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Character and water quality of Sandpiper Pond: A coastal pond assessment, fifteen years after restoration

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Character and water quality of Sandpiper Pond:
A coastal pond assessment, fifteen years after restoration

By

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Abstract

Sandpiper Pond is a coastal pond at Huntington Beach State Park, South Carolina. Originally a tidal inlet surrounded by marshland, it was isolated in 1989 and rechanneled in 2004-2005 under a community-based wetland restoration project. The project was designed to restore the pond to a tidal inlet to improve water quality and biodiversity. Since then, the tidal connection with the ocean has been severed once more and the main influx of seawater occurs from the marsh during spring high tides. In this three-month study, the current state of Sandpiper Pond is evaluated using fundamental biogeochemical indicators that are indicative of the character (marine vs fresh water) and water quality (eutrophic status) of the pond. Biweekly sampling events are used to investigate and compare the conditions in the pond, ocean, and marsh, to indicate whether the intentions of the 2004-2005 restoration project are still satisfied to this day. Salinity has significantly increased in the pond since the restoration project and is identified as brackish in character. Water quality parameters, such as oxygen and chlorophyll concentrations, suggest that the pond is currently not highly eutrophic. It should be noted that this study is the culmination of other research studies conducted during other traditional and research courses taken in the past and emphasizes the expectations of the Honors program.

Introduction and motivation

Sandpiper Pond is a coastal pond at Huntington Beach State Park, in Georgetown County, South Carolina. The pond was a former tidal inlet, located in a 35-acre marsh system, and a natural nesting area that supported many populations of wading and shore birds. The pond was cut-off from tidal inundation following the construction of the Murrells Inlet jetties and Hurricane Hugo in 1989 (Tosso et al. 2005). This marine habitat became increasingly influenced by freshwater inputs that altered the ecological stability in the pond. Increases in freshwater vegetation, especially invasive *Phragmites* sp. and *Typha* sp., replaced the natural community of *Spartina sp.* and overgrew in the tidal flats (Luken and Walters 2008). In addition, eutrophication and subsequent hypoxia had led to repeated fish kills (Tosso et al. 2005).

Restoration of tidal exchange in Sandpiper Pond was suggested to lead to rapid re-establishment of the marsh habitat and a habitable environment for birds (salt flats and tidal washes) to increase their abundance and serve as a breeding ground. Connection with the ocean was accomplished by cutting a channel 15 meters-wide in April 2005 (Figure 1, Luken and Walters 2008), that closed due to sedimentation over the following year and was recut in September 2006 (Figure 2, Tosso 2006). While salinity, pH and nutrient concentrations became typical of marine conditions, eutrophication and hypoxic events in Sandpiper pond persisted, and any changes have been deemed temporary. Since that restoration event, there hasn't been an effort to revisit the character of this tidal pond and its status with regards to water quality and eutrophication standards. This study aims to evaluate both aspects during a winter-to-spring transition period when nutrient build-up is likely to give way to photosynthesizer blooms, and hopefully provide an update on this pond's conditions.

Figure 1 The initial re-excavation of a channel from Sandpiper Pond through the barrier beach and extending into the ocean in April 2005 (From Luken and Walters 2008).

Figure 2 Aerial photograph of Sandpiper Pond (Huntington Beach State Park, Georgetown County, South Carolina) after cutting of the ocean tidal channel (from Tosso 2006).

Sandpiper Pond assessment

The salinity of Sandpiper Pond, compared to ocean and marsh salinities, will be the major determinant as to the present character of the pond, especially compared to the values reported by Tosso (2006). Rainfall patterns based on data from the National Centers for Environmental Information (NCEI 2019; Table 1) will be used to assess any variations between survey dates during the study period. The pond's water quality will be evaluated using the National Estuarine Eutrophication Standards published by Bricker et al. (1999; 2007), with respect to oxygen and Chlorophyll *a*, as well as nutrient concentrations (no longer considered a eutrophication indicator). In addition, the results of previous studies as part of coursework during BIOL 426H and MSCI 466 (Fall 2017) will be used to reinforce the conclusions of this study.

Study design

The 2019 Sandpiper Pond assessment consisted of five biweekly field surveys and sampling between February and April 2019 (Table 2). Field measurements and sampling of the pond took place at four stations: two in the north pond and two in the south, and one on the ocean side and one on the marsh side in each case (Figure 3). In addition, ocean and marsh water reference stations were also sampled to contextualize the conditions in the pond.

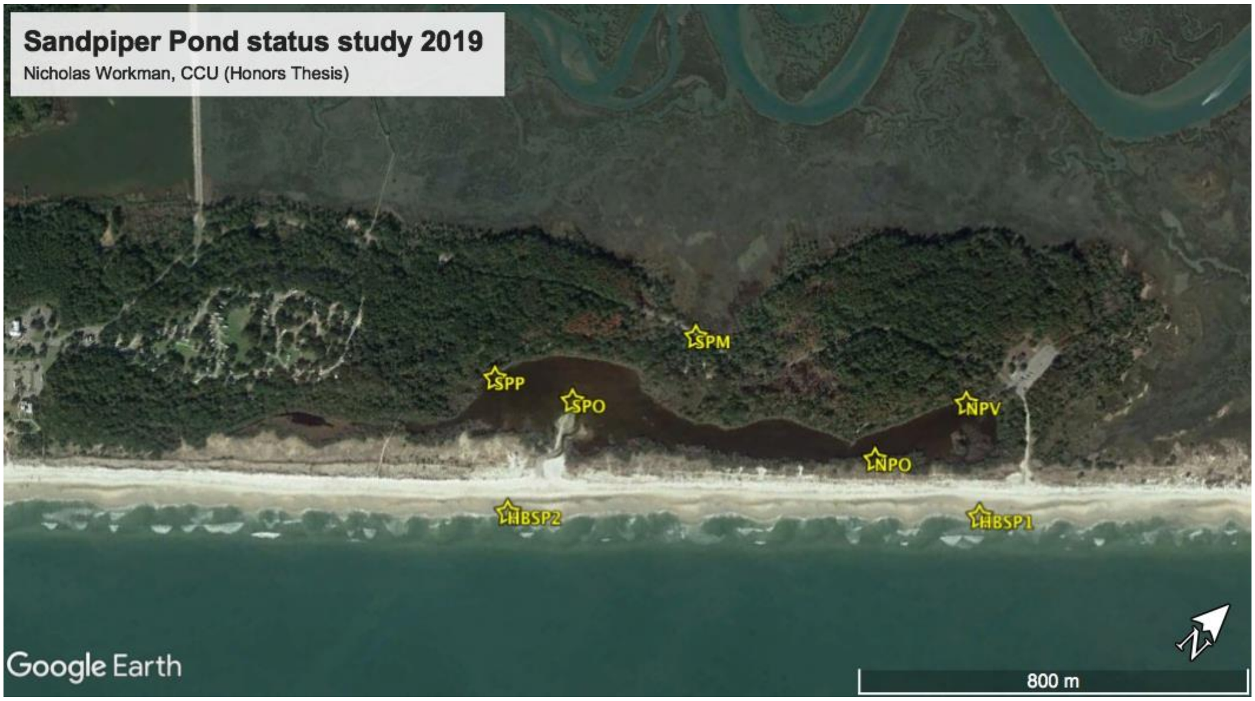

Figure 3 Study site and sampling stations. Two stations were sampled in each of the north (NP-) and south (SP-) segments of the pond: one station on the ocean side (-O) and one on the marsh side (-P or -V). Ocean water was sampled at two stations in the swash zone (HBSP-), while marsh water was sampled at the marsh location most proximal to the pond (SPM).

Table 1 Monthly total rainfall (NCEI 2019).

Date	**Rainfall (in)**
February 2019	1.10
March 2019	1.81
April 2019	5.10

Table 2 Sampling dates.

Date	**Tide**	**Weather**
February 2, 2019	Incoming Low	Overcast, Partly sunny
February 16, 2019	Outgoing Low	Sunny
March 2, 2019	Incoming Low	Overcast, Partly rainy
March 16, 2019	Outgoing Low	Sunny
April 2, 2019	Incoming High	Overcast, stormy

Materials and Methods

Field measurements of temperature, salinity, conductivity, and oxygen were conducted using a handheld YSI ProDSS meter and sensors (YSI Incorporated, Yellow Springs, Ohio, USA), while turbidity was determined using a Hach 2100-Q turbidimeter (Hach Company, Loveland, Colorado). Samples were collected for Chlorophyll *a*/Pheophytin *a* analysis using triplicate 125mL PE bottles, for each sample site. All samples were stored in ice during transportation to the lab. Upon arrival, pigment analysis samples were filtered onto Whatman GF/F glass-fiber filters, which were stored frozen until extraction. Chlorophyll *a* and Pheophytin *a* were determined fluorometrically using the EPA Method 445.0 (Arar and Collins 1999).

Results

The water quality results are presented as scatterplots for the duration of sampling. Five water properties (salinity, turbidity, chlorophyll, and dissolved oxygen) were separated in three graph categories: Spring 2019, North Pond 2005/2019, and South Pond 2005/2019. NOAA's estuarine criteria (Bricker et al., 1999; 2007) are included in the graphs, indicated by a red horizontal line, for Chlorophyll *a* (μg/L) and Dissolved Oxygen (mg/L). A one-way analysis of variance (ANOVA) was used to determine if there was a significant difference between the 2005 and 2019 mean values of the five water properties.

Salinity

Salinity in Sandpiper pond increased with each biweekly sample. Ocean salinity stayed relatively consistent and large variations were seen in the marsh sample. The mean salinity for February 2nd was roughly 10 psu, while April 2nd was 17 psu (Figure 4). In the North Pond (Figure 5) and South Pond (Figure 6), salinities were significantly greater than data from 2005 (p=0.00).

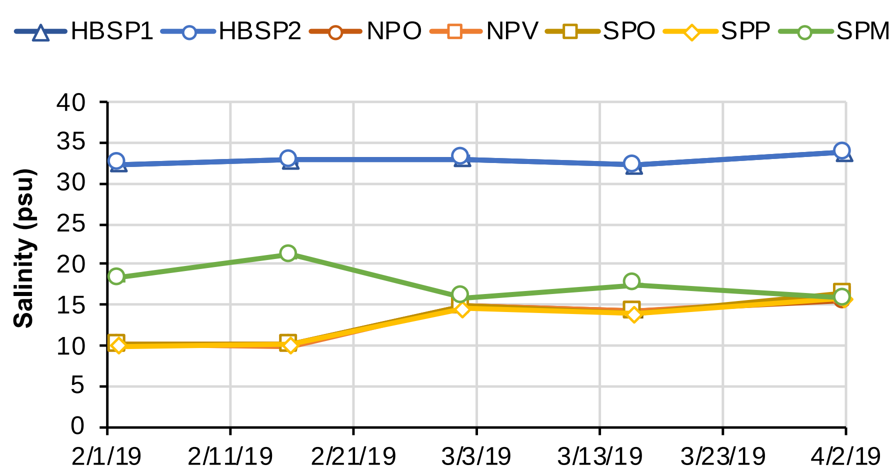

Figure 4 Salinities from the Spring 2019 survey

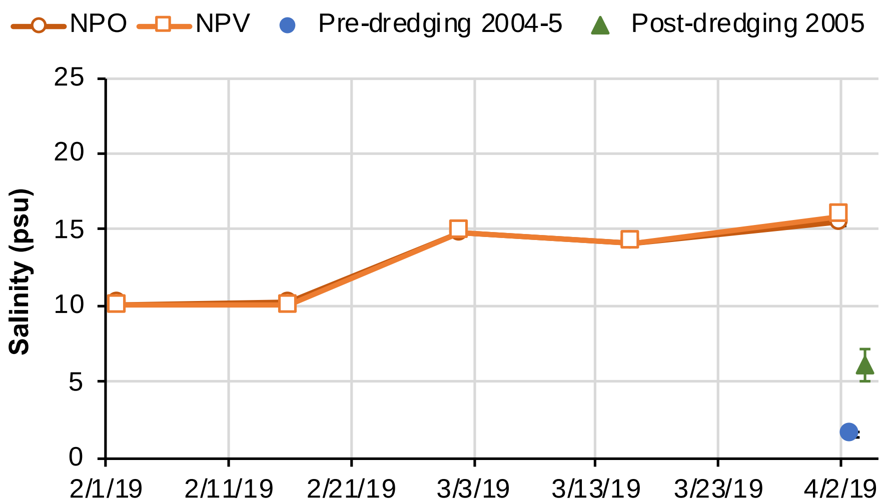

Figure 5 North Pond salinities from the 2005 and 2019 survey. Current salinity is significantly greater than salinities from 2005 (p=0.00).

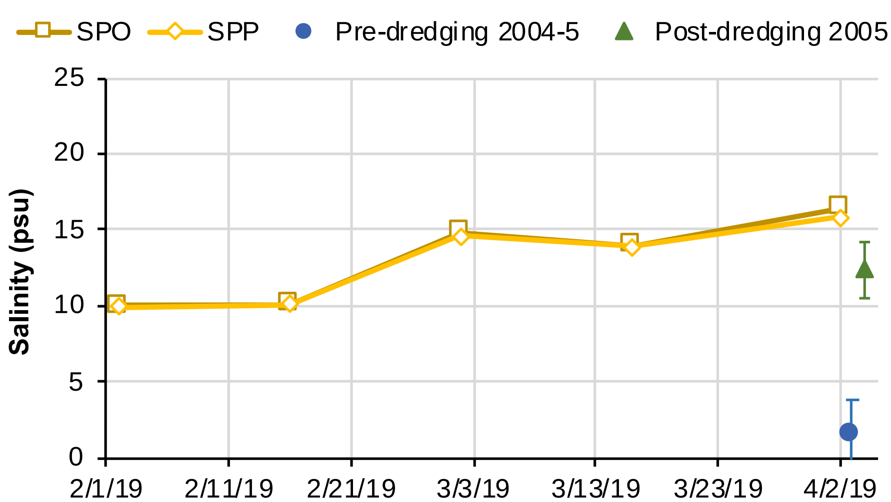

Figure 6 South Pond salinities from the 2005 and 2019 survey. Current salinity is significantly greater than salinities from 2005 (p=0.00).

Turbidity

Turbidities in Sandpiper Pond were greater at the beginning of sampling than the end and decreased roughly biweekly (Figure 7). This may possibly be due to slight increases in rainfall from February to March (Table 1). In the North Pond (Figure 8) and South Pond (Figure 9), turbidities were significantly greater than data from 2005 (p=0.04, p=0.03).

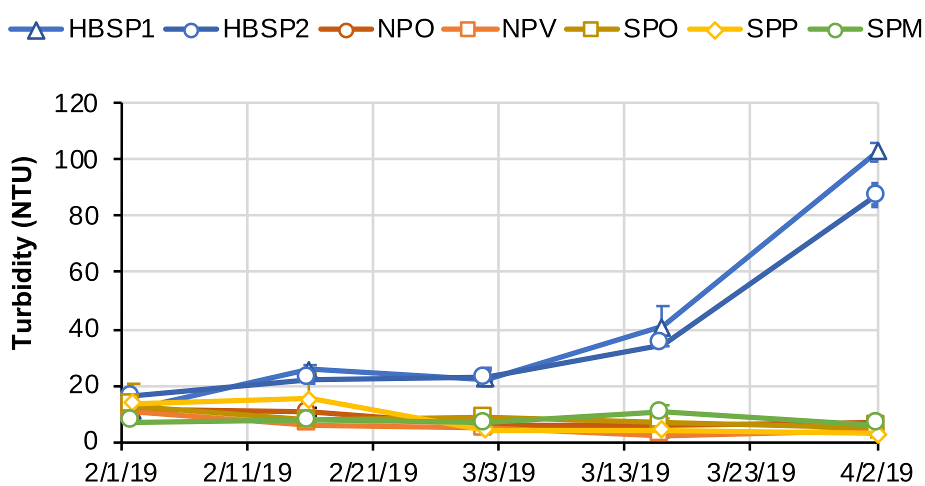

Figure 7 Turbidities from the Spring 2019 survey. High values for ocean samples are from storm conditions on last sample.

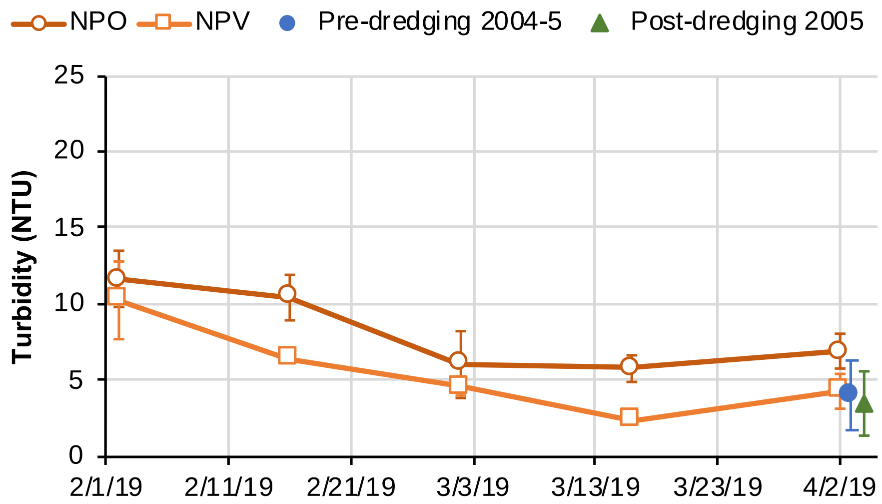

Figure 8 North Pond turbidities from the 2005 and 2019 survey. Current turbidity is significantly greater than turbidities from 2005 (p=0.04).

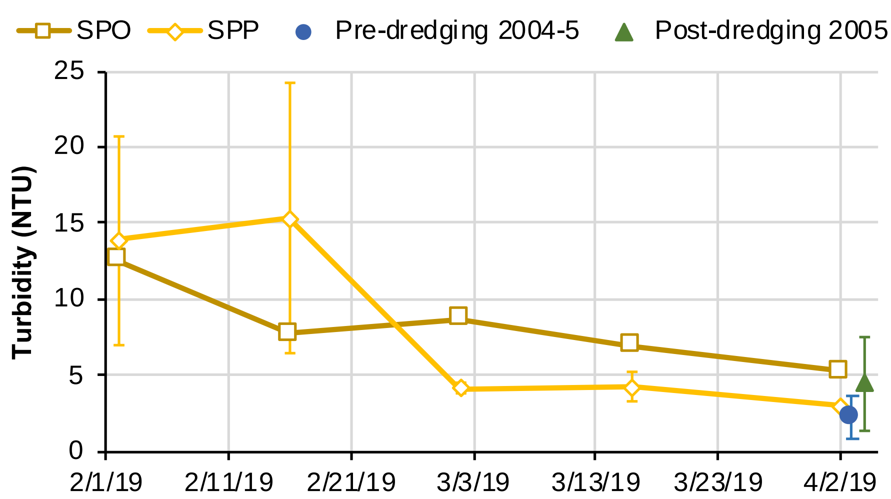

Figure 9 South Pond turbidities from the 2005 and 2019 survey. Current turbidity is significantly greater than turbidities from 2005 (p=0.04).

Dissolved Oxygen (DO)

With the exception of two samples, Sandpiper pond was currently either saturated or supersaturated (≥100%) with respect to percent saturation of DO (Figure 10). All samples on March 2nd increased in DO (% saturation). Samples at SPP were over 200%, while the rest of the pond had values less than 140%. In the North Pond (Figure 11) and South Pond (Figure 12), DO (% saturation) was not significantly greater than data from 2005 (p=0.09, p=0.07).

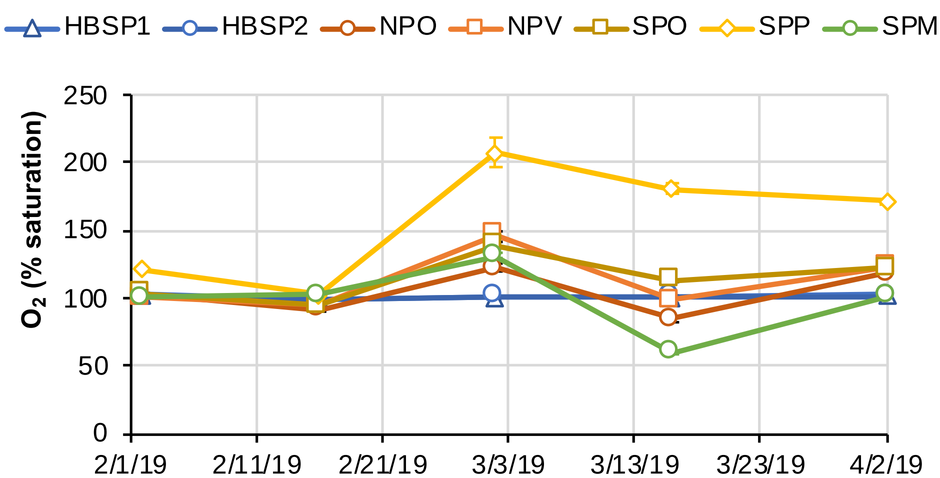

Figure 10 Dissolved oxygen (% saturation) from the Spring 2019 survey.

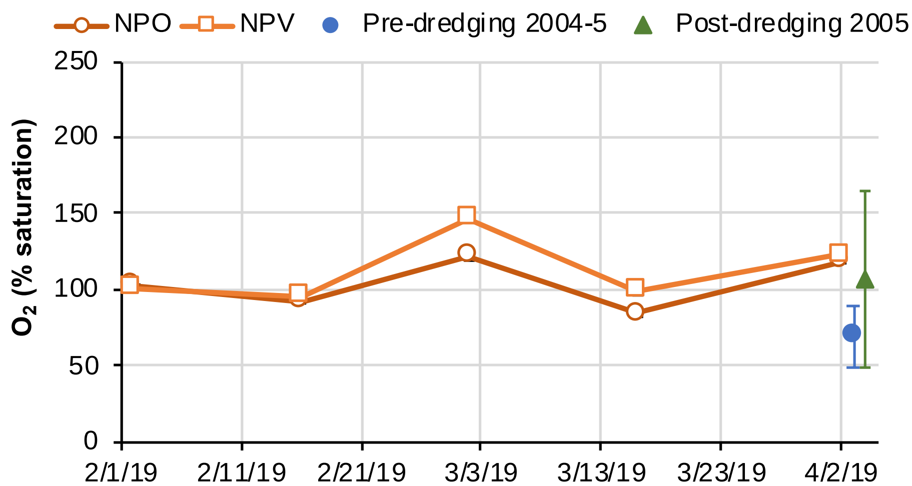

Figure 11 North Pond DO (% saturation) from the 2005 and 2019 survey. Current DO (% saturation) is not significantly greater than (% saturation) from 2005 (p=0.09).

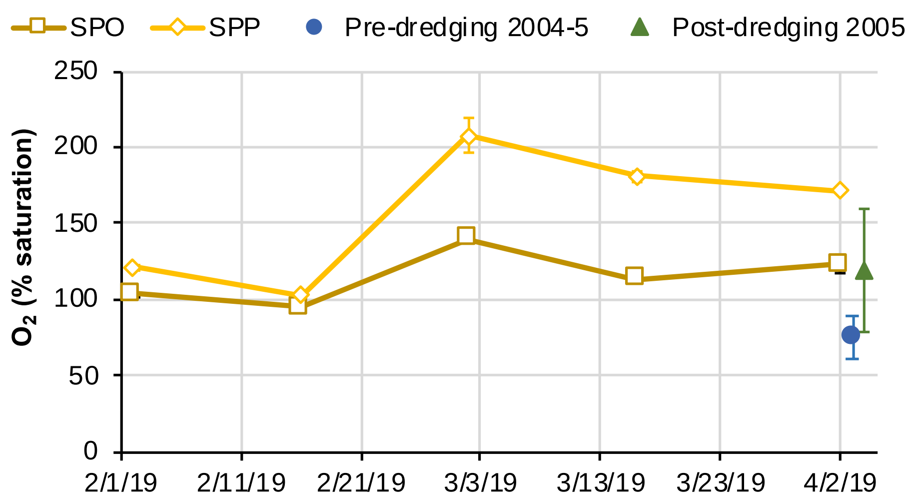

Figure 12 South Pond DO (% saturation) from the 2005 and 2019 survey. Current DO (% saturation) is not significantly greater than (% saturation) from 2005 (p=0.07).

Absolute dissolved oxygen concentrations can be compared to the NOAA's estuarine criteria. At 5 mg/L, this is the start of eutrophic conditions where biological stress occurs on the organisms. Values for 2019 have not reach below this threshold (Figure 13). In the North Pond (Figure 14) and South Pond (Figure 15), [DO] (mg/L) was not significantly greater than data from 2005 (p=0.07, p=0.22).

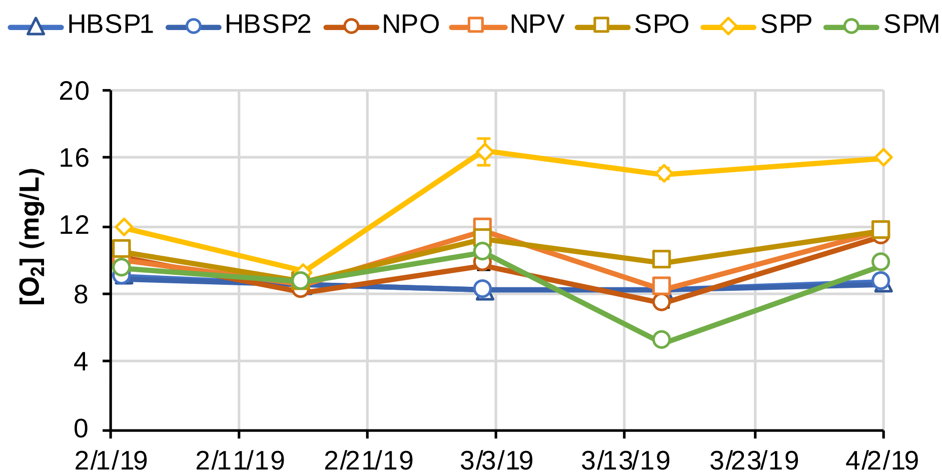

Figure 13 Dissolved oxygen (mg/L) from the Spring 2019 survey.

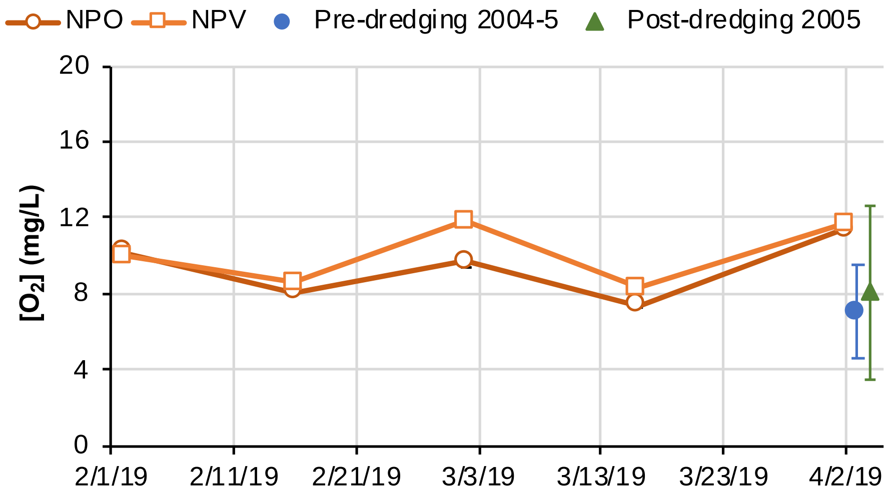

Figure 14 North Pond DO (mg/L) from the 2005 and 2019 survey. Current DO (mg/L) is not significantly greater than (mg/L) from 2005 (p=0.07).

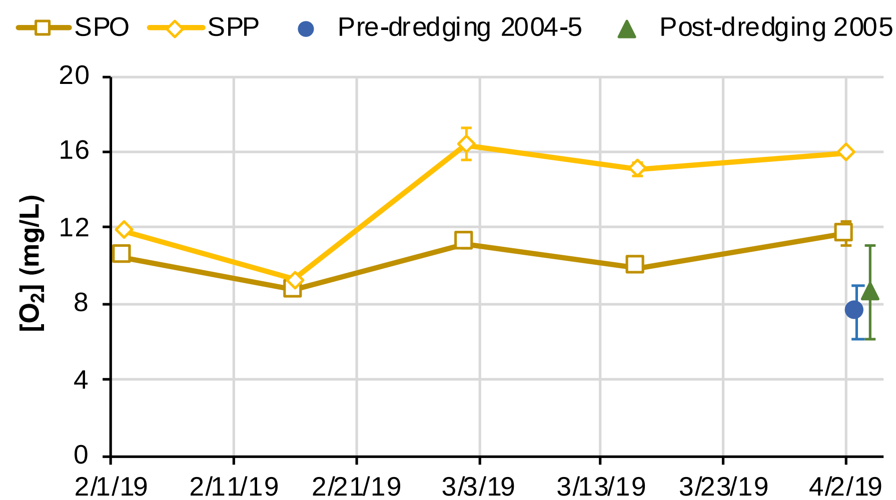

Figure 15 South Pond DO (mg/L) from the 2005 and 2019 survey. Current DO (mg/L) is not significantly greater than (mg/L) from 2005 (p=0.22).

Chlorophyll

Chlorophyll levels in Sandpiper were all, with two exceptions, at or below NOAA’s medium estuarine eutrophication levels (20 $\mu g/L$). The ponds average concentration decreased from around 15 $\mu g/L$ to 2.5 $\mu g/L$ (Figure 16). On February 16th, NMP had high eutrophication conditions with a value of 40 $\mu g/L$, coinciding with an increase also seen in the beach location. In the North Pond (Figure 17) and South Pond (Figure 18), chlorophyll was not significantly greater than data from 2005 (p=0.14, p=0.16).

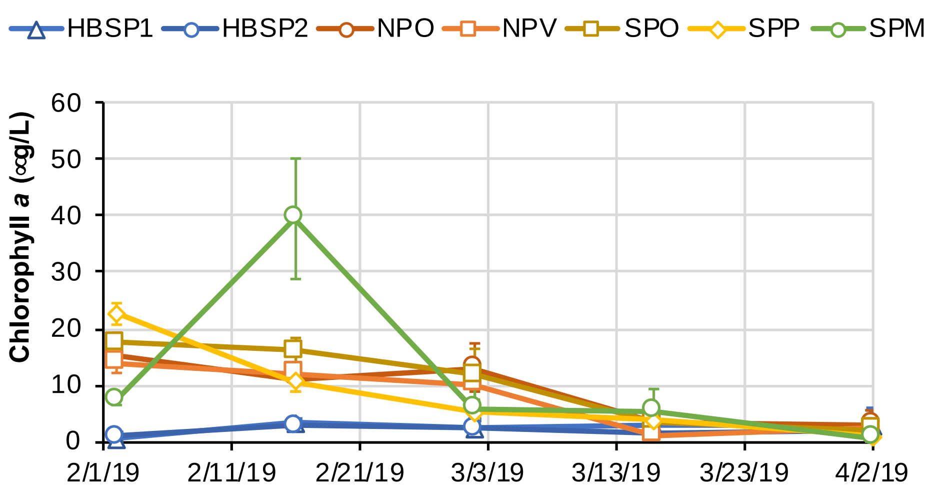

Figure 16 Chlorophyll concentrations (μg/L) from the Spring 2019 survey. The pond’s average chlorophyll concentration in the pond decreased from around 15 to 2.5 (μg/L) during the study period.

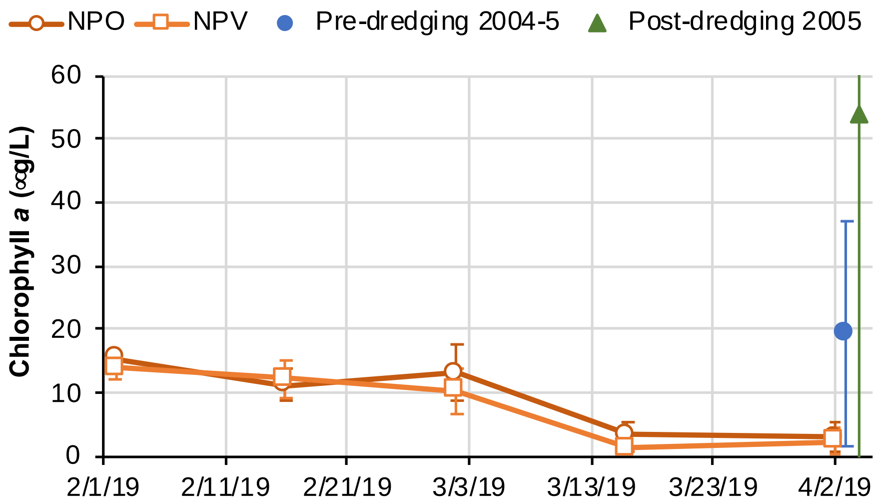

Figure 17 North Pond chlorophyll concentrations (µg/L) from the 2005 and 2019 survey. Current chlorophyll concentrations (µg/L) is not significantly greater than data from 2005 (p=0.14).

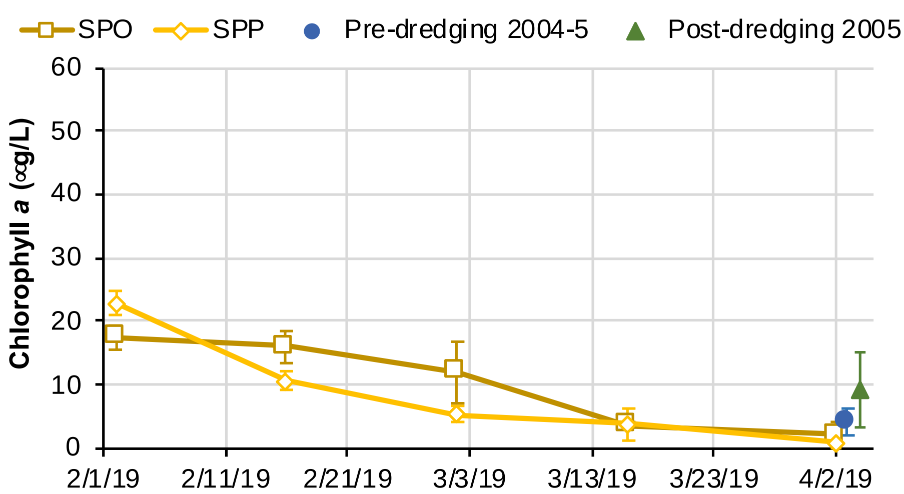

Figure 18 South Pond chlorophyll concentrations (µg/L) from the 2005 and 2019 survey. Current chlorophyll concentrations (µg/L) are not significantly greater than data from 2005 (p=0.16).

Discussion

Current status of the pond

Following the restoration project, it was deemed that cutting the channel's into Sandpiper Pond was a poor attempt to restore marine conditions. Plans were made to replace a 12–inch diameter pipe with two 18-inch diameter pipes. The introduction of the pipes and increase in tidal creeks has allowed for increases in the flow of brackish water from the saltmarsh to the pond. In fact, the pond's salinity has significantly increased since 2005. While Sandpiper Pond did not assume a marine character short-term, it exhibits a brackish character long-term. Salinities could have increased biweekly during samples from evaporation and low precipitation. Marsh and Pond salinities on April 2nd also were very similar, possibly supporting the idea of ebb tidal flows from the salt marsh being the primary mechanisms controlling since this was the only incoming high tidal cycle sampled.

Turbidity showed a significant increase also during the study period. This could have been the result of the spring nesting season. Through the entire duration of Spring sampling, the pond was occupied by several shore and wading birds. Additionally, the pond is no longer tidally connected, possibly lowering the mixing rate of pond water and allowing for the settling of particulate matter, much quicker than that of the swash zone samples on the beach.

Dissolved oxygen levels (% saturation and mg/L) currently suggest that the pond is not under eutrophic conditions and were not significantly different from 2005. However, as water temperatures increase in the coming months, DO may begin to decrease as the algal mats are no longer diffusing oxygen into the pond. There are currently large algal mats around the entire shoreline of the pond, which may be an early indicator of possible eutrophic conditions if not closely monitored (Figure 19). Water in the South Pond is also deeper and denser in algal vegetation. Both benthic and surface algal mats were abundant and may contribute to the higher concentrations than seen in the North Pond. Similarities in early algal growth may be the result for data suggesting no significant difference.

Figure 19 Photo taken at NPO on April 2nd, 2019. This site is where the old separation for North and South Pond begins. Algal mats are seen around the shore on both sides.

Chlorophyll in the pond decreased weekly from med to low eutrophic conditions. On February 16th, NMP had high eutrophication conditions with a value of 40 µg/L, coinciding with an increase also seen in the beach location. It can be suggested that this was the first spring bloom of the season. The high value in the marsh may be the result of larger amounts of nutrient concentrations, resulting in ideal blooming conditions for phytoplankton. To make this project stronger, a longer time series is needed to fully capture eutrophic conditions and to properly compare them with 2005 values.

My work in Sandpiper Pond began in Fall 2017 with biological surveys on the ichthyofauna of the pond. The pond was largely composed of euryhaline species, typical of salt marshes (Workman 2017a). Euryhaline species are capable of surviving in high salinities from increased water temperatures and low oxygen concentrations, typical of summer eutrophic conditions (McCormick et al., 2013). Vincent (2010) looked at the difference in growth rate of *Mugil cephalus* between a non-isolated pond and Sandpiper Pond, considered an isolated freshwater pond. A significant difference was determined that suggested growth rates in Sandpiper are less due to a constant osmoregulatory requirement and lack in reproduction. However, salinities from Fall 2017 were as high as 34 psu, the same as seawater, suggesting the pond was once or is subject to spring tide or ebb tidal flows that attempt to establish a natural marine channel.

Additionally, sampled icthyofauna were surveyed for the presence of ectoparasites to serve as an early bioindicator of water quality. High fingerling density induces bio-ecological stress to fry (Passino, 1984) and makes the fry more susceptible to parasitic infection (Sneisko, 1974). The parasite community of fish shows considerable variation with the environmental conditions in which fish live (Hossain et al. 2008). Several species of trichodinids, single-celled ciliated protozoans, were identified and suggest that the pond had acceptable water quality to support the fish and an obligately dependent organism (Smith and Schwarz, 2008; Workman, 2017b). Heavy deposition of sand in the natural channel from Hurricane Florence and Michael in 2018 have since closed off any remnant channel. This closing of the channel may possibly lead to a future decrease in ichthyofauna introductions, limiting the food source of the nesting wading and shorebirds. This will ultimately have an effect on the rate at which algae in the pond is consumed and the growth rate of icthyofauna (Vincent, 2010).

The Future of Sandpiper Pond

For this survey, water quality parameters suggest that the pond is currently not highly eutrophic. However, further monitoring is required to confirm this suggestion as the winter-to-spring transition period, where nutrients build-ups lead to algal blooms, occurs on a longer time scale. Two aspects that we didn't examine were the phytoplankton diversity of the pond and the hydrological influence of the ocean's close proximity.

Identifying phytoplankton diversity and their assemblage can be useful to predict possible blooms, carbon to nutrient affinity ratios, and nutrient uptake (Bonachela et al., 2011). This biological survey would complete the aquatic food web of the pond to further explain the ecological interactions occurring in the pond. Additionally, the competitive exclusion principle may apply to the certain phytoplankton since the pond is similar to an impoundment, challenging "the paradox of the plankton" (Hardin 1960; Hutchinson 1961).

Lastly, calculating the hydrologic pumping of the pond can explain the importance of groundwater transfer and hydrological mixing from the near ocean (Phillips and Shedlock, 1993). With these two additional surveys, Sandpiper Pond would have had chemical, biological, physical, ecological, and geographical surveys, representing every aspect of the Marine Science Major. Confirmation has been given that Sandpiper Pond is connected to the marsh by two culverts passing under the North beach road at the location of our SPM station (Figure 3).

I only wish for continued monitoring in this pond since it has almost become an impoundment. If one main source of input can be determined, introductions of flora and fauna from the marsh can be tracked with ease. Continued monitoring may help aid in future management of federally and state endangered wading and shore-birds: such as Woods Storks (*Mycteria americana*), Piping Plovers (*Charadrius melodus*), and Wilson Plovers (*Charadrius wilsonia*), as they continue to utilize this coastal impoundment (Dikun 2008).

Relation to the Honors experience

Since entering the Honors program, I have been encouraged to produce no less than my best work. I wanted to integrate skills learned from numerous traditional and research courses, into a personal research project to really emphasize the expectations of the Honors program.

During MSCI 305H, 397H, 476, and my involvement in several 399s, I have gained the proper skills to work proficiently and independently under each research advisor in a professional setting. In Marine Chemistry (MSCI 305H), I became very familiar and interested in water quality methodology, as a similar assessment to that of my Honors project is required for MSCI 305L. During my work in MSCI 397H, I was introduced to sedimentary biogeochemical analyses, which require using precise volumes of solutions to detect low concentrations of nutrients and other water quality parameters. My involvement in 305H and 397 helped me further refine analytical skills that I gathered from my first MSCI 399. Marine Plankton (MSCI 497), taught me how to do biochemical analyses on living organisms, how to use growth of an organism as a bioindicator, and helped train me to call myself a plankton ecologist. In addition to skills development, the course required a study of choice. I selected to do phytoplankton diversity vs. depth in Winyah Bay, which required multiple boat collections, biochemical analyses, and a presentation that help strengthen my skills as a researcher.

All of the coursework stated above have led me back to question my original research, encouraging the purpose of the MSCI 497H. This project ties together all the courses, skills, techniques, and methodology gained from past studies, and tries to revisit a question addressed fifteen years ago. My Honors project helps further my passion to attend a Master’s program or to continue as a researcher, and that’s the best honors experience I could have ever achieved.

Acknowledgements

A very special thank you to Dr. Angelos Hannides for his continued support and contributions to this project. Without him, this project would not have been possible. Thank you to the Honors College for printing materials needed for the Spring 2019 Undergraduate Research Competition. Lastly, thank you to all those who contribute to making Huntington Beach State Park one of my favorite locations in the Grand Strand region of South Carolina.

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