WATERSHED DYNAMICS, SOUTHWESTERN FLORIDA

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Watershed dynamics, southwestern Florida

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INTRODUCTION

Estuaries are of particular ecologic, environmental, and economic importance (e.g., Day et al., 1989; McLusky, 1989). The estuarine ecosystem is one of our most biologically productive ecosystems. As a consequence, numerous terrestrial and aquatic species, including many endangered and rare species, depend on estuarine habitats; most economically important fish and shellfish spend at least part of their lives in estuaries. Pritchard (1967) defined an estuary as "a semi-enclosed coastal body of water which has free access to the ocean and within which seawater is measurably diluted by freshwater from land drainage." This coastal setting of estuaries makes them particularly susceptible to human-induced modification and deterioration. In southern Florida in particular, draining of wetlands, urbanization, and agriculture have resulted in many environmental changes. These include alteration of drainage patterns, which in turn modifies estuarine salinity and sediment influx. The loss of wetlands, which serve as natural filters for pollutants, leads to the introduction of urban and agricultural pollutants.

Not all change in estuarine systems is human induced. Estuaries represent the balance between wave, tidal, and fluvial processes; the point of balance constantly changes and varies throughout the estuary. Estuaries develop during transgressions and their lifespan reflects the interplay between rate of sea-level rise and rate of sediment infilling (Nichols and Biggs, 1985; Dalrymple et al., 1992). In Florida, a decrease in the rate of sea-level rise about 3,200 years ago fostered the development of extensive coastal wetlands characteristic of the peninsula today (Wanless et al., 1994). Since 1930, tide gauge records show an increased rate of sea-level rise; in response, coastal erosion has increased (Wanless et al., 1994).

The theme of our project in Florida was to study effects of both natural and human-induced change. Our field area was the Rookery Bay National Estuarine Research Reserve (RBNERR) and adjacent lands.

ROOKERY BAY NATIONAL ESTUARINE RESEARCH RESERVE

RBNERR provided an ideal location for a project on estuaries as well as an excellent and diverse staff. RBNERR is a research facility on Florida's southwestern coast just south of Naples, one of the fastest growing cities in the U.S. RBNERR is managed by Florida's Department of Environmental Protection (DEP) and is one of NOAA's 23 National Estuarine Research Reserves, which are protected for long-term research and education. The Reserve proper comprises 12,500 acres, but the DEP manages almost 100,000 acres of adjacent lands and waterways. These combined areas served as our field sites and include actively accreting and relatively inactive barrier islands, mangrove wetlands, oyster reefs, and extensive estuarine bays and channels. Because of its location, the estuary is affected by urban growth, agricultural runoff, the introduction of exotic species, and changes in patterns of groundwater flow and surface runoff. Researchers from the Reserve have set up numerous sites for monitoring water level, nutrients, temperature, and salinity; some records extend back to 1955. RBNERR staff and their research records provided valuable sources for consultation and comparison.

Barrier islands. Barrier islands are coast-parallel, elongate bodies of sand that lie seaward of an estuary or lagoon. Their seaward location makes them more susceptible to marine, as opposed to estuarine, processes. Barrier islands most commonly occur on sandy wave-dominated or wave-influenced coasts characterized by broad shallow-sloping shelves and relatively low tides (typically 0-3 m). Wind, waves, and tides modify the barrier island. Major storms can greatly alter erosional and depositional regimes by redistributing beach and dune sands, forming washover deposits, and dissecting the island (Elliot, 1986; Isla, 1995).

Several mechanisms have been proposed for the origin of barrier islands (Reinson, 1992; Isla, 1995) including spit elongation in the direction of longshore currents, submergence of coastal beach and dune complexes, and emergence of submarine bars. As islands mature, plants colonize the sands, thereby increasing substrate stability and resistance to erosion. Eventually, a rich community of plants and animals may develop (Leatherman, 1979).

In southern Florida, barrier islands help protect the estuaries and mainland from wave and storm erosion. They also serve as nesting sites for a variety of birds and sea turtles.

Mangrove wetlands. Mangroves are a diverse group of salt-tolerant (halophytic), woody plants that dominate subtropical to tropical wetland areas. Four species representing four families flourish in Florida's mangrove wetlands: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*) and rarely, buttonwood (*Conocarpus erecta*). Species display zonation, in part, as a function of tides (Lugo and Snedaker, 1974). The red mangrove dominates along the edges of tidal channels and on mangrove islands.

Mangrove wetlands protect against erosion and wave and storm damage. The characteristic aerial roots of the red mangrove baffle currents and trap fine organic-rich sediment facilitating vertical accretion (Cahoon and Lynch, 1997) and progradation. The protected environment around the roots provides refuge for juvenile fish and invertebrates, and the roots themselves serve as a firm substrate for colonization by algae and invertebrates. Leaf and branch litter forms the base of many estuarine food webs either directly (in the case of detritivores) or indirectly as decomposition releases nutrients used by phytoplankton. The emergent parts of the plants serve as nesting sites for numerous local and migratory birds. Thus, the health of mangroves is of great importance to the health of the estuary. Some of the wetlands that had been cleared or altered for development currently are being restored in DEP-managed areas.

Oyster reefs. Oysters are common in tropical to temperate estuaries. Their ubiquitous occurrence reflects their broad tolerance to temperature (e.g., Bahr, 1976), oxygen, salinity (e.g., Wells, 1961), and turbidity and current speed (Lenihan, 1999). Though oysters show a broad range of tolerance for these environmental factors, they grow optimally within a narrower range.

In southern Florida, the eastern oyster, *Crassostrea virginica*, dominates; it grows on firm substrates (e.g., mangrove prop roots) or forms reefs that are typically oriented perpendicular to flow. Oyster reefs, like mangrove wetlands, are particularly important to the health of estuaries. They too prevent marsh erosion and serve vital ecological roles. Their ability to establish hard-substrate islands on soft-bottom estuaries results in a greater diversity of habitat that attracts a variety of invertebrates. They serve as a food source for aquatic (e.g., crabs and snails) and terrestrial (e.g., birds and humans) predators. As suspension feeders, the oysters filter large volumes of water extracting phytoplankton, upon which they feed, and concentrating heavy metals and pathogens, which can be passed on to predators. Thus, they serve as water-quality indicators. One pathogen, the protozoan *Perkinsus marinus*, directly parasitizes oysters, thereby increasing oyster mortality (Lenihan et al., 1999).

Bays and channels. The DEP-managed waters and lands can be divided into three coast-parallel bands: open water of the Gulf of Mexico, a 1.5- to 8-km-wide area composed of islands isolated by a network of estuarine bays and waterways, and a 8-km-wide area of estuarine wetlands dissected by meandering drainage channels that trend roughly perpendicular to the coast. Salinities of the waters in these three areas range from marine at the Gulf to near fresh at the upstream parts of the drainage. Salinities at any particular site can vary throughout the day as a function of tidal influence, as well as seasonally. The greatest range in salinities typically occurs in the wetland drainage channels.

Students working in or on the water (or on oyster reefs) concentrated their efforts in two or three of the drainage canals and the bays immediately seaward of them. The three channels were chosen to show varying degrees of human alteration and influence (see Fig. 1). Henderson Creek runs through the core of RBNERR. Its location nearer developed areas leaves it susceptible to urban and agricultural pollution. Blackwater River largely drains state- and federally protected lands and is therefore relatively pristine. Faka-Union is a dredged, straight canal. Immediately "upstream" of the canal lies the 240-km^2 South Golden Gate Estates, a grid of constructed drainage canals that since the late 1960s has greatly modified natural flow by channelizing excessive amounts of freshwater into the Faka-Union canal. Differences among these estuarine drainage canals are evident in the field and the interpretation and importance of those differences were the emphasis of most of the student research during the academic year.

Water management practices in Henderson Creek and Faka-Union are scheduled for revision. Many of the results from the student projects will help guide these efforts.

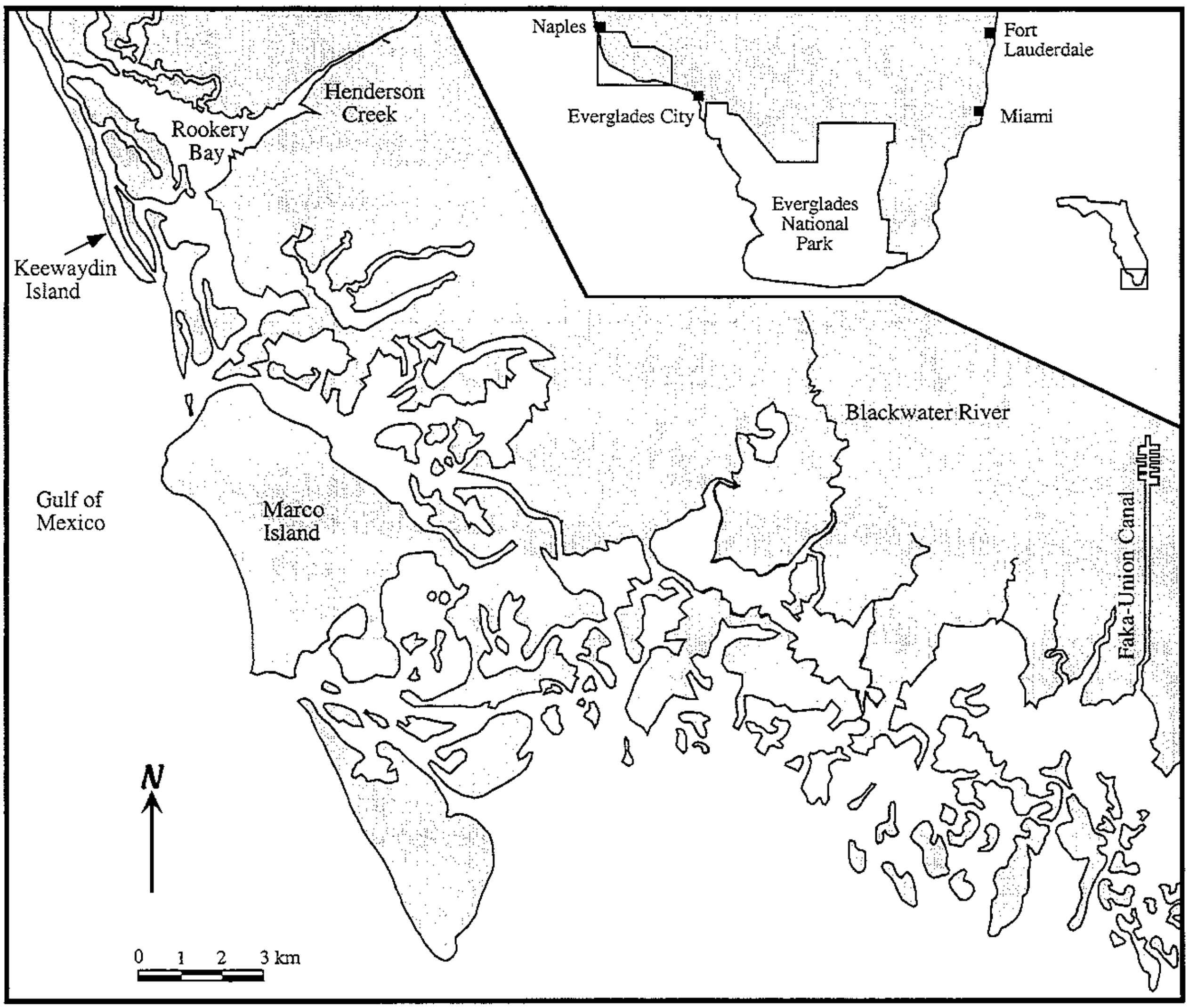

Figure 1. Simplified maps of southern and southwestern Florida; close-up map includes most of the study areas. Windstar is located in the southern part of Naples, just to the north of the detailed map; Cocohatchee Canal is located about 5 km to the southeast.

STUDENT PROJECTS

The completed research is diverse and ranges from sedimentology to geomorphology to ecology and paleoecology. All of the research had environmental applications, and much will be of use to the RBNERR. A summary of the ten projects follows. Refer to Figure 1 for locations of sites.

Christina (Nina) Berglund (Carleton College) compared natural mangrove forests in the Henderson and Faka-Union areas and in a site (Windstar) located in the southern part of Naples to restored areas in those regions. Restoration efforts began 7 to 17 years ago. Nina concentrated on the development of soils (peats) and how the substrate reflected forest composition and time of development.

Steve Brewster (Florida Gulf Coast University) studied growth and development of the eastern oyster, *Crassostrea virginica*, by designing, constructing, and deploying a series of oyster-recruitment platforms. He placed the platforms in up- and down-estuary oyster reefs in Henderson Creek, Blackwater River, and Faka-Union. To study growth of already established oysters, Steve devised a method using tetracycline to mark current size of numerous oysters in large clusters; the tetracycline marker will allow him to document growth over time.

Leah Briney (Whitman College) investigated the occurrence of the parasite *Perkinsus marinus* among oysters in the Rookery Bay region. She predicted that human-induced water-quality changes inflict environmental stresses on the oysters, thus causing them to be more susceptible to disease. She compared the degree of infection in oysters from Henderson Creek and Faka-Union estuaries.

Liz Fuller (Amherst College) examined the live and dead assemblages of soft-bottom bivalve communities in the Faka-Union channel and adjacent bay. She predicted that the large volumes of freshwater would eliminate species that prefer more normal marine salinities characteristic of the Blackwater River area.

Meghan Hicks (Beloit College) studied the biodiversity of clusters ("clumps") of oysters that commonly occur on oyster reefs. She collected from up- and down-estuary parts of Henderson Creek, and in a down-estuary part of Blackwater River. Testing the application of the Theory of Island Biogeography to oyster-clump size, she predicted that on any given reef, large clusters would harbor a greater diversity of animals.

Karyn Novakowski (Franklin & Marshall College) investigated the growth of Keewaydin Island, thereby documenting the dynamic nature of this island. She used historical aerial photographs, sediment cores, and topographic profiles.

Autumn Oczkowski (Washington & Lee University) carried out a companion study to Berglund's by focusing on the geochemistry of cores taken from natural and restored mangrove areas. She investigated the relative concentration of four major elements (Fe, Mg, Ca, and K), predicting that they would reflect degree of substrate development.

Robin Rousu (Whitman College) compared water quality of Henderson Creek and Blackwater River. She determined the concentration of chlorophyll-a, which is an indicator of phytoplankton abundance, which, in turn, reflects nutrient levels.

Jessica Wilkening (Cornell College) studied live and dead assemblages of molluscs from sand and mud substrates in Henderson Bay and Blackwater Bay. She predicted that the mollusc communities would reflect human impact in the Henderson watershed.

Chris Willman (Indiana University and Purdue University at Indianapolis) focused on the effects of water-control structures (WCS) on channel morphology and sediment characteristics. Blackwater River, which lacks a WCS, served as a control. Henderson Creek, Faka-Union Canal, and Cocohatchee Canal (located about 6 km southeast of Faka-Union) each have a different type of WCS.

VISITORS AND INTERACTIONS WITH SCIENTISTS

Five faculty from Keck colleges and one faculty member from the University of Miami visited the project (see list on cover page). The five Keck-college mentors visited the field sites of their students and, when needed, helped their students in the lab; some of the mentors went out with students other than their own to become more familiar with the estuarine environments.

The following table summarizes interactions with other scientists, lab workers, and volunteers. In addition to those listed below, many of the staff at RBNERR and FGCU provided ideas, encouragement, and discussion.

Participant	Affiliation	Help/Expertise Provided
David Addison	The Conservancy of Southwest Florida	Research talk on sea turtle behavior.
Bob Bachand	FGCU	Library support and talk.
James Burch	Big Cypress Preserve	Advised 2 students.
Larry Brand	University of Miami	Helped 1 student develop field and lab protocol; accompanied her into field 1 day; shared data.
Sharon Bush	RBNERR	Field support and data acquisition for 2 students.
Dianne Cole-Bronczyk	RBNERR, volunteer	Field support for 2 students.
Win Everham	FGCU	Advice/help to 2 students.
Matt Finn	consultant	Guide services and field support for 2 students.
Judy Haner	RBNERR	Short talk about mangrove restoration (focus of 2 student projects).
Rhonda Holtzclaw	FGCU	Lab support for 3 students in particular.
Todd Hopkins	RBNERR	Research talk. Access to personal library.
Jerry Jackson	FGCU	Research talk.
José Leal	Bailey-Matthews Shell Museum, Sanibel Island	Research talk. Access to museum specimens and library. Helped 2 students.
Mike Lucas	FGCU	Lab support for 2 students in particular.
Gary Lytton	RBNERR, director	Talked about RBNERR mission. Facilitated logistical support by RBNERR.
Mary Newman	FGCU	Lab support.
Jill Ryder	RBNERR	Access to data and photos for 1 student.
Mike Shirley	RBNERR	Access to data and photos for 1 student.
Sam Stamper	RBNERR, volunteer	Several days of field support and use of boat for 2 students.
Heather Stoffel	RBNERR	Field support and data acquisition for many students.
Mica Suzuki	University of Miami	Data sharing with 1 student.
Steve Theberge	RBNERR	2 days as a guide for the entire group.

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Characterization of Mangrove Peat from Southwest Florida

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INTRODUCTION

The restoration of mangrove forests is an increasingly important management issue in Southwest Florida because of rapid urban development. Restoration of these mangroves is important for estuary health. Rookery Bay National Estuarine Research Reserve (RBNERR) has been the pioneer of mangrove restoration in the area. This study is the preliminary approach to examining mangrove peat as a factor of restoration function of these forests. Peat is partly decayed unconsolidated plant matter with high moisture content. The overall objective of this study is to characterize the peat in restored forests and to compare it to that in natural areas. Variables examined will be bulk density, organic content, and water content all with respect to depth, as the influence of substrate on restoration.

METHODS

Cores were taken at Windstar, Henderson Creek, and Faka-Union Canal. The forests were characterized by mapping and measuring diameter at breast height (DBH) of trees in that area. Approximately 5cc samples were taken every 5cm from each core. Samples were at 60 degrees C for 24 hours. Organic content was calculated by loss on ignition.

STUDY SITES

Henderson Creek: This site was located within the RBNERR along Henderson Creek. In 1972, the area was destroyed when a pond was excavated and dredged material was deposited. In 1992, the area was cleared, flushing cuts were dug, fill was removed, and trees were planted. Immediately adjacent to the restored site is a natural, undisturbed mixed mangrove forest, which has been used as a control for the monitoring of the mitigation project. Based on historical aerial photographs

Windstar: This golf course and multi-family community is located in South Naples on the east shore of Naples Bay. In August 1982, restoration began on land that was covered with fill as a result of dredging the channel in the bay. A reference site of estimated age >50 years, was established in a natural mangrove forest adjacent to the restored site. The area is thought to have been undisturbed for at least 60 years.

Faka-Union: Two other sites were examined as references. The first was an old-growth forest of more than 50 years and the second was termed "transgressive" as it had developed from salt marsh to white mangrove forest about 10 years ago.

FIELD OBSERVATIONS

Henderson Creek-Natural Site (A): The site was a mature, mixed forest of black, red, and white mangroves. There was approximately a 17 m canopy. The density of trees in the area was not very high. DBH ranged from 1.27-28.66 with an average of 6.71 cm. The largest trees were white mangroves.

Henderson-Creek Restored Site (B): One core was taken above the fill and one was taken in a flushing cut, in order to access the material below the fill. The ground was very wet, black organic material with very little peat. The trees were much denser here than the control site and dominated by whites. The few reds were either small or medium. The canopy was 12 m.

Windstar-Natural Site (C): This area was less dense than Site A. The dominant species was red then black, and then white. Based on size, the blacks were older than the reds. The canopy was approximately 6 m.

Windstar-Restored Site (D): The area was so dense it was impossible to count the trees individually. There were an estimated 75 percent white, 22 percent red, and 3 percent black. The canopy was 2.44 m.

Faka-Union Old Growth Site (E): The trees were large and scattered. The area was not as open as Site C. The trees were whites with red seedlings scattered throughout. The canopy was 10 m high.