

**LITERATURE REVIEW OF EXISTING BIOLOGICAL DATA
TO IDENTIFY POTENTIAL BIOLOGICAL INDICATORS FOR THE
HENDERSON CREEK WATERSHED STUDY**



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1.0 INTRODUCTION AND GRANT GOALS

Rookery Bay National Estuarine Research Reserve (RBNERR) is one of the few pristine, mangrove-forested estuaries in the U.S. It is a documented critical breeding ground for commercial and recreational fisheries and provides habitat for a variety of coastal birds and marine mammals. It also provides a location for passive recreation for thousands of people each year who want to enjoy the beauty of the Rookery Bay Estuary.

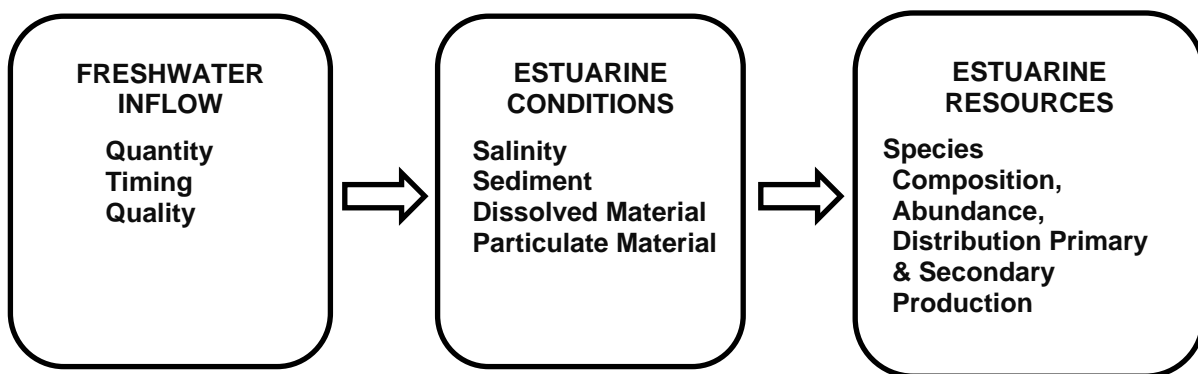
Estuarine health is dependent upon the quantity, quality, and timing of freshwater inputs. The Henderson Creek watershed has been historically impacted by widespread dredge and fill operations used to drain large tracts of land for development and an increasing demand for freshwater to sustain the densely populated coastal communities. As a result, much less water is being retained within the landscape of the watershed, which has reduced natural storage and groundwater recharge. The health of the Estuary and its wildlife depend on seasonally appropriate flows of freshwater that fluctuate from approximately 134 million cubic feet per day in the wet season to 0 in the dry season. In addition, the growing population of Collier County requires more and more freshwater from the Henderson Creek watershed because of saltwater intrusion in the coastal supply wells. Balancing the water needs of people with the needs of natural systems instigated the grant that is funding this study. Watershed managers are tasked with finding ways to understand and manage water flow parameters that balance the needs of people with those of the natural systems. Ultimately, the goal of the grant will address this challenge by increasing knowledge of the water flow parameters necessary to maintain estuarine health in Rookery Bay, provide understanding of the attitudes of water users (general public), to formulate future educational efforts, and to develop a community-based decision making tool for water use and allocation.

This literature review provides an overview of the existing literature, provided by the RBNERR staff and other scientists, which examines the historical and existing biological conditions within the Henderson Creek Watershed and other southwest Florida estuaries. Our goal is to provide a summary of the existing literature and data available and identify any data gaps. Ultimately, the information will be utilized to synthesize and analyze data to determine relationships between freshwater inflow and ecological responses, with the overall purpose of identifying threshold conditions that will be used in conjunction with the proposed hydrodynamic model to understand the Rookery Bay Estuary system's response to freshwater inflow.

2.0 STUDY OBJECTIVES RELATED TO FRESHWATER INFLOWS

Estuaries are the location where freshwater discharging from the adjacent lands mix with saltwater from the ocean. Thus, variations in the water quality, quantity, release rate, and method of freshwater inflow, have an effect on the physical, chemical, and ecological attributes of the estuary. Freshwater is an important resource for human beings not only for consumption, but also for numerous economically important activities such as agriculture, urban, and industrial uses (Morrison and Greening, 2011). This results in a difficult task for policy makers when it is necessary to develop and implement management programs that satisfy the freshwater needs of the general public as well as the freshwater resources necessary for the natural ecosystem to function in a healthy and sustainable fashion.

Henderson Creek Watershed is located in Collier County, one of the fastest growing counties in the United States. Collier County includes a portion of the original Everglades water flow way and a large portion of the county is considered environmentally sensitive lands. More than half of the county is managed by either state or federal agencies. Therefore the opposing land uses of land development versus large conservation areas create a unique situation when it comes to protecting the estuary and balancing the needs of a growing population by managing freshwater inflows (RBNERR CD). For resource managers in coastal areas it will be essential to maintain appropriate flows in freshwater to the estuary and marine areas to protect the ecology of the estuary through the full range of freshwater to marine habitats. The figure below depicts the relationship between man-made freshwater inflows to the estuary and how it impacts physical and chemical habitat conditions that ultimately impact the species composition and productivity of the estuarine system (Morrison and Greening, 2011).



Overview of effects of freshwater inflow on estuaries, based on Alber (2002)

The goal of developing a local-scale hydrologic model for the Rookery Bay Watershed is to model existing and historic water budget scenarios to determine changes in hydrologic conditions. Understanding those changes will help RBNERR address establishing target flows, defined as the amount of freshwater flow needed to sustain a balanced Rookery Bay estuary, as well as meeting the needs of the water needs of the general human population. By conducting a preliminary characterization of the

watershed's biologic condition with respect to historic conditions, we will attempt to identify biological indicators that may be useful in assessing the effects of freshwater inflow into the estuary.

2.1 RESOURCE-BASED APPROACH

Resource-based approaches for managing inflow identify specific resources or environmental conditions. However, these biological indicators, which are specific species or habitat types that are very sensitive to estuarine conditions i.e. salinity, may not be the same by the general public. For example, the South Florida Water Management District (SFWMD) suggested utilizing bald cypress (*Taxodium distichum*) as a key indicator species for use when establishing a minimum flow levels (MFL) for the Loxahatchee River and Estuary (Alber and Flory 2002). The review panel acknowledged the fact that high salinities can kill cypress trees, however since they live long and are slow to respond, it would be a slow indicator. The general public placed a very high value on cypress trees in relation to recreational activities such as kayaking and thus did not want to see the mortality that would occur due to increases in salinity and strongly objected to using this species as an indicator species.

In another example, SFWMD proposed an MFL for the Caloosahatchee Estuary that utilized three species of submerged aquatic vegetation (SAV), ell grass (*Vallisneria americana*), shoal grass (*Halodule wrightii*), and turtle grass (*Thalassia testudinum*). Initially, Chamberlain and Doering (1998) conducted research and concluded that the indeed SAV species do have preferred salinity ranges and therefore could be used as targets. At that time, the general public did not recognize SAV as a highly valued resource and therefore were not supportive of this approach. However, once the SFWMD described how the optimal flows determined for the these SAV species would also be beneficial for fish, shellfish and other resources, the general population became very supportive and proactive. It is imperative to link the resource chosen by the scientists to those valued by society, and to provide this information to the public.

3.0 DATA COLLECTION METHODOLOGY

3.1 LITERATURE REVIEW METHODOLOGY

Electronic searches were made using open-access, limited-access, and subscription-access databases to collect literature used to compile information relevant to determining potential biological indicators for Henderson Creek based on salinity. Major use was made of Google Scholar and the University of Miami library data bases as well as requested documents provided by federal sources such as the USFWS, USGS, SFWMD and through personal communication with researchers and managers. Searches were conducted using names of known authors and relevant estuaries as well as species names and common names of estuarine species common to the RBNERR. Key-words were searched to identify articles and publications related to this effort, such as: estuaries, biological indicators, salinity, Rookery Bay, Henderson Creek, minimum flow, and many other related terms. Citations were obtained through interlibrary loans or electronically via web-delivery systems. In addition, literature cited within published reports and papers were evaluated for pertinent additional articles and references.

3.2 INTERVIEWS

There is widespread recognition that a tremendous amount of scientific data collection has occurred within the RBNERR as well as in many of the adjacent estuaries. Many stakeholders broadly agree that establishing a common set of science-based, ecological indicators and metrics is essential for guiding future restoration and protection activities. Therefore, interviews with local scientists are an invaluable tool for assessing existing data, potential data gaps, and proposed biological metrics that could be utilized to characterize the health of the estuary and how it responds to freshwater inflow.

Local scientists were contacted and either responded to an electronic questionnaire or via an informal telephone interview. Below is a list of those individuals interviewed and their affiliation(s):

Michael J. Barry	Institute for Regional Conservation
James Beever	Southwest Florida Regional Planning Council
Peter Doering	South Florida Water Management District
Ernie Estevez	Mote Marine Center for Coastal Ecology
Katie Laakkonen	City of Naples Natural Resources Department
Jeffrey R. Schmid	Conservancy of Southwest Florida
Michael Shirley	Guana Tolomato Matanzas National Estuarine Research Reserve
Aswani Voley	Florida Gulf Coast University

4.0 SUMMARY OF LOCAL EXPERTS INTERVIEWS

Below is a list of the interview questions and the various responses. This listing is not intended to represent a consensus view; rather, it merely summarizes opinions pertaining to existing scientific data and potential use of various ecological metrics that could be used for the Henderson Creek Watershed study. The full responses are included in Appendix A.

1. What has been your experience with the Rookery Bay Reserve?

All of the scientists have had experience with either analyzing and/or collecting ecological data in Southwest Florida. The majority of the interviewees have worked specifically in the Rookery Bay National Research Reserve.

2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?

All of the interviewed scientists have conducted scientific research in Southwest Florida estuaries.

3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?

- *Altered freshwater inflow patterns (volume and timing) and degraded water quality (particularly septic tank effluent).*
- *Oyster populations have remained relatively stable with some fluctuations based on wet, dry, and normal years.*
- *The construction of the canal systems in the 1950-1960's has had the biggest environmental impact. Henderson Creek no longer receives surface water flow, it is all one point source and that generally means too much or too little freshwater. It appears that the water is not only coming from Henderson Creek but the Lely canal system is also diverting water to the creek.*
- *Changes in flow because of canals, shoreline hardening.*
- *Water quality and clarity has decline significantly. Areas of seagrass beds have been lost. Wind driven turbidity has increased. In the upper watershed freshwater wetlands and uplands have been lost to development and the hydrology less natural.*
- *I would select proportion of live/dead oysters, submerged aquatic vegetation, and benthic invertebrates. I would sample for these seasonally. I would suggest Bob Chamberlain and Peter Doering with the SFWMD and Sid Flannery with the SWFWMD.*
- *Upstream non tidal vegetation affected by drainage (shortened hydro-period) and exotic plant invasion and increased development. The rest of areas included changes from freshwater/brackish marsh, hydric pine flat woods, wet cabbage palm*

woodland or upland woodlands to areas with mangroves and/or buttonwood (i.e. tidal influence reaches in further). Fire suppression in many areas results in denser shrub cover, other areas are now being burned again. Buttonwood die-offs in many areas including coastal berms. Some hardwood die offs. Some areas of young buttonwoods vigorous in edges of coastal hammock with scattered dead hardwoods (example N Keywadin). Some black mangrove basins with die-offs. Outer portions of outer islands in Ten Thousand Island areas have continued retreat many meters since I began camping in the area and evident on aerials.

- *Reduction of freshwater coming down Henderson Creek and the need for establishing a Minimum Flows and Level (MFL) for that waterbody since Marco Island also pulls from Henderson Creek for their water supply.*
4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?
 - *The majority of the suggested publications have been incorporated into the literature review.*
 5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?
 - *I have had some success using land and seascape metrics such as SAV, oysters, and live vs dead mollusk shells. The best fit of a resource against modeled salinity changes I ever found involved oligohaline marshes in the Myakka River.*
 - *SFWMD is currently using SAV in the Caloosahatchee. They looked at historical and current distributions and then chose indicators for segments: Valissinaria - low salinity; Oysters - mid-range salinities, and Thalassia -high salinity.*
 - *Given their benthic, sedentary nature oysters make excellent candidates to make cause-and-effect relationships. They are sensitive to salinity changes. In addition, oysters provide food, shelter and habitat for a number of species (nearly 300). Therefore when observing oyster responses, one is not just looking at a single species, but a whole community.*
 - *Though not necessarily the ONLY or MOST IMPORTANT but would like to see more monitoring of buttonwood scrub /buttonwood woodland, marsh areas, and hydric pine flat woods and cabbage palm woodland near edge of tidal influence as these areas have changed considerably since 1940 all trending to greater abundance of salt tolerant species less of intolerant species. And of course in mangrove forested areas SETS*

- *Linking fish species to specific salinities would be an option. In addition, crabs could be utilized as a biological indicator of salinity. The mud crab has a wide salinity tolerance, whereas the porcelain crab prefers high salinities. Perhaps utilizing the fish and crabs together would be most beneficial.*
 - *In addition to fish data, success of growth, survival, and recruitment of oysters to upper Henderson Creek based on reference conditions in the Fakahatchee Bay/River.*
 - *At a minimum, collecting fisheries data (diversity and abundance) in combination with the water quality continuous datasonde data. A long term dataset already exists for this and monitoring could be replicated into the future to track changes to the estuary due to changing salinity regimes and flows. Additional indicators could be oyster density, distribution and health; mangrove distribution, and mud crab ratios (see past study conducted by Michael Shirley).*
6. Do you have anything to share in terms of an indicator species for this project?
- *Oysters and seagrass (SAV) will make excellent indicator species.*
 - *May want to use multiple indicators for the salinity gradient.*
 - *The primary goal should be to restore biodiversity of oyster reef-based communities (fish and invertebrates) using a reference site approach. Single species management should be discouraged.*
 - *Buttonwood when dead persists long time in mangrove areas and is less tolerant than mangroves of higher salinities. Would like to see more ground-truthing of areas where it has died and track upper areas on edge of tidal areas. Marks the edge of tidal influence fairly well. Also tracking pines is ok if all strata and track fire data with it.*
7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?
- *The majority of the suggested publications have been incorporated into the literature review.*
8. What type of data or what research questions would you use to develop biological metrics for a future MFL?
- *I would look at salinity tolerances of various life stages of species such as oysters. Much of this information is already available. Once this is combined with salinity-flow relationships, we can easily suggest MFLs.*

- *Look at other MFL's in the region.*
 - *Consider multiple indicators.*
 - *Relative abundance of steno-haline and eury-haline oyster reef crab populations relative to Fakahatchee Bay.*
 - *Growth, Survival, and Recruitment of oysters in upper Henderson Creek versus Fakahatchee Bay/River*
 - *Data on oysters, SAV, Chlorophyll, CDOM, Turbidity, water clarity, salinity and flow rate.*
 - *For fisheries data, the research question could be how has diversity and abundance of species changed with changes in salinity and flow. Changes to the distribution of specific species that are more freshwater tolerant or saltwater tolerant can be used as indicators. For oyster distribution and health, a research question could be how increased flows to Henderson Creek may affect optimal suitable habitat for oyster reefs and how those flows may increase oyster health (reduce parasitic infection of Perkinsus marinus for example).*
9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?
- *Robust key species such as oysters and sea grasses harboring a diverse community of fish and crustaceans.*
 - *Does this creek have an instream barrier? That would make a big difference.*
 - *High live oyster to dead oyster ratio;*
Healthy SAV;
Chlorophyll less than 11;
CDOM less than 70;
Turbidity less than 18 NTU;
Water clarity 1 meter or more.
 - *Healthy oyster reefs that support extensive invertebrate populations, robust mangrove systems that allow Rookery Bay to be vital nursery ground for many fish and invertebrate species as well as bird rookeries, and diverse fish assemblages to support the food chain.*
 - *Freshwater flow from upstream less extreme; Fire and exotic control above mangrove forested areas*

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?

- *Lessons learned from various CERP projects and Caloosahatchee estuary could be used in Henderson Creek.*
- *It was noted that if you want to manage salinity, it is important to consider other things that affect salinity such as tide and wind and it is important to manage the flow at the location where you have control not further downstream.*
- *This list is extensive and I cannot list them all. I would suggest forming a local expert team and avoid consulting researchers from distant areas and unfamiliar with southwest Florida. A community profile of the Creek is a good starting point to identify potential environmental indicators that are present and those that were historically present but now absent. After measuring the indicators for a year a sensitive analysis of the parameters should determine which are most sensitive to hydrologic conditions.*
- *A major problem with attempting to assess the overall health of Henderson Creek is the lack of baseline data prior to the construction of US 41.*
- *Establishing the correct freshwater inflow is not an easy problem to solve since Marco Island wants more freshwater. It is very difficult to balance the needs of the community versus the needs of the estuary.*
- *Many lessons can be learned from all of the research that has been conducted on oyster reefs, mangroves, seagrass, etc. in the Caloosahatchee Estuary as well as the St. Lucie Estuary by Florida Gulf Coast University, the South FL Water Management District, St. Lucie County, etc.*
- *Expansion or restoration of freshwater wetlands upstream in Belle Meade and more natural flow into Henderson Creek, ie buffer wetlands, would be big help.*

5.0 EXISTING ENVIRONMENTAL LITERATURE – POTENTIAL BIOLOGICAL INDICATORS

The presence, condition and numbers of types of fish, insects, algae, plants, and other organisms provide important information about the health of estuarine ecosystems. Biological indicators are any species or group of species that can be used to monitor the health of an ecosystem through investigation or monitoring of their function, population, or status. Candidate species that can be used as targets, indicators, or criteria to detect potentially detrimental effects of changes in salinity in riverine estuaries due to structural or hydrologic alteration are presented here along with several case studies conducted in RBNERR or similar estuaries.

5.1 Vegetation

5.1.1 Seagrass

Seagrass communities are recognized as keystone species in the estuarine environment and are useful bio-indicators given their response to changes in water quality (Livingston et al., 1998; Fourqurean et al., 2003; Dawes et al., 2004; Lirman et al., 2008). Variation in the morphometrics of seagrass has been correlated with a number of factors, including salinity (Phillips, 1960; Durako, 1995; Doering and Chamberlain, 2000; Irlandi et al., 2002; Hackney and Durako, 2004). Changes to seagrass populations can be caused by salinity variation and by changes in average salinity (Estevez 2000; 2002). In addition, certain seagrass species will not adapt to erratic freshwater inflows, which is also true for sessile benthic fauna which are then replaced by eurytopic species (Estevez 2000; 2002). Therefore, optimal flows determined for seagrass will also be beneficial for other resources including fish, plankton, and invertebrates such as shrimp, crabs, and oysters (Chamberlain and Doering 1998; Estevez 2000; 2002). The SFWMD listed turtle grass (*Thalassia testudinum*) and shoal grass (*Halodule wrightii*) as potential indicator species for changes in salinity (see Estevez 2000). Studies conducted in the Caloosahatchee estuary estimated a freshwater inflow rate $<79 \text{ m}^3 \text{ s}^{-1}$ to avoid lethal salinity for shoal grass (Doering et al. 2002).

SAV Distribution- Case Studies from Southwest Florida

Historically, extensive beds of the seagrass, specifically *Halodule wrightii* were found at southern end of Rookery Bay west of Shell Island and northern end of Rookery Bay while extensive beds of the green alga *Caulerpa sp.* were found near the eastern edge of deeper water along the western side of Rookery Bay and the red algae *Gracilaria sp.* and *Aghardiella sp.* were abundant in push-net samples from western Rookery Bay (Woodburn 1964). Woodburn suggests Hurricane Donna may have destroyed *Thalassia* beds in Rookery Bay similar to destruction observed in Estero Bay since bottom sediments in Rookery Bay are favorable to growth of *Thalassia*. Yokel (1975) estimated 20% of Rookery Bay floor supported seagrass species.

Sheridan (1997) sampled 25 sites in Johnson Bay of dominant *Halodule wrightii* seagrass beds (also included *Syringodium*, *Thalassia* and *Halophila*) for benthic faunal abundance and biomass indicating the presence of multiple extensive seagrass beds in Rookery Bay.

Estevez (2000 and 2002) provides an overview of SAV responses to inflow change:

Salinity changes affect seagrass distribution and community structure; changes in morphology, physiology, and productivity also occur but studies of such phenomena risk missing the larger impacts occurring at landscape levels

Seagrass changes include extirpation, decline in species diversity, shifts in location or relative size, "halo" effects, shortened seasons for species with annual cycles, and alternation of species within particular estuarine reaches

Seagrass distribution and community structure may change soon, after only a few years, following large salinity changes, but seagrass changes can continue for long periods after the onset of inflow alterations

Seagrass changes caused by inflow and salinity changes are amplified by changes to estuary geometry or connections to the sea and sometimes changes are beneficial

Seagrass changes are caused as much by changes in salinity variation as by changes in average salinity conditions; most case studies involve erratic pulses of large volumes of fresh water

Seagrasses may never adapt to salinity conditions driven by erratic freshwater inflows this is also true of benthic faunal communities that are simply replaced by assemblages of eurytopic species

Locker and Wright (2003) conducted benthic habitat mapping of RBNERR in 2002 and found areas with high backscatter in imagery indicating the presence of SAV as either sparse seagrass or macroalgae (Fig. 2). Vegetation was found in sediment samples at Hall Bay and 2 sites in northwest Rookery Bay while sparse vegetation was visible from the boat. Samples of *Halodule wrightii* and *Halophila decipiens* were found by hand searching and in push cores (Fig. 3). Locker and Wright (2003) estimated areas 1-40% or 40-90% cover as indicated in benthic habitat mapping imagery (Fig. 4).

In Henderson Creek (2003-2005), 41 acres were identified to have patch seagrass cover with a total of 95 acres in Rookery Bay comprised of Turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), star grass (*Halophila engelmannii*), Manatee grass (*Syringodium filiforme*) and paddle grass (*Halophila decipiens*), (Vasquez and Schmid SIMM Report #1; Table 1). Seagrass cover was determined to be declining due to unknown causes when compared to historical presence of SAV and continued research was suggested (Vasquez and Schmid, SIMM Report #1).

High freshwater inflow during the summer wet season in Naples Bay shifts the salinity gradient and results in a shift of seagrass distribution restricted to the lower region of the Bay (Schmid et al. 2006). The resulting shift changed seagrass diversity to be dominated by euryhaline species. In addition, Locker and Jarrett (2006) conducted benthic habitat mapping in Pumpkin Bay revealing SAV (*Halophila engelmannii* and *Ruppia maritima*), macroalgae, algal mats and oyster reefs (see Fig. 20 and 27 in Locker and Jarrett 2006).

Seagrass assessments conducted by Schmid (2009) indicated significant differences in the morphometrics of *Thalassia testudinum* within Estero Bay. The northern area had the lowest biomass; northern and southern areas had shorter blade lengths compared to the central areas; and south-central and southern areas had wider blades with the widest in the southern area. The distribution of blade lengths among the sampling areas is consistent with the salinity patterns in Estero Bay, but the different distribution of blade widths suggests that some other water quality parameter, such as nutrient availability or light attenuation, is also influencing the southern areas.

RBNERR surveys conducted in 2010 indicate percent cover of SAV today is comparable to surveys conducted in the 1940's (668.3 acres of SAV = 0.68% total cover) (Barry et al. 2012). According to Barry et al. (2012), "although 830 acres (0.9%)

of the area was mapped as Submerged Aquatic Vegetation (SAV) including seagrass and algae, this is not considered a complete or precise number as these vegetation types were not ground-truthed. It is hoped that existing seagrass data from RBNERR staff and USGS researchers could someday be used to edit the polygons and produce a more accurate portrayal of these important features of the reserve.”

5.1.2 Aquatic Plants

The SFWMD listed *Vallisneria americana* as a potential indicator species for changes in salinity (see Estevez 2000). Studies conducted in the Caloosahatchee estimated that freshwater inflow of $>8.5 \text{ m}^3 \text{ s}^{-1}$ would produce tolerable salinity for *V. americana* (Doering et al 2002). Kraemer et al. (1999) transplanted *V. americana* within the Caloosahatchee to determine physiological responses to a salinity gradient and found 100% mortality of low salinity upstream transplants due to light limitation and sediment burial, while downstream high salinity (>15 psu; upper salinity tolerance for species) beds died within 2-4 weeks of transplanting. This study highlights that other factors covary with salinity and may also play a role in determining the distributional limits of SAV with estuaries. Changes in macroalgal abundance or composition due to salinity variance may significantly affect fish abundance due to their dependence on macroalgae since nekton species composition is related to salinity, sediment type and aquatic vegetation (Colby et al. 1985). For example, O'Donnell (2013) suggests higher freshwater input into Faka Union, RBNERR may result in lower macroalgal abundance which will result in lower fish and related prey recruitment. In particular, pinfish (*Lagodon rhomboides*) has affinity for specific macroalgae and changes in macroalgal abundance could affect fish abundance as seen in Faka Union, an altered estuary, where lower fish species diversity was found coupled with less macroalgal cover when compared to the Fakahatchee reference site (O'Donnell 2013). *Gracilaria* spp. (Rhodophyta) are not useful as active bio-indicators because they can tolerate large fluctuations in light, temperature, and salinity (Bird et al 1979; Yarish and Edwards 1982).

In addition, an increase in the presence of red drift algae indicates higher nutrient input from sources of freshwater including storm-water, canals and rivers used for water management (Schmid et al 2006). Marsh plants may not serve as good biological indicators since they are more affected by water level and soil moisture than salinity (Estevez 2000; 2002).

5.1.3 Mangroves

The wide range of salinity tolerances of mangroves, particularly of the species found in South Florida including *R. mangle*, *A. germinans*, and *L. racemosa* may not allow for the use of mangroves as a biological indicator directly (Blasco et al. 1996). However, mangroves may be used as indicators of coastal change since variance in hydrology and estuary salinity may change mangrove species distribution (Blasco et al. 1996). For example, a decrease in salinity may increase the potential for less salt tolerant species (*A. germinans*, and *L. racemosa*) to expand their range. Red mangroves have been found to have higher growth and increased survivorship in higher salinities (100-200 mol m⁻³) than in lower salinities (Werner and Stelzer 1990; Smith and Snedaker 1995) making freshwater input ideal for less salt tolerant species. Historically, anthropogenic hydrological changes resulted in lowered freshwater retention and increased salinity in Rookery Bay causing decreases in lagoonal dinocysts, brackish diatoms and increased abundance of mangroves (Donders et al. 2008). Therefore, increasing freshwater inflow may cause mangrove ranges to return to more historic distribution (Barry 2009; Krauss et al. 2011). In addition, while changes in salinity may not directly influence mangroves, the composition and structure of sessile communities on mangrove roots including oysters, sponges, and tunicates may be used as biological indicators (Linton and Warner 2003). Potential vegetative biological indicators along with their salinity tolerance ranges are listed in Table 2.

5.2 SHELLFISH

5.2.1 Oysters-Eastern Oyster (*Crassostrea virginica*) and commensals

Historically, extensive oyster beds were found along the mangrove shoreline covering approximately 25 acres on the north side of the mouth of Henderson Creek (Woodburn 1964). More current surveys and benthic mapping imagery indicate fairly extensive live oyster reefs and banks within RBNERR (Wilber 1992; Patillo et al. 1997; Mattson 2002; Volety et al. 2003; 2009; Tolley et al. 2005; Goodman et al.). Locker and Wright (2003) indicated the location of oyster beds lining the mangrove fringe in Rookery Bay and few bars in Henderson Creek which are exposed at low tide through benthic habitat mapping imagery (Fig. 4) and monitoring data collected by Goodman et al (RECOVER 2010) showed high live oyster density, mean productivity and spat recruitment in Rookery Bay. Eastern oysters are not only a commercially important species found within RBNERR, but also serves as essential habitat for other invertebrates, plankton and larval fish species and the SFWMD has indicated that oysters should be included as biological indicators (see Estevez 2000). Currently, oyster populations in the Caloosahatchee Estuary are currently at a cautionary level due to altered hydrology of Everglades Restoration where the growth and survival of oysters are being affected by extreme ranges of salinity (Volety et al. 2009). It has been suggested that a high

live:dead oyster ratio would be a key ecological indicator of a healthy Henderson Creek estuary (Beever; pers. comm.).

Salinity ranges for the *C. virginica* are dependent on life stage: egg and larvae= 10-15 psu; larval growth= 10-29 psu; spat settlement= 16-22 psu; juvenile and adult growth= ~ 5 to 40 psu (Loosanoff 1953; Davis and Calabrese 1964; Patillo et al. 1997). In laboratory experiments, highest body condition indexes occurred in oysters raised between 15 and 25 psu with very low growth rates observed below 5 psu (Hielmayer et al. 2008) while a minimum of 10 ppt is required for growth of adults (Shumway 1996). The optimal salinity range for adults is 10-20 ppt and although adults can withstand high salinity for short periods of time, the incidence of parasite infestation and disease increases with increases in salinity and temperature (Kinne 1971; Cake 1983). Freshwater flow that maintains salinities < 22 psu are recommended for reef development (Patillo et al. 1997). Studies have shown that exposure to extended low salinity (i.e., 5 psu for juveniles and 3 psu for adults) results in mortality (Volety et al. 2003) and sustained freshwater inflows may kill entire oyster populations (Gunter 1953; Mackenzie 1977). However, regardless of salinity tolerance, increases in flow rates may actually displace planktonic organisms including oyster larvae and remove them from the estuary (Yokel 1979; Schmid et al. 2006).

5.2.2 Crabs

Tolley et al. (2012) conducted a study on the effects of freshwater inflow on larval fish and crab settlement onto oyster reefs in Estero Bay, Florida including Faka Union and the Caloosahatchee. The salinity range for the study area in Estero Bay was 13.24 (2.07) to 33.40 (0.48) ppt. Oyster densities were highest in Estero Bay with limited freshwater input and low oyster densities were found in Caloosahatchee and Faka-Union where higher freshwater input occurred. Oyster reef commensals had varying salinity regimes: higher mean salinity affinity= *P. armatus*, *Panopeus spp*, *A. heterochaelis*, and *Gobiosoma robustum*; lower mean salinity affinity = *R. harrisii*, *G. strumosus*, and *G. bose*. Spatial and seasonal patterns suggested an important role of salinity on the density of oyster reef-resident decapods and fishes during the summer wet season when substantial recruitment of green crabs coincided with periods of lower salinity. Larvae of many species advected seaward and away from oyster habitats during times of elevated freshwater inflow which creates spatial gaps between planktonic larvae and settlement areas similar to findings by Yokel (1979) and Schmid et al. (2006). Size of gap is larger for reefs with greater exposure to freshwater inflow resulting in increased larval drift, higher predation risk and reduced settlement of oyster reef commensal larvae.

Shirley et al. (2004) conducted a study in RBNERR to investigate the relative abundance of stenohaline and euryhaline oyster reef crab populations as a tool for

managing freshwater inflow to estuaries. Oyster reef crabs responded to changes in temporal and spatial salinity regimes indicating that select benthic macro-invertebrates are useful bio-indicators for assessing the influence of freshwater inflow. Large volumes of freshwater into Faka-Union Bay were responsible for consistently low STENO:EURY crab values. Henderson Creek has higher mean salinities due to management strategies as well as periods of higher salinity fluctuations followed by periods of lower salinity fluctuation during the wet season. Therefore, crab populations responded to each salinity change resulting in higher and lower STENO:EURY than other estuaries investigated.

Other shellfish including bay scallops, *Rangia* clams and *Polymesdoa* clams have been studied as potential biological indicators in response to changes in salinity. Bay scallops (*Argopecten irradians*) are a commercially important species and are essential for water quality and clarity of estuarine systems. Minimum reported salinity for adult scallops is 14 ppt; embryos 25-35 ppt and 15-35 for larvae (optimal at 25 ppt) (Tettelbach and Rhodes 1981; Winter and Hamilton 1985). *Rangia* clams have been studied as an indicator of ecological effects of salinity changes in coastal waters (Hopkins et al. 1973). It was determined that *Rangia cuneata* has a system of compensating reactions that allows adjustment to changes in salinity over the range from 0 to 38 ppt and over the temperature range from 10 to 35C without mortality. However, a change in salinity, either up from near 0 or down from 15 ppt and above, is necessary to induce spawning and the embryos and early larvae can survive only in salinities between 2 and 15 ppt (Hopkins et al. 1973). Optimal salinity ranges for *Rangia cuneata* = adults 0-18 ppt, embryos 6-10 ppt and larvae 2-20 ppt (Cain 1973; Swingle and Bland 1974; Salle and de la Cruz 1989). Additionally, *polymesdoa* clams have been indicated as molluscan bioindicators of tidal rivers and inshore waters (Estevez et al. 2005). Reported salinity ranges for *Polymesoda carliniana* in Southwest Florida = 1-20 psu (Gainey 1978; Montagna et al 2008).

5.2.3 Crustaceans

Many species of crustaceans have been mentioned in the literature as either ecologically important to the RBNERR or as potential biological indicators including blue crab, pink shrimp, brown shrimp, grass shrimp, white shrimp as well as echinoderms including brittlestars and urchins. Rookery Bay was listed as a nursery grounds for pink shrimp and grass shrimp by Woodburn (1964) indicating that the estuary plays an important role within the commercial fishery. In addition, Browder et al. (1986) found pink shrimp peak in wet season and blue crab peak in dry season indicating a potential salinity dependence. Therefore, hydro-biological monitoring programs established in the Peace, Alafia and Hillsborough Rivers include species such as pink shrimp, grass shrimp and blue crab as candidate species (see Estevez 2000) and the SFWMD

suggests using plankton, blue crabs, and panaeid shrimp as biological indicators of five Gulf estuaries including Charlotte Harbor and the Caloosahatchee. See Table 2 for a list of potential invertebrate biological indicator species and salinity ranges.

5.3 FISHES

Historically, Rookery Bay has been described as an important nursery ground or habitat for both sport and commercially important fish species. Woodburn (1964) identified the commercial striped mullet fishery in Rookery Bay as well as a sport fishery dominated by snook, mangrove snapper, redfish and spotted seatrout. In addition, Woodburn (1964) collected push net and seine samples to examine fish communities around Shell Island and in the south and north end of Rookery Bay. An abundance of fish species were prominent in Rookery Bay and are listed in Table 4.

Since that time, large alterations have been made to the estuary resulting in hydrological changes including a shift in salinity which may affect these important fisheries. Thus, hydro-biological monitoring programs have been developed to determine that can be used as indicators for minimum flow determinations in estuaries while learning how these targets are affected by extreme structural and hydrologic alteration. It is important to consider mainstream and backwater salinity regimes due to species preference for different portions of the estuary (Stevens et al. 2004). The SFWMD determined the following species to be candidate species for Florida estuaries (see Estevez 2000): red drum, snook, spotted seatrout, striped mullet, hogchoker and bay anchovy.

Rubec et al. (2006) conducted a study to assess the influence of changes in freshwater inflow on the distribution and relative abundance of estuarine species including fish and shrimp in Rookery Bay. Species distribution and abundance of Rookery Bay was compared to Fakahatchee Bay which served as a reference site due to the natural sheet-flow delivery of freshwater into the system. During the dry season (May 2003), salinity was similar in both bays (30-33 g/L). However, marked differences in salinity were found between Fakahatchee Bay (8-16 g/L) and Rookery Bay (30-31 g/L) during the wet season (August 2002) due to the prevention freshwater inflow entering the bay through the weir situated at the head of Henderson Creek. This study identifies many species based on their low, moderate or high salinity affinity. Low salinity (<10 g/L) affinity species included year of young (YOY) spot, juvenile sheepshead, juvenile sand seatrout, juvenile red drum, juvenile spotted seatrout, and juvenile bay anchovy. Moderate salinity (> 10 g/L to < 25 g/L) affinity species included juvenile and adult kingfish, YOY spotted seatrout, and adult bay anchovy while high salinity (> 25 g/L) affinity species were identified as juvenile spot, YOY and adult sheepshead, juvenile spotted seatrout, juvenile and adult pink shrimp, adult hardhead catfish, juvenile and adult snook, YOY and adult spotted seatrout, and juvenile and adult pinfish. Rubec et al. (2006) determined that the predominate (30-33 g/L) and the available (18-33 g/L) salinity ranges of Rookery Bay were unsuitable for species with low salinity affinity while

moderate salinity affinity species were restricted to portions of Henderson Creek. Heavy rainfall during the summer wet season shifted salinity to 2-29 g/L making a larger portion of Rookery Bay available to low affinity species. Therefore, Rubec et al. (2006) estimated that many estuarine species' life stages would benefit from increase freshwater flow into Rookery Bay during both wet and dry seasons, however cautioned that careful attention be paid to differences in salinity affinity based on life stage.

Shirley et al. (2004) compared nekton species composition as a biological indicator of altered freshwater inflow between three South Florida Estuaries including Faka Union, Henderson Creek and the Fakahatchee. The Fakahatchee served as the reference site due to its natural sheet-flow delivery of freshwater into the system. Results indicated that altered freshwater input adversely affects species abundance particularly in Henderson Creek which had significantly less nekton catch per unit (CPU) than the other two estuaries. The water management of Henderson Creek results in higher average salinity most of the year compared to Fakahatchee and Faka Union but also results in higher salinity fluctuations followed by periods of lower salinity fluctuations. Shirley et al. (2004) identified over 75% of the fish catch in Henderson Creek were comprised of spotfin mojarra, pinfish, pigfish and bay anchovy. However, Yokel (1975a; b) found Henderson Creek to be dominated by pinfish, silver jenny, pigfish, silver perch, spotfin mojarra, and lane snapper indicating a shift in species composition. Fakahatchee had higher species diversity and nekton abundance than both Faka Union and Henderson Creek (Carter et al. 1973). Results indicated that species composition was directly related to salinity, sediment type and aquatic vegetation (Colby et al. 1985; Shirley et al. 2004)

In addition to the above studies, several studies have indicated fish species found in abundance within either RBNERR or estuaries with similar attributes such as fish communities or salinity ranges or have been listed as candidate species for biological indicators. Table 5 provides a list of those species along with the location of the study, the source/reference as well as important attributes such as salinity affinity, salinity tolerance or other important life history characteristic for fish communities found in RBNERR.

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the source/reference as well as important attributes such as salinity affinity, salinity tolerance or other important life history characteristic for fish communities found in RBNERR.

5.4 SUMMARY OF LITERATURE SEARCH

Below is a list of **some** of the relevant discussion items that was identified in the literature:

- Seagrass cover was determined to be declining due to unknown causes when compared to historical presence (Vasquez and Schmid, SIMM Report #1);
- Changes in macroalgae abundance due to salinity variance may significantly alter fish abundance (O'Donnell 2013);
- Mangroves have a wide salinity tolerance, particularly those found in southwest Florida, and therefore may not be used directly as a biological indicator. However, mangroves may be used as indicators of coastal change since variance in hydrology and estuary salinity may change mangrove distribution (Blasco et al. 2006).
- Changes in salinity may not directly influence mangroves, but perhaps the sessile communities on their roots such as oysters, sponges, and tunicates may be potential indicators (Linton and Warner 2003);
- There is extensive data pertaining to oyster mapping and salinity tolerances available;
- Regardless of salinity tolerances, increased flow rates may actually displace oyster larvae and remove them from the estuary (Yokel 1979; Schmid et al. 2006);
- A study has been conducted to investigate the relative abundance of stenohaline and euryhaline oyster reef crab populations for managing freshwater inflow to estuaries (Shirley et al. (2004);
- Henderson Creek has high salinity fluctuations due to management strategies and it appears that the crab populations responded to each salinity change resulting in higher and lower STENO:EURY than other estuaries investigated (Shirley et al. (2004);
- Multiple studies have been conducted that compare nekton species composition as a biological indicator of altered freshwater inflow between three South Florida Estuaries including Faka Union, Henderson Creek, and the Fakahatchee Bay. The Fakahatchee Bay is used as a reference site due to the natural sheet flow delivery of freshwater to the system as compared to Henderson Creek which has the weir at its mouth that regulates freshwater inflow.

- Comparison of studies conducted over the past 30 years have shown a change in species composition of fish that is believed to be directly related to changes in salinity, sediment type, and aquatic vegetation. Some of these fish are commercially significant to the region.

6.0 RESULTS AND DISCUSSION

The majority of the literature reviewed in this report has been provided or based on research conducted by current and former RBNERR staff. Many thanks to all of these scientists who help the Reserve fulfill its mission which is:

“to provide the basis for informed coastal decisions through research, land management, and education.”

Utilizing the baseline information gleaned from the literature review, interviews with local ecologists, and the upcoming GIS and in-depth photo interpretation effort, the Project Team will be able to present data to stakeholders and attempt to choose appropriate biological indicators that can be utilized for the development of a watershed model that will maintain the integrity of Henderson Creek Estuary.

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Figures

- Figure 1 Henderson Creek Study Area
- Figure 2 Benthic Habitat Mapping Imagery in RBNERR
- Figure 3 Examples of SAV in Rookery and Halls Bay
- Figure 4 Interpretation of Side-Scan Imagery

Date: 09/20/13 Rev: Date: N/A P#: DR GIS Analyst: JG Map Document: Watershed.mxd Project Number: 002521-00 C: PDF Document: 2521_Henderson_Creek_Watershed_AUG_20130330.pdf Plot Size: 8.5 x 11

Legend

- Rookery Bay National Estuarine Research Reserve
- Rookery Bay Watershed
- Henderson Creek Approximate Location

Naples Bay

Rookery Bay

Johnson Bay

Tarpon Bay

Barfield Bay

Henderson Creek

Palm Bay

Gullivan Bay

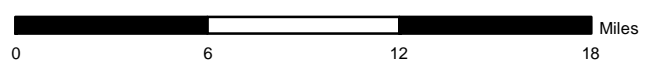


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Figure 1 - HENDERSON CREEK STUDY AREA

Rookery Bay
Collier County, Florida



Data Source: -SFWMD
Image Source: -2010 Microsoft

Coordinate System: NAD 1983 Florida State Plane West



Figure 2. Benthic habitat mapping imagery conducted by Locker and Wright (2003) indicating the presence of SAV in RBNERR.

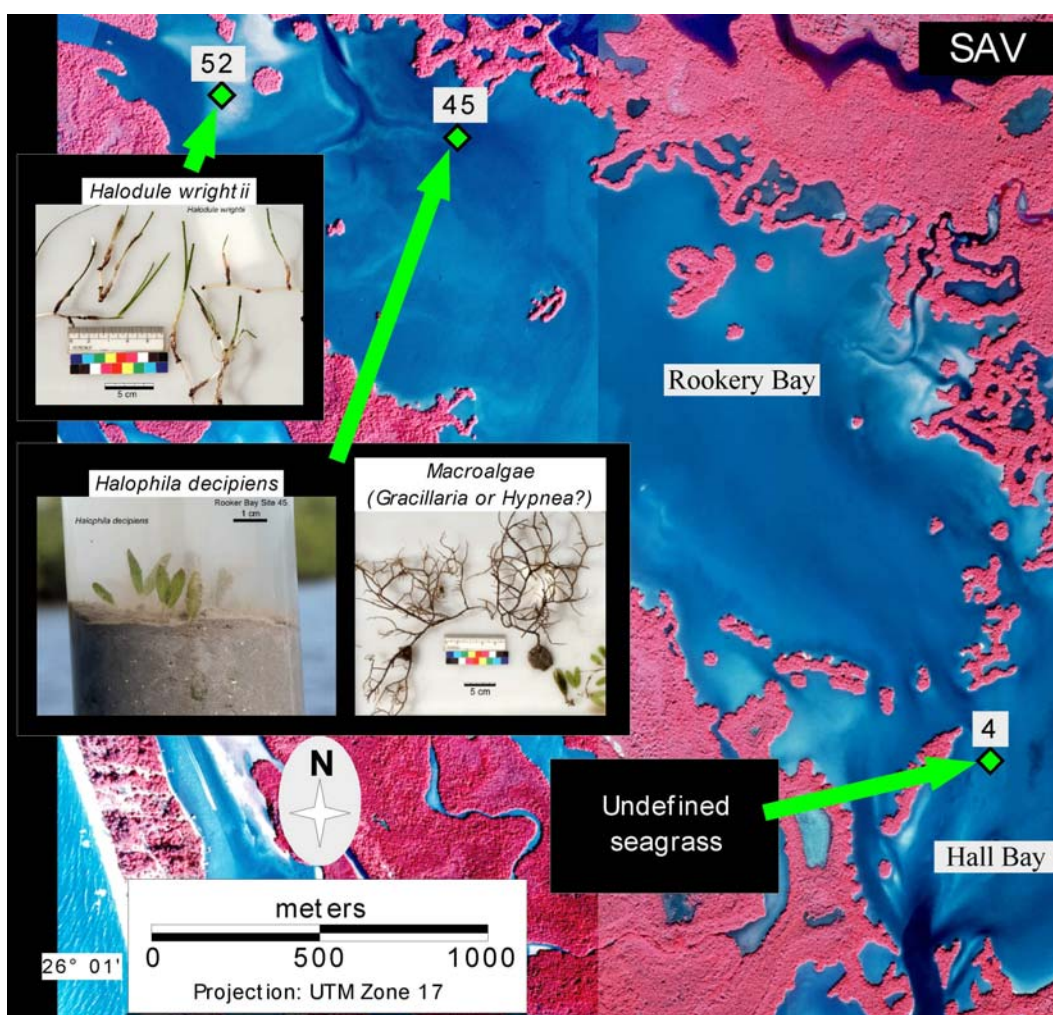


Figure 3. Examples of SAV recovered in Rookery and Hall Bays by Locker and Wright (2003). The recovered SAV corresponds to areas identified by side-scan sonar as SAV bottom types.

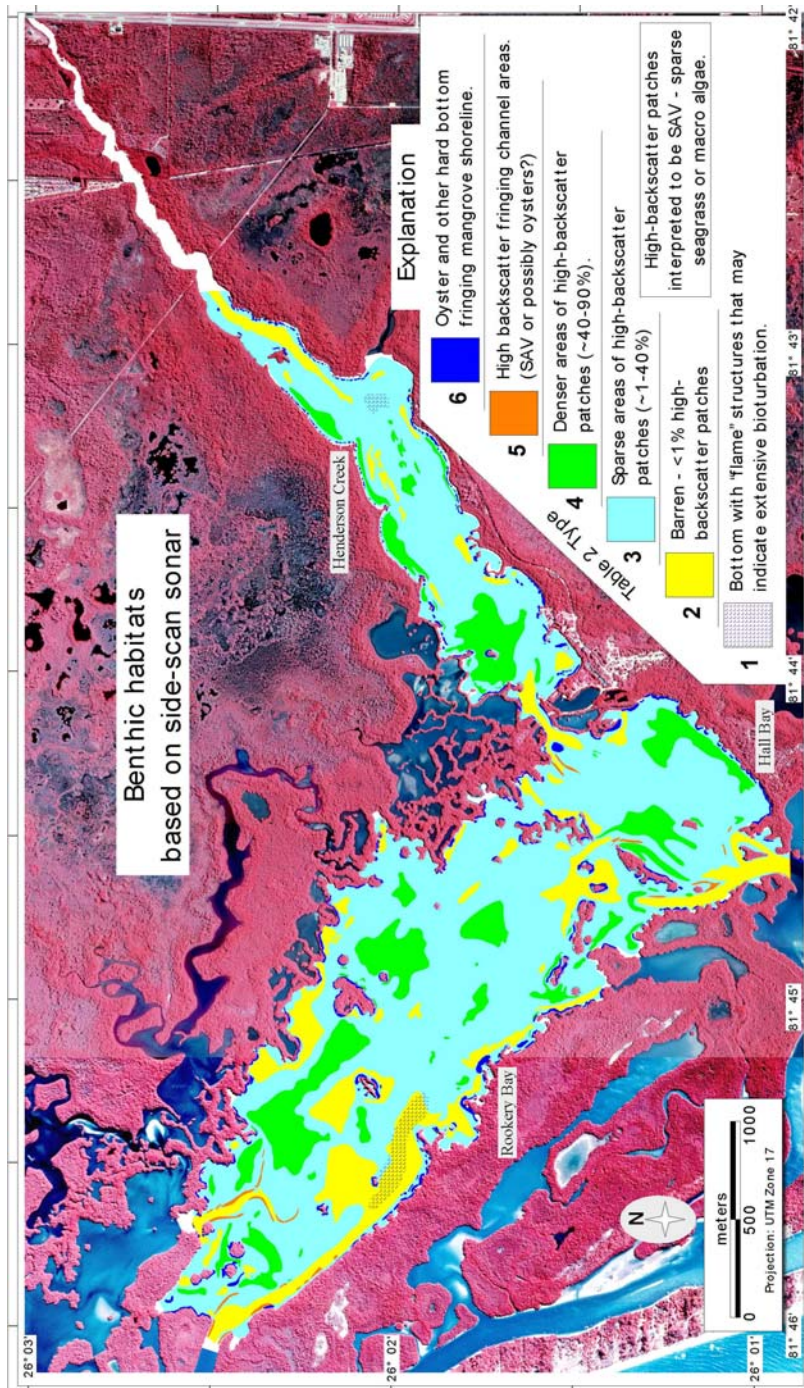


Figure 4. Interpretation of the side-scan imagery with respect to benthic habitats by Locker and Wright (2003). The primary characteristics are based on the density of high-backscatter patches attributed to SAV (sparse seagrass or macroalgae). The green areas (40-90% patches) are probably most prone to supporting seagrass, as the only seagrass observations were from areas in the green zones. The side-scan imagery verified that oyster beds are restricted to fringing accumulations next to the mangrove shoreline or the oyster banks (mostly lower Henderson Creek into Hall Bay) that are visible in DOQQ aerial photos.

Tables

Table 1	Seagrass Acreage in Rookery Bay Aquatic Preserve 2003-2005
Table 2	Potential Vegetative Biological Indicators for Henderson Creek
Table 3	Potential Crustacean Biological Indicators
Table 4	Abundant Common Fish Species 1964
Table 5	Candidate Fish Species as Biological Indicators for Henderson Creek

Table 1. Seagrass acreage in the Rookery Bay Aquatic Preserve, 2003-2005

	Henderson Creek	Hall Bay	Rookery Bay	Cape Romano	Pumpkin Bay	Faka Union Bay	Fakahatchee Bay	Total
Patchy	41	31	95	335	80	0	101	683
Continuous	0	0	0	345	0	0	0	345
Total	41	31	95	680	80	0	101	1,028

Table 2. Potential vegetative biological indicators for Henderson Creek

Species	Source	Site	Salinity range
Seagrass			
Halophila engelmannii	Dawes et al 1987	Indian Bluff Island and Homosassa River, Florida	5 - 35 ppt
	Merino et al 2009	Gulf of Mexico	2.0 - 36 ppt
Halophila decipiens			
Thalassia testudinum	Lirman and Cropper 2003	Biscayne Bay	Thalassia max growth at 30 - 40 psu (lowest growth at 5 psu and 45 psu)
Halodule wrightii	Doering et al 2002	Caloosahatchee	Mortality and reduced growth between 6 - 12 psu; higher shoot density > 12 psu
	Dunton 1996	Guadalupe Estuary and upper Laguna Madre, Texas	5 - 55 ppt
Ruppia maritima	Strazisar et al 2013	Florida Bay	Germination rates restricted to salinity < 25 psu
Syringodium filiforme	Merino et al 2009	Gulf of Mexico	3.9 -16.9 ppt
	Lirman and Cropper 2003	Florida Bay	Max growth at 25 psu (growth drops significantly at all salinities higher and lower)
Aquatic Plants (SAV)			
Vallisneria	Twilly and Barko 1990; Mattson 2002	Suwannee River Estuary	Max salinity range of 05.- 12 psu average annual salinity
	Doering et al 2002	Caloosahatchee, Florida	Reduced growth at 10-15 psu; lower shoot density > 10 psu
Macroalgae			
Gracilaria	Bird and McLachlan 1986	Atlantic and Pacific Ocean	Maximum growth 15 - 38 ppt
	Dawes et al 1999	Florida Keys (Pigeon Key and Bahia Honda Key)	Experimental units 20 and 30 ppt
Hypnea	Dawes et al 1976	Tampa Bay	15 - 45 ppt with optima at 20 ppt
Mangroves			
	Blasco et al 1996	Worldwide Review	Various salinity tolerances for R. mangle (red), A. germinans (black) and L. racemosa (white)
	Werner and Stelzer 1990	Key Largo, Florida	R. mangle had higher growth in 150 and 200 mol m-3 and increased survivorship than freshwater controls
	Smith and Snedaker 1995	Biscayne National Park, Florida	Increased growth and development at 5 psu vs. 36 psu

Table 3. Potential crustacean biological indicators for RBNERR with salinity affinities and potential ecological implications.

Species	Location	Source	Attribute
Blue Crab	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: Blue Crab 5-15 psu
	Louisiana and Texas	Guerin and Stickle 1992	Maximum energy absorption and growth of juveniles between 10-25 ppt
Pink shrimp	Florida Bay	Browder et al 2002	Penaeus duorarum salinity range 2-55 ppt; optimal growth at 30 ppt
Brown Shrimp	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: Brown Shrimp 10-20 psu
Grass Shrimp	Lab experiments (China)	Liao et al 1986	Palaemonetes nugio salinity range 3-45 ppt
White Shrimp	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: White Shrimp 5-10 psu
Oyster crabs	Faka Union, Fakahatchee and Henderson Creek	Shirley et al 2004	Henderson Creek has higher mean salinities due to management strategies as well as periods of higher salinity fluctuations followed by periods of lower salinity fluctuation during the wet season. Therefore, crab populations responded to each salinity change resulting in higher and lower STENO:EURY than other estuaries
	Faka Union, Fakahatchee and Henderson Creek	Shirley et al 2004	Oyster reef crabs respond to changes in temporal and spatial salinity regimes- benthic macroinverts are useful bioindicators for assessing the influence of FW inflow
	Faka Union, Fakahatchee and Henderson Creek	Shirley et al 2004	Large volumes of FW into Faka-Union Bay responsible for consistently low STENO:EURY crab values
Echinoderms	Tampa Bay	Talbot and Lawrence 2002	Brittlestar (Ophiophragmus filigraneus) tolerant of low salinity but demonstrated decreased production, low respiration and high excretion at 16 psu when compared to 22 and 30 ppt
	Tampa Bay	Talbot and Lawrence 2002	Changes in salinity may affect range of habitat and restrict brittlestar to areas of bay with higher salinity
Urchins/Gastropods	Biscayne Bay	Irlandi et al 1997	Canal freshets killed urchins (Lytechinus variegatus) but not snails (Lithopoma techum) in laboratory exposures similar to water management practices- urchin grazing was depressed whereas gastropod grazing was increased by variable salinity therefore feeding behavior and larger-scale trophic effects may accompany altered freshwater inflow

Table 4. Abundant species common in push net and seine samples collected from Rookery Bay by Woodburn in 1964.

Species	Scientific name
pinfish	<i>Lagodon rhomboides</i>
yellowtail	<i>Bairdiella chrysur</i>
pipefish	<i>Syngnathus spp</i>
tonguefish	<i>Syphurus plagiusa</i>
sheepshead	<i>Archosargu probatocephalus</i>
grunt	<i>Haemulon plumieri</i>
goby	3 species
mojarra	<i>Eucinostomus gula</i>
catfish	<i>Galeichthys felio</i>
mangrove snapper	<i>Lutjanus griseus</i>
striped mullet	<i>Mugil cephalus</i>
silver mullet	<i>Mugil curema</i>
flounder	<i>Paralichthys albigutta</i>

Table 5. Candidate fish species as biological indicators for Henderson Creek

Species	Location	Source	Attributes
Red drum	Rookery Bay	Rubec et al. 2006 (Texas Parks and Wildlife)	Juvenile red drum = low salinity affinity species; Predominate (30-33 g/L) and available (18-33 g/L) salinity ranges of Rookery Bay unsuitable for low affinity species; Wet season shifts salinity to 2-29 g/L making a larger portion of the bay available to low affinity species
	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Affinity for lower salinity during certain life stages (psu not noted within report)
Snook	Big Cypress	EPA 1973 (Big Cypress Ecosystem Analysis)	Salinity gradient = 0.3 to 29.7 ppt; No positive correlation between salinity and successful capture in seines
	Big Cypress	EPA 1973 (Big Cypress Ecosystem Analysis)	Adult snook are euryhaline and may not be good indicator species, but the majority of their prey including <i>Lagodon rhomboides</i> (pinfish), <i>Anchoa mitchilli</i> (bay anchovy), <i>Harengule pensacolae</i> (sardine), <i>Eucinostomus gula</i> (mojarra), <i>Synodus foetens</i> (lizardfish), and <i>Floridichthys carpio</i> (goldspotted killifish) typically inhabit the higher salinity regions of the estuary. Shrimp and crabs were also abundant prey items for adults.
	Big Cypress	EPA 1973 (Big Cypress Ecosystem Analysis)	Abundant prey for juvenile snook included grass shrimp as well as <i>Poecilia latipinnia</i> , <i>Gambusia affinis</i> , <i>Lophogogius cyrinodies</i> , and <i>Menidia beryllina</i> which show affinity for particular salinities
Tarpon	South Florida	Zale and Merrifield 1989	Salinity preference 0-47 ppt
Spotted Sea Trout	Rookery Bay	Rubec et al. 2006 (Texas Parks and Wildlife)	Juvenile spotted seatrout = low affinity species; Predominate (30-33 g/L) and available (18-33 g/L) salinity ranges of Rookery Bay unsuitable for low affinity species; Wet season shifts salinity to 2-29 g/L making a larger portion of the bay available to low affinity species
	Rookery Bay	Rubec et al. 2006 (Texas Parks and Wildlife)	YOY spotted seatrout = moderate salinity affinity species; restricted to relatively small area of Henderson Creek
Sawfish	Caloosahatchee	Simpfendorfer et al 2011	Affinity for salinities between 18-24 psu and movements targeted to stay within range
Striped mullet	Crystal River and Seahorse Key, Florida; Texas estuaries; Hawaii (lab experiments)	Collins 1985; Simmons 1957; Sylvester et al 1975	Adults 0-75 ppt; highest survival of eggs was at 32 ppt; larvae 24-36 ppt
Hogchoker			No data
Bay Anchovy	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: Bay Anchovy 20-25 psu
	Rookery Bay	Rubec et al. 2006 (Texas Parks and Wildlife)	Adult bay anchovy = Moderate salinity affinity species; restricted to relatively small area of Henderson Creek
Shad	Georgia Estuaries	Michaels 1993	Significant linear relationship between juvenile shad and average FW flow during May and June (indicates salinity dependence)
Menhaden	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: Menhaden 5-10 and 15-20 psu
Croaker	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: Croaker 5-20 psu

Table 5. Candidate fish species as biological indicators for Henderson Creek

		Shervette et al 2007	Croakers show faster growth at 5 psu than 25 psu (<i>Micropogonias undulatus</i>)
Pinfish	Guadalupe Estuary	Rubec et al. 2006 (Texas Parks and Wildlife)	Preferred salinity: Pinfish 25-50 psu
	Texas	Shervette et al 2007	Pinfish (<i>Lagodon rhomboides</i>); growth significantly higher at 15-30 psu, but may show local adaptation to range of salinity from 0-75 psu
	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Shows affinity for specific macroalgae (type not determined within report)
Kingfish	Rookery Bay	Rubec et al. 2006 (Texas Parks and Wildlife)	YOY and adult kingfish = Moderate salinity affinity species; restricted to relatively small area of Henderson Creek
Spot	Texas	Shervette et al 2007	Spot show faster growth at 10-24 psu than 5 psu (<i>L. xanthurus</i>)
Silver Perch	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Affinity for higher salinity within Rookery Bay (psu not denoted within report)
Lane Snapper	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Affinity for higher salinity within Rookery Bay (psu not denoted within report)
Code Goby	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Affinity for higher salinity within Rookery Bay (psu not denoted within report)
Gulf Flounder	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Affinity for higher salinity within Rookery Bay (psu not denoted within report)
Planehead Filefish	Fakahatchee, Faka Union and Pumpkin Bay	O'Donnell 2013	Affinity for higher salinity within Rookery Bay (psu not denoted within report)

APPENDIX A

Results of the Local Expert's Interviews



RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: 9/26/13

INTERVIEWER:

INTERVIEWEE: Mike Barry

SUBJECT:

DURATION:

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?
Besides recreational activities within its boundaries for over 20 years, was recently contracted for vegetation mapping
2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?
Yes, multiple projects in and around area including TTINWR, Picayune (Belle Meade included), Collier Seminole, and the project mentioned above
3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?
Upstream non tidal vegetation affected by drainage (shortened hydroperiod) and exotic plant invasion and increased development. The rest of areas included changes from freshwater/brackish marsh, hydric pine flatwoods, wet cabbage palm woodland or upland woodlands to areas with mangroves and/or buttonwood (i.e. tidal influence reaches in further). Fire suppression in many areas results in more dense shrubs, other areas are now being burned again. Buttonwood die-offs in many areas including coastal berms. Some hardwood die offs. Some areas of young buttonwoods vigorous in edges of coastal hammock with scattered dead hardwoods (example N Keywadin)



Some black mangrove basins with die-offs. Outer portions of outer islands in Ten Thousand Island areas have continued retreat many meters since I began camping in the area and evident on aerials.

4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

See rpts. Recommend Taylor Alexanders data and Tom Smith veg plots

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

Though not necessarily the ONLY or MOST IMPORTANT but would like to see more monitoring of buttonwood scrub /buttonwood woodland, marsh areas, and hydric pineflatwoods and cabbage palm woodland near edge of tidal influence as these areas have changed considerably since 1940 all trending to greater abundance of salt tolerant species less of intolerant species. And of course in mangrove forested areas SETS

6. Do you have anything to share in terms of an indicator species for this project? Buttonwood when dead persists long time in mangrove areas and is less tolerant than mangroves of higher salinities. Would like to see more groundtruthing of areas where it has died and track upper areas on edge of tidal areas. Marks the edge of tidal influence fairly well. Also tracking pines is ok if all strata and track fire data with it.

7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

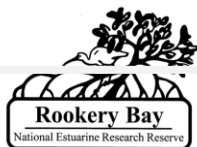
See rpt especially pub. Cited by Ken Krauss in TTINWR

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?

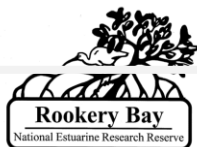
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9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?

Freshwater flow from upstream less extreme; Fire and exotic control above mangrove forested areas



10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere? Expansion or restoration of freshwater wetlands upstream in Belle Meade and more natural flow into Henderson Creek, ie buffer wetlands, would be big help.





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: September 25, 2013

INTERVIEWER: Dianne Rosensweig [Dianne@scheda.com]

INTERVIEWEE: James W. Beever III

SUBJECT: Henderson Creek Environmental Indicators

DURATION: 2 hours 26 minutes

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?

I have been interacting with the Rookery Bay NERR since its formation in 1977. I participated in its programs when I worked for FDER in 1984-1987. I was involved with its resources management and research program from 1988-1989 when I was with FDNR as the resource management and research coordinator for the southwest Florida Aquatic Preserves. I continued to work with Rookery Bay NERR when I worked for GFC/FWC from 1990 to 2006 in a number of different ways including the ADID, management planning, and project reviews, and I continue to interact on an as needed or invitational basis. .

2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?

Yes I have done research on mangroves and I am familiar with research that has been done there and that is ongoing.

3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?

Water quality and clarity has decline significantly. Areas of seagrass beds have been lost. Wind driven turbidity has increased. In



the upper watershed freshwater wetlands and uplands have been lost to development and the hydrology less natural.

4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

Not right off hand but there may be USFWS or USGS sources, particularly in the regional profile for Ten-Thousand Islands..

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

I would select proportion of live/dead oysters, submerged aquatic vegetation, and benthic invertebrates. I would sample for these seasonally. I would suggest Bob Chamberlain and Peter Doering with the SFWMD and Sid Flannery with the SWFWMD.

6. Do you have anything to share in terms of an indicator species for this project?

No.

7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

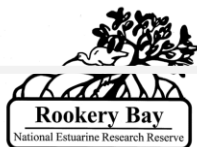
Beever III, J.W. 1995. Watersheds and wildlife, fishes and flows: Planning and Projects on the Peace River. Proceedings of the Wetlands '95 National Symposium on Watershed Management and Wetland Ecosystems, National Association of State Wetland Managers, Tampa, Florida, April 23-26, 1995.

Phillips, R.C. and V.G. Springer 1960. A report on the hydrography, marine plants and fishes of the Caloosahatchee River area, Lee County Florida. Florida State Board of Conservation. Special Report No. 5 : 34 pp.

Gunter, G. and G.E. Hall 1965. A biological investigations of the Caloosahatchee Estuary of Florida. Gulf Research Reports 21: 1-71.

Estevez, E.A. 1986. Infaunal macroinvertebrates of the Charlotte Harbor estuarine system and surrounding inshore waters. USGS Water-Resources Investigations Report: 85-4260

Chamberlain, R.H. and P.H. Doering. 1998.



Freshwater inflow to the Caloosahatchee Estuary and the resource-based method for evaluation. Proceedings of the Charlotte Harbor Public Conference and Technical Symposium; 1997 March 15-16; Punta Gorda, FL. Charlotte Harbor National Estuary Program Technical Report No. 98-02. 274 p.

Chamberlain, R.H. and P.H. Doering. 1998. Preliminary estimate of optimum freshwater inflow to the Caloosahatchee Estuary: A resource-based approach. Proceedings of the Charlotte Harbor Public Conference and Technical Symposium; 1997 March 15-16; Punta Gorda, FL. Charlotte Harbor National Estuary Program Technical Report No. 98-02. 274 p.

Doering, P.H. and R.H. Chamberlain 1999. Water quality and the source of freshwater discharge to the Caloosahatchee Estuary, FL. Water Resources Bulletin 35: 793-806.

Doering, P.H. and R.H. Chamberlain 1998. Water quality in the Caloosahatchee Estuary, San Carlos Bay and Pine Island Sound. Proceedings of the Charlotte Harbor Public Conference and Technical Symposium; 1997 March 15-16; Punta Gorda, FL. Charlotte Harbor National Estuary Program Technical Report No. 98-02. 274 p.

Fraser, T.H. 1997. Abundance, seasonality, community indices, trends and relationships with physiochemical factors of trawled fish in upper Charlotte Harbor. Bulletin of Marine Science 60(3): 739-763.

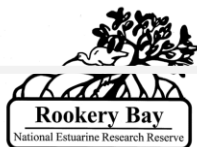
Flannery, M.S. and M. Barcelo. 1998. Spatial and temporal patterns of stream flow trends in the Upper Charlotte Harbor watershed. In Proceedings of the Charlotte Harbor Public Conference and Technical Symposium. Charlotte Harbor National Estuary Program. Technical Rept. No. 98-02.

Kraemer, G.P. , R.H. Chamberlain, P.H. Doering, A.D. Steinman and M.D. Hanisak. 1999. Physiological responses of *Vallisneria americana* transplants along a salinity gradient in the Caloosahatchee Estuary (SW Florida). Estuaries 22:138-148.

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?

Data on oysters, SAV, Chlorophyll, CDOM, Turbidity, water clarity, salinity and flow rate.

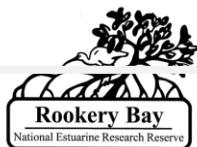
9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?



High live oyster to dead oyster ratio;
healthy SAV;
Chlorophyll less than 11;
CDOM less than 70;
Turbidity less than 18 NTU;
water clarity 1 meter or more.

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?

This list is extensive and I cannot list them all. I would suggest forming a local expert team and avoid consulting researchers from distant areas and unfamiliar with southwest Florida. A community profile of the Creek is a good starting point to identify potential environmental indicators that are present and those that were historically present but now absent. After measuring the indicators for a year a sensitivity analysis of the parameters should determine which are most sensitive to hydrologic conditions.





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: September 20, 2013

INTERVIEWER: Dianne Rosensweig

INTERVIEWEE: Peter Doering, SFWMD

SUBJECT: Henderson Creek

DURATION: Twenty Minutes

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?

None specific to RBNERR

2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?

No

3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?

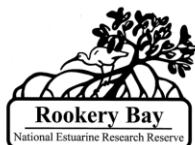
Changes in flow because of canals, shoreline hardening.

4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

Peter mentioned Jeff Schmid's Naples Bay report and Ernie Estevez earlier report.

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

He mentioned SFWMD using SAV in the Caloosahatchee. They looked at historical



and current distributions and then chose indicators for segments.

Valissinaria- low salinity

Oysters- middle

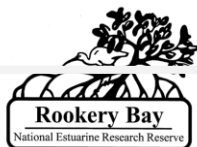
SAV-high salinity

6. Do you have anything to share in terms of an indicator species for this project?
May want to use multiple indicators for the salinity gradient.
7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

Irandi, Elizabeth 2006. Literature Review of Salinity Effects on Submerged Aquatic Vegetation (SAV) found in Southern Indian River Lagoon and Adjacent Estuaries.

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?
Look at other MFL's in the region.
9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?
No comment.
10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?

Peter noted that if you want to manage salinity, it is important to consider other things that affect salinity such as tide and wind and it is important to manage the flow at the location where you have control not further downstream.





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: Friday the 13th of October, 2013

INTERVIEWER: Dianne Rosensweig

INTERVIEWEE: Ernie Estevez

SUBJECT: Henderson Creek

DURATION: ten minutes

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?

No scientific work there, just rare meetings...

2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?

Nope- trust NERR to have done good work there, but it has not been a place I have followed.

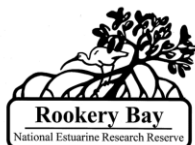
3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?

No experience there.

4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

Nope.

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?



I have had some success using land and seascape metrics such as SAV, oysters, and live vs dead mollusk shells. The best fit of a resource against modeled salinity changes I ever found involved oligohaline marshes in the Myakka River.

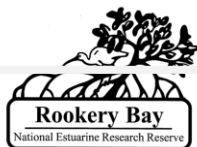
6. Do you have anything to share in terms of an indicator species for this project?
Nope, sorry.

7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?
See attached reprint from Estuaries. Let me know if you are interested in MFL work in tidal river settings along FL's west coast (or check SWFWMD's MFL web resources).

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?
See attached literature review.

9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?
Does this creek have an instream barrier? That would matter a lot.

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?
See attached reprint (and check out the entire issue—good stuff).





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: 9/25/2013

INTERVIEWER:

INTERVIEWEE: Katie Laakkonen

SUBJECT:

DURATION:

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?

The Rookery Bay Reserve is a vital partner to the City of Naples, Natural Resources Division. We partner with Rookery staff on projects including Greenscape (educating landscape companies on fertilizer BMPs), Trawling (collecting fisheries data for Naples Bay and Moorings Bay), Team Ocean (outreach and education), and the diversion of freshwater out of the Golden Gate Canal and into Henderson Creek.

2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?

I have seen various presentations regarding bird and turtle monitoring data, fisheries (shark and trawling) data, and water quality.

3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?

Reduction of freshwater coming down Henderson Creek and the need for establishing a Minimum Flows and Level (MFL) for that waterbody since Marco Island also pulls from Henderson Creek for their water supply.



4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

Yes. Rookery should have those on file.

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

At a minimum, collecting fisheries data (diversity and abundance) in combination with the water quality continuous datasonde data. A long term dataset already exists for this and monitoring could be replicated into the future to track changes to the estuary due to changing salinity regimes and flows. Additional indicators could be oyster density, distribution and health; mangrove distribution, and mud crab ratios (see past study conducted by Michael Shirley).

6. Do you have anything to share in terms of an indicator species for this project?
7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

I am familiar with dozens of peer-reviewed literature primarily relating to the Caloosahatchee River Estuary and the St. Lucie Estuary that address how salinity fluctuations affect flora and fauna. There are several publications written by Rookery Bay staff documenting affects to fisheries (Pat O'Donnell) and mud crabs (Michael Shirley) from variations in freshwater inputs.

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?

For fisheries data, the research question could be how has diversity and abundance of species changed with changes in salinity and flow. Changes to the distribution of specific species that are more freshwater tolerant or saltwater tolerant can be used as indicators. For oyster distribution and health, a research question could be how increased flows to Henderson Creek may affect optimal suitable habitat for oyster reefs and how those flows may increase oyster health (reduce parasitic infection of *Perkinsus marinus* for example).

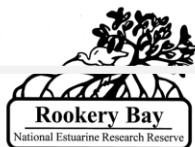


9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?

Healthy oyster reefs that support extensive invertebrate populations, robust mangrove systems that allow Rookery Bay to be vital nursery ground for many fish and invertebrate species as well as bird rookeries, and diverse fish assemblages to support the food chain.

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?

Many lessons can be learned from all of the research that has been conducted on oyster reefs, mangroves, seagrass, etc. in the Caloosahatchee Estuary as well as the St. Lucie Estuary by Florida Gulf Coast University, the South FL Water Management District, St. Lucie County, etc.





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: September 18, 2013

INTERVIEWER: Dianne Rosensweig

INTERVIEWEE: Jeff Schmid, Conservancy of Southwest Florida

SUBJECT: Henderson Creek

DURATION: 30 Minutes

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?

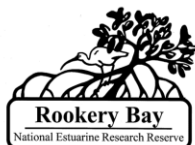
In 1997 Jeff conducted sea turtle research in the 10,000 islands. He joined the Conservancy in 2001 and has been working locally since then. He provided a report on the historical changes that have occurred in Naples Bay.

2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?

Yes. Jeff has been studying developmental habitat specific to sportfish since 2009. He noted that it was documented in the 1973 EPA report about the Ecosystems Analysis of the Big Cypress Swamp and Estuaries that the sampling site at the KOA campground adjacent to Henderson Creek was one of the most productive snook habitat areas in the entire region prior to the residential development.

3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?

Jeff believes that the construction of the canal systems in the 1950-1960's has had the biggest environmental impact. Henderson Creek no longer receives surface water flow, it is all one point source and that generally means too much or too little freshwater. He also mentioned that the water was not only coming from



Henderson Creek but the Lely canal system was also diverting water to Henderson Creek.

4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

Jeff has provided Scheda some historical papers. He also mentioned Bernie Yokel's research as well as Dave Adison who has 30 years of experience with the Conservancy.

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

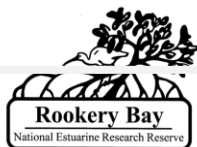
Jeff will be doing some specific research linking fish species with salinities for RBNERR. He also suggested using crabs as a biological indicator. The mud crab has a wide salinity tolerance, whereas the porcelain crab prefers high salinities. Perhaps utilizing the fish and crabs together would be beneficial. Jeff suggested contacting Chris Panko Graf about ongoing crab research on the Reserve.

6. Do you have anything to share in terms of an indicator species for this project?
Perhaps using multiple indicators.
7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

In addition to the literature he has already provided, he suggested a final report on salinity that has been recently completed for Naples Bay and he is going to put it on the Scheda FTP site.

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?

Same as above-multiple indicators.

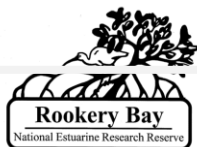


9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?

Jeff believes that the major problem with attempting to assess the overall health of Henderson Creek is the lack of baseline data prior to the construction of US 41. He suggested contacting Mike Barry.

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?

Jeff said that establishing the correct freshwater inflow is not an easy problem to solve since Marco Island wants more freshwater. It is very difficult to balance the needs of the community versus the needs of the estuary.





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: 9-18-2013

INTERVIEWER:

INTERVIEWEE: Mike Shirley

SUBJECT:

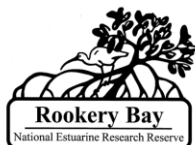
DURATION:

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?
Research Biologist 1990-1994; Resource Management Coordinator 1994-2000; Research Coordinator 2000-2006
2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area? **Yes/Yes**
3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?
Altered freshwater inflow patterns (volume and timing) and degraded water quality (particularly septic tank effluent).
4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?

Please see: Shirley, M.A. and S.L. Brandt-Williams (2003). **Characterization of the Rookery Bay National Estuarine Research Reserve**. CD-Rom. NOAA/CSC/20414-CD. Charleston, SC: NOAA Coastal Services Center.

Shirley, M., P. O'Donnell, V. McGee, and T. Jones (2005). **Nekton Species Composition as a Biological Indicator of Altered Freshwater Inflow: A Comparison of Three South Florida**



Estuaries. In: Estuarine Indicators (S. Bortone, editor) CRC Press, Boca Raton, Florida, pp 351-364.

5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

In addition to: Success of growth, survival, and recruitment of oysters to upper Henderson Creek based on reference conditions in the Fakahatchee Bay/River

Please see:

Popowski, R., J. Browder, M. Shirley and M. Savarese (2003). **Hydrological and Ecological Performance Measures and Targets for the Faka Union Canal and Bay.** Final Draft Performance Measures: Faka Union Canal. U.S. Fish and Wildlife Service Technical Document.

Shirley, M., V. McGee, T. Jones, B. Anderson and J. Schmid (2004). **Relative abundance of stenohaline and euryhaline oyster reef crab populations as a tool for managing freshwater inflow to estuaries.** *Journal of Coastal Research.* 45:195-208.

Shirley, M., P. O'Donnell, V. McGee, and T. Jones (2005). **Nekton Species Composition as a Biological Indicator of Altered Freshwater Inflow: A Comparison of Three South Florida Estuaries.** In: Estuarine Indicators (S. Bortone, editor) CRC Press, Boca Raton, Florida, pp 351-364.

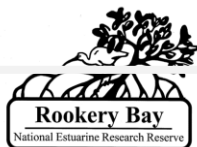
6. Do you have anything to share in terms of an indicator species for this project?

The primary goal should be to restore biodiversity of oyster reef-based communities (fish and invertebrates) using a reference site approach. Single species management should be discouraged.

7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

In addition to above

Shirley, M.A., J. Haner, H. Stoffel and H. Flanagan (1997). **Rookery Bay National Estuarine Research Reserve and Ten Thousand**



Islands Aquatic Preserve: Estuarine Habitat Assessment. Final Report #NA67OZ0463. Florida Department of Community Affairs, Florida Coastal Zone Management Program. 119pp.

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?

Relative abundance of stenohaline and euryhaline oyster reef crab populations relative to Fakahatchee Bay

Growth, Survival, and Recruitment of oysters in upper Henderson Creek versus Fakahatchee Bay/River

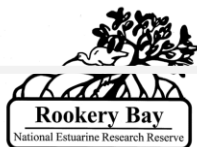
9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?

Using Fakahatchee Bay as reference site establish natural biodiversity and water quality targets modeled to seasonal patterns of freshwater inflow.

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere?

Please see:

<http://www.era.noaa.gov/pdfs/Sci-based%20Restoration%20Monitoring-%20Vol%201.pdf>





RESTORING THE ROOKERY BAY ESTUARY

A PROJECT CONNECTING PEOPLE AND SCIENCE FOR LONG-TERM COMMUNITY BENEFIT

Rookery Bay National Estuarine Research Reserve

Meeting Minutes

DATE AND TIME: Sept 18, 2013

INTERVIEWER:

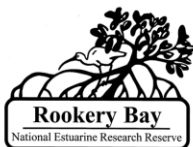
INTERVIEWEE: Aswani Volety

SUBJECT:

DURATION:

INTERVIEW QUESTIONS & RESPONSES

1. What has been your experience with the Rookery Bay Reserve?
I've had excellent relationship with Rookery Bay Staff and administrators to date.
2. Have you done any research or are you familiar with any research specifically in the Henderson Creek/Rookery Bay area?
My research focused on examining the health of oysters in Henderson Creek, Blackwater River and Faka-Union canal initially (1999-2001) and subsequently expanded to include Pumpkin Bay, Fakahatchee estuaries as well as Lostman's River.
3. Based on your experience, what have been the most noticeable ecological or biological changes in the Henderson Creek watershed over the last 50 years?
My research spanned that last 123 years or so, so I can only comment on my observations during this time. From my work, I think oyster populations have remained relatively stable with some fluctuations based on wet, dry and normal years.
4. Do you know of any historical SAV, oyster, fisheries or vegetation data or publications for Henderson Creek?
I do not.



5. If you were asked to choose a biological metric in the Henderson Creek/Rookery Bay Estuary for altered salinity and water delivery regimes, what would you choose and why? How would you monitor for that in the future? Is anyone else doing this that I should talk to?

Given their benthic, sedentary nature oysters make excellent candidates to make cause-and-effect relationships. They are sensitive to salinity changes. In addition, oysters provide food, shelter and habitat for a number of species (nearly 300). Therefore when observing oyster responses, one is not just looking at a single species, but a whole community.

6. Do you have anything to share in terms of an indicator species for this project? Oysters and seagrasses will make excellent indicator species.

7. Can you suggest any pertinent publications, or even grey literature, that illustrates how salinity variations have affected flora or fauna in Southwest Florida? Are any specific to the Henderson Creek watershed?

I will be glad to email some final reports that contain data and observations of oyster responses in the Henderson Creek and other Ten Thousand Islands estuaries.

8. What type of data or what research questions would you use to develop biological metrics for a future MFL?

I would look at salinity tolerances of various life stages of species such as oysters. Much of this information is already available. Once this is combined with salinity-flow relationships, we can easily suggest MFLs.

9. What do you see as possible key ecological attributes that are fundamental to a healthy Henderson Creek Estuary?

Robust key species such as oysters and sea grasses harboring a diverse community of fish and crustaceans.

10. Are there lessons/approaches from other restoration or research projects that you would recommend incorporating into this effort? What's worked elsewhere? Lessons learned from various CERP projects and Caloosahatchee estuary could be used in Henderson Creek.

