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How the Presence of Plastic in the North Pacific Gyre Affects the Growth of Thalassiosira through Remote Sensing and Laboratory Replication

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How the Presence of Plastic in the North Pacific Gyre Affects the Growth of *Thalassiosira* through Remote Sensing and Laboratory Replication

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Introduction

In the Pacific Ocean, the trash has largely accumulated in the North Pacific Gyre, also called the Pacific Garbage Patch (Derraik, 2002). The North Pacific Gyre is located at 140˚ E-120˚ W, 5-45˚ N, northwest of the Hawaiian Islands (Suga, 2008). This patch has had negative effects on the habitats, as seen through the research of organisms in the area (Goldstein, 2012).

Through the use of remote sensing, we are able to determine the approximate location of the garbage patch in the North Pacific Gyre (Figure 1). Monthly satellite images can be analyzed to determine the rate of growth or rate of decrease of certain parameters, such as atmospheric gases, chlorophyll a content, and dissolved organic matter (Aker and Leptoukh, 2007). Over the past decade, remote sensing data from the Goddard Earth Sciences Data and Information Services Center (Giovanni program) has shown a significant presence of summer chlorophyll a content and subsequent algae concentration in the North Pacific Gyre (Villareal, et al., 2012).

The research conducted studied the effects of plastic on algae growth, focusing on *Thalassiosira spp.*, which are a photosynthetic diatom found in the North Pacific Gyre. It is hypothesized that algae concentrations will be higher in regions with more plastic as there would be no competition for nutrients and more access to substrates near the ocean's surface.

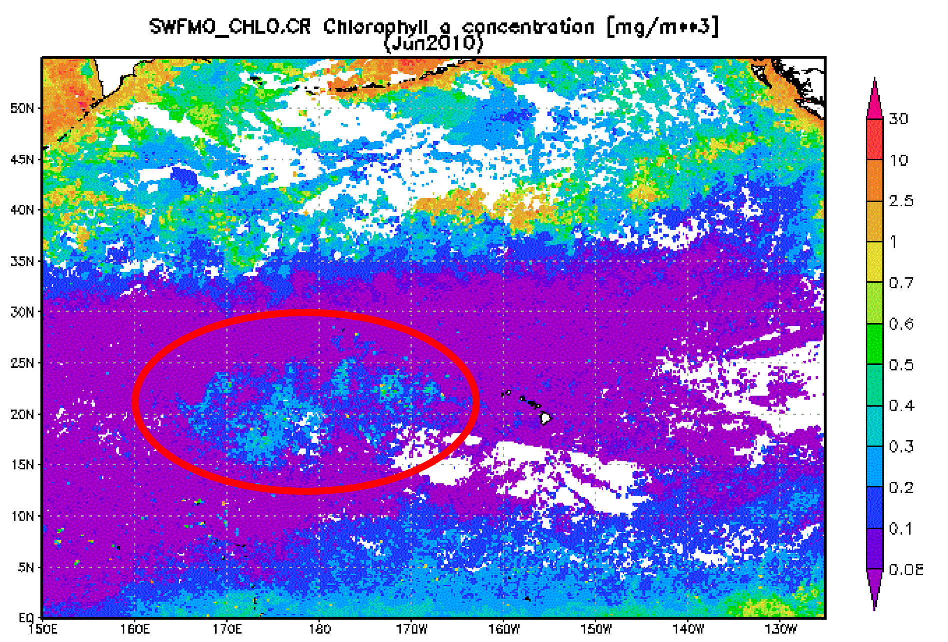


Figure 1: The concentration of chlorophyll a is substantially larger in the area of the Pacific Garbage Patch and the North Pacific Gyre than its surrounding area.

Methods

The experiment took place in 6- 100 ml beakers at $27^{o}C$, with a salinity of 36 ppm. One contained *Thalassiosira* as well as plastic, under UV light (Beaker A). One contained the diatoms without plastic under UV light (Beaker C). Another contained the plastic, the diatoms, but no UV light (Beaker D). One contained only the diatoms under dark conditions (Beaker B). There were 2 more beakers, each with only salt water. One was exposed to UV light (Beaker E) and the other was not (Beaker F). These were used to determine if any substance has access to the beakers and may disrupt the experiment. All of the beakers were covered and had holes to allow gas exchange.

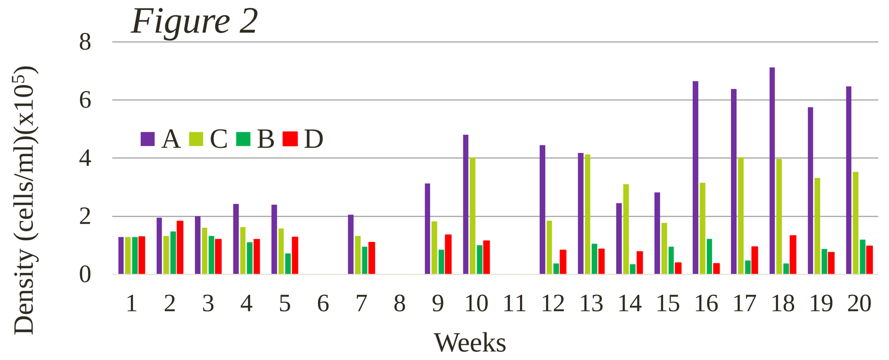
The plastic added was cut into small strips, no more than a centimeter in length and width. This plastic came from plastic bags, which contain polyethylene. 20 of these plastic pieces were added to the two plastic-containing beakers.

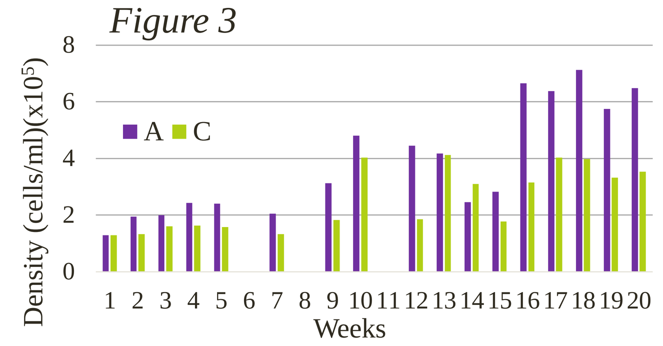
To calculate the concentration of algae, samples were taken from each beaker to determine the starting number of cells in each beaker. The concentration of viable *Thalassiosira* was calculated by using a hemocytometer and trypan blue. 25 µl of trypan blue was added to 100 µl of the diatoms, and mixed carefully. This was then be pipetted into a hemocytometer, which was used to count the number of cells per milliliter. The trypan blue dyed any cells that were not living. Eventually the concentration of viable cells were calculated.

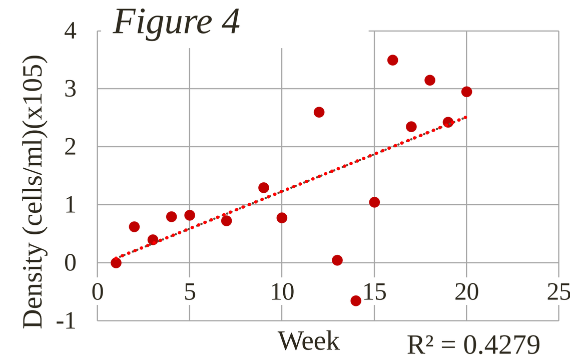
Over the 20 week period, the diatoms were checked on, and water levels were maintained. The diatoms grew over the course of 20 weeks, with algae levels calculated once every week to two weeks. The rates of increase were compared between Beakers A and C as well as Beakers B and D. Only comparisons were made, as there was not enough data collected to perform statistical analysis.

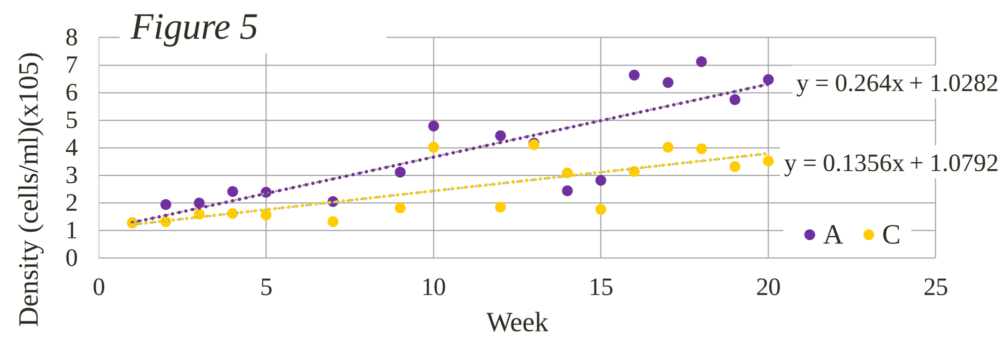
Remote sensing data was collected from the SeaWiFS satellite using the Giovanni Program. This data was used to compare the chlorophyll a content over specific seasons and time periods and used as additional comparison of algal density in the North Pacific Gyre over 10 years.

Results









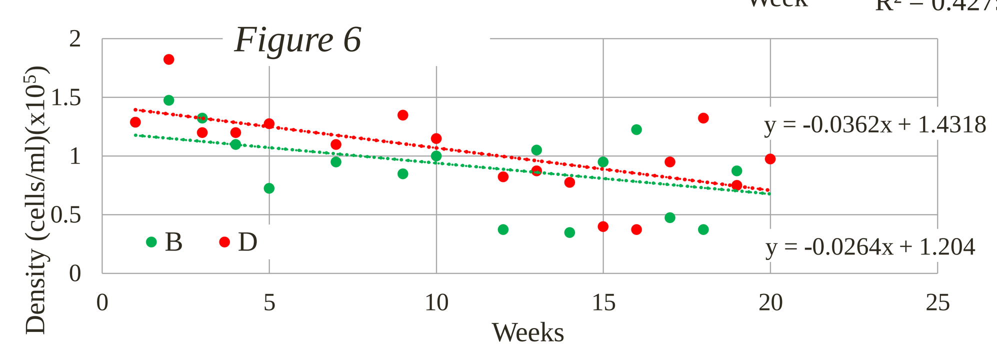


Figure 2: Average cell density (cells/ml x10^5) under four conditions- A: UV light with plastic; B: No UV light, no plastic; C: UV light, no plastic; D: No UV light, plastic. Algae cells were counted in five out of the nine boxes (1 mm^2) and averaged.
Figure 3: Average density of algae cells (cells/ml x10^5) under UV light (Beakers A and C) compared over 20 weeks.
Figure 4: The density (cells/ml x10^5) of Beaker C subtracted from Beaker A over 20 weeks.
Figure 5: The rate of increase of algae cell density (cells/ml x10^5) for Beakers A and C (under UV light) 20 weeks. The rate of increase for Beaker A is 0.264 cells/ml x10^5/week, and the rate of increase for Beaker C is 0.1356 cells/ml x10^5/week.
Figure 6: The rate of decrease of algae cell density (cells/ml x10^5) for Beakers B and D (no UV light) over 20 weeks. The rate of decrease for Beaker B is -0.0264 cells/ml x10^5/week, and the rate of decrease for Beaker D is -0.0362 cells/ml x10^5/week.

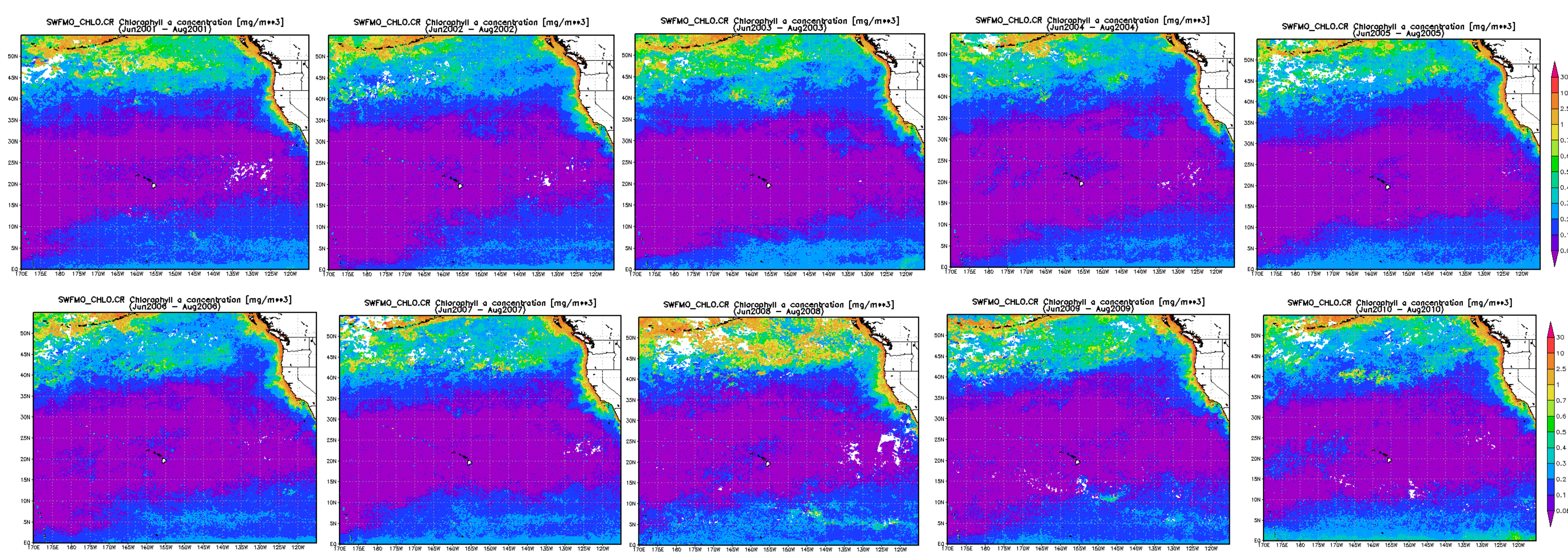


Figure 7: Chlorophyll a content measured from SeaWiFS from June-August, 1999 to 2010 (Giovanni Program).

The general observation was that the algal density under UV light in Beakers A and C was greater than under no UV light in Beakers B and D (Figure 2). Also, it was observed that there was no algae or any type of phytoplankton present in the two control beakers, Beakers E and F. Beaker A had the greatest algal density than any other beaker in every week except Week 14.

When comparing Beakers A and C, it was shown that the algal density in Beaker A was greater than the algal density in Beaker C, with the exception of Week 14 (Figure 3). Also, the difference between the algal density in Beakers A and C generally increased as the weeks progressed (Figure 4).

Algal density was shown to increase over the 20 week period for Beakers A and C as they were under UV light. The rate of increase of the algal density was greater in Beaker A than it was in Beaker B with the exception of a couple outliers observed in Weeks 13 and 14 (Figure 5).

The algal density in Beakers B and D seemed to decrease over the 20 week period. The rate of decrease was slightly greater for Beaker D than for Beaker B (Figure 6).

Through remote sensing, it is difficult, and we are unable to determine whether the chlorophyll a content has been increasing throughout the past decade as a result of the Pacific Garbage Patch. The chlorophyll a concentration measured throughout from 1999-2010 has varied greatly (Figure 7).

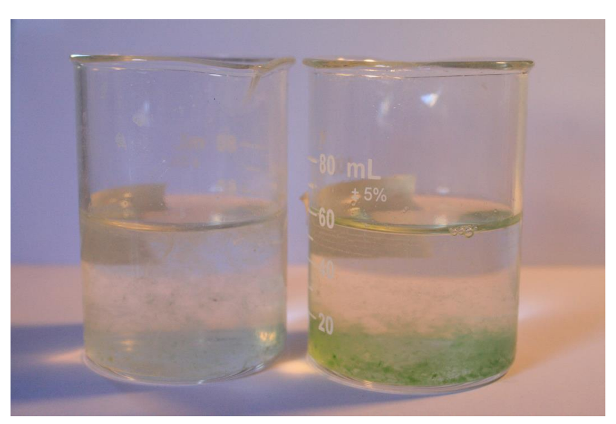


Figure 8: Beaker A is on the left, Beaker B is on the right

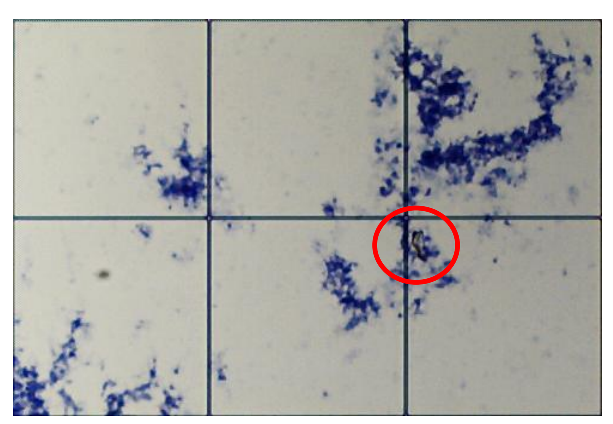


Figure 9: Images of Thalassiosira under a microscope

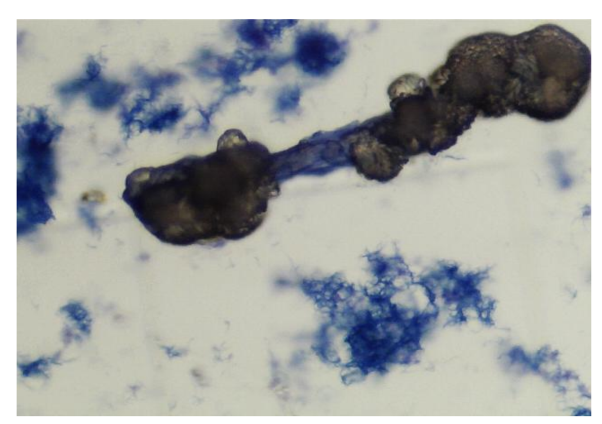


Figure 10: Algae under a microscope attached to a piece of plastic

Discussion

Throughout the 20 week period that this experiment took place, it was generally noted that the concentration of *Thalassiosira* increased at a greater rate with the presence of plastic and UV light than at any other condition (Figure 2). The difference in the rate of increase throughout the experiment between A and C suggests that algae production was slower when plastic was not present (Figure 4). There were several data points between Weeks 13 and 15 that showed a decrease in the algal density in both Beakers A and C. There were no external conditions known that would have caused this. Statistical analysis was not able to be completed as there were not enough data points. Even though statistical analysis was not available, the observations allowed us to infer that there may have been a positive relationship between the presence of plastic and the amount of algae in a specific area (Figure 5).

We are unable to compare the data observed in Beakers B and D, as the data sets are very close together and fluctuate weekly (Figure 6). Because of this, we could not infer that plastic allowed for a greater algal density in all conditions. Even though this is the case, a lack of UV light decreased algal density whether plastic is present or not because photosynthesis cannot take place (Hoganson and Babcock, 1997). From the data, we could suggest that the presence of plastic did not have any effect on algae if they are not undergoing production. Further studies are needed to determine the cause of this, and whether the rate of decrease in Beaker D is consistently greater than the rate of decrease of Beaker B.

The remote sensing data obtained from the Giovanni Program was not done over a long enough period of time to allow us to infer that there had been a steady increase in the chlorophyll a content with the increase in the Pacific Garbage Patch (Figure 7). The Pacific Garbage Patch was predicted and observed by the NOAA between 1985 and 1988, but had been observed as early as 1970 (Day, Shaw, and Ignell, 1988). If data is able to be collected from this time, we could better study a correlation between the plastic and chlorophyll a content in the North Pacific Gyre.

Though it was observed that algae is denser in normal oceanic conditions with plastic, it was not necessarily as healthy. The algae under UV light without plastic was much greener in color than the algae under UV light with plastic (Figure 8). The chlorophyll content may have decreased as a result of the plastic, even though algal density was increasing. If this was the case, then the increase in algal density seen through the remote sensing images may have been understated. It was unknown as to if and why a decrease in chlorophyll content occurred. The algae was hardly visible in Beakers B and D as there was a decrease in algal density. There was no difference observed in the color between these two beakers. Further studies will be needed show why algae exposed plastic were not as green as algae that was not exposed to plastic.

In the future, more data points will need to be collected to allow for statistical analysis. The outliers in Weeks 13 and 14 partially skew the data and the regression line in Figure 4. If this observation were to span an entire year with data being taken daily, outliers would not have as large of an effect on the overall outcome as they did in this experiment.

Conclusion

While statistical analysis was not used, it is important to use this data as stepping stone toward future studies in this topic. As the primary producers in their community, diatoms play an important role in the interactions between trophic levels. Questions as to why the density of *Thalassiosira spp.* increased with plastic should be sought out. Also, a replication of this experiment that includes upwelling, nutrients, and temperature changes in the North Pacific Gyre can be done to further investigate the increase of algae in this area. A lack of competition due to a decrease of nutrients may have also caused an increase in the algae blooms. Competition between trophic levels will need to be examined to show how different organisms affect the algae in the North Pacific Gyre. Lastly, Climate Change and temperature increases in the ocean may also play a role in algal density. Future research will need to be done to successfully determine the role that plastic and other factors play in algae density.

Acknowledgments

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Thalassiosira spp. were obtained from Carolina Biological Supply.