Comparing Changes in Salinity with Plankton Community Composition in ACE Basin Estuary, South Carolina

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BIO 318 - Field Studies in Marine and Estuarine Biology

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Submitted 8 February 2016

Abstract: The biodiversity of an aquatic community is often representative of its relationship with abiotic factors of the environment, including water salinity and temperature. Transitional zone plankton communities are especially indicative, as they respond quickly to changes in environmental conditions. To study how changes in salinity in an estuarine ecosystem affect the plankton communities that live there, plankton samples were collected from a single site in Mosquito Creek, a tidal waterway in A.C.E Basin, South Carolina, in December, 2015. Samples were taken every hour from high to low tide, allowing for observation through one tidal cycle. The salinity and temperature of the water were recorded at each time increment. Using species richness, the diversity of the plankton community was shown to be directly and significantly related to the salinity of the water. It was determined that variation in species identification among researchers was a limiting factor, but our methods were such that it likely did not significantly affect the accuracy of our findings.

Introduction

Phytoplankton serve as primary producers in nearly all aquatic ecosystems, and are responsible for roughly half of all global photosynthetic activity (Carlowicz, 2009). The health of freshwater and marine communities relies heavily on phytoplankton populations, due to their role as the premier autotrophs within their ecosystems. The respiration levels of phytoplankton populations are highly reflective of the stability of the entire community, resulting in phytoplankton being reliable indicator species for aquatic ecosystems (Serret, 2001; Jaanus, 2009). Zooplankton, on the other hand, are eukaryotic organisms that interact with phytoplankton populations through a predator-prey relationship (Deason, 1981), and are often found wherever phytoplankton populations occur in abundance. Without this dynamic, phytoplankton populations would quickly grow beyond carrying capacity, resulting in ecologically devastating algal blooms (Anderson, 2002; Diersing, 2009). For this reason, the maintenance of healthy population levels of both phytoplankton and zooplankton species are equally important to the ecological stability of our biosphere.

As plankton communities are found in abundance across a range of highly variable aquatic conditions, the adaptations of each population must be specific to the region in which they are found. Marine plankton populations, for example, are adapted to high salinity conditions, where those adapted to freshwater conditions would not be able to survive (Muylaert, 2009). Between these extreme ranges, however, are intermediate populations, which are adapted to brackish conditions (salinity between 2-20 ppt) (Paasche, 1975). Among the ecosystems that exhibit such conditions are estuaries. Estuarine systems are coastal transitional zones characterized by an intersection of water from freshwater and marine biomes, resulting in a stratification and mixture of salinities (Muylaert, 2009; Potter, 2010). Plankton communities in these ecosystems are specially adapted to regular cycles in salinity, which result from tidal activity. Physiological adaptations among these communities include tolerance to a range of intermediate salinities, while behavioral adaptations include regular vertical, or diel, migrations (Mann & Lazier, 2006).

A considerable indicator of the health of a community is its biodiversity, or simply the number of species in a defined area (Campbell, 1997; Karleskint, 2013). In every community, the possibility of competitive exclusion by one or more populations threatens its diversity, both in terms of species richness and relative abundance (Aschehoug & Callaway, 2015). The likelihood of competitive exclusion developing in a community is closely linked with the frequency of disturbance in the ecosystem (Ormond, 1997). Estuaries typically exhibit relatively high levels of disturbance, due to their position as transitional zones between full saltwater and freshwater conditions (Pollack, 2010). These disturbances affect the estuarine plankton communities, which, because of their role as environmental indicators, reflect the health of the ecosystem as a whole through their diversity levels (Serret, 2001). Recording the species richness of these communities throughout the salinity range of an estuarine system provides insight as to the ecological dynamics of the entire system. While it is known that plankton populations can migrate in response to the salinity gradient (Laprise & Dodson, 1994), there is value in understanding the specific changes in community composition within a region.

For our study, a site was chosen at Mosquito Creek, a diurnal tidal waterway within the Ashepoo-Combahee-Edisto (ACE) Basin estuary, near Charleston, South Carolina. In terms of water quality, Mosquito Creek is a particularly dynamic aquatic system because of its use as a boating route and its vulnerability to water runoff from surrounding areas (Wenner, 2005). Additionally, the ecosystem undergoes regular changes in salinity as the Ashepoo River transports saltwater inland with the tide, and freshwater from further inland flows out as the tide recedes. This dynamic allows the salinity tolerances of different plankton populations to be observed in a discrete area over a relatively short period of time. While it is unclear whether the plankton populations move constantly with the current or remain relatively stationary throughout the tidal cycle, the diversity of the phytoplankton and zooplankton communities within an observed salinity range provides insight as to changes in community composition in varying salinities.

In order to quantify these changes in the composition of an estuarine plankton community, the salinity of the water at the Mosquito Creek site was recorded throughout one eight-hour high-to-low tide cycle. Additionally, community surveys of the plankton community found at the time of each salinity measurement were performed. Significant changes in the diversity of the plankton community were hypothesized to coincide with the observed variations in salinity. Specifically, it was predicted that the diversity of the plankton community would reach its peak at the maximum salinity value of the water. Species richness, Shannon's Index of

Diversity, and the ratio of phytoplankton species to zooplankton species were used as measurements of diversity in an attempt to quantify any observed patterns or changes in the community composition. The question we attempted to answer with this study was whether there was any significant relation between the community composition of plankton and variability of estuarine salinity at different times of the day.

Methods

Sample collection - A single site at Mosquito Creek (Green Pond, South Carolina) was selected for sampling during mid-December, 2015. The site was accessed via an aluminum pontoon dock, and water samples were collected roughly 3 meters from the bank. Beginning at high tide (9:00 am), the first water sample was taken by submerging a Wisconsin Plankton Net below the water level, allowing water to flow through the fine mesh for 30 seconds. Within the same time period, salinity was measured using a calibrated refractometer, and temperature was recorded (after submerging 30 seconds to allow equilibration) using a small glass thermometer. These water sample collections were repeated 8 times, once per hour, until low tide (4:00 am), with salinity and temperature being recorded analogously each time.

Sample analysis - After each sample was collected, it was transferred to a small paper cup and labeled. The sample was then stirred within the paper cup to ensure a homogeneous mixture, and 1 mL was pipetted evenly onto a 20x50 mm Sedgewick rafter counting cell. Three such replicates of each sample were generated in individual counting cells, and a 10x10 mm square of each counting cell was marked off. Using a dissecting microscope under 10x magnification, each of three researchers analyzed the plankton community within each replicate cell. The total number of unique species observed within each 10x10 mm cell was recorded to determine its species richness. In order to generate an estimate for the entire population within the 20x50 mm counting cell from the 10x10 mm portion analyzed, the number of individuals within each species observed was multiplied by ten.

Data analysis - From the collected data, the sum of the number of unique species from each replicate was generated to determine the species richness (α-diversity) for the combined (phytoplankton and zooplankton) plankton sample. The phytoplankton α-diversity was then divided by the zooplankton α-diversity to generate a ratio of phytoplankton-to-zooplankton for each sample. Finally, the α-diversity of the combined plankton sample was used to calculate a Shannon's Index value for each sample community. The resulting data from these methods of measuring biodiversity were used to determine a relationship between salinity and biodiversity of the estuarine plankton community. Regression analysis was used for each of four relationships, (1) combined plankton community diversity (α-diversity) vs. salinity, (2) phytoplankton-to-zooplankton ratio vs. salinity, (3) combined plankton community diversity (Shannon's Index) vs. salinity, and (4) combined plankton community diversity (α-diversity) vs. temperature, in order to evaluate the significance of any exhibited relationship from the eight sample collections.

Results

The salinity of the sample site in Mosquito Creek decreased by an average of 1.1 ppt each hour through the eight-hour sample cycle. The maximum salinity was observed at the first sample collection (high tide, 9:02 am), and the minimum salinity values were found at the final two sample collections (low tide, 2:59 pm & 4:00 pm) (Table 2). The water temperature ranged from a maximum of 23.0°C at the noon sample collection to a minimum of 17.0°C at the final sample collection (Table 1).

Table 1. Water salinity and temperature data for Mosquito Creek (SC) site, December, 2015.

Time	**Salinity (ppt)**	**Water temp. (°C)**
9:02 am	20.0	-
9:59 am	19.0	-
10:59 am	17.0	21.0
11:59 am	17.0	23.0
12:59 pm	14.0	18.0
1:57 pm	14.0	18.0
2:59 pm	12.0	19.0
4:00 pm	12.0	17.0

The α-diversity of the plankton community at the Mosquito Creek (SC) sample site was shown to have a direct and significant relationship with the salinity of the water. (Figure 1a; r^2 = 0.741, P = 0.006). The ratio of phytoplankton-to-zooplankton species of the plankton community at the Mosquito Creek (SC) sample site was shown to have a direct but statistically non-significant relationship with the salinity of the water. The trend suggested toward significance, but was likely influenced by the heavily weighted value of 4.5 at 17.0 ppt (Figure 1b; r^2 = 0.280, P = 0.2). Using Shannon's Index as a measure of diversity, combined plankton community diversity was found to be directly related with salinity, but the relationship was not statistically significant. The trend suggested toward significance (Figure 1c; r^2 = 0.319, P = 0.1). As an additional measure, the temperature of the water at the sample site was taken at each collection and compared to the species richness of the plankton community. These two variables displayed a positive relationship, but was not significant. The trend strongly suggested toward significance (Figure 1d; r^2 = 0.634, P = 0.06).

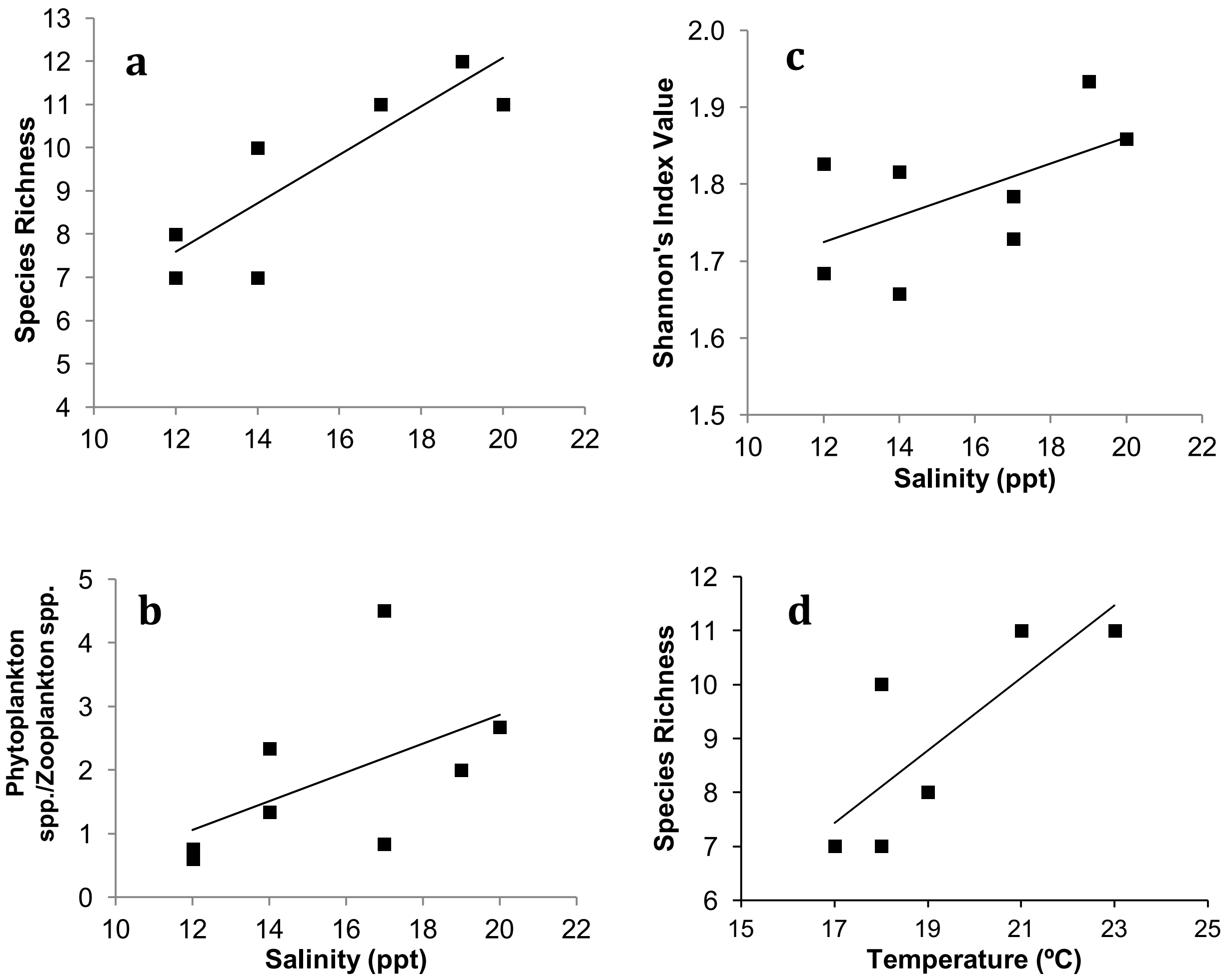

Figure 1. (a) Species richness (α-diversity) of the combined plankton community vs. water salinity. **(b)** Ratio of phytoplankton species to zooplankton species within the plankton community vs. water salinity. **(c)** Community diversity (Shannon's Index) vs. water salinity. **(d)** Species richness (*a*-diversity) vs. water temperature at Mosquito Creek site. All sample collections from Mosquito Creek (SC) site, December, 2015.

Discussion

The results of the study supported our original hypothesis: salinity and combined plankton community diversity were shown to have a positive and significant relationship, using species richness as a measure of community composition. As shown in Figure 1(a-d), From the eight water samples collected at the Mosquito Creek (SC) site, 74% of the change in richness was explained by changes in salinity, 28% of the change in the ratio of phytoplankton species to zooplankton species was explained by changes in salinity, 32% of the change in diversity was explained by changes in salinity, and 63% of the change in richness was explained by changes in temperature. The observed changes in community composition are potentially a result of certain plankton populations having different salinity tolerances. Some of the changes in which species were observed within each sample can likely be explained by the water current, which was relatively strong approaching the midway point between high and low tide. However, certain plankton species, especially larger zooplankton, are capable of vertical migration within the water column, and do so in response to light-dependent phytoplankton abundance (Cushing, 2008). Therefore, it can be assumed that at least a portion of the species observed are capable of resisting water currents and migrating primarily in response to environmental stresses.

Our experiment sought to understand how the phytoplankton and zooplankton community of ACE Basin, South Carolina responded to the daily salinity cycle, which results from the diurnal tide dynamic of the water in that region. Assuming that a certain quantity of the individuals observed at the Mosquito Creek site are capable of lateral migration in spite of interference from strong currents (Wooldridge & Erasmus, 1979), our results provided insight into changes of plankton community composition compared to the changing salinity of the water throughout its tidal cycle. It was shown that, at high tide, the diversity of the combined phytoplankton and zooplankton community is at its highest. Even if the majority of the plankton population is unable to migrate laterally against strong currents (Ketchum, 1954), our experimental results indicate that the highest levels of plankton community diversity are in the higher salinity waters towards the ocean, and wash inland with the tide. These findings are in contrast with previous studies that suggest zooplankton populations are most abundant and active in relatively low salinities (Kimmerer, 1998; Jensen 2010).

One limitation of our study was the lack of the first two water temperature data points. It was not until the third sample collection, at 11 am, that our group became aware of our access to the necessary instruments. Because there were only six temperature data collections, it was difficult to establish any significant relationship between plankton community composition and water temperature. The six water temperature data we did collect indicated a range of 6°C in just five hours, which would be an extreme range in comparison to historical temperature data for ACE Basin waterways. These data indicate that waterways in this region typically exhibit temperature ranges of 1-2°C in that time span, as reported by the National Estuarine Research Reserve System. It is likely that, with more temperature data collections, the temperature range recorded would, on average, be narrower than indicated by our results.

Another limitation in our study was in the observed variation in each researcher's ability to identify individuals within the sample replicates. After completing our sample analysis, we attempted to quantify the discrepancies in our species identification. This was done by generating another water sample replicate, following the same methods as the previous collections. Each researcher analyzed the same 10x10 slide replicate individually, and the identified species were compared. Two of the four members identified just 33% of the maximum number of species identified, and six of the total species were identified by just one member (Appendix, Table 2). It was determined that this limitation did not impair the accuracy of our results substantially, due to the design of our methods. Because the sample community composition was determined by compiling all of the unique species observed in each of the three replicates, it us unlikely that any species went unrecorded by the entire group.

Future experiments would benefit from an increase in the number of samples taken, and potentially factoring in multiple sample sites. Specifically, extending the sample range to at least one 24-hr cycle would permit the observation of the salinity range throughout the entire diurnal tide cycle of ACE Basin. Because the phytoplankton are light dependent, it is likely that light conditions would factor into the community composition in addition to water quality. Sampling additional sites would benefit the research by allowing conclusions about the ACE Basin plankton community in general, rather than a single site within the region. The changes in biodiversity we observed may be specific to our specific sample site in Mosquito Creek, and unique from the other waterways in ACE Basin. By only sampling a single site, we limited our conclusions to a very specific area. Even without these amendments, however, our results were sufficient in establishing a clear and direct relationship between salinity and plankton community composition at our sample site.

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Appendix

Table 2. Phytoplankton and zooplankton species identified by researchers A-D from a common sample replicate, collected at Mosquito Creek (SC) site, December, 2015.

Species	A	B	C	D
Adult Copepod	**2**	**4**	**3**	**2**
Thalassionema	0	0	0	**1**
Chaetoceros	0	0	0	**2**
Skeletonema	0	**3**	**3**	**4**
Amphiprora	0	**7**	**7**	**7**
Medusa	**1**	0	**9**	**2**
Fish Egg	0	0	**1**	**1**
Rhizosolenia	0	0	**1**	**1**
Polychaete	0	0	**1**	0
Zoea	0	0	**1**	0
Barnacle Larvae	0	0	**1**	0
Guinardia	0	0	**4**	0
Rotifer	**2**	0	**4**	0
Coscinodiscus	**5**	**3**	**9**	**5**
Total ind. identified	**10**	**17**	**44**	**25**
Total spp. identified	**4**	**4**	**12**	**9**