Reopening a tidal pass: implications for changes in water column optical properties and seagrass habitats

FINAL REPORT

Eric C. Milbrandt\textsuperscript{a}, Richard D. Bartleson\textsuperscript{a}, David Fugate\textsuperscript{b}, Alex Rybak\textsuperscript{a},
Mark A. Thompson\textsuperscript{a}, Loren Coen

\textsuperscript{a}Marine Laboratory, Sanibel-Captiva Conservation Foundation
900A Tarpon Bay Rd.
Sanibel, FL 33957

\textsuperscript{b}Florida Gulf Coast University
10501 FGCU Blvd.
Fort Myers, FL

04/06/11
EXECUTIVE SUMMARY

Blind Pass separates Sanibel and Captiva Islands and has historically closed and opened in response to a variety of anthropogenic and natural processes. In recent years, the inlet was closed until July 2010 when the dredging project was completed and the pass was reopened. The effects of reopening a tidal pass was the subject of this two-plus year research study which examined the baseline conditions of the water column and seagrass communities before the pass was reopened and evaluated the effects on these properties and habitats after the pass was open. To effectively make this comparison, a BACI (Before After Impact Control) study design was applied where Blind Pass was the impacted tidal inlet and nearby Redfish Pass to the North was the natural control site. There are two of SCCF’s RECON (River, Estuary, and Coastal Observing Network) instrument packages on pilings; one near Redfish Pass and the other near Blind Pass. A third identical instrument package (mobile RECON) was used to conduct high spatial resolution grid sampling around the bay and Gulf of Mexico sides of the passes. Water quality monitoring occurred seasonally (wet&dry) with 5 events before the opening of the pass and 2 events after the opening. During these trips the following parameters were measured at the surface and near the bottom in water with depths greater than 1.5 m; salinity, temperature, dissolved oxygen, chlorophyll a, CDOM, depth, light attenuation, and turbidity. The same parameters minus light attenuation were measured hourly at the two fixed RECON stations throughout the study period. The water column properties were hypothesized to reflect the increased dilution of bayside water with the Gulf of Mexico. Salinity was expected to increase, CDOM was expected to decrease, and chlorophyll a was expected to decrease. Turbidity was expected to increase initially as a function of greater tidal velocities and resuspension of fine particles deposited when Blind Pass was closed. Other discrete water samples were also collected for a related project and analyzed for this report.

In addition to examining the water column, the baseline conditions and responses of seagrass habitats surrounding Blind Pass and Redfish Pass were examined. The transect-based sampling approach was modified from existing monitoring protocols developed by the Florida DEP Aquatic Preserve office in Punta Gorda. Seagrass sampling occurred during the peak growing season (May) before and again after Blind Pass was dredged open. Seagrasses habitats were expected to respond to the clear water conditions introduced when Blind Pass was opened. This was hypothesized to include; increases in shoot densities, changes in species composition, and decreases in epiphyte loads.

Given the seasonal and interannual differences and potential meteorological differences and regional influences affecting the water column properties a novel analytical approach was used for the mobile RECON data. A normalized difference approach was applied, similar to that used in remote sensing for eliminating seasonal and eliminating changes caused by influences outside of the study area. There were significant increases in salinity and turbidity, with significant decreases in CDOM and chlorophyll a, but the effects were limited to less than 1.7 km from the inlet on the bayside. The fixed RECON continuously monitoring stations were
found to be located outside of the zone of influence and therefore did not detect the changes recorded during the mobile RECON sampling events.

There were increases in flow velocities and in flow volumes based on current meter deployments > 2.3 km from Blind Pass at a culvert connecting Clam Bayou to the estuary. The flow volume increase was confirmed using conservative mixing estimates based on CDOM concentrations.

The seagrass communities around Blind Pass were significantly different than those around Redfish Pass. *Halodule wrightii* was the dominant species around Blind Pass, while *Thalassia testudinum* was the dominant species around Redfish Pass. This was attributed to the depths at which seagrass grows around Blind Pass; which were much shallower than Redfish Pass and more likely to be exposed at low tides. There were no significant changes in shoot densities or cover that were attributable to the pass opening, as there was tremendous spatial variability within and among transects. There was a decrease in macroalgae cover after the pass was opened, but it is not known whether the increased flow velocities or changes in the water column properties were the cause. There was no expansion of the deep edge around Blind Pass and overall no observable effects that were specifically attributable to the opening of the inlet.
INTRODUCTION

When estuarine passes close, decreased water velocities on the estuary side can lead to increased sedimentation and accumulation of nutrients which can have negative effects throughout the ecosystem, including seagrasses and other communities. In addition, ‘colored’ waters derived from terrestrial runoff are not diluted by clear ocean water, potentially in reduced light levels to benthic primary producers. Previous studies of intermittently closing passes have focused on post-opening sedimentation processes (e.g., Davis and Barnard 2000, Tidwell and Wang 2006), circulation and dissolved oxygen (Gale et al. 2006), fish assemblages (e.g., Jones and West 2005, Pollard 1994, Young et al. 1997), nutrient and plankton communities (e.g., Perissinotto et al. 2000, Froneman 2002, 2004a,b, Everett et al. 2007) and benthic fauna (e.g., Dye and Barros 2005). Liu et al. (2005) used a model to examine the changes in physical-chemical parameters (current velocities, salinities) expected upon the opening of Midnight Pass near Sarasota FL, but little is known about changes in water quality, total suspended solids, and seagrass communities associated with the opening or closing of passes in Florida or elsewhere.

Blind Pass (Figs. 1-3) in southwest Florida was dredged to reopen its connection to the Gulf of Mexico restoring historic flows. The expectation is that this will benefit the surrounding habitats and ultimately restore finfish and other wildlife. The Pass is a narrow tidal inlet located between two islands, forming the boundary between the City of Sanibel and Captiva (unincorporated Lee County) and historically has opened and closed. The Pass receives little freshwater outflow and depends primarily on tidal flow to remain open. The causes of the pass closure are unknown, but beach re-nourishment and other stabilization measures have been cited. Besides potential anthropogenic changes that may have resulted in the pass closing, another likely reason is the natural migration of sand on and around barrier islands, which by their nature
are very dynamic and respond to storms, longshore currents, and tidal currents through complex interactions.

Since the most recent closure of Blind Pass, reduced water velocities have resulted in a variety of changes in water quality which may have caused the decline of seagrasses in the area. Reduced exchange with ocean water has resulted in generally darker, CDOM rich waters with higher turbidity on the Pine Island Sound side. This may trigger greater sedimentation rates, which likely cause a buildup of particles on seagrass leaves resulting in reduced light availability and reduced gas exchange with the water column (e.g., Koch 1994), limiting factors in seagrass productivity (e.g., Beer et al. 1977, Zimmerman et al. 1997). Higher sedimentation rates may also reduce sediment redox potentials which affect root health, increase benthic nutrient regeneration resulting in increased epiphytes and macroalgae (Bulthuis and Woelkerling 1983, Brush and Nixon 2002) and resulting in higher suspended particle concentrations when wave action increases, reducing available light. Water column nutrient concentrations are also higher because of the reduced exchange with the more oligotrophic Gulf water.

Seagrasses (or SAV) are opportunistic and generally hardy, but have declined in recent years in the vicinity of Blind Pass (Bartleson et al. 2006). In the long term, the reopening of the Pass should increase flow rates, lower nutrient, suspended solids and colored dissolved organic matter (CDOM) concentrations, while reducing sedimentation rates and sediment silt concentrations. These changes are all beneficial for seagrass habitat because they reduce nutrient concentrations and increase light availability. However, after reestablishing tidal exchange, increased velocities may temporarily increase resuspension of fine particles and nutrient loading rates to epiphytic algae and drift algae until excess nutrients are washed from the system. Sediment nutrient concentrations should decrease over time and eventually reduce the loading
rate. However, increased flow velocities may increase nutrient uptake by seagrass leaves and epiphyte growth (e.g., Cornelisen and Thomas 2002). Because estuaries are complex and dynamic systems, it is critical to sample water quality and seagrasses before and after opening the pass to know how the system actually responds.

We know that seagrass and mangrove communities are important both economically and ecologically, serving as major structural elements in estuarine and coastal waters (e.g., Odum et al. 1982, Virmstein et al. 1983, Dennison et al. 1993, Sheridan 1997, Valiela et al. 1997). These ecosystems provide significant ecosystem services (e.g., Costanza et al. 1997, Daily 1997, Peterson and Lubchenco 1997), including stabilizing sediments and inhibiting their re-suspension, sequestering atmospheric carbon and export carbon to other systems, improving water transparency, trapping and cycling nutrients, and protecting shorelines through wave energy reduction (e.g., Beck et al. 2001, 2003, Ellison and Farnsworth 2001, Valiela et al. 1997). They also provide feeding, breeding, and nursery habitat and refuges to numerous invertebrates, migratory birds, reptiles, marine mammals and many other important fish populations during some stages of their life cycle (e.g., Sheridan 1997, Halliday 1995, Beck et al. 2001, 2003, Orth et al. 2006, Duarte et al. 2008).

The Blind Pass area has historically been rich in important habitats including seagrasses (*Thalassia testudinum, Halodule wrightii, Ruppia maritima*), oysters (*Crassostrea virginica*), and mangroves (*Rhizophora mangle, Avicennia germinans, Laguncularia racemosa*). The area is located within the boundaries of Charlotte Harbor National Estuary Program and the Charlotte Harbor Aquatic Preserve. Numerous recreational and commercial finfish species once made Blind Pass a preferred fishing spot for snook, gray snapper, mullet, spotted seatrout, red drum, tarpon, and goliath grouper among others. Additionally, ecologically-important invertebrates,
such as horseshoe crabs, blue crabs, and brown shrimp were once common in the vicinity of the Pass along with species either listed as ‘Endangered’ or ‘Threatened’ including wood stork, piping plover, least tern, snowy plover (currently under study by SCCF), American crocodile and Florida manatee. Other local passes such as Redfish Pass, which was opened by a hurricane in 1921, still support these species.

The aim of the study is to evaluate the cascading effects of reopening a tidal pass on water quality and seagrass habitat. Blind Pass has been closed since 1998, and this study exploits this unique opportunity to understand whether this reopening completed on July 31, 2009 results in ecosystem improvements over a reasonably short-time scale. The Blind Pass reopening was predicted to cause changes in seagrass productivity and distribution and to accurately capture those this study was initiated prior to the dredging activities and continued thereafter.

MATERIALS AND METHODS

Fixed Station Real-Time Observations – SCCF Marine Lab operates seven real-time water quality monitoring stations (River, Estuary and Coastal Observing Network, or RECON) located within the Caloosahatchee River and Pine Island Sound between Lake Okeechobee and Redfish Pass (Fig. 4). In order to bring a regional overview to the information presented in this report, we evaluated data from the four fixed RECON stations nearest to the study area; Shell Point RECON, Gulf of Mexico RECON, Blind Pass RECON, and Redfish Pass RECON. Data from the four fixed RECON stations were plotted for a one year period before and after the opening of Blind Pass and were evaluated to compare to mobile RECON data findings.

Biological, chemical, and physical parameters are measured by fixed RECON stations and data are autonomously sent back to shore and made web-accessible at http://recon.sccf.org
in near real time. Instruments are deployed and maintained from small boats with a maximum service interval of 1-2 mos. The instrument packages were each attached to pilings at depths of at least 1.5 m below MLLW (Mean Lower Low Water) adjacent to a deep water channel. A hemi-cylindrical aluminum cage (Fig. 5) served as a mounting structure for a WETLabs WQM, a Satlantic ISUS-V3 nitrate sensor, a WETLabs ECO FLS fluorometer, and a Satlantic StorX datalogger, a Satlantic 51-amp hour battery pack. The fluorometers for CDOM, chlorophyll \(a\), and turbidity are each equipped with a wiper system that closes over the optical port, conducting a sweep prior to each reading to minimize fouling. The CDOM fluorometer (WETLabs) is factory calibrated to quinine sulfate dihydrate standard (Velapoldi and Mielenz 1980).

Chlorophyll \(a\), turbidity, conductivity, temperature, dissolved oxygen, and pressures are measured by the WETLabs WQM (Orrico et al. 2007). The WQM is a modified Seabird 29 CTD with a fluorometer and a bleach injection system (BLIS) to protect the sensors from fouling. The WQM also contains an anti-fouling collar for the conductivity cell and wipers for the fluorometer head. Sensors are interconnected to a STOR-X controller with Subconn cables (Boston, Massachusetts) and powered by a battery pack with Subconn (Boston, Massachusetts) cables. Each instrument package can be scheduled to record and transmit data to the shore at adjustable, user-specified time intervals.

**Mobile RECON In situ Water Quality Monitoring** - Water quality samples were collected at 64 locations around Blind and Redfish Passes using the SCCF Marine Lab’s River, Estuary and Coastal Observing Network (RECON) mobile sensor package (Fig. 6). The mobile RECON instrument package is comprised of a hemi-cylindrical aluminum cage served as a lowering frame for a WETLabs WQM, a Satlantic ISUS-V3 nitrate sensor, a WETLabs ECO FLS fluorometer, and a Satlantic StorX datalogger. Configurations, tolerances, sensitivity, and
variability specifications of the sensors are available from the sensor manufacturers and on the website (http://recon.sccf.org). Mobile RECON sampling occurred in five events: (a) February 17-18, 2009 (dry season, before Blind Pass opening); (b,c) April 16-17 and July 29-30, 2009 (wet season, before Blind Pass opening); (d) October 17-18, 2009 (wet season, after Blind Pass opening); and (e) May 9-10, 2010 (dry season, after Blind Pass opening). Two of the mobile locations were selected at Blind Pass and Redfish Pass fixed RECON stations to establish linkages between the two datasets. Each of those two mobile locations were sampled twice (in two consecutive days) during each of the events to account for temporal data variability.

The R/V Tucker and mounted GPS were used to visit the grid of pre-determined stations. Some of the station locations were modified after the initial sampling event because of obstacles to navigation or insufficient water depth to deploy the sensor package (optimally requires 0.75 m). Upon arriving at the station, the instrument package was lowered to a depth of 0.2-1.4 m (mean 0.9, SD 0.2) and recorded each parameter for 2 minutes at 1 Hz. If the depth of the water was greater than 2.0 m, the instrument package was lowered to just above the seafloor (a depth of 1.6-3.9 m, mean 2.7, SD 0.6) to measure the degree of stratification. While the mobile RECON was deployed, triplicate discrete water samples were collected for eventual analysis at the laboratory and were stored in a cooler. Additionally, a handheld Hydrolab Quanta sonde (Hydrolab, Loveland) was deployed at similar depths and recorded for QA/QC purposes. Irradiance was recorded using two 2π planar sensors (Biospherical, San Diego) mounted on a lowering frame. The sensors, when deployed on the frame were separated by 0.6 m to obtain downwelling irradiance at two depths. The lowering frame and sensors were at least 0.25 m below the water’s surface to minimize variation caused by waves focusing light. The sensors recorded at 1 Hz for 30s on the sun-side of the vessel.
**Discrete Sample Collection** - In addition to information collected specifically for this study, we analyzed data from four water quality monitoring sites established by Bayous Preservation Association (BPA) within the Blind Pass Ecozone (Fig. 7). The first samples were collected by BPA in July 2007 and sampling continued until October 2008. Sampling resumed in April 2009 and ended in September 2010. This monitoring schedule resulted in 30 months of sampling before the opening of the pass and 14 months of post-opening samples. Sampling was conducted early in the morning just after sunrise at each of the four sites. Field measurements included: dissolved oxygen (DO), turbidity, pH, salinity, air and water temperature, Secchi depth, photosynthetically active radiation (PAR) and total depth using Hach Quanta® water quality sonde, LI-COR photosynthesis meter and Secchi disc. Discrete samples were analyzed by a certified analysis lab (Lee County Environmental Lab, Fort Myers) for total (TKN Kjeldahl) nitrogen, nitrate plus nitrite nitrogen, ammonia (NH₃), total nitrogen (TN), total phosphorus (TP), turbidity, corrected chlorophyll a, phaeophytin, and fecal coliforms. Chlorophyll a, phaeophytins and turbidity were analyzed at SCCF marine Lab from Aug. 2009 to Sept. 2010. All measurements and analyses followed Environmental Protection Agency (EPA) approved methodologies.

**Seagrass Habitat Surveys** – On May 7-8, 2009 (before pass opening) seagrass surveys were conducted at ten, 100-meter transects around Blind and Redfish Passes. Transects were revisited on May 20-21, 2010 (after pass opening). Transects were established perpendicular to the shoreline and pieces of PVC were used to mark the shallow edge and deep edge. A 100 m transect tape (Forestry Suppliers, Jackson) was extended between the shallow and deep edges. A
1 m² quadrat was placed at the deep edge, shallow edge, and at two positions along the transect selected from a random number table. Due to physical constraints, some of the transects were not 100 m long, however, four quadrats (shallow edge, deep edge, plus two random points along a transect) were sampled in all transects.

In each quadrat, time and depth was recorded and the total percent presence/absence (if a shoot was in a 0.1 x 0.1 m square it was counted) of each seagrass species plus macroalgae was determined. Shoot density for each species was determined and 5 blade lengths were measured (longest blade was selected from individual shoots). Blades were collected for the determination of epiphytes at the laboratory and stored in a cooler. The blades from each sample were placed into a shallow container and measured for lengths and widths. The epiphytic material was scraped from the blades using a razor blade. The scrapings were washed into a graduated cylinder and the volume was recorded. The water was then poured into a beaker, homogenized, and a known volume was removed with a graduated pipette. This water was filtered through a pre-weighed GFC filter, which was then washed with distilled water before drying at 60°C for one day and re-weighing. The dry weight per square cm of epiphytes was calculated from the dry weight divided by the surface area of 2 leaves. Above and belowground biomass was determined following a modification of Duarte and Kirkman (2007). Biomass samples were collected with a coring device (5 cm diameter) and sieved through a 3 mm sieve in the field, retaining the roots and shoots. At the lab, the species were separated and below and aboveground material was separated just below the basal meristem. Tissue was weighed to the nearest mg, and dried to constant weight at 60°C. Above and belowground biomass are reported in mg DW m⁻².
At the deep edge of each transect, a hand-held Hydrolab Quanta (Loveland, CO) was also deployed. The following physical parameters were recorded; salinity, temperature, dissolved oxygen (% saturation, mg l\(^{-1}\)), pH, and turbidity. Depth data was standardized to mean low, low water (MLLW) using estimates from tide stations at Redfish Pass and Galt Island (Nobeltec Tides and Current Pro®, ver. 3.3)

**Changes in flow and associated sediment transport processes** - The Sontek Argonaut XR was deployed at the Blind Pass culvert in the second week of August 2009 for over 2 weeks (at the beginning of the Pass opening).

The acoustic backscatter from the Argonaut can be used as a proxy for suspended sediments in the water column. The signal to noise ratio is the ratio of the amplitude of the acoustic backscatter to the instrument noise and provides a slightly better proxy. The second current profiler (Sontek ADP) deployment was from November 19 to December 08, 2010. The meter was deployed in a deep portion of the culvert flow way.

**Remote Sensing** - Two hyperspectral flights were planned one before and one after the Pass opening. The first flight attempt was undertaken on May 31, 2009, but it had to be interrupted due to unpredicted increase in cloud cover, and no imagery was collected. On June 14, the imagery was collected with clear skies but light winds created ripples on water surface declining the quality of the remote sensing data. The hyperspectral data products were not suitable for further analysis and it was determined that the ARCHER imaging system was not designed for mapping underwater habitats. Because the ARCHER camera was firmly attached to the bottom of the airplane, each individual image turned out to be taken from a different angle as the plane was constantly wiggling along its flight. As a result, the images have incomparable spectral
characteristics, and they cannot be merged together in a unified image for uniformly applying the correction and classification algorithms. Before merging, the 0.25-1GB images would have to be pair-wise matched to each other using the histogram matching procedure. To accomplish this task along, it would require more than 100 days of computer processing, which was beyond the scope of the study.

**Data analysis and synthesis** - The overall sampling design and analysis are depicted in Fig. 8, where Blind Pass (Impact) and Redfish Pass (Control) were compared before and after Blind Pass was dredged open. Cumulative total precipitation data was collected from the Lee County rain gauge located at the corner of Summerland and San Carlos Avenue for the one year before and after the opening of Blind Pass. In addition, flow data was collected from the US Army Corps of Engineers S-79 structure (W.P. Franklin Locks at Alva) located on the Caloosahatchee River at the upriver border of the estuary for one year before and after the opening of Blind Pass. Rainfall and flow data were analyzed for before and after differences using a Mann-Whitney nonparametric test in Minitab®.

Data from the fixed RECON stations are continuously stored in a remote database and then periodically uploaded to a relational database at the SCCF Marine Lab. Data for a period of one year before the opening of Blind Pass to one year after the opening were used for each of the four fixed stations for evaluating regional trends. Before/after data were presented in boxplots showing range, 25th and 75th percentiles, mean and median values.

The distance of each mobile RECON station from the middle of the pass was estimated from the GPS position recorded at each station in ArcGIS (ver. 9.3). Plots of April 2009 (before) and Nov. 2009 (after) were used as an example of the relative effect of distance on the
parameters recorded by the sensor package. The study areas around Blind Pass and Redfish Pass were segmented to examine the geographic influence of the pass opening in zones at increasing distance from the pass. The bay segments were delineated by the morphology of Sanibel/Captiva Islands, bathymetry, 2004 SFWMD seagrass aerial coverages, and sufficient number of sample sites (5 or greater) for statistics (ArcGIS, ver. 9.3). Pre- and post mobile data from all five sampling events were normalized within bay segment to account for seasonal differences using the following formula:

\[
\text{ND}_{wzi} = \frac{\text{OPEN}_i - \text{CLOSED}_i}{\text{OPEN}_i + \text{CLOSED}_i}
\]

(Eq. 1)

Where \( i \) is the location and OPEN is the period after Blind Pass was opened and CLOSED is the period at location \( i \) before it was opened. To compare bay segment to segment, the following formula was used:

\[
\text{ND}_{bzi} = \frac{\text{ZONE1} - \text{ZONE2}}{\text{ZONE1} + \text{ZONE2}}
\]

(Eq. 2)

Where \( \text{ZONE1} \) is a value of sample taken at either western or southern location of a pair of locations \( (i) \) on a date, and \( \text{ZONE2} \) is a value of sample taken at either eastern or northern location of a pair of locations \( (i) \) on a date. A complete set of within segment and among segment normalized difference values were generated (Fig. 9). A t-test was used to compare the normalized difference for each parameter before and after the pass was opened (SPSS, ver. 13). In a subsequent statistical analyses (described below), the stations within 1.7 km of the pass were analyzed with a BACI approach based on this analysis.
A before-after control impact (BACI) intervention analysis (Heck 2009; Hewitt et al. 2001) was performed on 12 bayside mobile RECON stations (Pine Island Sound Side) within 1.7 km of Blind Pass (impact) paired with 12 bayside mobile RECON stations within 1.7 km of Redfish Pass (control) site with a general linear model (GLM) ANOVA in Minitab® (Version 13.1). Given that the sensor package logs a sample every second, the data for that station and sampling event were averaged (n =120) for use in subsequent analyses. These were the sites nearest to the passes and had the highest likelihood of being of displaying significant effects. The impact-control sites were paired randomly. The GLM BACI analysis uses the difference between impact and control sites before and after to test the effects the opening has on each water quality parameter. Lavene’s test for equal variance was performed on each dependent variable to assure data conformed to the GLM model assumption of homogeneity of variance. Turbidity and CDOM data were square root transformed and chlorophyll was log10 transformed. No transformation was needed for nitrate, dissolved oxygen and salinity data. The difference between impact and control site water quality values were dependent variables, with before/after (fixed factor) and each sampling event (random factor nested within before/after) as the independent variables. A constant was added to the difference between impact and control site values so that the minimum value would be 1. A 2-way GLM was then run on the adjusted difference values (per Geraldi et al. 2009).

Discrete water samples (BPA, SCCF) were entered into a dedicated Microsoft Access™ (2007) water quality database housed and maintained at the SCCF ML. Descriptive statistics (mean or average, median, min, max, standard deviation (S.D.), sample number, n) were calculated for each parameter monitored and each station. For all but three parameters, a general linear model ANOVA was used on log-transformed or square-root transformed data to evaluate
differences before and after the opening of Blind Pass, between sites, and between wet and dry seasons. A subset of the parameters (turbidity, salinity and chlorophyll \( a \)), were analyzed with a non-parametric Kruskal-Wallis ANOVA on untransformed data. Whisker plots were used with the pooled data to present before and after statistics for each water quality parameter of interest. A Mann-Whitney Two-Sample U-Test was used to analyze rainfall and flow data from S-79 before and after the opening of Blind Pass. All analyses were conducted using Minitab® statistical software and an alpha (significance) level of \( p < 0.05 \).

Seagrass transect data were entered into a Microsoft Access database and checked for errors. Mean percent cover (\( n = 4 \)) and shoot density (\( n = 4 \)) were calculated for each of the ten total transects (SPSS, ver. 13) along with standard deviation for each sampling event. The data were plotted by transect (SigmaPlot, ver. 10) for \textit{Halodule wrightii}, \textit{Syringodium filiforme}, \textit{Thalassia testudinum}, and macroalgae. There was one transect at Redfish Pass that differed from the other four in species composition, percent cover, and shoot densities. Since biomass was collected at only two quadrats per transect, the means were calculated by area (Blind, Redfish) for each of the two sampling events. Comparisons among areas and sampling dates were made using a Generalized Linear Model (GLM) with percent cover, shoot density and biomass as dependent variables, with area and sampling event as independent. The GLM was run as a full factorial design to compare area, sampling event, and an interaction term. The GLM was run twice, once with all stations and once excluding the RFF transect because of its unique characteristics in species composition (see Results).

Seagrass community composition was examined using PRIMER (ver. 6). A dendrogram related the species composition and percent cover among the quadrats (\( n = 40 \)). Four of the quadrats did not contain any seagrass species and were removed prior to the analysis. An MDS
ordination of a Bray-Curtis similarity matrix was used to compare the community composition and relative percent cover of the three seagrass species. A two-way ANOSIM was used to determine whether the communities were significantly different (a) by year sampled (2009, 2010) and by location (Blind Pass, Redfish Pass). An interaction test was not possible using this analysis.

A BACI intervention analysis, as described above, was also performed on the dependent variables seagrass percent cover, macroalgae percent cover, seagrass shoot density and depth of the seagrass deep edge. The impact seagrass sites (Blind Pass) were paired with the control sites (Redfish Pass) as follows: BPA-RFB, BPC-RFC, BPD-RFD, BPE-RFF, BPF-RFH (see Results). For each pair of sites, data from the four sample quadrats were paired from deep to shallow quadrat and per seagrass type (see example in Table 1). A constant was added to the difference between impact and control site values so that the minimum value would be 1. A 2-way GLM was then run on the adjusted difference values (per Geraldi et al. 2009). Lavene’s test for homogeneity was performed on the independent variable data. No transformation was necessary for depth at deep edge, percent cover or shoot density data. The macroalgae percent cover data was cube root transformed before BACI ANOVA.

RESULTS

Regional patterns in rainfall amounts can strongly influence on the outcomes of this study, which is designed to examine the estuarine conditions within two distinct time periods. The regional patterns in rainfall in the year before the pass was dredged open and the year after (Fig. 10) were not largely different. Cumulative total precipitation for the 12 month monitoring period before the opening of Blind Pass was 113.3 centimeters compared to 147.2 centimeters in the 12 month period after the opening of Blind Pass. The mean monthly value before the
opening was 9.44 cm month\(^{-1}\) compared to 12.2 cm month\(^{-1}\) after the opening of the pass. A one-way ANOVA was performed on square root transformed daily rainfall data and there were no significant differences in the rainfall values for the year after the opening compared to before (Fig. 11; ANOVA, \(f=2.53\) \(p=0.112\), \(n=365\)).

Regional conditions can also be affected by the amount of freshwater discharge into the estuary. The nearby Caloosahatchee Estuary is unusual in that the freshwater inflow is partly determined by regulated releases of freshwater from a water control structure (Milbrandt et al. in prep). The volume of water released can have an effect on salinities and any number of the optical properties that were measured in this study. Freshwater flow at S79 was plotted for the year prior and the year after the dredged opening of Blind Pass (Fig. 12). Nearly one year before the opening of Blind Pass, a large tropical depression (TS Faye) dumped a large amount of rain and subsequently large volumes of water were released. This single event and the other freshwater releases from S79 before the pass was opened were significantly lower than during the period after the pass was opened. Flow from the S-79 structure (W.P. Franklin Locks at Alva) located on the Caloosahatchee River (see map; Fig. 4) was significantly greater for the year after the opening of Blind Pass (mean = 58.5 cubic meters per sec, cms) than before (mean = 49.7 cms; Figures 13; Mann-Whitney, \(p < 0.001\), \(n=365\)).

The fixed RECON stations distributed throughout the region (see map; Fig. 4) provided measurements of additional in situ parameters during the study period. These were used to determine whether there were regionally driven differences caused by precipitation or freshwater flows before and after the pass was dredged open. Descriptive statistics are listed for the fixed RECON stations in Tables 2-5. For the before and after comparisons, we compared the mean values. Given the large sample sizes associated with hourly recorded data, a parametric
statistical test was not applied to the fixed RECON data. Percentile plots were used to demonstrate the variability within each location and the values.

At the fixed RECON stations, salinity was significantly lower at all four fixed locations in the period after the pass was dredged open (Fig. 14). Mean salinity at all fixed RECON stations was lower during the period after Blind Pass was dredged open, suggesting also that freshwater flows differed during the two periods. The lower salinity during the post-opening period corresponded with significantly higher flow rates from S79.

Overall, CDOM was low at the fixed RECON stations with the exception of Shell Point (Fig. 15). This station is located near potential sources of new CDOM from freshwater sources and from shallow, hypersaline marine sources (e.g., Milbrandt et al. 2010). There was a decrease in CDOM at Blind Pass from 18.8 QSE to 16.7 QSE, but this is well within daily variability and does not reflect any significant changes. Gulf of Mexico and Redfish Pass fixed stations showed little changes in CDOM throughout the study period.

Turbidity is an optical measurement that can occasionally record a max or large value depending on whether there is an object (e.g. macroalgae, fish) blocking the sensor head. In the percentile plots, the mean values are accurate because of the large sample sizes but there are outliers that increase the upper percentiles and upper variability. Therefore, the upper values for turbidity and chlorophyll a are not shown to allow for improved interpretation (Figs. 16-17).

Mean turbidity at the Blind Pass (before, 13.2 NTU; after, 9.5 NTU) and Redfish Pass (before, 10.3 NTU; after, 7.2) RECON stations was lower in the year after the opening of Blind Pass compared to the year before Blind Pass was dredged open. In contrast, turbidity at Gulf of Mexico (before, 7.1 NTU; after, 13.8 NTU) and Shell Point (before, 4.8 NTU; after, 5.7 NTU) RECON had greater turbidity in the year after the opening (Fig. 16). Mean chlorophyll a at the
fixed RECON stations was higher at Shell Point (before, 3.2 µg l\(^{-1}\); after, 3.7 µg l\(^{-1}\)) and Redfish Pass (before, 2.4 µg l\(^{-1}\); after, 2.5 µg l\(^{-1}\)). In contrast, higher mean chlorophyll \(a\) was found at the fixed RECON stations Blind Pass (before, 2.8 µg l\(^{-1}\); after, 2.1 µg l\(^{-1}\)) and Gulf of Mexico (1.7 µg l\(^{-1}\); 1.2 µg l\(^{-1}\)) in the period before the pass was dredged open versus the period after (Fig. 17). Mean dissolved oxygen (DO) at the four RECON stations did not vary much in the year before the pass was dredged open and the year after. All four fixed RECON stations exhibited slight increases in DO in the year following the opening of Blind Pass, but the increases were small (Fig. 18).

**Mobile RECON In situ Water Quality Monitoring** – The five mobile RECON sampling cruises were conducted in Feb., Apr., July and Nov., 2009, and in May 2010. A grand total of 66 stations were visited over two consecutive days when there was an incoming, neap tide. The geomorphology of the two passes was dissimilar causing the distribution of the stations to differ slightly. Redfish Pass, which served as a control site in the Before/After, Control/Impact (BACI) study design contained more open water which allowed a grid of stations located roughly 0.5 km apart. The fixed RECON station demarked the easternmost boundary of the study area and the Gulf of Mexico demarked the western boundary. The impact area, Blind Pass, was being opened while during the study period. A similar grid of stations located 0.5 km apart was applied, but modified to examine the changes in water parameters within Dinkins Bayou, Sunset Bay, and Roosevelt Channel. These three sub-bays are semi-enclosed and mangrove-lined.

While changes (e.g., lower CDOM, higher salinity) were expected at the fixed RECON stations, they were not observed at greater distances from the opened Pass. The changes were
occurring in the immediate vicinity of the opened Pass were captured in the analysis of mobile RECON data collected during five sampling events (three before opening, two after).

The two study areas, Blind Pass (impact) and Redfish Pass (control) were divided into 4 bay segments for analysis. The segments were determined using the same criteria, as described in the methods, but the size and distance of the segments differed slightly between Blind Pass and Redfish Passes due to differences in geomorphology and bathymetry. Blind Pass is a low volume inlet with a long channel supporting evidence that it is easily closed, either by natural or anthropogenic factors while Redfish Pass is a high volume inlet with a short channel between the barrier islands. Once divided into bay segments before and after comparisons were made within each segment and between similar segments (e.g., Bay West Redfish vs. Bay West Blind) were made using normalized differences (described in the methods). The results are summarized in Fig. 19, additional details and the results of the full factorial design can be found in Appendix 1. The pair-wise comparisons are also shown on the map of the study area (Fig. 9).

Only the West Bay (B1) segment in Blind Pass demonstrated significant changes after the pass was dredged open. The significant differences in water parameters in the Bay West (B1) segment of Blind Pass included decreases in CDOM, KdPAR, Nitrate, and chlorophyll a, and increases in salinity. The other segments in Blind Pass were not significantly different before and after the pass was opened. All segments in Redfish Pass were not significantly different before and after Blind Pass was dredged open. One example was plotted with measured values (as opposed to normalized differences) was plotted for CDOM in Figure 20, where differences were observed in the mobile RECON data before (Apr., 2009) and after (Nov., 2009) the pass was opened, but only in the 1-2 km radius of Blind Pass. In this example, stations were grouped by distance from the center of the pass to the Gulf of Mexico (negative classes) and to Pine
Island Sound (positive classes). The number of stations in each distance class used in this example is reported in Table 6. At Blind Pass (Fig. 20A), CDOM was lower after the pass was opened within 2.8 km on the bay side of the center of the pass. At Redfish Pass (Fig. 20B), CDOM was similar in all distance classes before and after Blind Pass was opened. There were no differences on the Gulf of Mexico side of the pass or at distances greater than 2.8 km of Blind Pass. This example also demonstrates that the changes were limited to a small area around the inlet which rendered the fixed Blind Pass RECON (5 km east of the inlet) unable to detect differences caused by the opening of the pass.

Box-whisker plots and descriptive statistics of parameters at a subset of stations collected with the mobile RECON were summarized in Figures 21-26. The subset of stations were within 1.7 km of the inlet based on the findings of the previous analyses that changes associated with the pass opening were limited to those stations near the pass. At Blind Pass, CDOM demonstrated the greatest differences before and after Blind Pass was dredged open. CDOM was generally lower near Blind Pass after the inlet was opened (Fig. 21). CDOM at Redfish Pass (Fig. 23) was similar before and after the pass was opened, but was more variable. Nitrate was lower at Blind Pass after the pass was opened at Blind Pass but nitrate was higher at Redfish Pass (Figs. 21, 23). Turbidity was higher at Blind Pass after the pass was opened, but did not change at Redfish Pass (Figs. 21, 23). Chlorophyll a was lower at both Blind Pass and Redfish Pass after the opening. Dissolved oxygen and salinity were unchanged (Figs. 22, 24). KdPAR was lower at Blind Pass after (1.39) versus before (1.59). The lower KdPAR values indicate greater transparency and were comparably lower at Redfish Pass before (1.19) and after (1.11).

The mobile data were also statistically analyzed by parameter using the general linear model (GLM). Only stations on the bay side of the pass, within 1.7 km were used for the
analysis (see map; Fig. 27). Using the general linear model (GLM) BACI applied to mobile RECON data, there were no significant changes in turbidity (GLM ANOVA, $f = 0.20$, $p = 0.684$), salinity (GLM, $f = 1.12$, $p = 0.367$), chlorophyll $a$ (GLM, $f = 0.00$, $p = 0.997$), or DO (GLM, $f = 1.05$, $p = 0.384$), before and after the opening of Blind Pass. However, there were significant decreases in both CDOM (GLM ANOVA, $f = 15.84$, $p = 0.028$) and nitrate (GLM ANOVA, $f = 12.66$, $p = 0.038$) at Blind Pass after the pass was dredged open compared to before.

Additional discrete samples were collected during the study period and analyzed for this report. For pooled turbidity data from the BPA study sites (see map; Fig 7), the median value of 14.1 NTU (Nephelometric Turbidity Units) was found to be significantly higher after the opening than the median turbidity value of 5.5 NTU before the opening (Kruskal-Wallis, $K = 8.11$, $p < 0.001$; $n = 175$). When before and after values by season (wet or dry) are compared, the median turbidity was higher after the opening of Blind Pass during both wet (Kruskal-Wallis, $K = 5.13$, $p < 0.001$; $n = 99$) and dry seasons (Kruskal-Wallis, $K = 6.32$, $p < 0.001$; $n = 76$). The median salinity of 34.5 PSU for the BPA study sites collected after the opening of the pass was found to be significantly lower than the median salinity of 37.2 PSU before the opening (Kruskal-Wallis, $K = 3.36$, $p < 0.001$; $n = 56$). In a comparison by season (wet versus dry), significantly lower salinity was found after the opening of Blind Pass during dry season (Kruskal-Wallis, $K = 5.46$, $p < 0.001$; $n = 76$) and no significant differences during the wet season (Kruskal-Wallis, $K = 0.22$, $p = 0.825$; $n = 96$). As expected, the dry season median salinity (37.35 PSU) was significantly higher than the wet season salinity (34.75 PSU). For the pooled BPA study sites, the median chlorophyll $a$ value of 7.82 µg/L after the opening of Blind Pass was found to be significantly greater than the median chlorophyll $a$ value of 3.95 µg/L for
the period before the opening (Kruskal-Wallis, $K = 4.34, p = 0.014; n = 176$). When comparing by season (wet or dry) there were significantly higher chlorophyll $a$ occurred after the opening during the dry season (Kruskal-Wallis, $K = 4.92, p < 0.001; n = 76$) but no significant differences were found for the wet season. There was also a significantly higher level of chlorophyll $a$ during wet season as compared to dry season (Kruskal-Wallis, $K = 5.10, p < 0.001; n = 176$).

When comparing sites, the Clam Bayou site had higher values of chlorophyll $a$ while Roosevelt Channel site had significantly lower concentrations compared to the other sites (Kruskal-Wallis, $K = 2.24, p = 0.014; n = 176$).

For nutrients from the discrete samples for the BPA study sites, no statistical significance was found between the mean value of 0.71 mg/L for total nitrogen after the opening of Blind Pass compared to the mean value of 0.79 mg/L before the opening of blind pass (ANOVA, $F = 1.14, p = 0.2875; DF = 1$). However, mean wet season TN was found to be lower after the opening than wet season TN before (Mann-Whitney, $U = 3758, p < 0.0167, n = 32$). No significant difference in dry season TN could be found between before and after data.

Furthermore the wet season TN was not found to be significantly different than the dry season TN for pooled data (ANOVA, $F = 0.27, p = 0.601; DF = 1$). Dissolved oxygen levels at BPA sites were higher during both dry and wet season after the opening of Blind Pass than before (ANOVA, $F = 10.26, p = 0.002; DF = 1$). In addition, the DO concentrations were shown to be significantly higher during the dry season than during the wet season (ANOVA, $F = 101.97, p < 0.001; DF = 1$). Overall, dissolved oxygen levels showed a significant increase after the opening of Blind Pass increasing from a mean of 3.5 mg/L to a mean of 4.1 mg/L (ANOVA, $F = 12.14, p = 0.001; DF = 1$).
Ten seagrass transects were established in May 2009; five were located around the Blind Pass inlet (see Fig. 28) and 5 were positioned around Redfish Pass (see Fig. 29). Transects were visited in May 2009 and again in May 2010 to revisit the deep edge, the shallow edge and two additional square meter quadrats in between. In general, transects around Blind Pass were dominated by *Halodule wrightii*, with the average percent cover per quadrat of 40-60% (Fig. 30). The standard deviation was high demonstrating the variability in cover within the transect. Mean shoot densities for *H. wrightii* were between 250 and 800 shoots m$^{-2}$ (Fig. 31). Generally, there was no consistent increase or decrease in either cover or shoot densities that were outside what was explained through natural variation. Transect BPF had no *H. wrightii* before the pass was opened but had 40% cover after it was opened, however, it was also the farthest away from the center of the inlet (1.7 km) of all the Blind Pass transects. There was very little *H. wrightii* at Redfish Pass with the exception of transect RFF, which had an average cover of 20% before and after Blind Pass was opened. Transect RFB did have some *H. wrightii* after Blind Pass was opened but not before.

*Thalassia testudinum* was the dominant species around Redfish Pass at all transects except RFF. The mean percent cover of *T. testudinum* at Redfish was 60-90% and overall was more dense than the *H. wrightii* found around Blind Pass (Fig. 32). Shoot densities of *T. testudinum* were between 100-500 shoots m$^{-2}$ (Fig. 33). Generally, there were no increases in cover or shoot densities around Blind Pass that could be attributed to increased water transparency. However, there was a marked decrease in mean shoot densities at transects around Redfish Pass before and after, suggesting that a regional factor such as salinity or temperature or other factors which vary annually could be important. There was *T. testudinum* at BPE and BPF, but the average did not increase outside of the natural variability. Transect RFF was dominated
by *Syringodium filiforme* and was different than the more typical seagrass community found around Redfish Pass.

*Syringodium filiforme* was not found in any of the quadrats around Blind Pass, but was the dominant species at RFF. Generally, *S. filiforme* was low in cover and shoot density (Figs. 34-35) and was not consistently different after Blind Pass was dredged opened.

There was a moderate (20%) to high (80%) cover of macroalgae at several transects around Blind Pass in May 2009, before the inlet was reopened (Fig. 36). During the same sampling event at Redfish Pass, macroalgae was found in moderate abundances at RFF, but was either not present or present in very low amounts at the other transects. The macroalgae around Blind Pass in May 2009 was identified as the following species; *Acanthophora spicifera, Dictyota cervicornis, Gracilaria bursa-pastoris, Gracilaria tikvahae, Hincksia onslowensis, Hydropuntia caudata, Hypnea spinella, Polysiphonia spp., Solieria filiformis, and Ulva flexuosa*. The species found around Redfish Pass in May 2009 were *Champia parvula, Cladosiphon occidentalis, Dictyota cervicornis, Hincksia onslowensis*, and *Hypnea spinella*.

After the pass was dredged open and the transects were revisited, the percent cover of macroalgae decreased to 5% or less at several of the seagrass transects around Blind Pass. There was a slightly different species composition collected at Blind Pass in May 2010 comprised of *Acanthophora spicifera, Agardhiella subulata, Gracilaria tikvahae, Hypnea spinella, Lomentaria baileyana*, and *Spyridia filamentosa*. There were low amounts of macroalgae around Redfish Pass in May 2010. The macroalgal species collected included; *Hypnea musciformis, Hypnea spinella, Spyridia filamentosa*.

Using BACI test with a 2-way ANOVA, no significant change could be found at the impact site (Blind Pass) for the following seagrass metrics; percent seagrass cover (GLM
ANOVA, $f = 0.62, p = 0.432$), shoot density (GLM ANOVA, $f = 1.09, p = 0.299$), percent macroalgae cover (GLM ANOVA, $f = 1.36, p = 0.251$), or depth at deep edge (GLM ANOVA, $f = 0.11, p = 0.754$).

Core samples (7.5 cm diameter) were collected from 2 quadrats randomly selected in the middle of the transects (Figs. 37-39). The deep edge and the shallow edge were purposely avoided because of differences in above- or below-ground biomass at the edge of the grass flat or in transition areas (Short et al. 2001). All biomass samples from a region (e.g., Blind Pass) were grouped because there were only 2 samples collected per transect. Mean above-ground biomass of *Halodule wrightii* at Blind Pass in May 2009 was 606 g DW m$^{-2}$ ($n = 10; S.D. 218$) and decreased to 158 g DW m$^{-2}$ ($n = 10; S.D. 260$) when resampled in May 2010 (Fig. 37). Below-ground biomass of *H. wrightii* was similar with 657 g DW m$^{-2}$ ($n = 10; S.D. 249$) in May 2009, decreasing to 180 g DW m$^{-2}$ ($n = 10; S.D. 260$) in May 2010. Biomass of *H. wrightii* at Redfish Pass was lower than at Blind Pass in May 2009 and was not found around Redfish Pass in 2010.

The dominant seagrass species at Redfish Pass was *Thalassia testudinum* (Fig. 38). Above-ground biomass at Redfish Pass in May 2009 was 3,265 g DW m$^{-2}$ ($n = 10; S.D. 2,001$) and decreased to 354 g DW m$^{-2}$ ($n = 10; S.D. 346$). Below-ground biomass for *T. testudinum* demonstrated a slight increase from 2009 from 1,100 g DW m$^{-2}$ ($n=10; S.D. 475$) in May 2009 to 1,219 g DW m$^{-2}$ ($n=10; S.D. 619$) in May 2010, but this increase is well within the natural variability. Both above-ground and below-ground biomass at Blind Pass decreased between May 2009 and May 2010. Below-ground biomass for *T testudinum* decreased from 397 g DW m$^{-2}$ ($n = 10; S.D. 549$) in May 2009 to 133 g DW m$^{-2}$ ($n = 10; S.D. 236$). Above-ground biomass for *T. testudinum* at Blind Pass decreased from 977 g DW m$^{-2}$ ($n = 10; S.D. 911$) in May 2009 to 425 g DW m$^{-2}$ ($n = 10; S.D. 433$).
Syringodium filiforme was not abundant at either Blind Pass or Redfish Pass (Fig. 39). The above- and below-ground biomass was low and highly variable because if it’s rare occurrence.

An important metric of seagrass health is the depth of the deep edge. The deep edge depth and position is determined by the amount of light reaching that critical depth to maintain growth. When seagrass transects were established in 2009, the edge was marked with PVC underwater and measured. Upon returning in 2010, notes on whether the seagrass had extended beyond the previous deep edge location and the depth was re-measured. In both sampling events, depth was corrected to the position of the tide during the sampling events (described in methods). Figure 40 shows the tide corrected depths at Blind Pass and Redfish Pass when recorded in May 2009 and May 2010. The deep edge at Blind Pass was 0.33 m (n = 5; S.D. 0.20) in May 2009 and 0.43 m (n = 5; S.D. 0.15) in May 2010. The position of the deep edge relative to the PVC, however, did not change. The deep edge depth at Redfish Pass was slightly deeper overall at 0.98 m (n = 5; S.D. 0.09) in May 2009 and increased to 1.13 m (n = 5; S.D. 0.21) in May 2010, but this difference was not significant and the differences fell within expected natural variability among transects.

Seagrass community composition was analyzed using PRIMER (ver. 6). A Bray-Curtis similarity matrix was created using species percent cover data for H. wrightii, S. filiforme, and T. testudinum. Macroalgae percent cover was not used for this analysis. A dendrogram relating the samples by relative similarity among quadrats is shown in Figure 41. The line at 70 percent similarity was used to cluster the quadrat community composition, based on similarity, in a non-metric MDS (Fig. 42). The two locations formed two clusters that were only 15 percent similar with a few exceptions where quadrats from Blind Pass clustered with quadrats from Redfish
Pass. These exceptions included samples labeled with BPF100 (2010), BPF54 (2009), BPF0 (2009), BPF0 (2010), BPF54 (2010), BPE14 (2009), BPE100 (2010), BPE32 (2009), BPE53 (2010), and BPF28 (2009); (the number stands for distance in meters from the beginning of a transect to the quadrat). When clusters are based on 70 percent similarity, the quadrats generally group by transect, as opposed to deep edge or shallow edge, or by year. From this analysis, a shift in seagrass community composition related to the opening of the inlet was not evident.

Flow and sedimentation - The current flow was generally rectilinear through the pass, and maximum currents were around 0.30 m s\(^{-1}\) during flood and 0.4 m s\(^{-1}\) during ebb. The few larger values of current were measured when the instrument was in the deeper mid-channel during the first couple of days of deployment.

Several sources of data and analysis were used to determine changes in flow after the inlet was dredged open and included; Lee County analyses plus the ADP deployments by SCCF and FGCU. Lee County and the engineering consultants (Neal et al., pers comm) determined the Escoffier Inlet stability curve for Blind Pass (Fig. 43). The stability curve predicts the Vmax based on the cross sectional area of the inlet.

The acoustic backscatter from the Argonaut can be used as a proxy for suspended sediments in the water column. The signal to noise ratio is the ratio of the amplitude of the acoustic backscatter to the instrument noise and provides a slightly better proxy. There is a clear tidal signal in suspended sediment concentrations with maximum concentrations occurring during ebb flow, suggesting a net flow of material in the direction of ebb tide (Fig. 44). However, this result may also be simply an artifact of the water column being shorter, thus the same amount of resuspended material may produce higher concentrations with less volume available to distribute itself. The relationship between current speed and signal to noise ratio is
fairly linear, suggesting that most of the suspended material is a result of local resuspension, rather than advection of concentration gradients.

The current velocity was higher during the second ADP deployment than it was during the first, peaking around 0.40 m s\(^{-1}\) during flood and 0.8 m s\(^{-1}\) during ebb. This increase is probably an underestimate because the deeper water depth corresponds to a larger cross sectional area. Again, there is a clear tidal signal in suspended sediment concentrations based on SNR, with maximum concentrations occurring during ebb flow (Fig. 44).

**DISCUSSION AND SYNTHESIS**

*Water Column Properties*

Changes in the optical properties of the water column were evident with the opening of Blind Pass in July 2009. However, analysis of the mobile RECON data demonstrated that changes were limited to within 1.7 km on the bay side of the dredged inlet. This limited the capability of the fixed RECON sensor packages to provide real-time conditions related to the dredging and subsequent opening of Blind Pass. Had the fixed stations been located within 1.7 km, a spatial model of the expected conservative mixing gradients (colored water mixing with clear water from the Gulf of Mexico) coupled to the time-series could have provided forecasts and hind casts of the water column. Given that few studies have examined the effects of opening an inlet between two barrier islands, the original assumptions about far ranging observable effects were incorrect. Given the multitude of confounding factors, including climate, rainfall, regulatory freshwater releases, and the complicated geomorphology around Blind Pass, it was necessary to examine the regional changes in water column properties during the period before the pass was opened compared to the period after. Changes which affected water quality on a regional scale are just as likely to affect the study area as the opening of the inlet. In parallel,
it was a requirement to include the examination of a nearby tidal inlet not likely affected by the opening of Blind Pass to provide a reasonable “control.” Redfish Pass was chosen as a control because of its close proximity to Blind Pass. Regional conditions such as precipitation or regulatory releases would equally influence the impact (Blind Pass) and control sites in similar ways, and thereby allowing for changes caused by the opening of the inlet to be distinguished and identified.

Even though ANOVA could find no significant difference in rainfall volume between the year before and the year after the opening of Blind Pass, the timing and intensity of the rainfall may have been different. There was more rain the year after the opening, but the variability of the rainfall data made it difficult to state the difference was significant. This is important because increased rainfall could have had a direct impact (due to dilution) on salinity, CDOM, and any parameter measurements such as nitrates and turbidity which are affected by storm runoff. Of the water column parameters measured, CDOM demonstrated the most obvious and consistent decrease after the pass was opened. There was no significant change in CDOM at Redfish Pass while at Blind Pass CDOM was lower within 1.7 km of the mouth of the pass after opening. There were no changes on the Gulf of Mexico side of either pass or at distances greater than 1.7 km of Blind Pass. The fixed Blind Pass RECON located 5 km from the inlet did not detect differences caused by the opening of the pass. The analysis, therefore, concentrated on the stations nearer the Blind Pass inlet using normalized differences within and among bay segments and a before and after, as well as control/impact analysis (BACI) using data from the mobile RECON.

Data from mobile RECON, fixed RECON stations, and discrete sampling (BPA data) indicated a number of changes occurred in water quality as a result of opening Blind Pass. Table
8 summarizes the findings of these analyses. The normalized difference analysis of mobile RECON data in the Bay West (B1) segment around Blind Pass indicated significant decreases in CDOM, increases in transparency, increases in salinity, and decreases in nitrate. Similarly, the BACI analysis demonstrated a significant decrease in CDOM and nitrate within 1.7 km of Blind Pass. Colored dissolved organic matter (e.g. tannins, color, gelbstoff) near Blind Pass decreased after the opening of the Blind Pass inlet while CDOM on the bay side of the Redfish Pass inlet (Fig. 20) remained unchanged. Of 864 CDOM measurements collected between January 2009 through January 2011 demonstrate mean CDOM near shore Gulf waters (10.2 QSE) are significantly lower than estuary waters (32.1 QSE) in the study area (SCCF, unpublished). The decrease in CDOM on the bay-side of Blind Pass after the inlet was opened can be explained by conservative mixing. Dilution of bay water with clear, low CDOM water in the Gulf of Mexico.

There are many possible sources of CDOM in estuaries including salt marshes (Tzortziou et al. 2009), bacteria (McKnight et al. 2000), and mangroves (Jaffe et al. 2003). The most commonly reported sources are terrestrial, originating from rivers and large watersheds (DelCastillo et al. 2000, Chen and Gardner 2004). Reports of dilution of bay waters, high in CDOM and salinity, with clear, high salinity Gulf of Mexico or oceanic waters are comparatively rare and unusual with the exception of Boss and Zanefield (2004) and Milbrandt et al. (2010).

If conditions were unchanged in the year after the opening of the Blind Pass inlet, a mixing equation (Fischer et al. 1979) estimates the mean volume as a function of changes in CDOM measured at BPA stations before and after Blind Pass was opened (Table 7). This estimation shows a large increase in mixing of bay water with Gulf water around the Blind Pass inlet. The magnitude of increase in mixing corresponded with the increase in flow velocities measured at the culvert connecting Clam Bayou to the estuary. Many other factors may have led
to changes in CDOM before and after the inlet was opened including rainfall variation between pre and post opening and other factors such as local surface water discharges and changes in the biological processes which produce CDOM. These factors may have also varied between years. However, the normalized difference approach using comparisons of “analogous” control and testing zones eliminates regional and seasonal differences and emphasizes relative zonal changes. This approach provided most comprehensive results for the studied highly dynamic systems. Originally, the normalized difference vegetation index (NDVI) was developed as a means to adjust for or “normalize” the effects of the solar zenith angle across a strong latitudinal gradient (Krigler et al. 1969, Rouse et al. 1973). This approach has not been often used outside of the remote sensing community. We used this approach in a novel way which preserved the simplicity of the algorithm and took advantage of its capacity to normalize temporal and latitudinal differences in water quality. We substituted the infrared and red reflectance signals in the NDVI formula with the effect and control measurements of the same water quality parameter. The normalized difference approach was used in two ways: 1) for within zone temporal differences between before and after time periods, and 2) for between zones spatial differences within a time period (before or after the Blind Pass opening). The second application of the normalized difference (between zones) was most effective as it produced comparable paired differences allowing to identify the significance of the temporal change for an affected zone in reference to a control zone. The within-zone temporal differences by themselves, without computing the normalized difference could not be used statistically since the number of seasons and timing of sampling were variable before and after the pass were opened.

A decrease in CDOM can have significant ramifications on seagrass community composition and condition if projected forward several years. One of the principle factors which
control seagrass distributions and community composition is availability of photosynthetically active radiation (PAR) at depth (Zimmerman et al. 1995). As CDOM decreases, the depth at which seagrass growth is limited is extended into deeper channels (Dennison 1993). As partial attenuators of light in the water column, CDOM, turbidity and chlorophyll $a$ can be used to model the light field at depth (Gallegos and Kenworthy 1996) and determine the light requirements for local populations and predict the changes that may occur (e.g., Milbrandt 2008) if low CDOM conditions persist around Blind Pass. A similar approach is currently used to restore and improve seagrass populations in the Indian River Lagoon (Steward et al. 2005). The BACI analysis of mobile RECON Kd(PAR) data before and after the opening could not find a significant decrease in Kd(PAR), however the analysis of normalized differences determined a significant decrease in Kd(PAR) in the Bay West (B1) segment. This discrepancy may be due to the increase in turbidity (scattering) which occurred while CDOM decreased. Turbidity is often highly variable temporally and may not have been well represented during the mobile RECON cruises.

Nitrate data was significantly lower after Blind Pass was opened using the ISUS sensor (Johnson et al. 2002) equipped on the mobile RECON sensor package. Discrete samples for quality control collected simultaneously with the in situ nitrate measurements did not detect any changes. All 41 discrete quality control samples had nitrate values below the detection limits of EPA method 353.1. The ISUS measurements for sites in which discrete quality control samples were collected overestimated nitrate by an average of 400%. While absorption in the UV by non-nitrate compounds is compensated for somewhat in the algorithm, it is believed that the high tannin waters of Southwest Florida (Coble 2007) can interfere and cause artificially high results. Additionally, the ISUS instrument was continuously operating in an environment where nitrate
was below 2 µM, which is the detection limit of the instrument and therefore should be treated with caution.

A significant increase in turbidity as a result of the opening of the Blind Pass was detected in the BACI analysis and the analysis of monthly discrete samples at the BPA sites. Concurrently, the fixed RECON located in the Gulf of Mexico demonstrated a significant increase in turbidity during the year after Blind Pass was opened while stations on the bay side of the barrier islands did not change. Two scenarios are proposed to explain the higher turbidity after the inlet was opened. A current profiler installed in the channel between Clam Bayou and Dinkins Bayou showed maximum velocities increased from 0.3 - 0.4 meters/second before the opening to 0.4 - 0.8 meters/second after the opening of Blind Pass. The significant increase in velocity likely increased the amount of resuspended fine sediment. The bayous near of Blind Pass are rich in fine sediments and organic matter associated with the fringing mangrove forests. The increase in velocity allows this reservoir of sediment to be mobilized and mix in the water column thereby increasing turbidity values. The newly opened pass advects water from the Gulf of Mexico into the areas around the inlet which may carry suspended carbonate silts from nearshore into the Blind Pass study area. The new dredged opening for Blind Pass was engineered to provide sand scouring water velocities (greater than 2 kts) through the pass to prevent a quick re-closure of the pass (Lee County 2011). We found significantly higher turbidity at the fixed Gulf of Mexico RECON stations during the year following the opening of Blind Pass compared to the year prior to the opening. This may be a result of greater storm frequency or intensity and possibly a greater suspended sediment load. If the mean turbidity of near shore Gulf waters was greater, it may have resulted in higher turbidity levels in the area near the opening. An additional consideration when evaluating changes in turbidity is bioturbation.
associated with benthic feeders and benthic organisms. Data from YSI data loggers mounted in Clam Bayou and the Wildlife Refuge often show a general diurnal pattern with turbidity increasing from morning until late evening and then decreasing during the nighttime hours (SCCF, unpublished). The benthic habitats of Southwest Florida are visited by striped mullet (Mugil cephalus) and other foragers. It is possible that the daytime feeding habits of mullet or activity of other diurnal benthic organisms may cause bioturbation significant enough to increase daytime turbidity measurements. If the opening of Blind Pass has promoted a significant increase in habitat utilization by organisms which cause bioturbation, we may see measurable differences in turbidity. Median turbidity values for two different data sets (mobile RECON and BPA discrete monitoring) suggested that the water near Blind Pass was within the typical values for Florida estuaries (3-7 NTU’s, Hand 2008) and very low compared to other estuaries worldwide (e.g., SWMP, NERR). Median turbidity values after Blind Pass was opened were well above 90th percentile values for Florida estuaries (Hand 2008). Southwest Florida is an ebb-dominated micro-tidal coast with numerous protected estuaries lined with sediment trapping mangrove communities. These characteristics produce estuaries naturally low in turbidity. It appears that the opening of Blind Pass has produced a temporary increase in turbidity related to a dramatic change in hydrodynamic or other characteristics. It is speculated that fine sediments accumulated in flow starved areas near Blind Pass and reopening the pass has allowed them to be transported to other areas within the estuary through tidal exchange. The fine sediments will eventually be relocated and result in a dynamic equilibrium with lower turbidity, similar to those more characteristic of a micro-tidal, sediment-trapping coastal morphology. Another potential for increased turbidity is from the dredging which may have spread a loosely consolidated later
of fine sediment in the region, that now is easily resuspended and, in time, will either consolidate or be transported out of the system.

Significant changes in chlorophyll a was detected in the normalized difference analysis of the mobile RECON data, but not the BACI analysis, fixed RECON, nor the BPA discrete samples. The differences were detected between the Bay West segment and the Bay Mid segment of Blind Pass (See Appendix). The lower chlorophyll in the Bay West segment suggested that clear water from the Gulf of Mexico may be diluting phytoplankton biomass with each tidal exchange, but the effect was limited only to within 1-2 km of the inlet.

There were no significant changes in chlorophyll a and dissolved oxygen for the four fixed RECON stations in the region or for BPA discrete samples. Both chlorophyll a and dissolved oxygen are often variable on a diurnal cycle (Reyes and Merino, 1991; Putland and Iverson, 2007; Erga and Skjoldal, 1990; Riauxa and Douvilléa, 1980). The design used in this study was unable to properly sample this variability, except at the fixed RECON platforms which were located at too great of a distance to record influences from opening the inlet. Of the greater than 1000 dissolved oxygen samples in either nearshore Gulf of Mexico and in nearby bayside waters collected for this study and related efforts showed a significantly greater DO in the Gulf waters (M. Thompson, unpublished data). Results from discrete monthly sampling at four BPA sites suggested dissolved oxygen levels were higher after the opening of Blind Pass but samples were not collected at a control site so it is difficult to connect the changes to the opening of Blind Pass and may be a function of regional trends. Alternatively, dissolved oxygen concentrations near Blind Pass may have higher DO values after being infused with the more oxygen rich Gulf waters.
Chlorophyll $a$ is an indicator of the biomass of phytoplankton (mostly micro-algae) present in the water column. Chlorophyll values can be significantly influenced by a multitude of factors including tide, precipitation, flow rate, CDOM, turbidity, nutrient concentrations, seagrass community, sediment type and salinity (Boyer et al. 2009). Analysis of over 1100 chlorophyll $a$ samples in near shore Gulf of Mexico waters verses chlorophyll $a$ in local estuary waters showed a significantly greater chlorophyll $a$ exists in estuarine waters (M. Thompson, personal communication, February 25, 2011). Conservative mixing and increased dilution of estuarine water near Blind Pass with lower chlorophyll $a$ containing Gulf waters would intuitively suggest chlorophyll $a$ concentrations would decrease after the inlet was opened, a decrease that was detected using the normalized difference approach (Appendix 1). However, it is likely that changes in chlorophyll $a$ were not detected using other methods due to the great variety of environmental conditions which influence chlorophyll $a$ and to the variability on a diurnal time scale. For example, the increase in turbidity at the Blind Pass estuarine stations associated with resuspension of fine sediment particles may increase the amount of available nutrients in the water column and cause an increase in phytoplankton growth (chlorophyll $a$) (Corbett, 2010) or increase the amount of benthic algae in suspension (Shimeta et al. 2003). Additionally, decreased CDOM levels after the opening could cause greater light availability to support water column primary production and a deeper photic zone.

Seagrass Habitats

There were direct seagrass and mangrove habitat losses as a result of the dredge footprint around the inlet. These losses of mostly sparse $H. wrightii$ were mitigated in a nearby no motor zone as a condition of the state and federal permitting. Subsequently, once the inlet was opened, it was hypothesized that the seagrass habitat surrounding Blind Pass would respond and more closely resemble that around a nearby inlet to the North, Redfish Pass.
Prior to the opening of Blind Pass, the surrounding seagrass community was dominated by *H. wrightii*, and contained abundant macroalgae. At 4 of 5 transects *H. wrightii* had the highest percent cover of the two other common Florida seagrass species. The depth where seagrass could grow around Blind Pass was from the mean low water mark to 0.3-0.5 m below mean low water. This narrow depth range of suitable habitat may be a function of a number of environmental and biological controls. These included; light attenuation (e.g., water clarity), epiphyte loads, salinity, and overgrowth by macroalgae. The deep edge of a seagrass habitat is generally considered the point at which the daylength and available light to produce adequate energy is sufficient for carbon fixation and to maintain cellular machinery (Hemminga and Duarte 2008). It is generally considered that a minimum of 20% of surface irradiance is necessary to sustain seagrass habitats, and that deeper water with less than 20% of surface irradiance will not have seagrass. Greater transparency in the water column can lead to extension of seagrasses to occupy deeper depths. This has been demonstrated on large scales in Tampa Bay (Greening 2006), Florida Keys (Fourqurean et al. 2002), and elsewhere.

Greater exposure to air during negative, spring tides is a consequence of a narrow depth range. *Halodule wrightii* (also called shoal grass) is more tolerant of moderate periods of exposure when the tide is low. Salinities in the region were comparable before and after, however, *H. wrightii* is more tolerant of lower salinities than either *T. testudinum* or *S. filiforme* and while the inlet was closed there may have been localized runoff decreasing salinities in the Blind Pass area.

In contrast, the seagrass community around Redfish Pass was dominated by *T. testudinum*. Another fundamental distinction at Redfish Pass was the greater depth range supporting seagrass habitat. The deep edge (1.0 m to 1.3 m) was greater at Redfish Pass than
Blind Pass. Greater water transparency and mixing with water from the Gulf of Mexico have created conditions which support a more typical deep seagrass assemblage of the Florida Keys (Durako 1994, Fourqurean et al. 2002, Kahn and Durako, 2006) or Lee Stocking Island, Bahamas (Dierssen et al. 2010).

*Syringodium filiforme* was absent from the Blind Pass area and was rare at most of the Redfish Pass transects (except RFF). In lower Pine Island Sound and San Carlos Bay, *S. filiforme* is the most frequently occurring species (CHAP report, 2008) in these locations, but Blind Pass and northward seems to be a break where *T. testudinum* becomes the more frequently occurring species. This natural transition may be related to salinity gradients and the proximity to the Caloosahatchee estuary, a source of CDOM, nutrients, and phytoplankton biomass.

The average percent cover of *Halodule* and *Thalassia* found by the Florida DEP’s Charlotte Harbor Aquatic Perserve (CHAP) Program in Pine Island Sound from 1999-2006 was less than 25% (Stearns 2007). At Redfish Pass the abundance of *Thalassia* was substantially higher than this average indicating a stable, healthy climax plant community. The *Thalassia* cover at Blind Pass was much lower, indicating a more variable or stressed environment. At Blind Pass, *Halodule* percent cover was substantially higher than that found by Stearns (2007) which is also indicative of a stressed environment. At Redfish Pass, *Halodule* coverage was lower due to the high abundance of *Thalassia*. *Syringodium* was less abundant at both locations than it was in the CHAP survey’s Pine Island Sound sites. Shoot densities of *Halodule* and *Thalassia* were higher at our sites than they were in the CHAP survey of Pine Island Sound sites (Stearns 2007).

Conditions in other Florida estuaries make seagrass condition comparisons difficult. Seagrass coverage in the Indian River Lagoon is quite variable in space and time, but percent
cover in some areas is similar to that at our sites (see Virnstein et al. 2007). Densities of
*Thalassia* at Redfish Pass sites are higher than in Florida Bay (Peterson and Fourqurean. 2001).
Plant densities in much of Florida Bay are limited by nutrient availability (Montague et al. 1988).

The impact site and control site had fundamental differences in species composition, as
demonstrated by the MDS and dendrogram. The two clusters were only 20% similar whereas
there were no obvious clusters separating the sampling event before from the sampling event
after the pass was opened. After Blind Pass was dredged opened, there was little to no response
at the impact site or the control site in seagrass communities. Two metrics were expected to
respond to the opening of the inlet; deep edge extension (shoots growing at deeper depths), and
increased shoot density. It is probable that the response time for a seagrass community is longer
than the 9 month period (4 months of growing season) from when the pass was opened. While
seagrass communities in Blind Pass will not likely be *T. testudinum*-dominated with the pass open, some deep edge extension and succession toward a community with colonization by *T. testudinum* or *S. filiforme* around Blind Pass are expected. Succession and shifts in composition
among these three species is not well understood, despite 20 years of research in Florida Bay and
elsewhere. Additional research through comparative studies and mesocosm approaches is
needed to better define the potential drivers (e.g., water quality versus biological) of succession.

One metric that changed around Blind Pass was the benthic macroalgal community
associated with seagrass habitats. At all transects, the percentage of macralgal cover decreased
from greater than 70% before the inlet was dredged open to less than 5% after. While
macroalgae associated with seagrass habitats around Redfish Pass was patchy and variable. In a
parallel study of macroalgae in the region, macroalgal cover at a variety of habitats did not differ
substantially in May 2009 and May 2010 (Milbrandt et al. 2010), suggesting that the opening of
the inlet, rather than regional conditions, may have been responsible for changes in the macroalgal communities. Increased tidal velocities may have created conditions which transport loosely attached or unattached algal fragments from the bay to the Gulf of Mexico. The inlet created greater dilution of bay water with oligotrophic water from the Gulf of Mexico, potentially decreasing available nutrients. In a manner more similar to Redfish Pass, the open inlet provides passage for grazers such as urchins (*Lytechinus variagatus*), and emerald parrotfish (*Nictholsina usta*) to seagrass habitats from the Gulf of Mexico (Coen et al. 2010). Heavier grazing pressure, physical transport and decreased nutrient availability or a combination could explain the decrease in macroalgal cover before and after Blind Pass was opened.

Biomass samples collected were separated to determine above- and below-ground components. There were marked decreases in above-ground and below-ground biomass from samples collected in May 2009 versus May 2010. In general, the biomass samples collected were not representative given the small sample size and extrapolation from a relatively small sample area (7.5 cm diameter coring devise) to 1 sq. meter. Additional samples or a larger coring devise is needed to more accurately sample, however, this involves additional equipment and time.

The data collected for this project are currently being used in several other projects including a water quality assessment of Captiva Island undertaken by SCCF Marine Lab for the Lee Tourism Development Council and water quality and seagrass assessment for the Ding Darling National Wildlife Refuge also undertaken by SCCF. The ability to use the data collected within this study with other ongoing assessment projects increases the value of the work accomplished here.
ACKNOWLEDGEMENTS

The work contained within this report was supported by a grant from Florida SeaGrant and the Sanibel-Captiva Conservation Foundation Marine Laboratory. All work was conducted pursuant to Florida Fish and Wildlife Conservation Commission Special Activity License number 08SR-1110 and a copy of this final report submitted to FWC. Lee County Natural Resources provided images and engineers depictions of the inlet and resources (R. Neal). Many SCCF staff assisted in the collection and preparation of these data for this report including A.J. Martignette and J.J. Siwicke.
Table 1. Example of how seagrass and macroalgal percent cover were paired for BACI GLM analysis.

<table>
<thead>
<tr>
<th>Station Pairing</th>
<th>Quadrat</th>
<th>Seagrass</th>
<th>Impact %Cover</th>
<th>Control %Cover</th>
<th>Difference Control-Impact</th>
<th>Adjusted Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPA-RFB</td>
<td>1</td>
<td><em>Halodule</em></td>
<td>94</td>
<td>0</td>
<td>-94</td>
<td>3</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>1</td>
<td>Macroalgae</td>
<td>88</td>
<td>0</td>
<td>-88</td>
<td>9</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>1</td>
<td><em>Syringodium</em></td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>197</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>1</td>
<td><em>Thalassia</em></td>
<td>0</td>
<td>97</td>
<td>97</td>
<td>194</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>2</td>
<td><em>Halodule</em></td>
<td>96</td>
<td>0</td>
<td>-96</td>
<td>1</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>2</td>
<td>Macroalgae</td>
<td>98</td>
<td>7</td>
<td>-91</td>
<td>6</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>2</td>
<td><em>Syringodium</em></td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>197</td>
</tr>
<tr>
<td>BPA-RFB</td>
<td>2</td>
<td><em>Thalassia</em></td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>197</td>
</tr>
</tbody>
</table>
Table 2. Blind Pass fixed RECON descriptive statistics.

<table>
<thead>
<tr>
<th>Station</th>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>StDev</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind Pass Before the Opening</td>
<td>CDOM</td>
<td>8265</td>
<td>18.842</td>
<td>13.86</td>
<td>15.034</td>
<td>0.165</td>
<td>1.26</td>
<td>94.84</td>
</tr>
<tr>
<td></td>
<td>DO</td>
<td>8252</td>
<td>6.1727</td>
<td>6.38</td>
<td>0.9787</td>
<td>0.0108</td>
<td>0.01</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>8252</td>
<td>2.8832</td>
<td>2.27</td>
<td>2.1113</td>
<td>0.0232</td>
<td>0.08</td>
<td>44.18</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>8218</td>
<td>0.1908</td>
<td>0.2</td>
<td>4.1145</td>
<td>0.0454</td>
<td>-20.9</td>
<td>35.7</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>8252</td>
<td>33.722</td>
<td>34.74</td>
<td>3.147</td>
<td>0.035</td>
<td>0.68</td>
<td>37.48</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>8252</td>
<td>13.242</td>
<td>5.68</td>
<td>26.589</td>
<td>0.293</td>
<td>0.24</td>
<td>200.25</td>
</tr>
<tr>
<td>Blind Pass After the Opening</td>
<td>CDOM</td>
<td>8730</td>
<td>16.782</td>
<td>11.7</td>
<td>11.908</td>
<td>0.127</td>
<td>3.64</td>
<td>189.69</td>
</tr>
<tr>
<td></td>
<td>DO</td>
<td>8633</td>
<td>6.2694</td>
<td>6.27</td>
<td>0.9817</td>
<td>0.0106</td>
<td>3.19</td>
<td>8.87</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>8634</td>
<td>2.0782</td>
<td>1.79</td>
<td>1.0638</td>
<td>0.0114</td>
<td>0</td>
<td>18.34</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>8094</td>
<td>3.4959</td>
<td>4</td>
<td>3.1024</td>
<td>0.0345</td>
<td>-12.6</td>
<td>37.7</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>8633</td>
<td>30.39</td>
<td>30.86</td>
<td>2.877</td>
<td>0.031</td>
<td>2.52</td>
<td>35.07</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>8634</td>
<td>9.494</td>
<td>5.18</td>
<td>19.521</td>
<td>0.21</td>
<td>0</td>
<td>199.89</td>
</tr>
</tbody>
</table>
Table 3. Redfish Pass fixed RECON descriptive statistics.

<table>
<thead>
<tr>
<th>Station</th>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>StDev</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redfish Pass Before the</td>
<td>CDOM</td>
<td>9132</td>
<td>15.873</td>
<td>14.2</td>
<td>6.803</td>
<td>0.071</td>
<td>0.73</td>
<td>98.14</td>
</tr>
<tr>
<td>Opening</td>
<td>DO</td>
<td>8518</td>
<td>6.3144</td>
<td>6.54</td>
<td>1.4324</td>
<td>0.0155</td>
<td>0.39</td>
<td>9.76</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>9112</td>
<td>2.4237</td>
<td>2.11</td>
<td>1.524</td>
<td>0.016</td>
<td>0.4</td>
<td>32.97</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>8648</td>
<td>-0.3605</td>
<td>0.6</td>
<td>4.6855</td>
<td>0.0504</td>
<td>-53.4</td>
<td>32.6</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>8789</td>
<td>34.956</td>
<td>35.59</td>
<td>2.005</td>
<td>0.021</td>
<td>20.84</td>
<td>37.54</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>9112</td>
<td>10.322</td>
<td>4.775</td>
<td>25.107</td>
<td>0.263</td>
<td>0.23</td>
<td>191.84</td>
</tr>
<tr>
<td>Redfish Pass After the</td>
<td>CDOM</td>
<td>8292</td>
<td>16.071</td>
<td>14.975</td>
<td>6.115</td>
<td>0.067</td>
<td>1.79</td>
<td>53.03</td>
</tr>
<tr>
<td>Opening</td>
<td>DO</td>
<td>7343</td>
<td>7.0016</td>
<td>7</td>
<td>0.965</td>
<td>0.0113</td>
<td>3.16</td>
<td>9.66</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>8069</td>
<td>2.5094</td>
<td>2.25</td>
<td>1.163</td>
<td>0.0129</td>
<td>0.38</td>
<td>17.06</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>7866</td>
<td>1.5893</td>
<td>1.3</td>
<td>4.6898</td>
<td>0.0529</td>
<td>-57.3</td>
<td>57.2</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>8069</td>
<td>32.954</td>
<td>33.45</td>
<td>2.558</td>
<td>0.028</td>
<td>0.01</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>8066</td>
<td>7.2</td>
<td>4.97</td>
<td>9.167</td>
<td>0.102</td>
<td>1.4</td>
<td>197.67</td>
</tr>
</tbody>
</table>
Table 4. Gulf of Mexico fixed RECON descriptive statistics.

<table>
<thead>
<tr>
<th>Station</th>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>StDev</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Mexico Before the Opening</td>
<td>CDOM</td>
<td>6530</td>
<td>18.221</td>
<td>16.35</td>
<td>8.631</td>
<td>0.107</td>
<td>1.91</td>
<td>83.6</td>
</tr>
<tr>
<td></td>
<td>DO</td>
<td>6529</td>
<td>6.3082</td>
<td>6.52</td>
<td>1.2613</td>
<td>0.0156</td>
<td>0.04</td>
<td>8.91</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>6529</td>
<td>1.7142</td>
<td>1.51</td>
<td>1.1271</td>
<td>0.0139</td>
<td>0.33</td>
<td>32.64</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>5807</td>
<td>3.691</td>
<td>3.2</td>
<td>2.9172</td>
<td>0.0383</td>
<td>-1.9</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>6529</td>
<td>34.487</td>
<td>34.82</td>
<td>1.733</td>
<td>0.021</td>
<td>20.03</td>
<td>41.05</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>6529</td>
<td>7.084</td>
<td>5.15</td>
<td>5.895</td>
<td>0.073</td>
<td>1.61</td>
<td>170.56</td>
</tr>
<tr>
<td>Gulf of Mexico After the Opening</td>
<td>CDOM</td>
<td>8571</td>
<td>17.072</td>
<td>16.12</td>
<td>5.453</td>
<td>0.059</td>
<td>5.18</td>
<td>57.08</td>
</tr>
<tr>
<td></td>
<td>DO</td>
<td>8567</td>
<td>6.3552</td>
<td>6.24</td>
<td>1.0025</td>
<td>0.0108</td>
<td>3.5</td>
<td>9.07</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>8571</td>
<td>1.2499</td>
<td>1.14</td>
<td>0.5822</td>
<td>0.0063</td>
<td>0.25</td>
<td>7.64</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>8472</td>
<td>1.707</td>
<td>1.5</td>
<td>2.742</td>
<td>0.03</td>
<td>-10.3</td>
<td>100.9</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>8567</td>
<td>33.456</td>
<td>33.66</td>
<td>1.262</td>
<td>0.014</td>
<td>25.12</td>
<td>36.21</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>8569</td>
<td>13.842</td>
<td>6.33</td>
<td>27.586</td>
<td>0.298</td>
<td>1.54</td>
<td>198.97</td>
</tr>
</tbody>
</table>
Table 5. Shell Point fixed RECON descriptive statistics.

<table>
<thead>
<tr>
<th>Station</th>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>StDev</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Point Before the</td>
<td>CDOM</td>
<td>7623</td>
<td>44.21</td>
<td>38.32</td>
<td>26.804</td>
<td>0.307</td>
<td>0.83</td>
<td>127.52</td>
</tr>
<tr>
<td>Opening</td>
<td>DO</td>
<td>7387</td>
<td>5.9757</td>
<td>6.11</td>
<td>1.0236</td>
<td>0.0119</td>
<td>0.99</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>7387</td>
<td>3.209</td>
<td>1.91</td>
<td>5.4013</td>
<td>0.0628</td>
<td>0.72</td>
<td>49.26</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>6465</td>
<td>5.4808</td>
<td>3.6</td>
<td>6.5335</td>
<td>0.0813</td>
<td>-4.5</td>
<td>48.6</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>7387</td>
<td>27.703</td>
<td>29.66</td>
<td>7.56</td>
<td>0.088</td>
<td>0.2</td>
<td>37.09</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>7387</td>
<td>4.7769</td>
<td>3.62</td>
<td>4.1276</td>
<td>0.048</td>
<td>1.09</td>
<td>51.74</td>
</tr>
<tr>
<td>Shell Point After the</td>
<td>CDOM</td>
<td>7784</td>
<td>46.31</td>
<td>42.23</td>
<td>20.029</td>
<td>0.227</td>
<td>12</td>
<td>112.41</td>
</tr>
<tr>
<td>Opening</td>
<td>DO</td>
<td>7783</td>
<td>6.3132</td>
<td>6.23</td>
<td>1.2981</td>
<td>0.0147</td>
<td>1.46</td>
<td>9.73</td>
</tr>
<tr>
<td></td>
<td>Chl. a</td>
<td>7785</td>
<td>3.7369</td>
<td>2.13</td>
<td>6.7146</td>
<td>0.0761</td>
<td>0.83</td>
<td>73.92</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>6234</td>
<td>10.405</td>
<td>9.5</td>
<td>5.243</td>
<td>0.066</td>
<td>-15.8</td>
<td>44.5</td>
</tr>
<tr>
<td></td>
<td>salinity</td>
<td>7783</td>
<td>24.549</td>
<td>26.41</td>
<td>6.798</td>
<td>0.077</td>
<td>3.19</td>
<td>34.81</td>
</tr>
<tr>
<td></td>
<td>Turb.</td>
<td>7785</td>
<td>5.736</td>
<td>4.15</td>
<td>8.974</td>
<td>0.102</td>
<td>1.3</td>
<td>197.26</td>
</tr>
</tbody>
</table>
Table 6. Distance classes for mobile RECON and the number of stations in each group. This scheme was used in the CDOM example comparing a sampling event before and after the Blind Pass inlet was opened. Negative distances are from the center of the pass to the Gulf of Mexico (m) and positive distances are from the center of the pass to Pine Island Sound.

<table>
<thead>
<tr>
<th>Location</th>
<th>Distance Class</th>
<th>Number of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind Pass</td>
<td>-1800</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>-750</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1800</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2800</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4000</td>
<td>5</td>
</tr>
<tr>
<td>Redfish Pass</td>
<td>-1800</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>-750</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>1800</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2800</td>
<td>5</td>
</tr>
</tbody>
</table>
Table 7. Colored dissolved organic matter and change in mixing volume at several locations surrounding the Blind Pass inlet. Mixing volume was calculated from Loder (1981).

<table>
<thead>
<tr>
<th>Period</th>
<th>Clam Bayou</th>
<th>Dinkins Bayou</th>
<th>Roosevelt Channel</th>
<th>Sunset Bay</th>
<th>Gulf of Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDOM Before Opening (QSE)</td>
<td>49.1</td>
<td>43.7</td>
<td>36</td>
<td>39.5</td>
<td>10.2</td>
</tr>
<tr>
<td>CDOM After Opening (QSE)</td>
<td>28.4</td>
<td>26.6</td>
<td>24.9</td>
<td>19.9</td>
<td>10.2</td>
</tr>
<tr>
<td>Change in Mixing Volume*</td>
<td>+11.5</td>
<td>+2.55</td>
<td>+2.55</td>
<td>+2.02</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

*estimated from (Loder 1981)
Table 8. Summary of analytical approaches for understanding the effects on Blind Pass opening on various water quality parameters. Bold text indicates a significant effect at $p < 0.05$; significantly lower (SL); significantly greater (SG), no significant difference (NSD), not applicable to the dataset (NA).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed RECON</th>
<th>Mobile RECON-Comparisons of Normalized Stratified Data</th>
<th>Mobile RECON-BACI Intervention Analysis on Data from 12 Nearest Sites</th>
<th>BPA Stationary Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>SL</td>
<td>NSD</td>
<td>NSD</td>
<td>SG</td>
</tr>
<tr>
<td>Salinity</td>
<td>SL</td>
<td>SG</td>
<td>NSD</td>
<td>SL</td>
</tr>
<tr>
<td>Chlorophyll $a$</td>
<td>SL</td>
<td>SL</td>
<td>NSD</td>
<td>SG</td>
</tr>
<tr>
<td>CDOM</td>
<td>SL</td>
<td>SL</td>
<td>SL</td>
<td>NA</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NSD</td>
</tr>
<tr>
<td>Nitrates</td>
<td>SG</td>
<td>SL</td>
<td>SL</td>
<td>SG</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>NSD</td>
<td>NSD</td>
<td>NSD</td>
<td>SG</td>
</tr>
<tr>
<td>Rainfall</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NSD</td>
</tr>
<tr>
<td>S-79 Flow</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>SG</td>
</tr>
</tbody>
</table>
LITERATURE CITED


Additional Cited Sources

Robert Neal, Lee County Marine Resources Division.
Fig. 1. Proposed footprint of the dredge for Blind Pass and the environmental impacts of the dredging on seagrass, mangroves, and beach elder (Lee County Natural Resources).
Fig. 2. Blind Pass dredge footprint in April 2010 (Lee County Natural Resources).
Fig. 3. Blind Pass bathymetry in January 2010, the pass was dredged open on July 31, 2009 (Lee County Natural Resources).
Fig. 4. SCCF Marine Lab RECON water quality monitoring stations are shown with red stars. Data from the Shell Point, Gulf of Mexico, Blind Pass, and Redfish Pass stations were analyzed to determine the regional conditions during the study period.
Fig. 5. SCCF Marine Lab RECON instrument package.
Fig. 6. Mobile RECON stations. These 66 stations were sampled in two consecutive days on an incoming neap tide. Sampling events occurred in February, April, July and November 2009, and again in February 2010. Blind Pass was dredged open on July 31, 2009. The GPS positions of each station for the February and April cruises are depicted.
Fig. 7. Locations of the four discrete water quality monitoring stations established by the Bayous Preservation Association (BPA) in 2006. Monthly discrete samples were collected from July 2006 until September 2010 (30 month before the opening, and 14 month after).
Fig. 8. Diagram of the overall design of the Blind Pass Opening study and the analytical approach of the data.
Fig. 9. Zoning and paring mobile RECON stations for the normalized difference analyses. These selected 51 stations (station located in Dinkins Bayou and Roosevelt Channel were excluded) were subdivided based on the morphology of Sanibel/Captiva Islands, bathymetry, seagrass coverage, and sufficient number of sample sites (5 or greater) for statistics.
Fig. 10. Daily precipitation (A) measured at a nearby rain gauge (Lee County) in south Fort Myers during the study period (Aug. 2008 to Aug 2010). The red line indicates the day that Blind Pass opened by dredging.
Fig. 11. Box-whisker plot of daily rainfall 1 year before (n = 365) and 1 year after (n = 365) the dredged opening of Blind Pass (Aug 2009). A paired t-test was used to compare daily rainfall.

Unable to find significant difference in precipitation in 12 months following opening of Blind Pass

0.409 0.315
Fig. 12. Daily flow rate from S-79 (Franklin Locks) during the study period. This structure discharges freshwater from the Lake Okeechobee watershed into the Caloosahatchee Estuary. The red line indicates the date when Blind Pass was dredged open.
Fig. 13. Box and whisker plot of daily flow (cfs) from S-79 (Franklin Locks) before (n = 365) and after (n = 365) the dredged opening of Blind Pass. The median flow for the year after the opening of Blind Pass was found to be significantly greater than during the monitoring period before.
Fig. 14. Box-whisker plots of salinity at four fixed SCCF RECON monitoring stations during the study period (Aug. 2008- Aug. 2010). Mean salinities were lower in the region after the dredged opening of Blind Pass due to climatological conditions.
Fig. 15. Box-whisker plots of CDOM at the SCCF RECON fixed sites during the study period (Aug. 2008- Aug. 2010).
Fig. 16. Box-whisker plots of turbidity at four fixed SCCF RECON monitoring stations during the study period (Aug. 2008 - Aug. 2010). Turbidity was higher in the Gulf of Mexico in the period after Blind Pass was dredged open.
Fig. 17. Box-whisker plots of chlorophyll $a$ at four fixed SCCF RECON monitoring stations during the study period (Aug. 2008- Aug. 2010).
Fig. 18. Box-whisker plots of dissolved oxygen at four fixed SCCF RECON monitoring stations during the study period (Aug. 2008- Aug. 2010).
Fig. 19. Summary slide of the changes in optical and water parameters before and after Blind Pass was dredged open, as recorded by mobile RECON. The study areas were divided into segments based on depth, sample number and the location of seagrass habitats in ArcGIS (ver. 9.3). The approach is described in the text; the results from each pairwise comparison and the associated statistical analyses can be found in Appendix 1.
Fig. 20. Chromophoric dissolved organic matter (CDOM) recorded by the mobile RECON instrument package at stations around Blind Pass (A) and Redfish Pass (B), before and after Blind Pass was dredged open. The pass was opened on July 31, 2009. Distance classes differ for Blind Pass and Redfish Pass because of the unique aspects of each pass with respect to morphology. Negative distances are stations from the center of the pass into the Gulf of Mexico. Positive distance classes are from the center of the pass into Pine Island Sound. The number of stations in each class varies and is reported in Table 6.
Fig. 21. Box-whisker plots of mobile RECON stations (< 1.7 km bayside of Blind Pass) showing mean, median and range of values for (A) Colored Dissolved Organic Matter (CDOM), (B) Nitrate, (C) Turbidity. Mean values are represented by the red circle, median is the solid black line, the box represents the 25th and 75th percentiles, and range is represented by the vertical whiskers.
Fig. 22. Boxplots showing mean, median and range of values (<1.7 km from the inlet) at Blind Pass for (D) Chlorophyll a, (E) Dissolved Oxygen (DO), (C) Salinity. Mean values are represented by the red circle, median is the solid black line, the box represents the 25th and 75th percentiles, and range is represented by the vertical whiskers.
Fig. 23. Box-whisker plots of mobile RECON stations (< 1.7 km bayside of Redfish Pass) showing mean, median and range of values for (A) Colored Dissolved Organic Matter (CDOM), (B) Nitrate, (C) Turbidity. Mean values are represented by the red circle, median is the solid black line, the box represents the 25th and 75th percentiles, and range is represented by the vertical whiskers. CDOM and nitrates were found to be significantly lower after the opening of Blind Pass. No significant difference could be found for other parameters.
Fig. 24. Boxplots showing mean, median and range of values for (D) Chlorophyll $a$, (E) Dissolved Oxygen (DO), (C) Salinity. Mean values are represented by the red circle, median is the solid black line, the box represents the 25$^{th}$ and 75$^{th}$ percentiles, and range is represented by the vertical whiskers.
Fig. 25. Boxplots showing mean, median and range of values for Blind Pass (A) light attenuation (Kd) for wavelengths 433-453 nm and (B) light attenuation (KdPAR) for photosynthetically active radiation (PAR). Mean values are represented by the red circle, median is the solid black line, the box represents the 25\textsuperscript{th} and 75\textsuperscript{th} percentiles, and range is represented by the vertical whiskers.
Fig. 26. Boxplots showing mean, median and range of values for Redfish Pass (A) light attenuation (Kd) for wavelengths 433-453 nm and (B) light attenuation (KdPAR) for photosynthetically active radiation (PAR). Mean values are represented by a red circle, median is the solid black line, the box represents the 25th and 75th percentiles, and range is represented by the vertical whiskers.
Fig. 27. Map of mobile RECON stations and the sub-set of stations used for the BACI analysis.
Fig. 28. Locations of the seagrass transects and quadrats around Redfish Pass. The position of each quadrat was determined with a Trimble GeoXT as described in the text.
Fig. 29. Locations of the seagrass transects and quadrats around Blind Pass. The position of each quadrat was determined with a Trimble GeoXT as described in the text. The transects were established in May 2009 and revisited in May 2010. Blind Pass was dredged open on July 31, 2009.
Fig. 30. Mean percent cover of Halodule wrightii at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09. Halodule wrightii was the dominant species at transects around Blind Pass (BPA-BPF), and was less common around Redfish Pass (RFB-RFH). No consistent trends in percent cover were observed with the dredged opening of Blind Pass.
Fig. 31. Mean shoot density of *Halodule wrightii* at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09. *Halodule wrightii* was the dominant species at transects around Blind Pass (BPA-BPF), and was less common around Redfish Pass (RFB-RFH).
Fig. 32. Mean percent cover of *Thalassia testudinum* at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09. *Thalassia testudinum* was the dominant species at transects around Redfish Pass (BPA-BPF), and was abundant at the deeper quadrats around Blind Pass, especially BPE and BPF.
Fig. 33. Mean shoot density of *Thalassia testudinum* at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09. *Thalassia testudinum* was the dominant species at transects around Redfish Pass (RFB-RFH).
Fig. 34. Mean percent cover of *Syringodium filiforme* at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09. *Syringodium filiforme* was comparatively less dominant in the study area. The exception was RFF, where *S. filiforme* was the dominant species.
Fig. 35. Mean shoot density of *Syringodium filiforme* at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09.

No *Syringodium filiformis* was found at the Blind Pass transects.
Fig. 36. Mean percent cover of macroalgae at fixed transects sampled in 05/09 (n = 4) and 05/10 (n = 4). The pass was dredged open on 7/31/09. After the pass was dredged open, there was lower percentage of macroalgal cover.
Fig. 37. Mean (A) above- and (B) belowground biomass of *Halodule wrightii* from Blind Pass (BP; n = 10) and Redfish Pass (RF; n = 10), before and after Blind Pass was dredged. The pass was dredged open on 07/31/09. The average shoot: root ratio for all samples containing measurable biomass was 0.96 (n = 19) for *H. wrightii*. 
Fig. 38. Mean (A) above- and (B) belowground biomass of *Thalassia testudinum* from Blind Pass (BP; n = 10) and Redfish Pass (RF; n = 10), before and after Blind Pass was dredged. The pass was dredged open on 07/31/09. The average shoot:root ratio for all samples collected with measurable tissue was 1.43 (n = 25) for *T. testudinum*. 
Fig. 39. Mean (A) above- and (B) belowground biomass of *Syringodium filiforme* from Blind Pass (BP; n = 10) and Redfish Pass (RF; n = 10), before and after Blind Pass was dredged. The pass was dredged open on 07/31/09. The average shoot:root ratio for all samples containing measurable tissue was 0.89 (n = 2) for *S. filiforme*. 
Fig. 40. Tide-corrected depth of the deep edge of SAV before \((n = 5)\) and after \((n = 5)\) Blind Pass was dredged open at fixed transects.
Fig. 41. Dendrogram of seagrass quadrats by transect, quadrat position and year. Similarity values from a Bray-Curtis Similarity Matrix and the relationship among quadrats are shown (PRIMER, ver. 6).
Fig. 34. Non-metric Multi-Dimensional Scaling (MDS) ordination of seagrass quadrats. Quadrats were clustered at 70% similarity. The two main clusters distinguishing Blind Pass and Redfish Pass are only 20% similar.
Fig. 43. Escoffier Inlet stability curve developed for Blind Pass (see Neal et al., Lee County Natural Resources).
Fig. 44. Signal to noise versus current velocity from an SCCF/FGCU ADP deployment at Clam Bayou.
Appendix 1. Normalized difference full-factorial results plus statistics