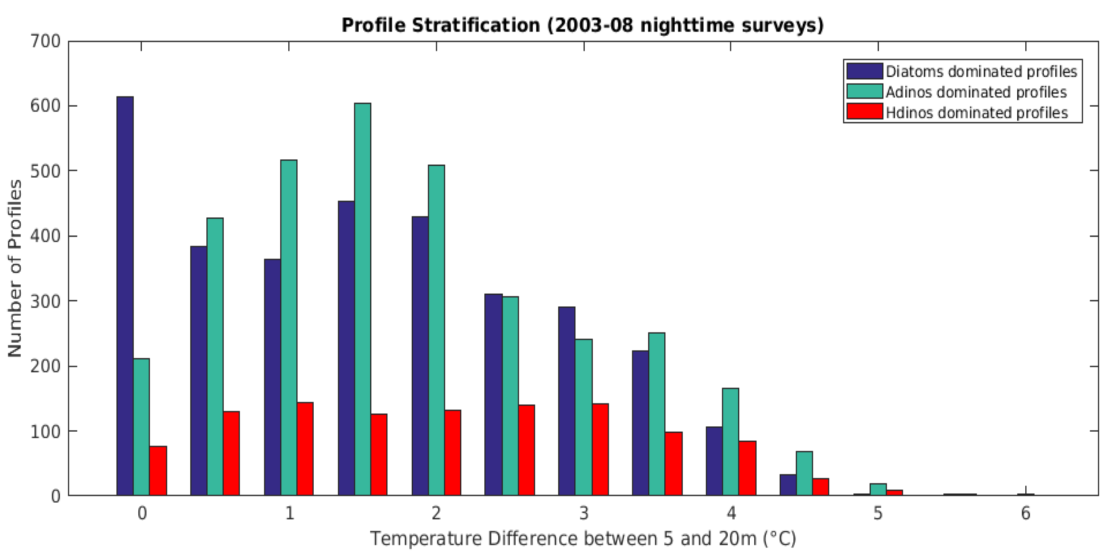

Figure 5. Histogram of stratification separated by plankton type dominance showing how many profiles are described by each stratification bin.

The number of profiles dominated by autotrophic dinoflagellates seemed to peak between 1 and 2 °C temperature differences and the number of profiles began to decrease on either side of these values (This suggests that around a 1.5 °C temperature stratification is optimal for autotrophic dinoflagellates.). There was no correlation between heterotrophic dinoflagellate dominance and stratification. After this, the histogram (Figure 5) was divided even further so that each bar revealed what the proxy values separated by percentiles were in each profile.

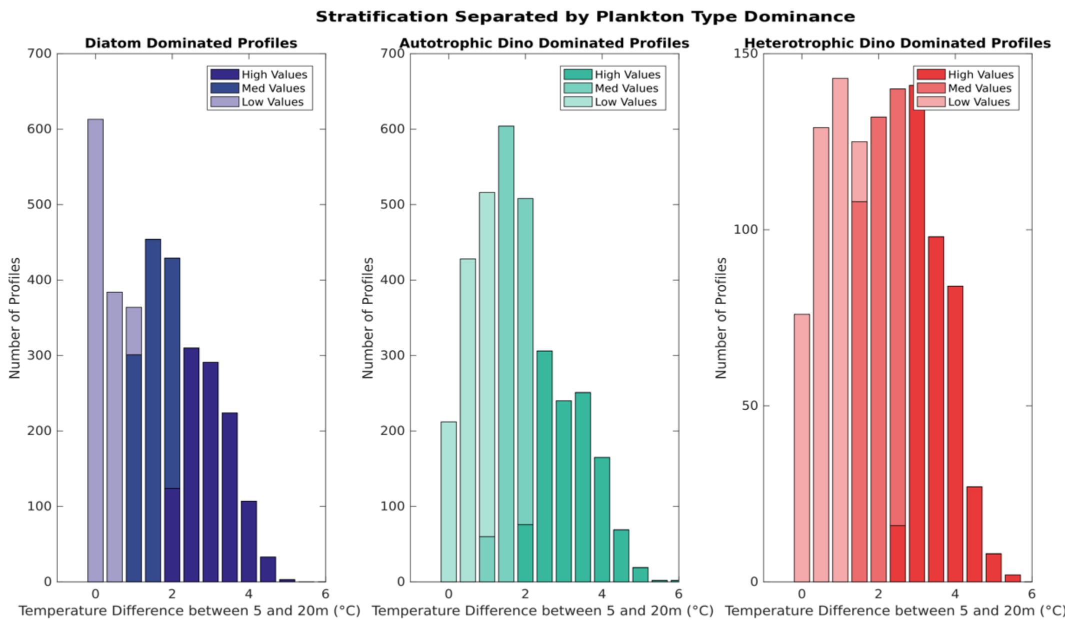

Figure 6. Stratification separated by profiles dominated by plankton type showing the actual proxy values by percentiles.

What we find (Figure 6) is that when the values are separated into percentiles so that they can be classified as either low, medium, or high values, the profiles that are account for when the stratification was low were made up of all low proxy values, and the profiles that account or when the stratification was high were made up of all high proxy values. (This makes it seem as though all three of the plankton types prefer when the stratification is high, or maybe the high stratification is correlated with more favorable growth conditions.)

Wind Turbulence

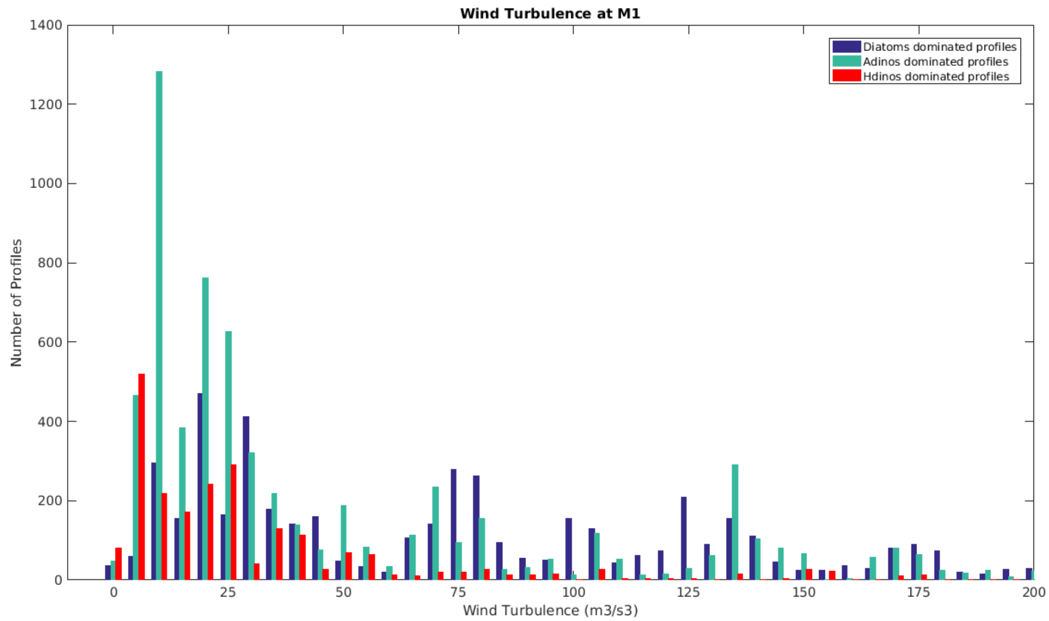

Figure 7. Number of profiles accounted for in each wind turbulence bin, separated by plankton types.

When looking at the wind turbulence (Figure 7), it is not obvious but there are more profiles considered to be autotrophic dinoflagellate dominated when wind turbulence is weaker compared to the diatoms who have a larger range of wind turbulences at which they dominate at. The heterotrophic dinoflagellates also seem to dominate more at lower wind turbulences.

Bathymetry

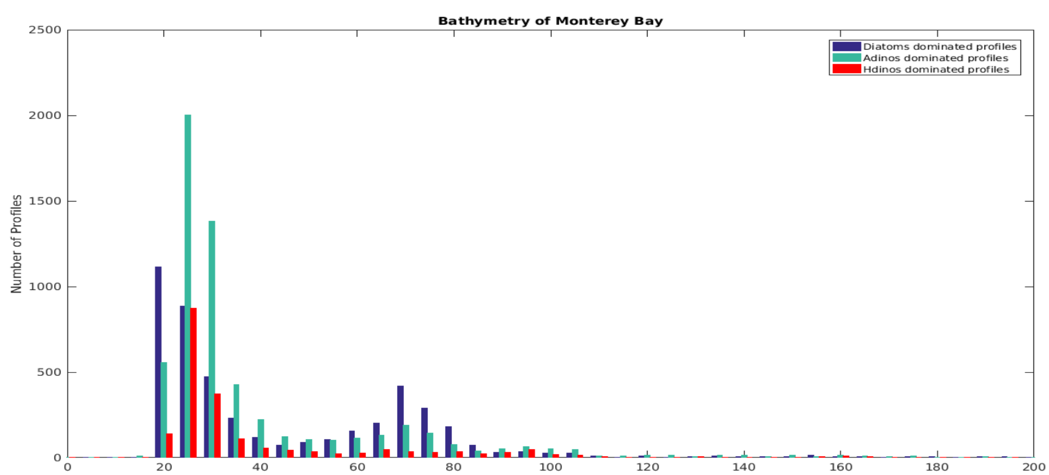

Figure 8. Number of profiles in each bin of bathymetry measurements separated by plankton type dominance.

The depth of the water column had no real defining differences affecting plankton type dominance, however one can see (Figure 8) four different peaks. One peak is a large dominance on diatoms in shallow waters around 20 meters, another is the dominance of diatoms around 70 meters and then the last two are the autotrophic dinoflagellate dominances, and the heterotrophic dinoflagellate dominances, around 25-30 meters.

Time

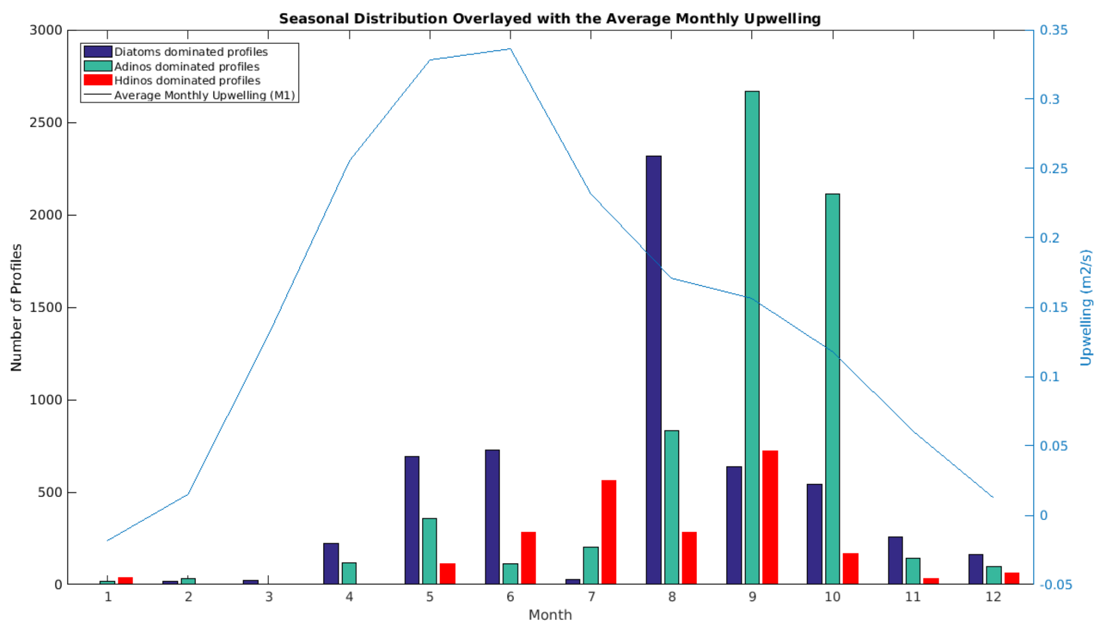

Figure 9. Seasonal distribution of plankton type dominance with the average monthly upwelling overlaid.

For time, it seems as though the autotrophic dinoflagellates dominate later into the year, as seen (Figure 9) with the two distinct peaks in September and October (months 9 and 10 respectively), and that diatoms dominate earlier in the year. Diatoms also seem to dominated when the upwelling is stronger, whereas the autotrophic dinoflagellates dominate when the upwelling is weaker. (However, because of the sampling effort, no conclusion based on time of the year can be made because a majority of the samples were taken in the same three month period which could explain why there are so many diatoms in August when they are thought to be more in Spring.

Thermocline Depth

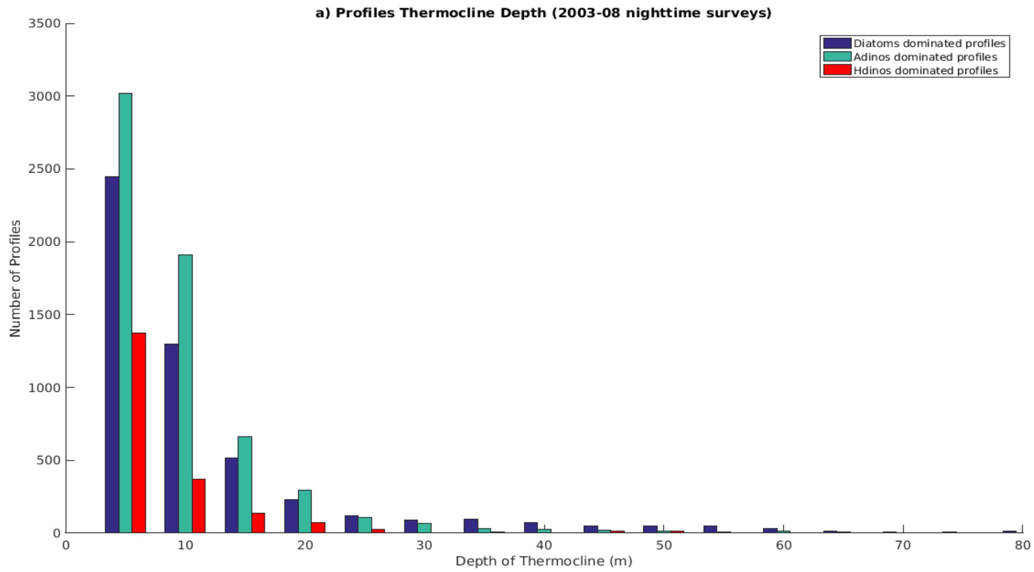

Figure 10. Number of profiles for each thermocline depth bin separated by plankton type dominance.

All three plankton types followed a similar pattern for the depths of the thermocline (Figure 10) where there are a lot more profiles when the thermocline is shallow and then the amount of profiles in each bin decreases as the thermocline depth gets deeper until it is only the diatoms that have dominating profiles.

Oxygen and Nitrate

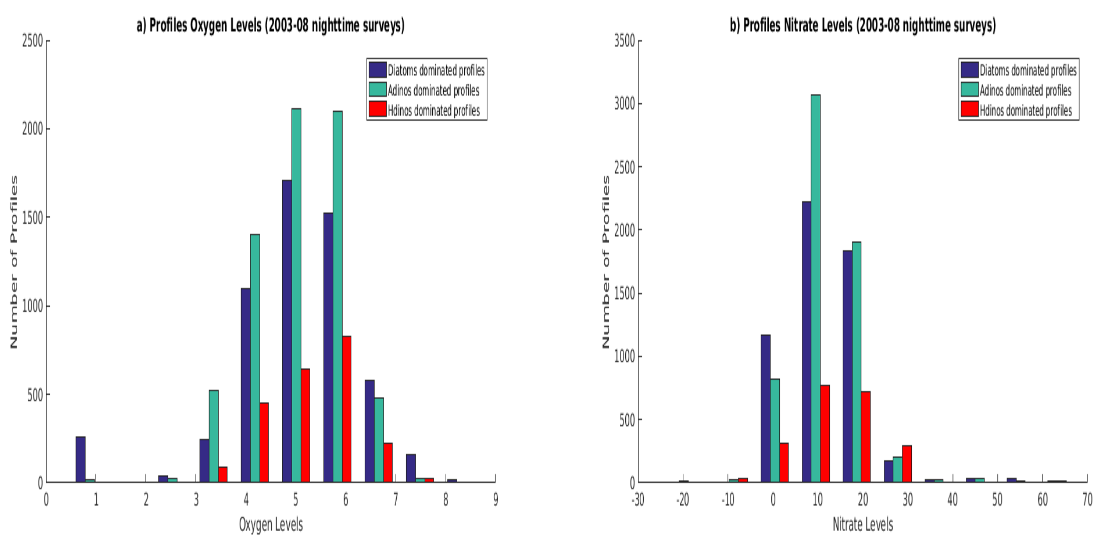

Figure 11. Number of profiles in each oxygen and nitrate value bin separated by plankton type dominance.

There was no conclusion able to be made for oxygen or nitrate. For oxygen (Figure 11a.), it looks like each plankton type has a different peak oxygen it dominates at, however the range is so similar, no specific values can be drawn out and used as a conclusion for promoting dominance. The nitrate levels (Figure 11b.) held no conclusion either.

Sea Surface Temperature

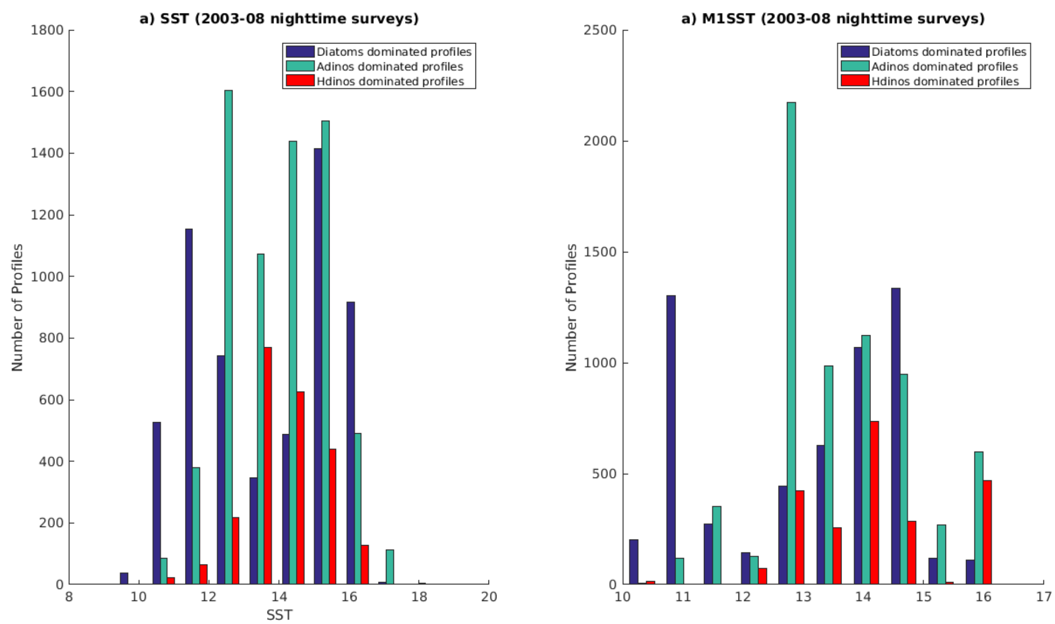

Figure 12. Number of profiles associated with each SST bin ranges separated by plankton type dominance.

There was no relationship between plankton type dominance and either SST derived from the AUV Dorado or SST recorded at M1 (Figure 12).

Area in the Bay

There was also no relationship between the area of the bay and the plankton type dominance. (See Appendix for more information)

Discussion

The only meaningful data that was able to be gathered was stratification, bathymetry, and wind turbulence. The original hypotheses again were that there would be a correlation between plankton type dominance and space (in the Bay) and time (of year). However, both of these turned out to bare no conclusions. This could possibly be due to the sampling effort. Since there was so much data taken in the months of August, September, and October (Figure 2), the data set is missing out on another valuable time period for plankton: Spring. Diatoms are seen to bloom more in springtime whereas autotrophic dinoflagellates bloom in the autumn (Edwards & Richardson 2004). If this is true, and the data does suggest that it is (Figure 9), then there would be a significant chunk of diatom dominated profiles missing from the overall calculation. The stratification followed the hypothesis that dinoflagellates would prefer more stratified waters which stems from one such paper (Cushing 1989) describing how the ratio of respiration to maximal photosynthesis predicts how well diatoms and dinoflagellates respond to stratified waters. Since this ratio is low in diatoms, meaning the maximal photosynthesis is greater than the respiration, they can survive in weakly stratified waters, however this same ratio is almost three times as high in autotrophic dinoflagellates meaning they need strongly stratified waters. This would also assumingly coordinate with upwelling and wind turbulence. Since strong upwelling promotes less stratification, it would make sense that if diatoms prefer less stratification then they would also prefer stronger upwelling. This however was not seen on a direct plankton type dominance comparison; this was only see in the overlay of the average monthly upwelling over the seasonal distribution (Figure 9). This could again, be likely attributed to the sampling effort (Figure 2).

In addition, there was a strong correlation between low wind turbulence and the domination of autotrophic dinoflagellates. Autotrophic dinoflagellates have flagella, which is like a tail that allows them to maneuver through the water column searching for light, nutrients, or food. This tail is also what makes less wind turbulence more preferable. This tale is of evolutionary important because it allows them to actively move to find the resources they need. However, when there is a lot of turbulence this trait because null since they would not be able to move against any ocean currents (Margalef 1978). So then naturally, they would prefer when there is no turbulence and thus they can move freely. Another paper (Richlen &Lobel 2011) found that total dinoflagellate abundance, depending on species, was determined by water motion, and that 4 different species showed a negative correlation with water motion. This means that as there is an increase in water motion, there is a decrease in dinoflagellate abundance.

It was interesting, however, to find that there were a markable number of profiles dominated by diatoms at a depth shallower than the autotrophic dinoflagellates because usually it is understood that the dinoflagellates are closer to the surface than diatoms, since diatoms are pelagic dwellers and dinoflagellates are more surface dwellers. There was a peak deeper in the water column more usual of what is thought of diatoms, however the relative number of profiles compared to the surface peak was small. One idea would be that this is during an upwelling time period so therefore the plankton would be moved up in the water column with the movement of the water, however since most of the data was collected during the autumn months this would not be probable. Upon closer reading of literature, I found that dinoflagellates are known to migrate vertically to deeper waters to access more nutrients at night (Hasle 1950). All of this data is based off of nighttime data collections because the fluorescence and bioluminescence needed to be utilized to find the proxy values for the phytoplankton types. Therefore, if these were only night dives then it would be possible that what is being collected are dinoflagellates moving into deeper waters for the night.

It was not surprising to note that there was no real relationship between oxygen and nitrate values because all three plankton types need the same criteria and the only real difference would be if one type could handle deplete oxygen or deplete nutrient conditions better than the other type, but that would require large amounts of data during times of these conditions to compare to normal conditions. Also, it was interesting that thermocline depth held no relationship to plankton dominance because I would have thought that a deeper thermocline depth would have correlated to less stratification and a shallower thermocline depth would have translated into greater stratification based off how both of them are calculated by temperature. This however was not the case and is probably due to the fact that thermocline and stratification are not the same thing and more goes into both of their physics then just temperature.

While I was not expecting for there to be a big difference between domination based on location in the Bay I had thought that maybe there were locations that were preferable to some plankton types. However, this was not the case. It seems even more like this would be likely since diatoms prefer stronger upwelling, then they would be more focused in the Northern part of the bay (Graham & Largier 1997), however because the sampling effort was so focused on the northern part of the Bay then if this were the case it would show a marked dominance of diatoms, however there were actually more autotrophic dinoflagellates in the Bay as a whole (Figure 3).

Conclusion/Recommendations

In conclusion, while there was data supporting the idea that autotrophic dinoflagellatess prefer stratified waters and dominate later into the year, there is not enough evidence to conclude whether other physical factors have an effect on plankton type dominance in the Bay. If I could spend more time on this project then I would look into figuring out a way to be able to compare the data over the entire dataset, and look for trends in longer time periods, and for there to be more surveys in other months rather than just a focus on the Autumn months.

Acknowledgements

I would like to thank, first and fore mostly, my amazing mentor Monique Messié who has been integral to my internship and to this project. She has helped me learn so much about the job and about programming and I am amazed each time of think about how much I got out of this internship. I would like to thank Severiné Martini for her advice and help along the way. Also, I would like to give a huge shout out George Matsumoto and Linda Kuhnz for helping us interns out and being great mentors. The whole of MBARI Staff have been so amazing, kind, and helpful. I can never see another job meeting these standards. Finally, shout out to my fellow interns who have been a seriously amazing group of people who I am so glad to have gotten the change to meet.

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