Spring 5-2021

Organic matter spatial and temporal patterns in coastal sands of Long Bay, South Carolina

Kayla B. Christofferson
Coastal Carolina University, kbchristo@coastal.edu

Organic matter spatial and temporal patterns in coastal sands of Long Bay, South Carolina

By

Kayla Christofferson

Marine Science

Submitted in Partial Fulfillment of the
Requirements for the Degree of Bachelor of Science
In the HTC Honors College at
Coastal Carolina University

Spring 2021

Louis E. Keiner
Director of Honors
HTC Honors College

Angelos K. Hannides
Assistant Professor
Department of Marine Science
Gupta College of Science

Table of contents

Abstract 2

Introduction 3

Hypotheses 4

Methods 5

Results 8

Discussion 12

Literature Cited 13

Abstract

Sandy coastlines serve crucial functions to coastal economies and coastal ecology alike. In the past, organic-poor sands were considered of lower importance than organic-rich muds. Recent studies showed that sands' low organic matter concentrations are due to high biogeochemical cycling rates, driven by rapid physical exchange, but remain infrequently studied. I present time-series of sand mass-loss-on-ignition (LOI, an organic matter proxy) profiles from February 2017 onwards at multiple sites along Long Bay, South Carolina. LOI profiles exhibit subsurface maximum values, unlike the typical decrease with depth in muddy sediments. I hypothesize that organic matter distribution with depth is affected by different biogeochemical cycling rates, specifically respiration, at different depths. I compare seasonal patterns of organic matter and sand chlorophyll to detect whether organic matter content is affected by primary productivity cycles. This baseline study may assist in evaluations of disturbances of sandy shores of the Grand Strand in the future.

Introduction

Coastlines, especially sandy beaches, are crucial key areas for the economy. The sandy coastlines support about 39% of the United States population and generates a total of $285 billion in 2017 (Houston, 2018). However, they also are determined to have ecological significance, as they provide habitat to different species and reduce flood risk (Elko et al. 2015).

Sandy beaches have highly permeable sediments, which enhances the ecological functions as the exchange of the sediment column and the moving water column causes a high biogeochemical cycling rate (Rocha, 2008). This exchange of the coastal zone is important to understand as it distributes organic matter and nutrients, which gives insight of the ecological role of sandy sediments.

In previous studies sandy sediments were regarded to be organic-poor, especially in comparison to organic-rich muddy sediments (Meyer-Reil, 1986). This led to the assumption of sandy sediments being less important to supporting the ecology of the coastline, as the low organic matter concentration would indicate low biogeochemical activity. However, in more recent studies there is evidence that the organic matter is low due to the rapid physical exchange between the sand column and the water column and modification of organic matter by benthic organisms (Rusch et al., 2000).

This study explores sedimentary loss-of-ignition (LOI) as a proxy for organic matter in the swash zone of several sites in Long Bay, South Carolina over a period of three years (February 2017-February 2020). A previous study by Vess and Hannides (2018) was conducted at one site, Waties Island, for the years 2017-2018. I expand that data set to the latest data, and supplement it with data from six other sites. I test for any spatial patterns of organic matter with depth and along the coast. In the case of the long-term time-series at Waties Island, I contrast LOI patterns with those of chlorophyll a to test if organic matter concentration is influenced by primary production as that varies seasonally.

Hypotheses

- The minimum organic carbon concentrations will occur at the surface, where organic matter is produced by photosynthesis, with maximum concentrations at greater depths.
- Average concentrations will differ from site to site, with the northern-most sites closer to the Cape Fear river discharge having a higher average than the southern sites.
- Primary productivity changes seasonally, so peaks of organic matter concentration will coincide with peaks in chlorophyll *a* in spring.

Methods

Study Sites

All of the study sites are located in Long Bay, South Carolina (Figure 1): Caswell Beach (CWB), Holden Beach (HDB), Waties Island (WIB), Singleton Swash (SSB), Myrtle Beach State Park (MBSP), Huntington Beach State Park (HBSP), and Pawley's Island (PIB). With the exception of WIB, which was sampled on a monthly basis, all other sites were visited on a quarterly (or less frequent) basis by the sand biogeochemistry research program at Coastal Carolina University.

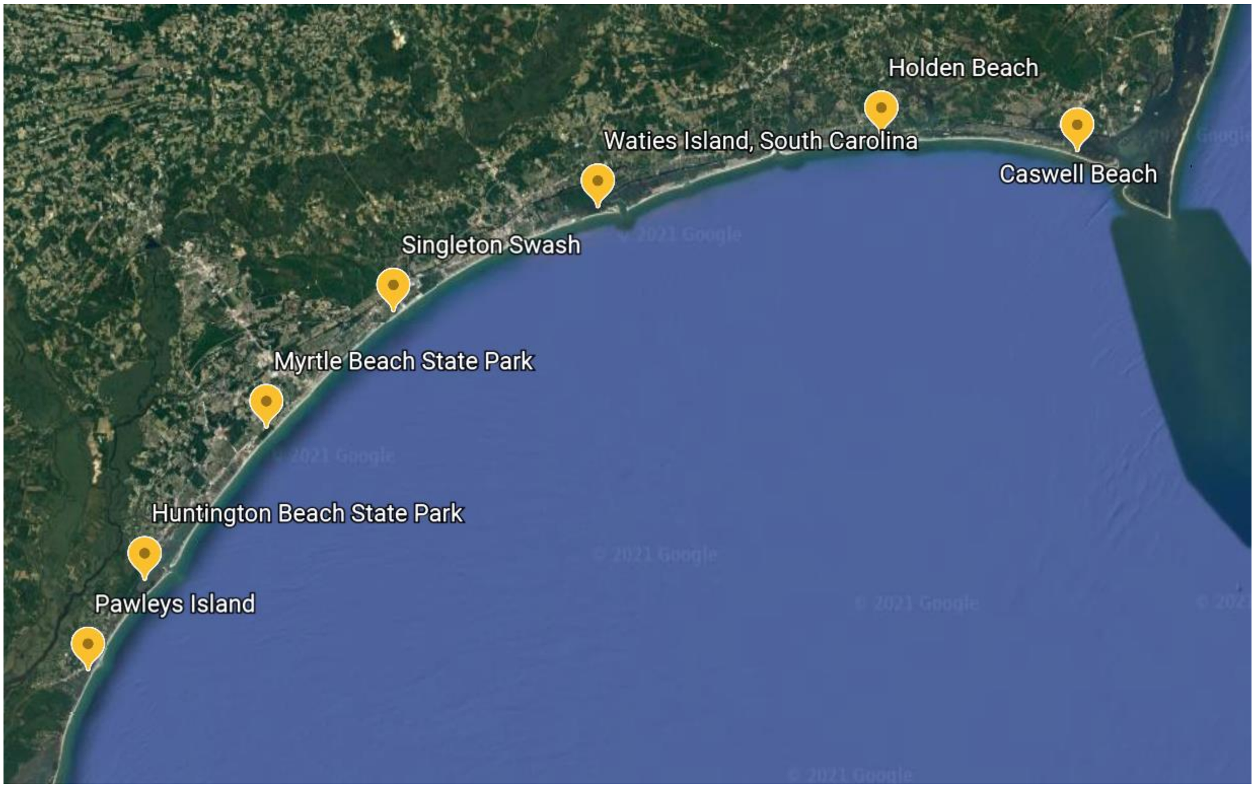

Figure 1. Long Bay, South Carolina study sites.

Sample processing

Sand for this study was collected by piston coring using an Icelandic piston core (Aquatic Research Instruments, Hope, Idaho, USA). Each piston core was collected at low tide using a hollow plastic cylinder with a piston attached to a metal hammer. The cylindrical shell was hammered into the sediment to a minimum depth of 60 cm. The shell was extracted and capped to minimize water loss. Each core was frozen and then sliced into depth sections of 10 cm. A subsample was taken from each cross-section and placed into a pre-weighed, labeled glass vials and reweighed for analysis.

Piston cores were collected from February 2017 to February 2020, on a monthly frequency for Waties Island and less frequently at other stations. Where more than one site was visited, sampling at all stations took place within 5 days. A total of 62 piston cores were collected from all sites over the three-year span of the study.

Sample analysis

Samples were processed using the LOI technique outlined in Kristensen (1990) and Santisteban et al. (2004). Samples were dried for 12-24 hours at 65˚C before being cooled and weighed. Then the samples were combusted at 550˚C for 4 hours in a muffle furnace. Once cooled, the combusted samples were reweighed and stored.

Calculations

The weights recorded during sample analysis were used to calculate the masses of the wet, dry and combusted samples: m_{wet} , m_{dry} , m_{comb}, respectively. The mass of pore water, m_f, was estimated as follows:

$$m_f = (m_{wet} - m_{dry}) / (1\text{- Sal}_{\text{frac}}) \qquad 1$$

where $\text{Sal}_{\text{frac}} = Sal / 1000$, and *Sal* is the salinity of surface water measured prior to sampling using a YSI package. Subsequently, the mass of salt, m_{salt}, in the dried sample was estimated as follows:

$$m_{salt} = m_f - (m_{wet} - m_{dry}) \qquad 2$$

and was then subtracted from m_{dry} and m_{comb} to give the salt-corrected mass of particles, m_{g_dry} and m_{g_comb} , in the dry and combusted samples, respectively. In turn, the salt-corrected masses were used to calculate loss-on-ignition at 550 ^{o}C (LOI_{550}) as follows:

$$LOI_{550} = \frac{m_{g\_dry} - m_{g\_comb}}{m_{g\_dry}} \times 100$$

Data analysis

Data processing, figure generation and statistical analysis were conducted using Microsoft Excel. Average and standard deviation values for each depth layer were calculated for every depth section of every piston core. Average and standard-deviation values of LOI concentration were plotted as depth profiles (at depth section mid-depth) for every time point at every site. Those depth profiles are omitted from this thesis for brevity.

For every site and every time point, I calculated average and standard deviation LOI_{550} values, as well as minimum and maximum values along with the depths at which they occurred. These are the metrics I used to test my hypotheses.

Results

Average and standard deviation LOI_{550} values, as well as minimum and maximum values along with the depths at which they occurred at Waties Island Beach are shown in Figure 2. Minimum values typically occur in the depth interval closest to the surface, with outliers occurring at August and September 2017, April 2018, and May 2019. The depths of the maximum values vary throughout the lower depths, with an outlier at February 2019.

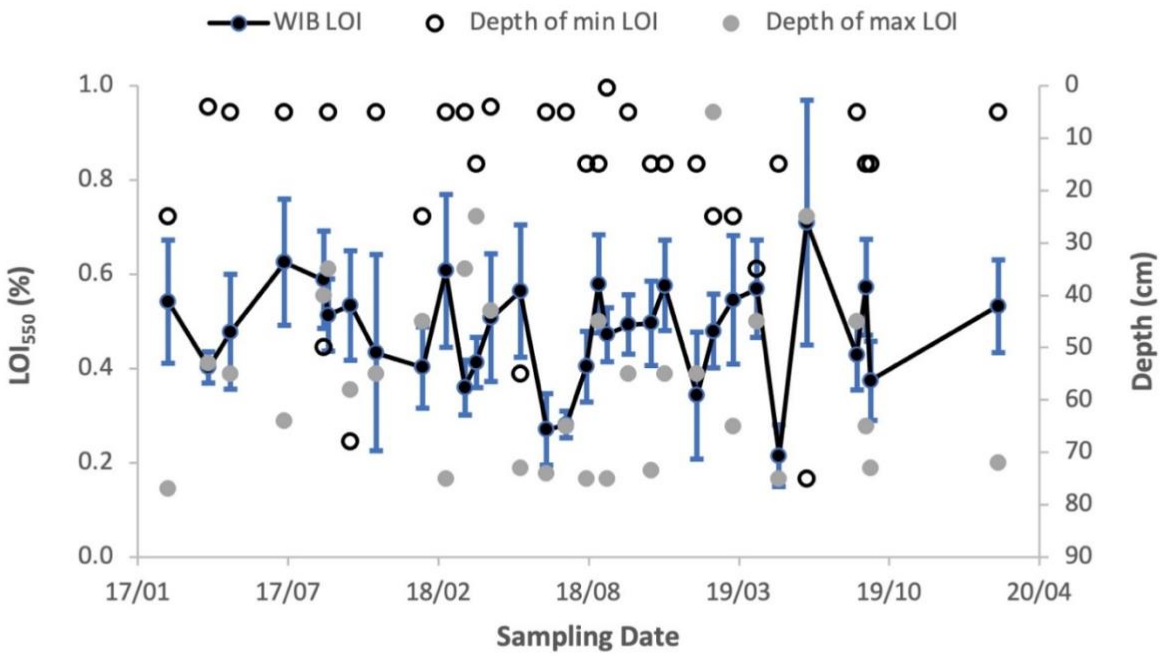

Figure 2. LOI_{550} (average ± 1 standard deviation) and the maximum and minimum depth of LOI analysis as a function of time (YY/MM).

Average LOI_{550} values at each site and time point (Figure 3) do not indicate a significant difference between stations. An exception is January 2018, when there is a distinct difference between the north sites and the more southern sites.

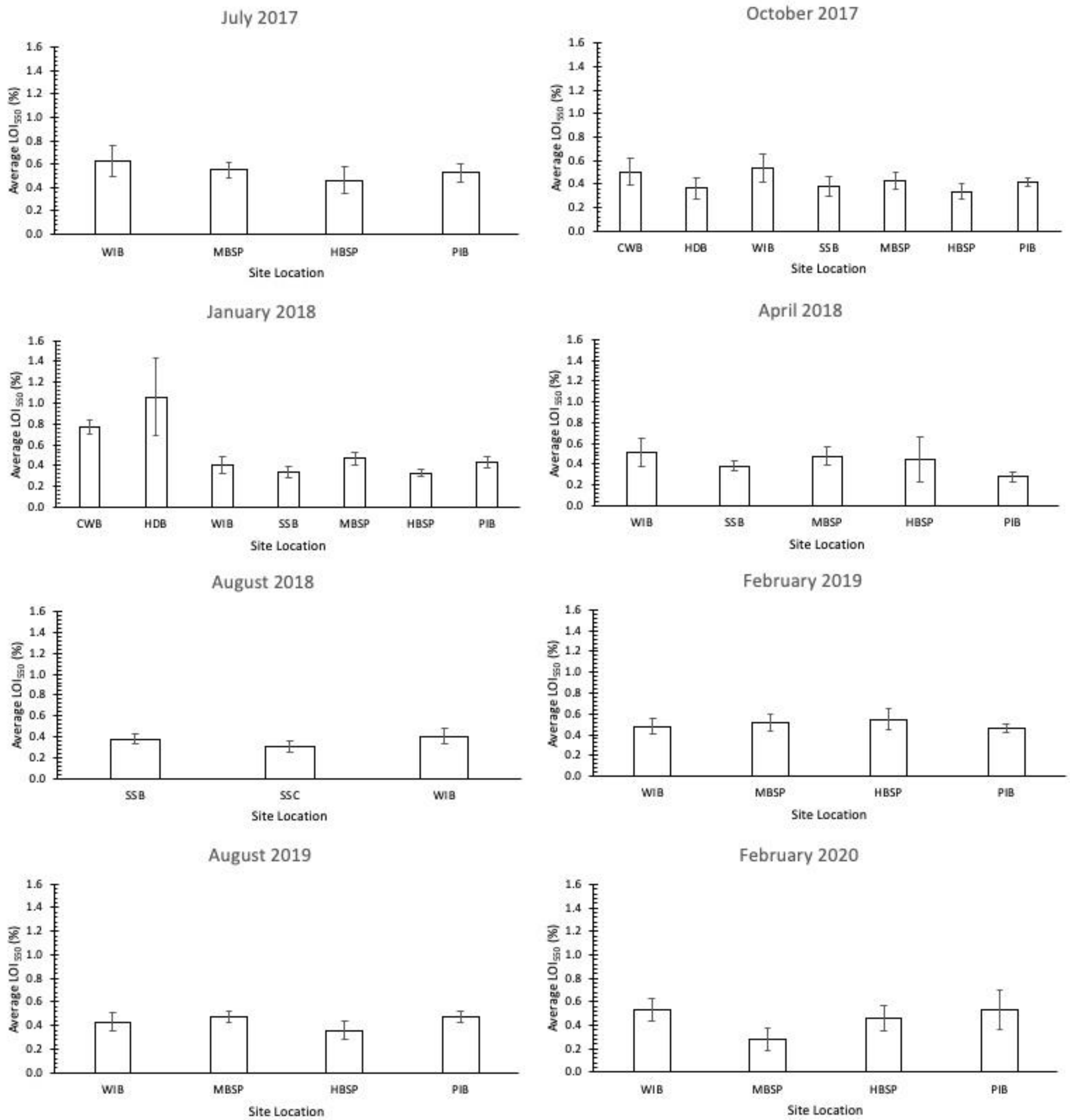

Figure 3. LOI_{550} (average ± 1 standard deviation) at all stations on each sampling event with the sites being arranged from north to south (left to right).

Average LOI_{550} values as they change with time at the most frequently monitored stations (Figure 4) do not indicate a significant pattern with time.

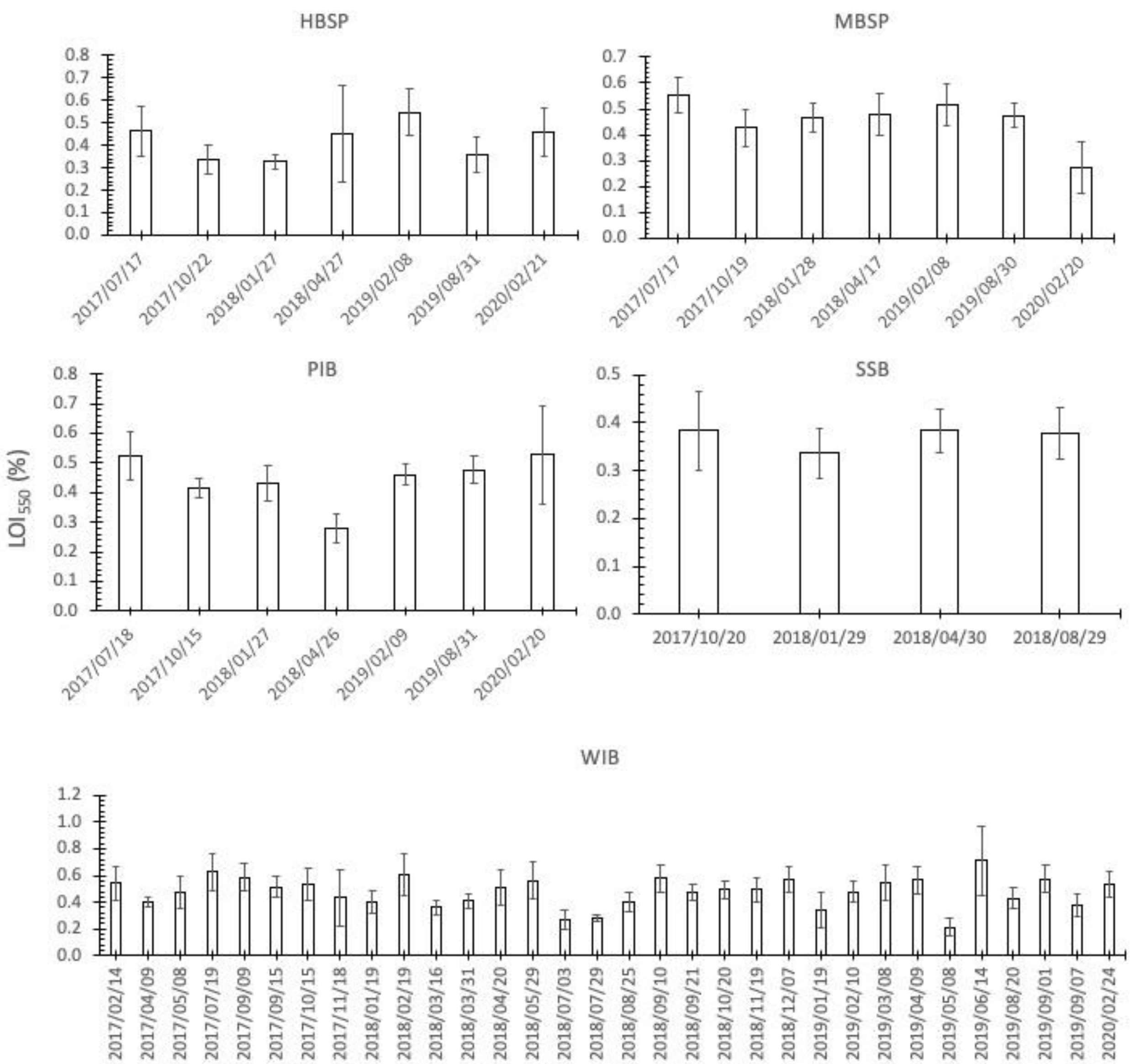

Figure 4. LOI_{550} (average ± 1 standard deviation) plotted against time of sampling event at the five most monitored stations.

Temporal patterns were investigated more closely at Waties Island Beach, where monthly data is available and can be compared with Chlorophyll *a* concentrations. Peaks of LOI may coincide with peaks in Chlorophyll a (e.g., during February and August 2017, May 2018, and June 2018) while on other cases they don't (Figure 5a). A property-property plot (Figure 5b) indicates poor correlation between LOI and Chlorophyll *a*.

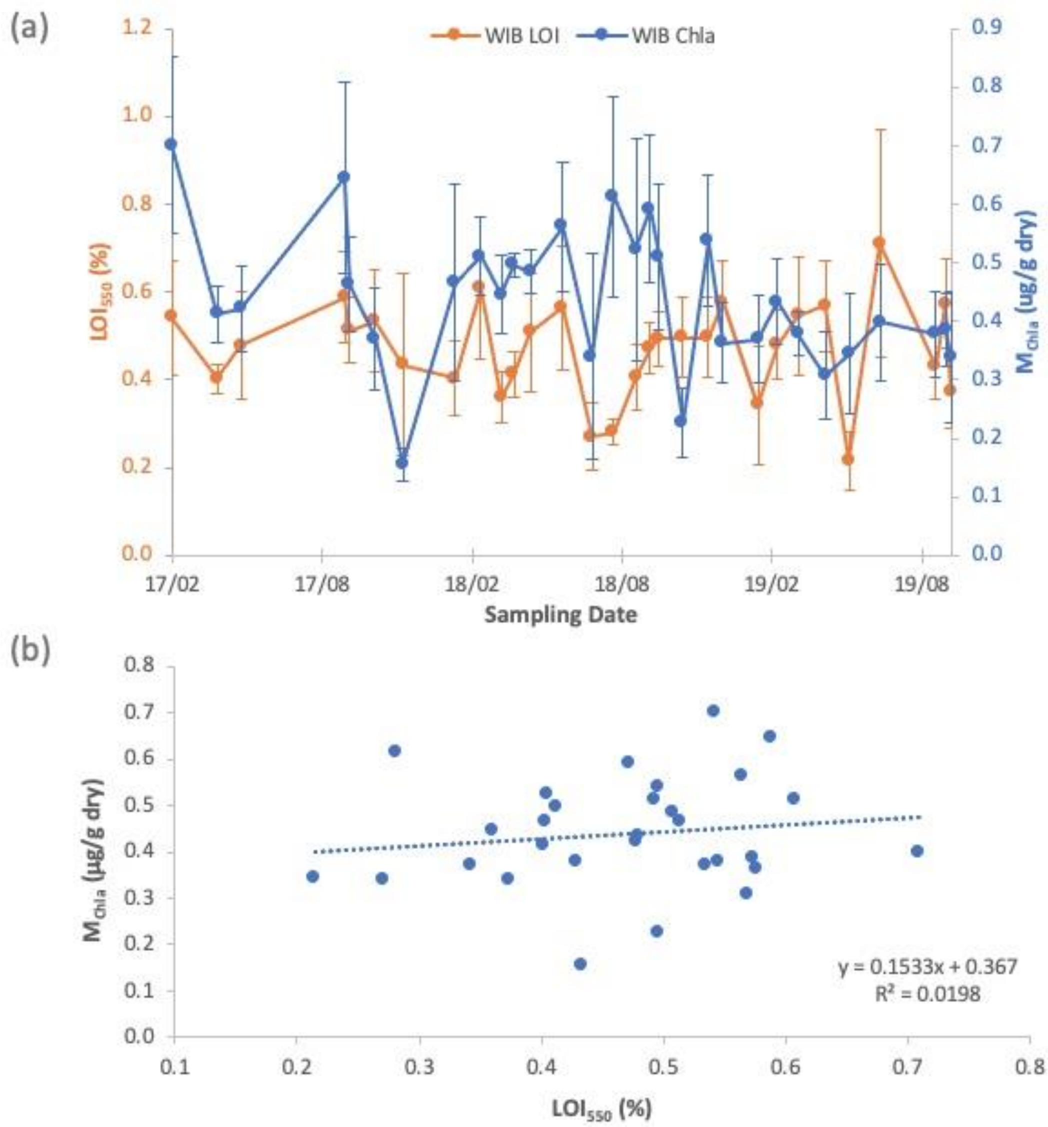

Figure 5. LOI_{550} (average ± 1 standard deviation) plotted (a) along Chlorophyll *a* against time, and (b) against Chlorophyll *a* (standard deviations excluded for clarity).

Discussion

The measured LOI values have averages (0.19-0.97%) that is typical of the low concentrations found in sandy sediments (Meyer-Reil 1986). The majority minimum LOI values were found to be at the surface or just below 15cm, whereas the maximum LOI values were distributed at greater depths (Figure 2). This pattern for sediments is not to be expected as primary productivity occurs at the surface, so normally the maximum organic values occur at the upper layers of muddy sediments. However, minimum values in the upper layer of the sand are typical of sandy sediments (Rush et al. 2000). This pattern indicates rapid turnover of the surface layer, which influences the distribution of organic matter within the sediment. The deeper maxima indicates that burial of organic matter, due to not all carbon being used during respiration or being completely flushed out with the sand and water mixing.

There is no major difference in LOI values between the sites at a particular site (Figure 3). The January 2018 data suggests that the northern-most sites might have slightly larger averages of LOI. More frequent monitoring at all the sites could confirm this finding.

Temporal differences can only be tested at Waties Island Beach (Figure 4). Although most seasonal peaks in LOI and chlorophyll *a* do not match up exactly, there are frequent similar patterns of corresponding highs and lows. The peaks of both happen in late winter and summer (Figure 5a), with the summer months having the larger peaks. This suggests that as primary productivity increases at the start of spring and into the summer months there will be more organic matter within the sediments. This is expected since photosynthesis will increase so to organic carbon will increase in the sand column. High variability prevents the detection of a relationship between LOI and Chlorophyll *a*, i.e., productivity.

Literature Cited

Elko, N., F. Feddersen, D. Foster, C. Hapke, J. McNinch, R. Mulligan, H.T. Ozkan-Haller, N. Plant, & B. Raubenheimer (2015), Coastal Forum: The future of nearshore processes research. Shore & Beach, 83(1), 13-38.

Houston, J. (2018) The economic value of America's beaches – a 2018 update. Shore & Beach, 86(2), 3-13.

Kristensen, E. (1990) Characterization of biogenic organic matter by stepwise thermogravimetry (STG). Biogeochemistry 9: 135-159.

Meyer-Reil, L.A. (1986) Spatial and temporal distribution of bacterial populations in marine shallow water surface sediments, p. 141-160. In Lasserre, P. and J.-M. Martin (Eds.), Biogeochemical processes at the land-sea boundary. Elsevier Press, Amsterdam, Netherlands.

Rusch, A., Huettel, M., & Forster, S. (2000) Particulate Organic Matter in Permeable Marine Sands-Dynamics in Time and Depth. Estuarine, Coastal, and Shelf Science, 51, 399-414.

Santisteban, J.I., Mediavilla, R., López-Pamo, E., Dabrio, C.J., Ruiz Zapata, M.B., García, M. J.G., Castaño, S., and Martínez-Alfaro, P.E. (2004) Loss on ignition: A qualitative or quantitative method for organic matter and carbonate mineral content in sediments? Journal of Paleolimnology, 32, 287–299.

Vess D., Hannides, A. (2018), Sedimentary organic matter dynamics at a high-energy beach, C-SURF Technical Report, 2, 1-8.