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Correlation Between Ocean Acidification and Zooplankton in the South Pacific Gyre

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Abstract

The South Pacific Gyre is a naturally occurring carbon sink, meaning that it absorbs atmospheric carbon dioxide by dissolving it into the moving surface water.The dissolution of CO2 level will dictate the water's acidic levels a larger the concentration of dissolved CO2 is known to increase the salt water's acidity. A great amount of the ocean's biomass is composed of calcifying organisms,which produce tests or shells made from calcium carbonate CaCO3.The goal of our project is to determine if there is a correlation between the water acidity across various locations, as we sailed through the South Pacific gyre and the biomass and/or biodiversity in those same locations. By studying the connection between zooplankton and acidification will allow for a better understanding of the ocean environment as acidification continues to increase. We conduct nine nighttime and twelve daytime collections which indicated no statistical significance. Our research along the S-282 cruise track was unable to find any positive or negative correlations between pH levels and zooplankton density.

Keywords

South Pacific, Zooplankton, Biodiversity, Carbon sink

Correlation Between Ocean Acidification and Zooplankton in the South Pacific Gyre

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Abstract

The South Pacific Gyre is a naturally occurring carbon sink, meaning that it absorbs atmospheric carbon dioxide by dissolving it into the moving surface water.The dissolution of CO_2 level will dictate the water's acidic levels a larger the concentration of dissolved CO_2 is known to increase the salt water's acidity. A great amount of the ocean's biomass is composed of calcifying organisms,which produce tests or shells made from calcium carbonate $CaCO_3$.The goal of our project is to determine if there is a correlation between the water acidity across various locations, as we sailed through the South Pacific gyre and the biomass and/or biodiversity in those same locations. By studying the connection between zooplankton and acidification will allow for a better understanding of the ocean environment as acidification continues to increase. We conduct nine nighttime and twelve daytime collections which indicated no statistical significance. Our research along the S-282 cruise track was unable to find any positive or negative correlations between pH levels and zooplankton density.

1 INTRODUCTION

The man-made production of greenhouse gases (i.e. carbon dioxide) is well established in scientific literature as the link to a sharp increase in surface temperature over the past 200 years. Beginning with the Industrial Revolution, the concentration of CO_2 in the atmosphere increased from 280ppm to 390ppm[1]. The term anthropogenic carbon (C_{Anth}) refers to carbon emissions that are created by human activities. The Pacific Ocean is known to be a substantial C_{Anth} sink because it is an area that can absorb the C_{Anth} from the atmosphere as a result of its immense size[2]. The ocean currents in the South Pacific Ocean circulate counterclockwise because of the direction of trade winds and the Coriolis force. The currents act to isolate an area of the Pacific Ocean called the Southern Gyre. The Southern Gyre is known to be the Earth's largest ocean desert because the currents allow for little upwelling of nutrients from deep areas of water columns. There is also very little land or wind in this region, so nutrients are unlikely to drift or be displaced by wind[3]. Thus, the low levels of nutrients in the region result in extremely low primary productivity in the surface ocean. The South Pacific Gyre is a naturally occurring carbon sink, meaning that it absorbs atmospheric carbon dioxide through dissolution on the moving water[4]. The dissolution of CO_2 can change the chemical properties of water.

Figure 1. SSV Robert C Seamans.

A larger concentration of dissolved CO_2 increases its acidity, thus decreasing the pH. Greater acidity can affect the biomass, which is sensitive to environmental changes. A larger concentration of dissolved CO_2 increases its acidity, thus decreasing the pH. Greater acidity can affect the biomass, which is sensitive to environmental changes. For example, increased acidification had a notable negative effect on zooplankton biodiversity and biomass in small freshwater lakes in the Adirondack Mountains[5]. A significant amount of the ocean's biomass is composed of calcifying organisms which produce tests or shells made from calcium carbonate ($CaCO_3$). The

acidification of the oceans has led to decreased calcification rates and therefore weaker shells for organisms that depend on calcium carbonate shells[6]. The impact of increased acidification of the ocean and the incurred weakening of calcium carbonate shells on the biomass and biodiversity is not well understood.

Figure 2. S-282 crew on the head rig of the R.C. Seamans docked in Auckland, NZ.

The purpose of this research is to determine if there is a correlation between the water acidity across various locations within and around the South Pacific gyre and changes to the biomass and/or biodiversity. The S-282 Crew of the SSV Robert C Seamans collected pH, biomass and biodiversity readings along during a journey through the Southern Gyre (Figure 1, Figure 2). Neuston tows are the most common method used for obtaining sea surface samples and were in this study used to evaluate the biomass and biodiversity. Surface samples of the water were collected to profile the chemical properties and characterize the biomass and biodiversity of the region. The pH of the water and 100-counts and bio-volumning of the plankton in the neuston layer were collected. 100-Counts and Biovoluming are techniques used to determine the relative biodiversity and biomass on station. Diel vertical migration causes the bio density in the neuston net to be larger at night than during the day. Therefore, the time of the day at which the neuston tow occurs needs to be controlled. In order to account for any possible discrepancies due to diel vertical migration, we chose to analyze daytime and nighttime measurements from neuston tows separately.

2 METHODS

Neuston tows were deployed and surface samples collected at twelve different stations during the day at 14:00 (Table 1) and during the night at 02:00 (Table 2). The neuston tow technique utilizes a neuston net, a cod-end jar, a bucket for biomass sample collection, and a bucket for the rinse biomass sample. The net itself has a rectangular pyramid profile with a jar attached to the apex of the net. This is the cod-end jar that the biological samples funneled into, which can be removed for the net for testing. The tow was carried out at a vessel speed of approximately 2 knots and lasting a duration of 30 minutes so that the neuston net was pulled one nautical mile. Once the tow was completed, the neuston net was retrieved and the cod-end jar was emptied into the bucket; the contents is labeled as the pristine sample. Following sample collection, the jar was returned to its position and the net was rinsed from top to bottom to ensure that all biomass was retrieved. All products from the rinse were transferred to the bucket reserved for the rinse biomass sample. A 100-count was conducted to identify the species in the biomass. The pristine sample was strained and observed in a petri dish. The first hundred specimens identified were recorded along with the corresponding time, date, location, and number of specific individual species. All specimens were then returned to the collection. The biomass of the gathered zooplankton was obtained by recording the water displacement when all acquired organisms were added to a graduated cylinder containing water.

Figure 3. A Neuston Tow being conducted portside of the Seamans.

The materials for a surface sample included a metal bucket for collection and a bottle for pH. The collection happened during the same time as the neuston tow in order to uphold accuracy. The bucket was rinsed at least twice with the surface water before the collection took place in order to ensure it did not influence the temperature of the sample and remove any sources of contamination. Upon collection of the surface water, each of the bottles were rinsed with the collected water three times before being filled up. This process was implemented to prevent possible contamination from

Table 1 The bio density, surface pH and Shannon-Weiner Diversity Index (SWDI) for each station during the day.

Station number	Biodensity	Surface pH	SWDI	Latitude	Longitude
S282-001-NT	0.0007	8.183	0.64	15°45.0' S	171°42.0' W
S282-003-NT	0.0011	8.212	0.19	17°21.6'S	173°7.5' W
S282-004-NT	0.0005	8.212	0.26	17°37.0' S	173°43.1' W
S282-005-NT	0.0077	8.205	0.41	18°39.5' S	174°8.9' W
S282-006-NT	0.2259	8.212	0.40	18°38.6' S	174°7.9' W
S282-011-NT	0.0016	8.188	0.58	18°24.0' S	178°41.2' E
S282-015-NT	0.0060	8.302	0.53	19°38.0' S	177°32.5' E
S282-017-NT	0.0203	8.149	0.41	21°3.2' S	176°42.2' E
S282-019-NT	0.0048	8.138	0.71	22°48.0' S	176°2.6' E
S282-021-NT	0.0049	8.328	0.06	24°32.3'S	175°44.8'E
S282-023-NT	0.0026	8.085	0.21	26°14.1' S	175°14.9' E
S282-025-NT	0.0037	8.147	0.30	27°51.0'S	174°38.5' E

Table 2 The bio density, surface pH and Shannon-Weiner Diversity Index (SWDI) for each station during the night.

Station number	Biodensity	Surface pH	SWDI	Latitude	Longitude
S282-002-NT	0.0006	8.217	0.52	16°28.4'S	172°20.4' W
S282-010-NT	0.0063	8.236	0.51	18°51.6'S	179°28.8' E
S282-012-NT	0.0113	8.209	0.62	18°27.6' S	178°23.3' E
S282-014-NT	0.0207	8.172	0.45	18°46.7' S	178°3.3' E
S282-016-NT	0.0115	8.313	0.70	20°21.3' S	177°4.1' E
S282-018-NT	0.0088	8.185	0.63	21°58.5' S	176°28.8' E
S282-020-NT	0.0047	8.129	0.39	23°38.8' S	175°43.9' E
S282-022-NT	0.0143	8.121	0.51	25°25.8' S	175°38.1' E
S282-024-NT	0.0095	8.048	0.55	27°9.8' S	174°38.5' E

past samples collected. The measurement of pH was carried out as soon as possible due to the sensitivity of the sample and its measuring process. It is also important that no air remained trapped in the pH sample, as the dissolution of certain compounds presented in the air may influence the measurement.

A spectrophotometer was used to process the surface sample. The instrument was allowed to equilibrate for at least 30 minutes before use. The spectrophotometer cell was rinsed with 10% HCl and then filled up completely with deionized water to be calibrated. After calibration, the cell was rinsed three consecutive times with water from the sample collected to remove any remaining residue from previous data collection. The cell was then filled with the sample water so that an air bubble no greater than 1.5cm in length remained. The absorbance values at wavelengths 434nm, 578nm and 730nm were recorded. This process was repeated with the sample water after 75 μL of m-cresol purple dye was added. All absorbance values were recorded.

3 RESULTS

Data was collected at twelve stations in the daytime (Table 1) and the nighttime (Table 2). The latitude and longitude of each station was recorded and is indicated below. All the stations indicated a large abundance of copepods. Pteropods and siphonophores were also present, although when one type was abundant the other was not. Chaetognaths and other snails also made appearances. No other organisms were significantly present. Surface pH levels appear to decrease as the latitude increases. During the daytime, the maximum value for the Shannon-Weiner Diversity Index is 0.71 and the minimum value is 0.19. The average value is 0.392. For the samples collected at night, the maximum value is 0.70 and the minimum value is 0.39. The average value is 0.542. Thus, there was a larger extent of biodiversity present at night. The average pH of the water sample for daytime stations was 8.195, and the maximum and minimum were 8.328 and 8.085. The average pH at nighttime stations was 8.181, while the maximum and minimum were 8.313 and 8.048. Therefore, pH values were higher during the day than at night. The relationship between the surface pH values and biological density was modeled using a linear regression for daytime values (Figure 4) and nighttime values (Figure 5). Both fits exhibit a negative slope. Meaning that as the pH increases, the bio density decreases – ultimately contradicting our hypothesis. As our R^2 values are in the order of 1% for both

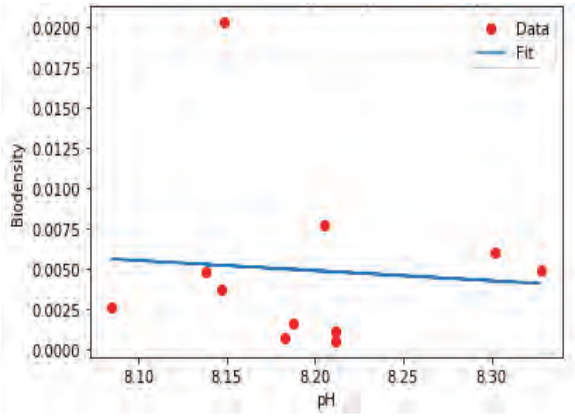

Figure 4. Variation of biodensity with pH values in samples collected during the day (y=(-0.0063)x + 0.06, R^2=0.0062).

relationships, we may conclude that the data collected is not statistically significant to observe a correlation as a linear regression. However, this only shows that the linear model is not adequate, as it is not a formal hypothesis test for the relationship. As the ship moved from

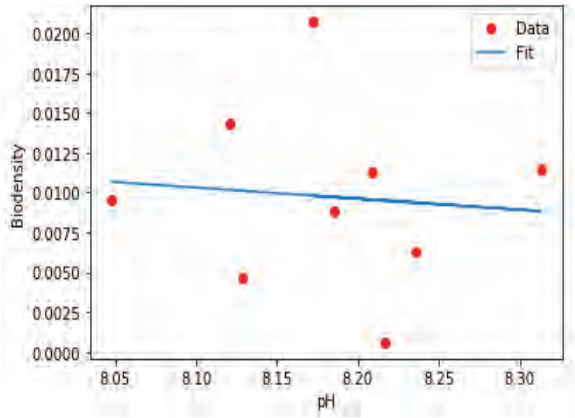

Figure 5. Variation of biodensity with pH values in samples collected during the night (y=(-0.007)x + 0.07, R^2=0.0092).

American Samoa to the Kingdom of Tonga, slight variations in the surface pH levels were observed. The water's basicity increased upon entering the Tonga-Kermadec oceanic ridge, decreasing again as we approached the territory of Fiji. The largest variations occurred as the ship entered the South Pacific gyre, where water acidity increased as the latitude increased in the southern direction. This is as expected, since the South Pacific is known to be an atmospheric CO_2 sink[7]. There are no apparent trends regarding the variation of zooplankton density during the day (Figure 6) and during the night (Figure 7) across the cruise track. Neuston nets were not deployed across the Tonga-Kermadec region due to adverse weather conditions. The island of Vava'u in the Kingdom of Tonga was found to have large patches of

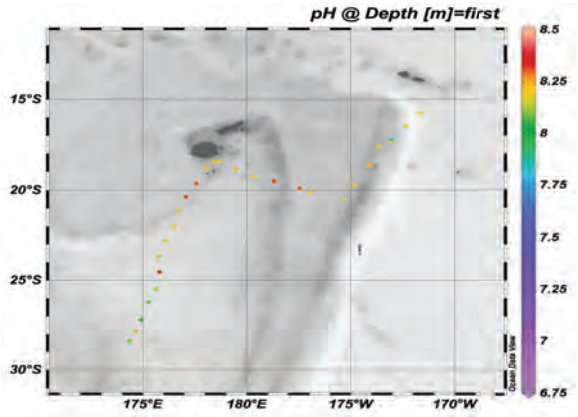

Figure 6. Variation of the surface pH in the S-282 cruise track.

surface water covered by macroalgae which resulted in an inaccurate measurement of zooplankton density.

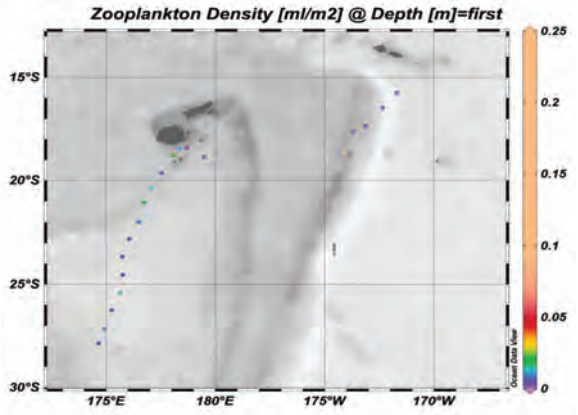

Figure 7. Variation of Zooplankton density in the S-282 cruise track.

4 DISCUSSION

A sequence of surface sampling was performed along the cruise track of the ship in attempts identify if there is a correlation between zooplankton abundance and ocean acidification. If a correlation were to be determined between increasing acidity and decreasing bio density, the stage would be set for future studies to begin diagnosing if the decreasing bio density is the result of the increasing acidity and why. However, the data regarding acidity and bio density of various stations during the night and the day do not indicate that there is a correlation between the values. Surface pH appeared to decrease as the boat moved further south along the cruise track. However, the zooplankton density did not appear to follow a trend. Although we expected to observe a decrease in zooplankton density with lower pH levels, this correlation was not reflected in the data.

Thus, our data did not indicate a positive or negative correlation between pH levels and zooplankton density.

As a result of poor weather conditions, there are gaps in the data collection. Some data points were not collected because of the dangers presented to the ship and crew if the scientific equipment were deployed. The missing data prevents us from analyzing an accurate characterization of the stations. Although it is encouraged that future research aim to fill such data gaps, the reality is that it is unlikely any individual cruise will be able to obtain all the necessary data points to be able to access necessary analysis because the weather and sea state are such unpredictable variables. In the future, data from a variety of cruises should be compiled to increase the number of data points for portions of the trip that frequently encounter bad weather and unexpected events. An example of an unexpected event occurred at station S282-006-NT, where a substantial amount of macroalgae was obtained with the collection. This affected the measurement of the zooplankton density and the data point was disregarded as a result.

Data regarding the surface pH and the characterization of zooplankton was obtained using surface samples. Sample methods such as meter net deployments or hydrocast deployments would have provided data about the zooplankton abundance and diversity at different depths. If these methods were to be employed, the pH of different depths could be identified. Zooplankton tend to feed on phytoplankton at night but migrate to deeper areas of the water to avoid predators in a process called diel vertical migration. The density values identified in this study are higher during the night than during the day and thus suggest that diel vertical migration among zooplankton is occurring. By obtaining data regarding pH and zooplankton at a variety of depths, such as below the photic zone, a study can better characterize each station. Moreover, simply obtaining a more expansive collection of data points, even if only with surface samples, would provide a stronger characterization of the zooplankton density and thus the distribution of zooplankton at different times in the day.

This study sought to understand the relationship between rising ocean acidification and the abundance of zooplankton. Contrary to the hypothesis, the density of zooplankton did not exhibit a significant trend. This study was meant to serve as a prerequisite for future studies that may further investigate the impacts of the increasing acidity of ocean waters on biodiversity. Further studies should focus specifically on the biomass and biodiversity of an organism with calcified shells. This study did not allocate additional resources to conduct analysis on a specific organism. Organisms with calcified shells are especially important to this research as their shells are known to weaken in acidic environments[6]. By characterizing the relationship between the pH of the sample and the organisms with $CaCO_3$ shells, the scientific community can gain more knowledge regarding the results of climate change on biodiversity.

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