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# The Dynamics of Sedimentary Chlorophyll α at a High-Energy Beach

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# The Dynamics of Sedimentary Chlorophyll α at a High-Energy Beach


By

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## Abstract

Productive sandy beaches are one of the most crucial areas serving our ecosystem today. While often overlooked in scientific research, productive beaches have many essential functions that lead to the preservation and protection of many different species as well as ecological wellness and stability. A key factor that is linked to this productivity is the presence of chlorophyll in the sediments. Piston cores of the sediments at the low-tide mark at Waties Island, South Carolina, were collected across multiple years and subsequently analyzed for chlorophyll concentrations through fluorometry after acetone extraction and acidification. Each core profile was processed to calculate maximum and minimum chlorophyll concentrations, the depths at which they occurred, and the integrated concentration of chlorophyll α. These were all plotted against time to determine patterns in the changes of these different factors with time. Findings suggest that chlorophyll α concentrations do vary with depth seasonally and that their levels are higher overall in the upper layers of sediments.

## Introduction

The importance of productive beaches is highly significant across the globe. They contain microbes that drive nutrient cycling and extract organic matter through processes such as mineralization (McLachlan et al., 1981). They are essential for fueling the food web through housing many different primary producers, grazers and predators (Van Tomme et al., 2014). Sandy beaches also provide nursery habitats, which allow for a safer breeding and feeding zone for many different organisms on land and in the ocean (Jarrin and Miller, 2013). These beaches allow for filtration of water and increased nutrient cycling through different biogeochemical processes (Hamada et al., 2017). In addition to providing ecological benefits, they provide physical ones as well. They buffer storms from decimating the coast, allow for the economic development of a region through tourism, and have many different cultural uses (Nel et al., 2014).

One of the reasons these environments have such important ecological functions is due to the microbial photosynthesizers in the sediment. The photosynthesizers, mainly diatoms, produce high amounts of chlorophyll α which contribute energy to the higher levels of the trophic system (Bergamino et al. 2016). This exhibits that chlorophyll can be used as a proxy to predict photosynthesizer biomass in the sediments. These microorganisms determine different shifts in resource availability through this chlorophyll production by creating different trophic niche productivity (Bergamino et al. 2016). Where there are higher concentrations of photosynthesizers, there are higher concentrations of other species, showcasing their essentiality in a well-nourished, productive sandy beach ecosystem (Bergamino et al. 2016).

Previous studies have suggested that chlorophyll α production is the highest is at the sandy surface, where areas with highly concentrated diatoms exist in coloured patches of sand (Bianchini and Hannides, 2019). These patches of sand are aggregations of microbial cells that are encased in an extracellular polymeric substance matrix known as biofilms (Donlan, 2002). In order to flesh out research on these chlorophyll α concentrations throughout the sediment layers, this study sought to research the changes in its levels across years of sampling. This study attempted to detect patterns in the chlorophyll masses and concentrations seasonally, over time and with depth. These observations were plotted against time to visualize this research and come to conclusions about the productivity of a high-energy beach.

## Hypotheses

1. Concentrations of Chlorophyll α will be higher at the surface layers, where light can stimulate photosynthesis.
2. The concentrations of Chlorophyll α will vary with depth throughout the sedimentary column, with the highest concentrations at the surface.
3. The concentrations of Chlorophyll α will vary seasonally, with the highest concentrations occurring in the spring and summer with extended sunlight.

## Methods

*Study Site*

The samples used in this study were gathered at Waties Island Beach in South Carolina, United States. Seated on the Grand Strand in South Carolina, Waties Island is a smaller underdeveloped barrier island. Because it is private and relatively untouched, it is a useful site for researching natural processes. The 58 completely processed cores were collected at the low-tide line of the beach at Waties between the years of 2016 and 2020.

Figure 1. Image of Waties Island Beach, South Carolina. All samples were collected in the sandy region of this island.

*Piston core Sampling and Processing*

The samples utilized in this study were collected on a monthly basis between November 2016 and October of 2020. The cores were taken at low tide using a piston to drive them into the ground. The piston was attached to a hammer which moved a hollow plastic cylindrical shell through the sediments for at least 60 cm and no more than 80 cm. The cylindrical shell was then removed from the sand and capped to preserve the water and sediments. The cores were then frozen and eventually brought back to room temperature by heating them up using water and friction. Slices of the core were taken about 10 cm apart, for the entire lengths of the cores. Each cross-section then had two subsamples taken which were placed in glass vials that had previously had their empty mass recorded for analysis.

*Chlorophyll* α *Analysis*

Each sample's chlorophyll α concentration was determined with the approach in Hannides et al. (2014) and measured by fluorometry (Arar and Collins 1997). using a Turner Designs Trilogy fluorometer. The samples were then decanted to remove the excess fluid from the substrate and after drying for 72-96 hours the dry mass of each sample was recorded.

*Data processing*

All data were tabulated and processed in Microsoft Excel. Integrated chlorophyll was calculated as follows, using porosity, $\varphi$, density, $\rho_g$, and the sediment layer thickness, $z_i$:

$$\sum_{Depth\ interval\ i=1}^{Depth\ interval\ i=f} Chl\ a = [Chl\ a]_i \times (1-\varphi) \times \rho_g \times z_i \times \frac{10^4\ cm^2}{m^2}$$

## Results

In general, the higher masses of chlorophyll α were found to be between 0.6-1.1 5 μg/g dry, while the lower masses were found to be between 0-0.5 μg/g dry (Figure 1). In the earlier recordings, from November of 2016 until November of 2018, it was found that the maximum masses could be lower in certain samples than the minimum values recorded in other samples (Fig. 1). After November of 2018, the maximum values maintained an overall higher rate than the minimum sample values did (Fig. 1).

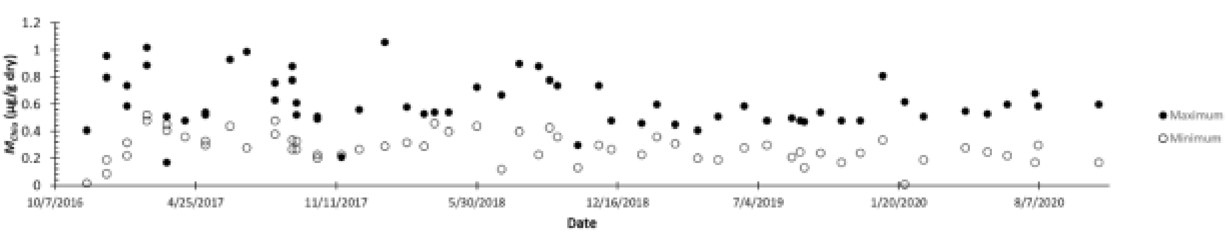


**Figure 1.** Mass of maximum and minimum Chlorophyll α concentrations (ug/g dry) as a function of time.

Overall, higher chlorophyll α concentrations were generally found closer to the surface (Figure 2). As predicted, most of the maximum chlorophyll α concentrations were found between 0-25 cm beneath the sandy surface (Fig. 2). Likewise, the minimum concentrations were mostly located between 35-70 cm beneath the surface (Fig. 2). However, there are outliers from both data sets as some of the maximum values were present at the bottom of the sediment column, while other minimum values were present at the top (Fig. 2). A trend is found often with the maximum values being the lowest in November for the first few consecutive years (Fig. 2).

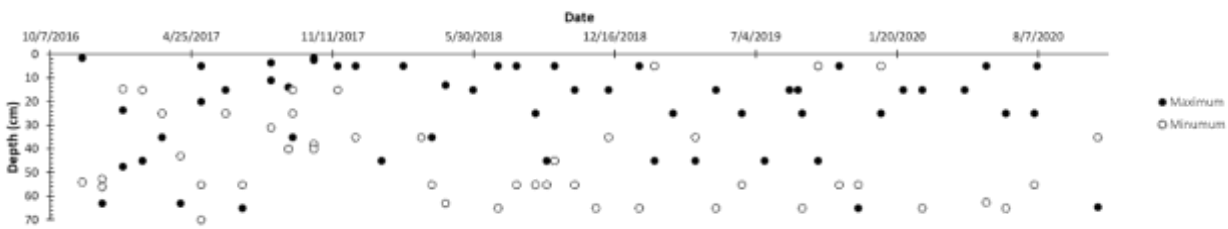


**Figure 2.** Depths (cm) of maximum and minimum Chlorophyll α concentrations (ug/g dry) as a function of time.

The results from the integrated chlorophyll α concentration calculations integrate the overall levels of chlorophyll α per each core taken (Figure 3). Greater values were more frequently located from July to September during the warmer summer months. The lowest levels were displayed most often during the months from September to March with some outliers.

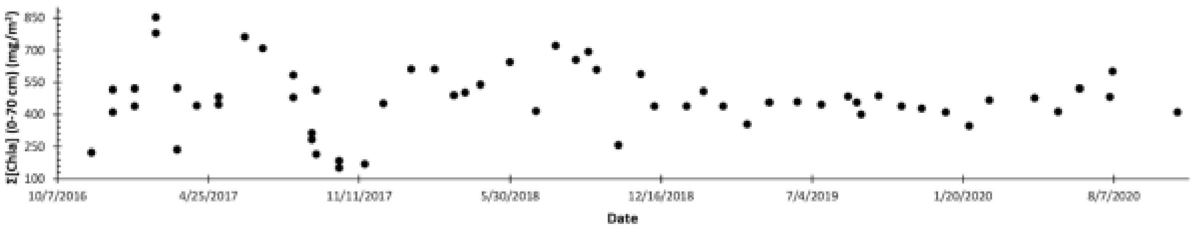


**Figure 3.** Integrated chlorophyll α concentrations (mg/m$^2$) from November 21, 2016 to October 30, 2020.

## Discussion

This study presented evidence that sandy beaches are productive environments. Chlorophyll α levels throughout the sediments maintained masses on average between 0.2 and 0.9 µg/g dry sediment. This showcases the presence chlorophyll α has in the sedimentary column in sandy beaches, confirming the productivity of this sandy beach. Chlorophyll α was present throughout the entirety of the 70 cm column, with various levels at various depths. Minimum values were generally ranged between 35-70 cm, while maximum values were concentrated between 0-25 cm beneath the surface. These values verify the greater presence of chlorophyll α near the surface layers of the sediments. This is likely due to the presence of light stimulating photosynthetic microorganisms.

However, outliers were present with a subset of the maximums appearing in the month of November. This shows that the concentration did vary with depth, affirming the previously made hypothesis. Integrated chlorophyll α calculations confirmed that the concentrations did vary seasonally. The higher values were generally found from June-September, with the lower values appearing from October-February. The high concentrations in the summer months again affirm that the greater presence of light has a large impact on the concentrations and stimulation of different diatoms. However, concentrations did stabilize in the later years from late 2018 to 2020. During these years the values maintained levels around 400-600 mg/m$^2$.

The study of high-energy beaches is a crucial ecological niche that, if better understood, could greatly benefit the environment in the future. Further measurements and experimentation should be performed to better understand the patterns described above given changes in master-parameters such as temperature, light availability, tidal stage, etc.

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