Hunger in the Ocean: The Decline of Phytoplankton in the North Pacific

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Diatoms, the most abundant type of phytoplankton, have experienced a significant decrease throughout the last decade. This is linked to a decline on the availability of nutrients, explained by a decrease in the flow of the mixed layer, (the layer where diatoms reside). Nutrients such as silicate, phosphate, and iron that are normally upwelled from the ocean floor to the mixed layer, nevertheless nutrients are not reaching it. From this, the following question arose: How has climate change affected the concentration of phytoplankton in the North Pacific between 1998-2012, and how has this decrease in the amount of phytoplankton put the total primary production of the ecosystem of the area at risk?

CONCERNING FIGURES

By relating this declining trend in the North Pacific with physical oceanic conditions, it was concluded that the shallow of the mixed layer depth (MLD), and the increase in the photosynthetically available radiation (PAR), as a result of the climate variability, (Figure 1) are determinant factors in the availability of essential nutrients for diatoms.

Figure 1: Percent Change per Year in the Physical Conditions, Nutrients, and Phytoplankton Composition

Analyzing the data displayed in figure 1 it is important to note that diatoms percentage change per year since 1998 has been one of the highest in the northern hemisphere, curiously the percentage change per year of the Mixed Layer Depth (MLD) is the same as the value for diatom's concentration. (Figure 2 corroborates this). In addition it can also be noticed an increase in the Photosynthetically available radiation (PAR) associated with an increase in temperature that started in 2008. In the same way by comparing the images displayed in figure 2 the change in diatom concentration is evident as from 1998 to 2012 the concentration changed from 0.75 mg/m3 to 0.25mg/m3 (from green to light blue).

Figure 2: Satellite of images from SeaWiFS and MODIS Terra missions showing phytoplankton concentration of march 1998 and march 2012 in the North Pacific.

Subsequently, the same timeframe was studied for chlorophyll a concentration. (Figure 3 corroborates this). In addition it can also be noticed an increase in the Photosynthetically available radiation (PAR) associated with an increase in temperature that started in 2008. In the same way by comparing the images displayed in figure 2 the change in diatom concentration is evident as from 1998 to 2012 the concentration changed from 0.75 mg/m3 to 0.25mg/m3 (from green to light blue).

Figure 3: Graph of local zones where mixed layer has shallowed.

MIXED LAYER DEPTH IN RELATION TO CLIMATE CHANGE AND PACIFIC DECADAL OSCILLATION

Mixed Layer Depth (MLD) and thermal flux (the rate of heat energy transfer through a given surface, per unit time) have an inverse relationship. Therefore, with a significant increase in temperature, MLD becomes shallower. While the reasons for the decrease of the MLD in the northern latitudes of the Atlantic and Pacific Oceans remain unclear, one hypothesis is that it could be related to the strong asymmetry in the transient response of air temperature to increasing CO₂, with the Northern Hemisphere warming up slightly faster than the Southern Hemisphere 1 (Meek et al., 2007). This hypothesis makes human responsibility due to the increasing CO₂ emissions in the atmosphere.

Figure 4: Mixed Layer Depth vs. Temperature

Another hypothesis is that these trends may be directly related to larger climate oscillation such as the Pacific Decadal Oscillation (PDO) and the North Atlantic Oscillation (NAO). The PDO is a climate oscillation that is based on the variation of North Pacific sea surface temperature, and in the north Atlantic has oscillations of 0°C-30°C. 2 (Mantua et al., 1997). In the late 1990’s, the PDO entered a cold phase that only lasted for 4 years and was followed by a warm phase that lasted for 3 years before switching again to a cold phase after 2003 (W. Gregg et al., 2007). The diatom declines reported here are mostly found in the western and central portion of the North Pacific, where MLD temperature increases, consistent with the phases of the cold phase. There have been several reports that the PDO and NA0 have a decadal variability in phytoplankton (using total chlorophyll) as well as the wind and magnitude of the blooms. (W. Gregg & C. Rousseaux).

DIATOMS AND THE NORTH PACIFIC ECOSYSTEM

Globally, diatoms contribute to ~50% of Oceanic Biomass Production of which, 86% is synthesize in the North Pacific. This certainly evidences importance of diatoms in both, the local North Pacific ecosystem and the entire ocean. In order to understand the way the local ecosystem be affected by the diatoms’ decline, Abiotic and biotic functions of diatoms within the ecosystem must be mentioned.

Abiotic Factors:

Marine phytoplankton helps to establish the ratio of nutrients such as nitrogen and phosphorous in the deep sea layer, as they release nitrogen and phosphorous to the environment in a ratio of 16:1. Scientists who model the carbon cycle have established the importance of marine nitrogen fixation as a fundamental biogeochemical process that is linked to the carbon cycle (the flow of carbon through ecosystems).

Additionally, apart from establishing nutrient ratios and fixation for the carbon cycle, phytoplankton also plays a fundamental role in it as the primary producer of the ocean. However, in the last 15 years due to climate change, primary net production has declined in the north pacific latitudes. Ocean changes in phytoplankton and chlorophyll are responsible for more than 50% of the decline of the net primary production.

The most important contribution of diatoms to the ecosystem, in the abiotic aspect, is their ability to absorb the carbon dioxide from the atmosphere and store it for millions of years when they die and sink, acting as a carbon dioxide regulator in the ocean. Nevertheless, as diatoms decline less carbon dioxide will be driven out of the atmosphere, thus contributing to global warming.

Biotic Factors:

Phytoplankton communities show different responses to climate variability throughout the years. In this sense, the ecosystem is significantly influenced by climate changes. Phytoplankton plays a very important role in regards to the flow of energy in its ecosystem as it is a primary producer, meaning that is the base of the food chain. Its importance relies on the fact that if the number of phytoplankton is reduced, primary consumers would be negatively affected due to the fact that their source of energy would decrease and consequently, primary consumers would die. As it is a chain, other trophic levels would also be affected leading in some cases to extinction of specific species that might be part of primary, secondary, tertiary or quaternary consumers.

FURTHER STUDIES AND CONSERVATION

The next step towards the understanding of the planktonic trends rely on further studies using new satellite a sensor technology such as the Pre-Aerosol, Clouds, and ocean Ecosystems (PACE) in order to reduce the uncertainties in planktonic distribution and concentration. Thus, there will be more a precise and accurate data to determine with certainty how and what factors of the climatic change can represent a threat to plankton not only in the North Pacific but on a global scale.

REFERENCES

W. Gregg & C. Rousseaux, "Recent decadal trends in global phytoplankton composition", AGU publications, vol. 29, Sep. 2015. Contained references 1.2.3, Figure 1
Mantua et al., "Weather and climate effects on the Pacific Decadal Oscillation (PDO) and the North Atlantic Oscillation (NAO)", J. Clim. 14, 2001-2012
AGU, "MIXED LAYER DEPTH IN RELATION TO CLIMATE CHANGE", http://www.agu.org/pubs/c持平?aid=11934
Figure 3: http://www.agu.org/pubs/c持平?aid=11934
Figure 4: http://www.agu.org/pubs/c持平?aid=11934
Background: http://www.giss.nasa.gov/ cgi-bin/datalog.cgi?aid=11934