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Investigation of a Possible Switch of Benthic Photosynthetic Organisms and Phytoplanktonic Organisms in White Point Swash, South Carolina

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By

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Abstract

This research study examined the possible switch from benthic photosynthetic organisms to phytoplankton in the water column at White Point Swash, Long Bay, South Carolina, and what is causing this switch to occur. During Dr. Hannides' and his group's studies at this and other swashes in the past, they noticed this phenomenon of the benthic photosynthetic organisms taking over during a certain time and then the phytoplankton in the water column taking over during a different time. In this study, I measured the relative benthic macroalgal area coverage and sedimentary chlorophyll *a* concentration as measures of the abundance of benthic photosynthesizers, and I compared them to the water column chlorophyll *a* concentration as a measure of the abundance of phytoplankton. I also analyzed pore water samples for sedimentary nutrients which were compared to water-column nutrients. Finally, I compared the above with water depth levels to account for light reaching the benthic photosynthetic organisms to account for the role these have on this switch. The results show that as water level rises benthic photosynthesizers decrease in abundance and phytoplankton abundance increases. Sedimentary pore water nutrient concentrations are much higher than overlying water concentrations and this suggests that light is the main limiting factor to benthic photosynthesizer growth.

Introduction

Today's coastal marine environments are facing a major threat to their health from elevated nutrient levels, causing faster algal growth and phytoplanktonic blooms, which can cause the environment to become hypoxic (Malone and Newton 2020). An environment with blooms of algae and other organisms affecting an environment negatively is a sign that eutrophication is occurring, which is when water quality is affected negatively due faster growth of algae and other organisms, in addition to higher concentrations of nutrients (Libes 2009). Eutrophication has become a bigger threat in more recent times due to anthropogenic activities, such as wastewater runoff and nutrient in flux from agriculture (Bricker et al. 1999).

This study investigated a site that is most likely undergoing eutrophication and looking at a phenomenon that was noticed by Dr. Hannides: a possible switch of benthic and planktonic photosynthesizers at White Point Swash, in Horry County, South Carolina. Specifically, this investigation looked into the cause of this possible switch to occur at this location: water level, nutrients, seasonal changes, or a combination. Legut et al. (2020) conducted a study in this area and found the sediments to have higher levels of nutrients than the water column, along with a connection with nutrient and chlorophyll a concentrations throughout the different seasons. They also a note about the change in water level via tidal flushing and its effect on the photosynthetic organisms. These findings indicate that benthic photosynthesizers aren't nutrient-limited but light-limited.

Planktonic organisms have been studied and found to have blooms during different times of the years, thus showing that the planktonic photosynthetic organisms have a connection with the changes in seasons (Peng et al. 2021). In other words, the changes in seasons could also be a factor in the switch from benthic and planktonic photosynthetic organisms that Dr. Hannides is observing in this location.

Legut's et al. (2020) study showing nigher levels of nutrients in the sediment could mean that the benthic photosynthetic organisms have the upper hand compared to the planktonic organisms. Therefore, shallow water depths that allow more light to reach benthic photosynthetic organisms create an ideal growing environment, due to high levels of both nutrients and light (Libes 2009). Local government dredges the main channel of this swash every year, which will cause the average water level to be lower, thus allowing for more light to the benthic photosynthetic organisms. Therefore, dredging can give the benthic photosynthetic organisms an advantage while the water level remains low.

Hypotheses

<u>Overarching Hypothesis</u>: The relative abundances of tidal-creek benthic and planktonic photosynthetic organisms vary due to changes in average water depth, light availability, nutrient availability, and seasons.

Hypothesis 1: Planktonic photosynthesizer abundances will be greater during the spring and summer.

Hypothesis 2: The higher the average water depth, the lower the abundance of benthic photosynthesizers, due to reduced benthic light availability.

Hypothesis 3: Dredging reduces the average water depth, increasing benthic light availability, leading to greater benthic photosynthesizer abundance.

Hypothesis 4: Sedimentary pore-water nutrient concentrations are higher than water-column nutrient concentrations, suggesting the lack of nutrient limitation of benthic photosynthesizers.

Methods

Study site

The study was conducted at White Point Swash in Horry County, South Carolina. The sampling location is adjacent to the long-term monitoring station, operated since May 2018 by the sand biogeochemistry program (Figure 1).

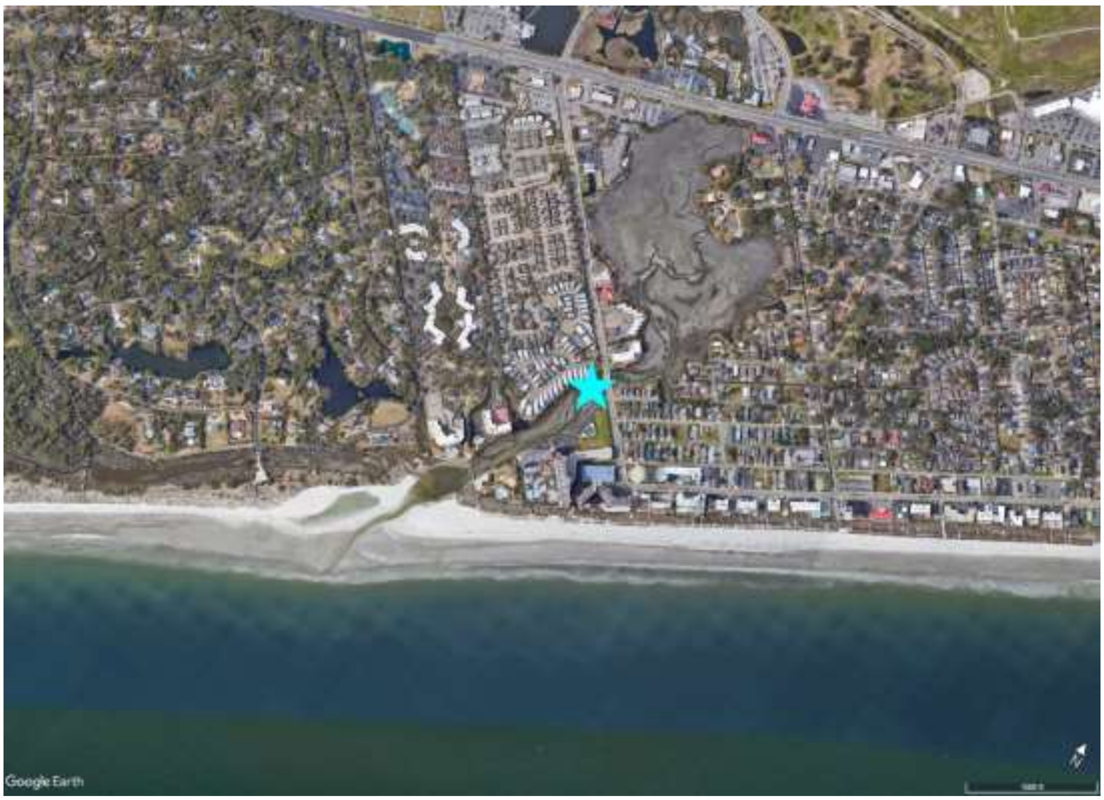

Figure 1. The location of the study site in Horry County, South Carolina (satellite image from Google Earth November 2022). The blue star represents the exact location of sampling, at the second bridge from the ocean.

Existing monitoring

This location has been monitored by the sand biogeochemistry program run by Coastal Carolina University since May 2018. At this location, there are loggers for water level, temperature, salinity, and oxygen that have been going since May 2018. Since November 2019, in addition to the above, there has been monthly monitoring for nutrient collection, chlorophyll, turbidity measuring, and photography collection of creek bottom coverage of macroalgae.

This research incorporates the water level logger data and the monthly monitoring data mentioned above, along with newly collected sedimentary chlorophyll and nutrient concentrations, in testing the hypotheses.

Sampling

Sampling for pore water samples and sedimentary chlorophyll *a*, was conducted once a month from September 2022 to April 2023 simultaneously with the regular monthly sampling. The pore water samples for nutrient measurements were collected with 30-cm long metal needles attached to syringes and filtered through 0.2 μm syringe filters into scintillation vials at a depth of 2.5 cm. Samples for chlorophyll *a* concentrations in the sediment were collected by plastic syringe cores, taking the top 2.5 cm of sediment, and transferred to preweighed glass vials. All samples were placed into a cooler for transport to the lab for processing and storage until analysis.

Laboratory Analysis

Sedimentary chlorophyll *a* concentrations were determined using the approaches outlined in Hannides et al. (2014). Chlorophyll was determined by fluorometry (Arar and Collins 1997).

Pore water was analyzed for nitrate (Schnetger and Lehners 2014), nitrite (Bendschneider and Robinson 1952), ammonium (Holmes et al. 1999), and phosphate (Murphy and Riley 1962). Dissolved inorganic nitrogen (DIN) was calculated as the sum of the concentrations of nitrate, nitrite and ammonium.

Image Analysis

Monthly photo images of benthic coverage were overlain with a ten-by-ten grid (sometimes ten-by-five) in Microsoft PowerPoint. Each square was assigned a value from 0 (no macroalgae) to 1 (100% macroalgal coverage) in 0.25 increments. All the squares were added to give a percentage value (where 50 squares were used, the final sum was multiplied by two). This was done by three individuals independently. Their coverage value for each image was averaged to obtain a percent macroalgal coverage per month.

Data Analysis

Data were examined visually and statistically using Microsoft Excel to test the hypotheses. A time-series graph was made to analyze the water level's effect on the abundance of benthic photosynthesizers, by plotting water level, average percent coverage of macroalgae, water column chlorophyll, and timing of dredging events. Macroalgal percent coverage was plotted against water level to test for a possible significant relationship.

To test if pore water nutrient concentrations play a significant role in abundances of the benthic photosynthesizers vs the planktonic photosynthesizers, two graphs were made of pore water versus overlying water concentrations of DIN and phosphate.

Results

There is a strong correlation between the seasons and over lining water (OW) chlorophyll *a* concentrations, with the spring and summer seasons showing the highest average concentrations of OW chlorophyll *a* from 2019-2023 (Figure 2). There is also a strong inverse correlation between the water level and the benthic macroalgae/OW chlorophyll a levels, with water levels of > ~60 cm showing a spike in benthic macroalgae and lower levels in OW chlorophyll *a* concentrations (Figure 2). The macroalgal coverage vs water depth plot shows that there is little to no growth of benthic macroalgae seen when the average water level is about ~60 cm at the study location (Figure 3).

The [DIN] and [PO_4^{3-}] in μmol/L show to be in higher concentrations in the sediment versus the overlying water (Figure 4 and Figure 5).

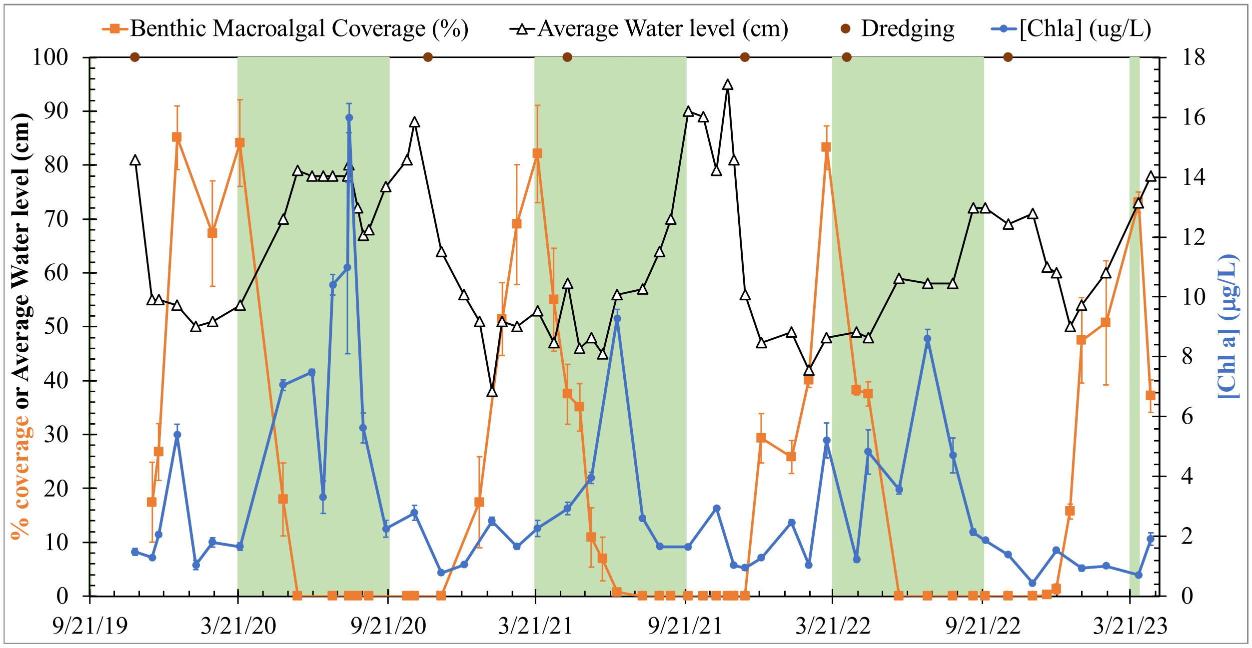

Figure 2. Average percent coverage of benthic macroalgae, the average concentration of overlying water chlorophyll a (ug/L), average water level for the previous fifteen days from the sampling date, and dredging events from 2019-2023 (error bars show +/- one standard deviation). The color lay out highlights the fall and winter seasons with the white sections, while the green sections showing the spring and summer months. The seasons were dated based off lunar eclipse and solstice times for the northern hemisphere (fall/winter: September 22nd-March 20th, spring/summer: March 21st-September 21st).

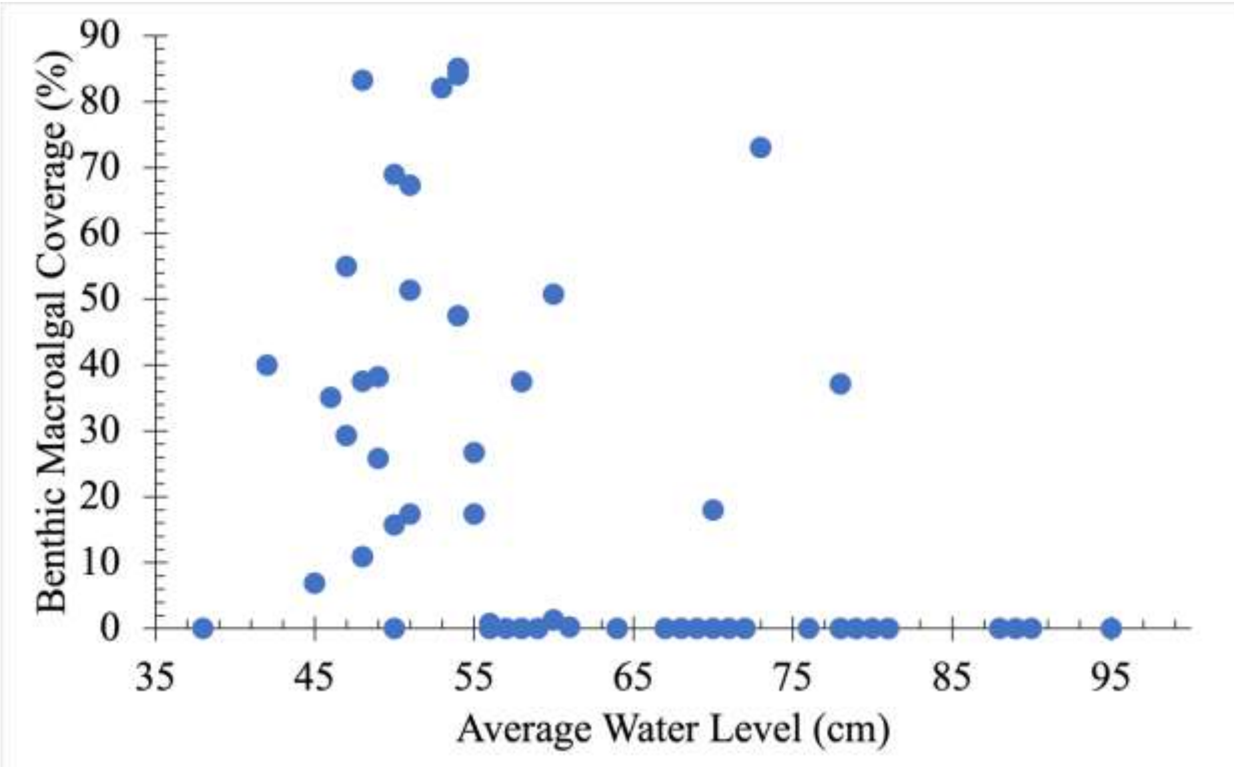

Figure 3. The benthic macroalgal coverage percent coverage graphed against the average water level (cm).

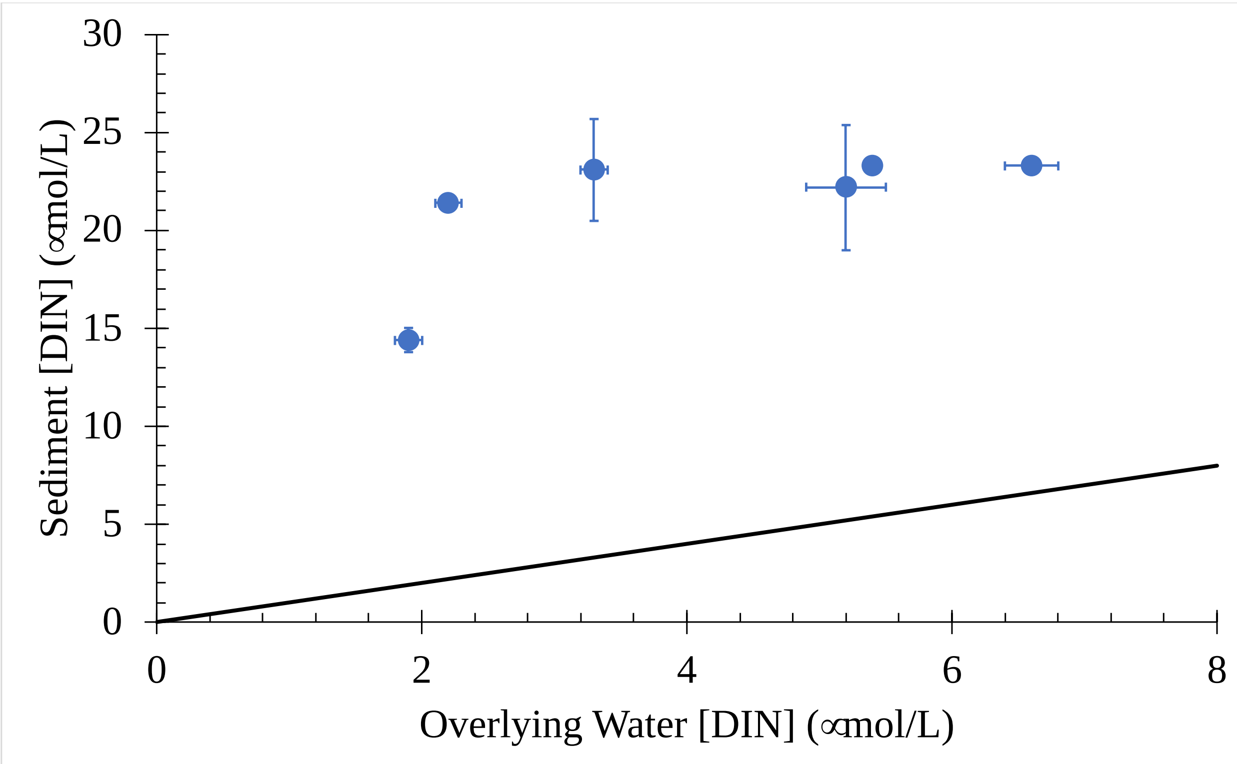

Figure 4. This graph shows the [DIN] in µmol/L in the sediment versus the overlying water +/- 1 SD, with the black line representing a 1:1 comparison.

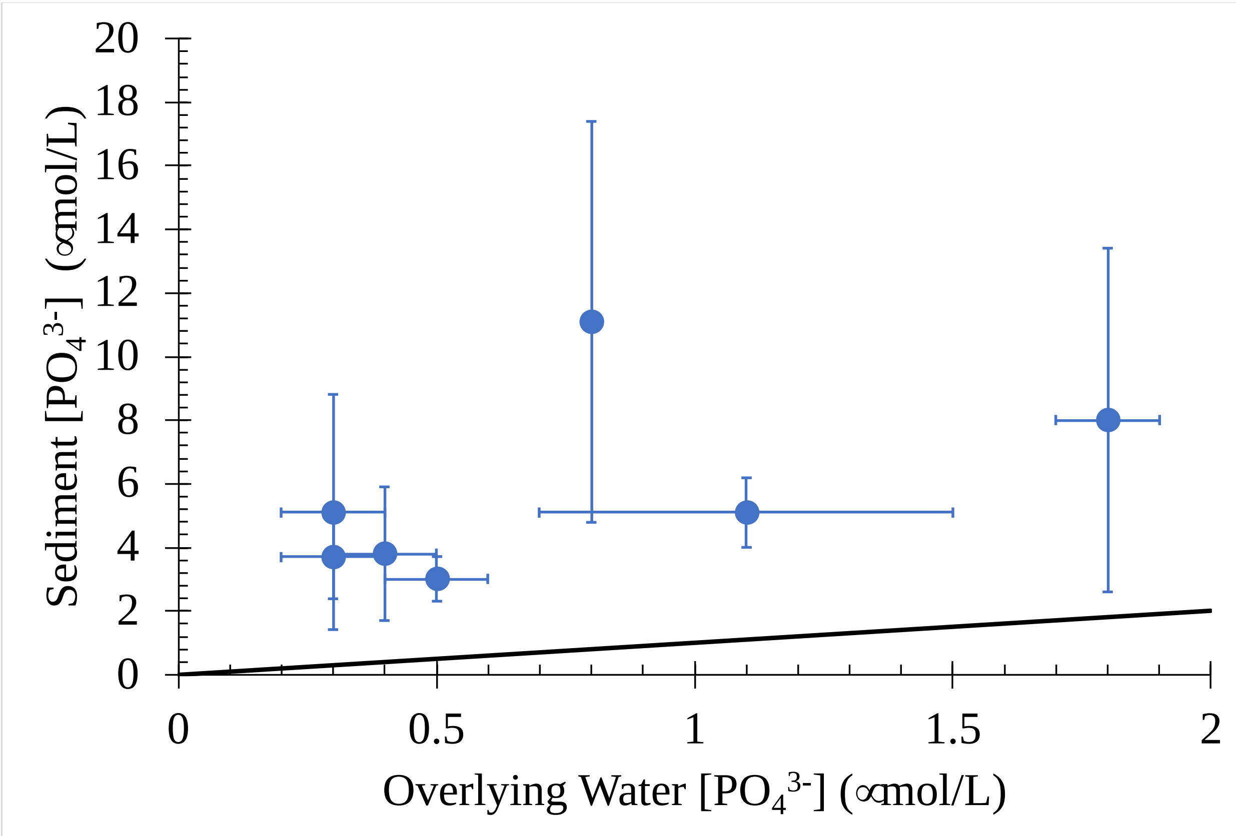

Figure 5. This graph shows the $[PO_4^{3-}]$ in mmol/L in the sediment and the overlying water +/- 1 SD, with the black line representing a 1:1 comparison.

Discussion

Overall, this research study supported the hypotheses stated at the beginning of the research. Hypothesis 1 involved analyzing planktonic photosynthesizer abundances to see if their abundances would be higher in the spring and summer. This hypothesis is supported based off the findings in Figure 2,, with the graph showing spikes in the [Chl a] in the spring and summer seasons from 2019-2023. The most likely explanation for the spikes of phytoplankton in the spring and summer is increased light levels and warmer sea surface temperatures, while other explanations such as shoaling hypothesis or the critical depth hypothesis (Chiswell et al. 2015) deserve further study.

Hypothesis 2 was that the higher the average water level will show a reduction in benthic photosynthesizers, which was also supported by the data. As the water level increases to an average depth roughly greater than 60 cm the growth of benthic macroalgae drops. Figure 3 shows the benthic macroalgal percent coverage versus the average water depth, and provides a clear picture of very little to no growth of benthic macroalgal above about 60 cm. This depth is still well within the photic zone, thus, looking back at Figure 2, the graph shows increase levels of [Chl *a*] during each drop in benthic macroalgal percent coverage. This phenomenon of benthic macroalgal percent coverage dropping with increased [Chl *a*] and average water level is more than likely due to an increased turbidity in the water, reducing the amount of light needed for growth.

Hypothesis 3 was that dredging of White Point would increase the abundance of the benthic macroalgal, due to increased light availability because of a shorter water column. The patterns in Figure 2 show a relationship with dredging events decreasing the average water level, which as a result show increased benthic macroalgal percent coverage. However, the increased growth of benthic macroalgae is delayed at some points and shows less growth at other points. This phenomenon could be explained by the effectiveness of the dredge, as well as the season the dredge occurred. There are two specific dredge events, both in the spring/summer highlighted zones that show a dredging event that did not decrease the average water depth as effectively as the other events. However, at both events, the down slope of the benthic macroalgal percent coverage does pause in its decreasing levels, but then continues to decrease shortly after the dredging event. Overall, the hypothesis is supported in that when the dredging events occurred, there was on average a positive response in benthic macroalgal percent coverage.

The final Hypothesis 4 examined the pore water nutrient concentrations compared to the overlying water nutrient concentrations, to see if the benthic photosynthetic organisms were nutrient limited. Looking back at figure 4 and figure 5, both graphs show the sediment contained higher concentrations of DIN and PO_4^{3-} in μmol/L. This would support the hypothesis, in that, the benthic photosynthetic organisms are not nutrient limited in their growth at White Point.

In summary, further research should be conducted to further support these findings. In addition to further research into the tested hypotheses, further research should be conducted on how the marine animal life response to the switch in benthic photosynthetic organisms and overlying photosynthetic organisms. In other words, does this switch in dominate photosynthetic organisms also bring a switch in a dominate species, which would also affect the upper food chains as well?

Acknowledgments

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