A comparison of water quality in the Blackwater River and Henderson Creek estuaries, southwest Florida

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INTRODUCTION

Because of their ability to cycle and store natural nutrients, estuaries are especially vulnerable to anthropogenic eutrophication. The rate of phytoplankton growth depends on light, water temperature, and availability of the limiting nutrient in the system. Increased inputs of nutrients have been shown to increase phytoplankton growth and primary production of estuaries, causing eutrophication. The suite of detrimental ecological effects associated with eutrophication including decreased food quality, noxious algal blooms, and anoxia, leads to changes in the composition of species across all trophic levels (Webb, 1981). Primary productivity can be indirectly measured by determining the standing crop of phytoplankton. This is commonly found by measuring the concentration of chlorophyll *a*, the most important photosynthetic pigment in the majority of algae (Miller et al., 1982).

Henderson Creek drains the Belle Meade water district and is the main source of fresh water to Rookery Bay, which empties into the Gulf of Mexico. Extensive housing developments, golf courses, several trailer parks, and the Belle Meade agricultural area are all located in the headwaters. There is heavy boat and marina use as well as occasional drainage from the city of Naples (Tedesco, 1999). *E. coli* bacteria have been found in the creek, indicating that leachate from septic tanks is indeed reaching the estuary (M.L. Tamplin, personal communication, 2000). A South Florida Water Management District weir blocks salt water from coming upstream as well as causing fresh water to flow into the estuary mainly in pulses. The western part of the estuary is in the Rookery Bay National Estuarine Research Reserve (RBNERR), an important wildlife habitat and recreation area.

Located approximately 16.5 km to the southeast of Henderson Creek, the Blackwater River is a similar, but comparatively pristine ecosystem. The river begins at a boat basin in Collier-Seminole State Park, flows through the Ten Thousand Islands National Wildlife Refuge, and becomes part of RBNERR. Because the majority of the watershed is protected and there is no weir restricting flow, Blackwater River is commonly used as an example of an undisturbed estuary. However, there are roads through the watershed and parts of the river have been altered for navigation. There is recreational boating and fishing, but much less than in Henderson Creek. The purpose of this study is to compare Henderson Creek to the Blackwater River to determine if the land use in its watershed is causing eutrophication.

METHODS

In late June of 1999, measurements and samples were taken along each estuary at both high and low tides. The 14 sampling stations on Henderson Creek stretched from just above the weir to the most seaward permanent water quality monitoring station (Fig. 1). Blackwater River's 11 stations started in the boat basin and again ended at the last permanent water quality station (Fig. 1). Using a small boat to visit each station, latitude, longitude, time, and water depth were recorded. Physical water quality parameters including temperature, pH, salinity and dissolved oxygen were measured at the water's surface and near the bottom with a YSI data sonde. Secchi disc transparency was determined in the shade of the boat. A water sample was taken to determine chlorophyll *a*. Three portions of each water sample were filtered, the filters were frozen, and then the pigments were extracted from the phytoplankton using dimethyl sulfoxide and acetone. A Turner 10-AU fluorometer was used to calculate the concentrations following EPA Method 445.0 (Arar and Collins, 1997). Dr. Larry Brand from the Rosenstiel School of Marine Sciences at the University of Miami collected and analyzed chlorophyll *a*, salinity, and temperature data for Henderson Creek at high tide simultaneously with this study.

contains very little Fe, and similarly trending K, Mg, and Ca. There is very little K and Mg (in the tenths of g/g's) between 4 and 42cm, a sandy section of core with thin shelly layers of about 1mm thickness. The highest levels of Fe and Ca occur between 42 and 47cm, an area consisting of thinly alternating laminations of white, grey and black silty mud.

Faka Union Site

The core taken from the older white mangrove forest has a very dark, reddish black organic rich parent material for the first 50cm of substrate. There are also high and greatly varying amounts of K, Mg, Ca, and Fe. At 50cm the substrate becomes a mottled mixture of sand and organics, and root abundance decreases with depth. Directly above this boundary (at ~40-45cm), K, Mg, Ca and Fe sharply increase and then decline to tenths of a g/g. It is not until below 80cm that abundance of Fe elevates and a sharp peak of Ca occurs.

Appearing similar to the middle of the aforementioned core (between 50 and 80 cm), the Transgressive Forest substrate contains very little and remarkably similar amounts of Fe, K, Ca, Mg.

DISCUSSION

The most apparent variations in cation behavior is dependent primarily on the parent material. There is an obvious correlation between the abundance of these elements and the type of substrate present. The increased iron, particularly at the bottom of the two of the Henderson cores and the Mature Faka Union core, may indicate a heavy metal sink, which is common in mangrove forests. The iron is indicative of higher sorpitive capacity for organics and possibly heavy metal concentrations as well (Ramanathan, 1997, Piascik et al., 1997).

The levels of Mg, K, and Ca all generally follow one another with depth in the cores. The only exceptions are the elevated Ca levels when shells or other forms of carbonates are present in the parent material. In both the Henderson and Winstar Restoration, cores have both high amounts of Ca and shelly materials present, as seen in Figure 2. In all three natural cores there are lower amounts of these three cations present, but the restoration cores have high amounts of Ca, and increased cation levels in the compacted organic rich substrate, under the fill. This may be a function of the mangrove plants' inability to penetrate the fill and absorb these cations or perhaps is a reflection of the compaction of the substrate.

Aside from the obvious physical evidence that mangrove roots are unable to penetrate the compacted and fill sediments, this biogeochemical analysis serves to further illustrate the differences between natural and restored mangrove forests. While the major chemical difference between these two depends primarily on the variations in parent material, the importance of this should not be overlooked. Mangrove plants in the restoration sites have different cation availabilities than do those in mature forests, although this may, in part, be attributed to their relative youth.

REFERENCES CITED

Bischof, Barbel G., 1995, Aerial photographic analysis of coastal and estuarine mangrove system dynamics of the Everglades National Park, Florida, in response to hurricane implications for the continuing sea-level rise: Thesis, University of Miami, Miami, FL.

Dawes, Clinton J., 1998, Marine Botany: John Wiley & Sons, Inc., Toronto, Canada, 480p.

Jeffery, David W., 1987, Soil~Plant Relationships, An Ecological Approach: Timber Press, Portland, Oregon, 295p.

McKee, Karen, L., Faulkner, Patricia L., 1999, Restoration of Biogeochemical Function in Mangrove Forests Of Southwest Florida, Rookery Bay National Estuarine Research Reserve Unpublished document, 32p.

Piascik, Henryk, Smolczynski, Slawomir, Orzechowski, Miroslaw, 1997, Sorptive properties of hydrogenic soils From the Vistula Estuary area: Soil Science, v. XXX/2, pp 15-22.

Proffitt, Edward, Devlin, Donna J., 1990, Winstar Mitigation Site, Final Progress Report, 11p.

Ramanathan, A. L., 1997, Sediment characteristics of the Pichavaram mangrove environment, south east coast of India: Indian Journal of Science, v., 26, p 319-322.

Research Staff, 1993, Henderson Creek Mitigation Project Report for the Period October 1992 through March 1993: Rookery Bay National Estuarine Research Reserve and Florida Department of Environmental Protection, Unpublished document, 15p.

Research Staff, 1992, Henderson Creek Mitigation Project Cumulative Report for the Period 1 January 1991 to 30 September 1992: Rookery Bay National Estuarine Research Reserve and Florida Department of Environmental Protection, Unpublished document, 21p.

RESULTS

Chlorophyll *a*. For the Blackwater River, the concentrations of chlorophyll *a* gradually decreased downstream from the boat basin (Fig. 2). They began to rise near the entrance to Mud Bay, and low tide levels became greater than those at high tide, with the most seaward concentrations reaching values similar to those in the boat basin. Low tide chlorophyll *a* levels averaged 0.736 μg/L, slightly less than the high tide average of 0.932 μg/L. The average concentration of chlorophyll *a* in Henderson Creek was 5.39 μg/L, over six times greater than in the Blackwater River. The distribution of chlorophyll *a* along Henderson Creek was much more erratic, with high magnitude oscillations from above the weir to station six. Downstream of station six, the chlorophyll levels were irregular, but generally decreased toward the Gulf. The largest concentration of 45.5 μg/L was just below the weir at high tide. The values for stations two through seven remained relatively stable, but considerably higher than those for the Blackwater River. After a sharp drop from station seven to station eight, the levels approached those at the Blackwater River. Chlorophyll *a* levels were slightly higher during high tide, averaging 6.1 μg/L compared to 4.68 μg/L at low tide.

Chlorophyll *a* data in this study did not exactly match that of contemporaneously collected samples analyzed at Rosenstiel. However, the two data sets for Henderson Creek at high tide are related by the equation

$$y = 0.22x - 1.3424 \qquad R^2 = 0.871$$

with "y" symbolizing the sample analyzed in this study and "x" that in the Rosenstiel laboratory. Station one is excluded because of its unusually high magnitude.

Salinity. The normal salinity for estuarine waters in the area under study varies greatly with season and precipitation and ranges from 10 to 40 ppt, being stable at 30 ppt (Tedesco, 1999). In the Blackwater River, the water at the bottom of the boat basin during low tide had a salinity of 36.56 ppt, greater than that of normal seawater. The bottom and surface salinities were almost identical throughout the rest of the estuary (Fig. 3). The salinity increased from the boat basin to station nine, and then began to level out near 35 ppt approaching the Gulf of Mexico. Henderson Creek was slightly less saline than the Blackwater River and showed smaller tidal fluctuations in salinity. Above the weir, the water was very fresh, with a salinity of only 0.79 ppt. The surface salinity sharply increased below the weir and remained nearly constant at around 8 ppt downstream to station six. Here it began to increase at the same rate as in the Blackwater River and show tidal differences of a similar magnitude. The salinity along the bottom of Henderson Creek was much higher than at the surface from station one to station nine and similar at stations ten through thirteen.

Temperature. Annually, the water temperatures in the region range from 11-37°C and average 27°C (Tedesco, 1999). For the Blackwater River, the average water temperature during low tide was 27.03°C; during high tide it was slightly above average at 27.53°C. During both high and low tides, bottom temperature showed a gradual increase of about 3° C from the boat basin to the Gulf of Mexico (Fig. 4). Surface temperature at low tide showed a similar trend, with a 2° C increase. At high tide, however, the surface temperature decreased a degree from the boat basin to station five and then rose a degree from there seaward. The waters of Henderson Creek were slightly warmer than those of the Blackwater River. The average water temperature was 28.25°C at low tide and 30.72°C at high tide. Temperature increased 2°C from below the weir to the outer bay. High tide water temperatures in Henderson Creek were approximately 1-4°C warmer than at low tide and more erratic than at low tide or in the Blackwater River.

pH. The average pH for the Blackwater River was 7.28 and was higher during high tide, averaging 7.42 compared to 7.14 at low tide. The lowest pH in either estuary, 6.43, was found at the bottom of the boat basin. The bottom pH gradually increased moving downstream from the boat basin (Fig. 5). The surface pH decreased from station three to station six or seven depending on the tide, then increased from station eight to station twelve. Henderson Creek was more basic than the Blackwater River, with an average pH of 7.51. Again, the water was less acidic during high tide, 7.67, than at low tide, when the average pH was 7.35. Above the weir, the water had a pH of 8.3, much more basic than anywhere else in the estuaries. Gradually becoming more basic toward the Gulf of Mexico, bottom water showed a much smoother trend in pH than water at the surface, which did not change in pH for stations one through seven. The pH rises from station eight to the outer bay.

Dissolved Oxygen. The average dissolved oxygen percentage in the Blackwater River was 23.66 %. At low tide, there was 24.85% dissolved oxygen, slightly more than at high tide with 22.28%. Other than at the boat basin, where the bottom had very little dissolved oxygen compared to the surface, dissolved oxygen levels did not change much with depth. Concentrations showed a relatively steady increased towards the Gulf of Mexico (Fig. 6). In Henderson Creek, the average dissolved oxygen is 43.64%, almost twice as high as the Blackwater River. The 55.18% average dissolved oxygen at high tide was much greater than the 32.1% average dissolved oxygen at low tide. The surface dissolved oxygen was very erratic, ranging between 7.9% and 119%. Almost every station experienced an increase in dissolved oxygen at high tide, the bottom dissolved oxygen steadily increased seaward.

Secchi. The Secchi disk transparency measurements showed no striking trends along the estuaries. The average Secchi depth was 0.88 meters for Henderson Creek and 0.74 meters for the Blackwater River. Both streams were slightly more transparent at high tide.

DISCUSSION

Chlorophyll *a*. The relatively high and erratic chlorophyll *a* levels in Henderson Creek compared to those of the Blackwater River indicate that eutrophication is indeed taking place. Most affected is the region from below the weir to station nine, where the estuary is not dominantly marine-influenced. Implying that the cause for the high primary productivity is terrestrial, this trend indeed points towards anthropogenic nutrients. The unusually high reading at station one during high tide suggests an algal bloom in the stagnant water below the weir.

Physical water quality. In contrast with the chlorophyll *a* findings, the dissolved oxygen levels indicate that Henderson Creek is not undergoing the depletion in oxygen that usually accompanies eutrophication. Actually, the estuary has more dissolved oxygen than does the Blackwater River, indicating an ecosystem that can support more oxygen-dependent organisms. However, the irregularity of the surface dissolved oxygen levels indicates that there is a disturbance in the natural processes that govern this parameter in the upper reaches of the estuary.

The other physical water quality parameters revealed some small differences between the two estuaries. Henderson Creek is more basic than the Blackwater River probably because of fewer mangrove leaves introducing tannic acid into the water. The higher temperature at Henderson Creek might be due to the water being less shaded. The salinity, dissolved oxygen, and pH of the bottom of the boat basin all suggest that the water there is stagnant and restricted from the rest of the estuary.

CONCLUSIONS

Land use in the Henderson Creek watershed is a likely cause of the differences between it and the Blackwater River regarding physical water quality and primary productivity. If the increased primary productivity in the upper reaches of Henderson Creek continues, the effects of full-scale eutrophication will probably occur. This will have a large impact on the wildlife in the estuary. It is possible, however, for estuaries to recover from even severe cases of eutrophication, but essential management actions that decrease the nutrient supply need to be taken, and recovery will not be immediate. Reducing the nutrient inputs to Henderson Creek in order to return it to more natural conditions will require some modifications in the practices of landowners in the watershed. Septic tanks should ideally be replaced by sewage treatment to avoid the introduction of effluent into the groundwater and eventually the estuary. The amount of chemical fertilizers used on lawns, golf courses, and crops should be lowered to minimize artificial nutrients in runoff.

REFERENCES CITED

Arar, E. J., and Collins, G.B., 1997, Method 445.0: *in vitro* determination of chlorophyll *a* and pheophytin *a* in marine and freshwater algae by fluorescence: Cincinnati, National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, 22 p.

Darnell, R.M., and Soniat, T.M., 1981, Nutrient enrichment and estuarine health, *in:* Neilson, B.J. and Cronin, L. E., eds., Estuaries and nutrients: Clifton, N.J., Humana Press, p. 225-245.

Miller, T.H., Frederico, A.C., and Millesan, J.F., 1982, Survey of water quality characteristics and chlorophyll *a* concentrations on the Caloosahatchee River system, Florida - final report, A: West Palm Beach, South Florida Water Management District Technical Publication 82-4, 159 p.

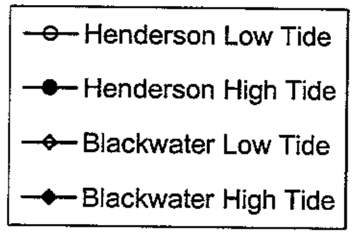
Tedesco, L. P., 1999, An introduction to southwest Florida's natural environment: a guide to accompany the 1999 Florida Keck Geology Summer Research Program: Indianapolis, IUPUI Department of Geology, 88 p.

Webb, K.L., 1981, Conceptual models and processes of nutrient cycling in estuaries, *in:* Neilson, B.J. and Cronin, L. E., eds., Estuaries and nutrients: Clifton, N.J., Humana Press, p. 25-46.

	Km downstream from station 1	
Station #	Blackwater River	Henderson Creek
0	N/A	above weir
1	boat basin	below weir
2	1.05	1.16
3	2.39	*
4	3.24	1.58
5	4.15	2.60
6	5.03	3.17
7	9.71	3.80
8	12.52	5.06
9	16.38	6.51
10	17.90	7.56
11	19.59	8.90
12	21.59	10.73
13	N/A	13.08

*Station 3 is located 0.2 km up the Manatee Basin tributary of Henderson Creek

Fig. 1: Station locations



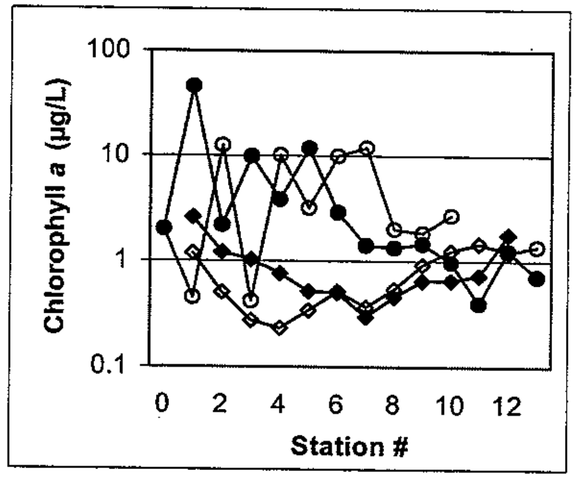


Fig. 2: Chlorophyll *a* concentration

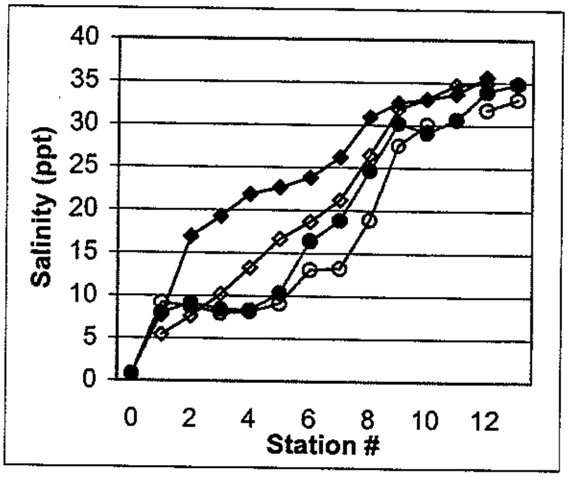


Fig. 3: Surface salinity

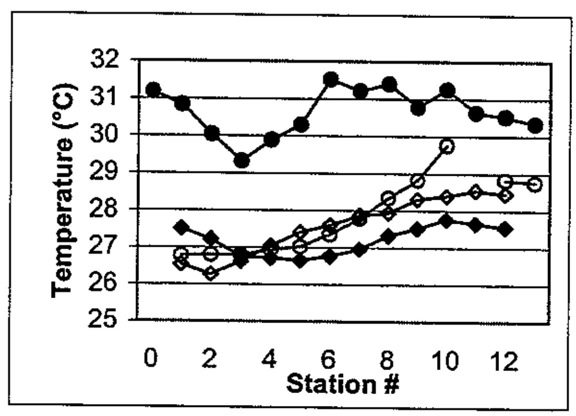


Fig. 4: Surface temperature

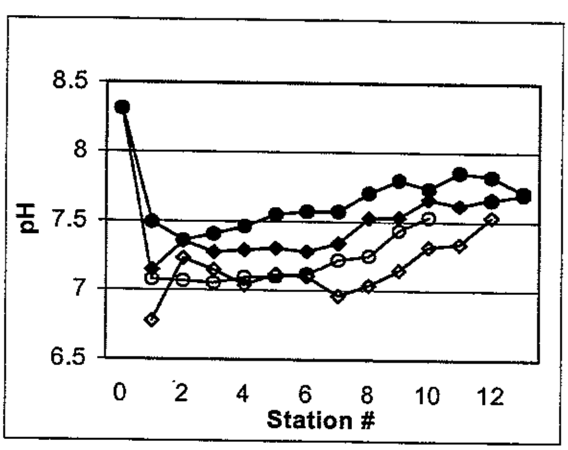


Fig. 5: Average of surface and bottom pH

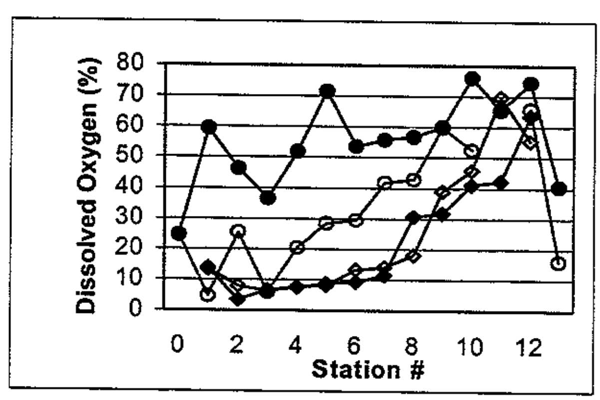


Fig. 6: Average of surface and bottom dissolved oxygen

MOLLUSCAN COMMUNITY RESPONSE TO PULSED AND NATURAL FRESHWATER INFLUX IN HENDERSON AND BLACKWATER ESTUARIES, FLORIDA

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INTRODUCTION

Estuarine areas are important ecological and geological systems worldwide. Estuaries store and provide nutrients for a diverse coastal ecosystem, naturally treat waters and sediments, and remove pollutants and toxins through biological, physical, and chemical processes (Clark and Sarokwash, 1978). Their sheltered and navigable waters, along with a unique setting, make estuarine areas an attractive place for development by humans. Landscape alteration associated with development is the most common stress on estuarine systems and has led to contamination and pollution of many estuaries in the United States (Sklar and Browder, 1998). One area in which extreme urbanization has had deleterious effects on estuaries is southwest Florida, one of the fastest growing areas in the country (Shirley et al, 1997).

Rapid urban and suburban growth in southwest Florida has stressed the water supply and altered the natural drainage of the land as water is diverted to prevent flooding of newly urbanized areas (Tedesco, 1999). By altering natural conditions and water quality within estuaries, humans may be altering the ecosystems they support. Here I determine the effects of pulsed release of freshwater on molluscan community composition by sampling infaunal mollusks in both Henderson (pulsed release) and Blackwater Bays (natural influx), near Naples, Florida.

Samples of the molluscan benthic community present in both sandy and muddy substrates near salinity monitors in both estuaries were analyzed to compare and contrast gradients in community composition between estuaries. Although changes in the community are expected along salinity gradients within each estuary, examination of between-estuary patterns should determine if pulsed freshwater influx has a significant effect on mollusk communities. If the pulsed freshwater influx does affect mollusk communities, one would expect the community composition would be different between Henderson and Blackwater Bays due to the extreme rate of salinity change from the freshwater pulses controlled by the weir in Henderson Bay. If the pulsed freshwater flow does not affect mollusk communities, one would expect a similar pattern of community structure in both Henderson and Blackwater estuaries in response to salinity. Results indicate that molluscan communities are responding to pulsed freshwater influx in the estuary.

MATERIALS AND METHODS

Samples were taken from two estuarine locations in the Rookery Bay National Estuarine Research Reserve and Ten Thousand Islands area in southwest Florida. A South Florida Water Management District (SFWMD) weir near the head of the creek controls Henderson Creek estuary's freshwater influx. Blackwater River estuary's freshwater influx is viewed as natural and unaffected, although caution must be exercised in using this assumption too widely (Tedesco, 1999).

The two estuaries are similar in structure and physiography and eventually connect to the Gulf of Mexico. Five homologues, points of approximately equal salinity conditions and geomorphologic positions, have been assigned to each estuary by Savarese (1999) to establish points for various comparisons between them. Homologous stations are similar in terms of their position with respect to the estuary salinity gradient, distance from freshwater source, substrate type, and physical features. Substrate type was also a factor in sampling. Two locations, one with a sandy substrate and one with a muddy substrate, were chosen for each homologue sampled to assess variation of mollusk communities related to substrate preference.

Field Methods. Four sites in each estuary, Henderson and Blackwater, were chosen near homologues 1 through 5 in the vicinity of YSI Datasondes (salinity monitors). Four replicate samples were taken, in sandy and muddy substrates, for a total of 8 samples at each site, a total of 32 samples were obtained from each estuary. Sediment was collected within a 1 m radius of the site, shoveled into a 5-gallon bucket, and sieved through a 2 mm mesh in the water to isolate gastropods and bivalves. One sediment sample from each site was also obtained.