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BAHIA GRANDE RESTORATION MONITORING

INTERIM REPORT – YEAR 2 (2006-2007)

by

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INTRODUCTION

The Bahia Grande wetland complex is located at the southernmost tip of Texas bordering the lower Laguna Madre ecosystem and within the Rio Grande Delta. The 21,762,451 acre Bahia Grande Unit is part of the Laguna Atascosa National Wildlife Refuge. The Bahia Grande Unit contains a wide diversity of habitat types including open bays, basins, lomas, low-lying flats, resacas, and native brush. The Unit's major wetland complex includes a series of three basins that historically functioned as shallow estuaries. Bahia Grande, the major wetland feature, is a large 6,500-acre basin. The other two basins, Laguna Larga and Little Laguna Madre, are somewhat smaller at 1,669 and 1,411 acres, respectively. This estuarine system was once an important nursery area, contributing to a productive sport and commercial fishery while also providing important habitat for wading birds and waterfowl.

Tidal exchange was severely reduced to Bahia Grande in the 1930s following the excavation of the Brownsville Ship Channel, deposition of the dredged material, and later the construction of Texas State Highway 48. For over 70 years, the basin maintained surface water only temporarily following extreme rainfall events or tropical storm surges. A majority of the time, the basin was barren and dry, and large amounts of sand and clay blew out of the basin impacting adjacent upland vegetation.

On July 16, 2005, the Brownsville Navigation District and Cameron County opened a 15 foot wide, 2,250-foot long pilot channel from the Brownsville Ship Channel to the Bahia Grande (marked as channel "E" on site map Fig. 1). This long-awaited event marked the beginning of restoring this unique system which will ultimately provide habitat for wildlife and fisheries resources, provide opportunities for public recreation and environmental education, improve public health and safety conditions in communities affected by blowing dust, and contribute to the local economy. A permanent channel, 150 foot wide and 9 foot below MSL, will eventually replace the pilot channel. The Texas Department of Transportation widened State Highway 48 to 4-lanes and constructed a 256-foot long bridge which will span the width of the permanent channel and has since allowed for the removal of the three small culverts that were restricting tidal flow into the system. In addition, construction of the internal channels that interconnect the three basins (Bahia Grande, Laguna Larga, and Little Laguna Madre) has been completed.

The reintroduction of water into Bahia Grande provides a unique opportunity, not only to begin restoration of the Bahia Grande wetlands, but to also document and evaluate the increased productivity and potential fisheries contribution from restoration of similar lost estuaries in the United States. Given the considerable investment of local, state, and federal dollars in the restoration of Bahia Grande, it is imperative to continue the monitoring program to evaluate whether current and future manipulations are producing the desired changes, to gauge how well the restoration site is functioning, and to evaluate the ecological health of specific habitats both during and after project completion (Keddy, 2000).

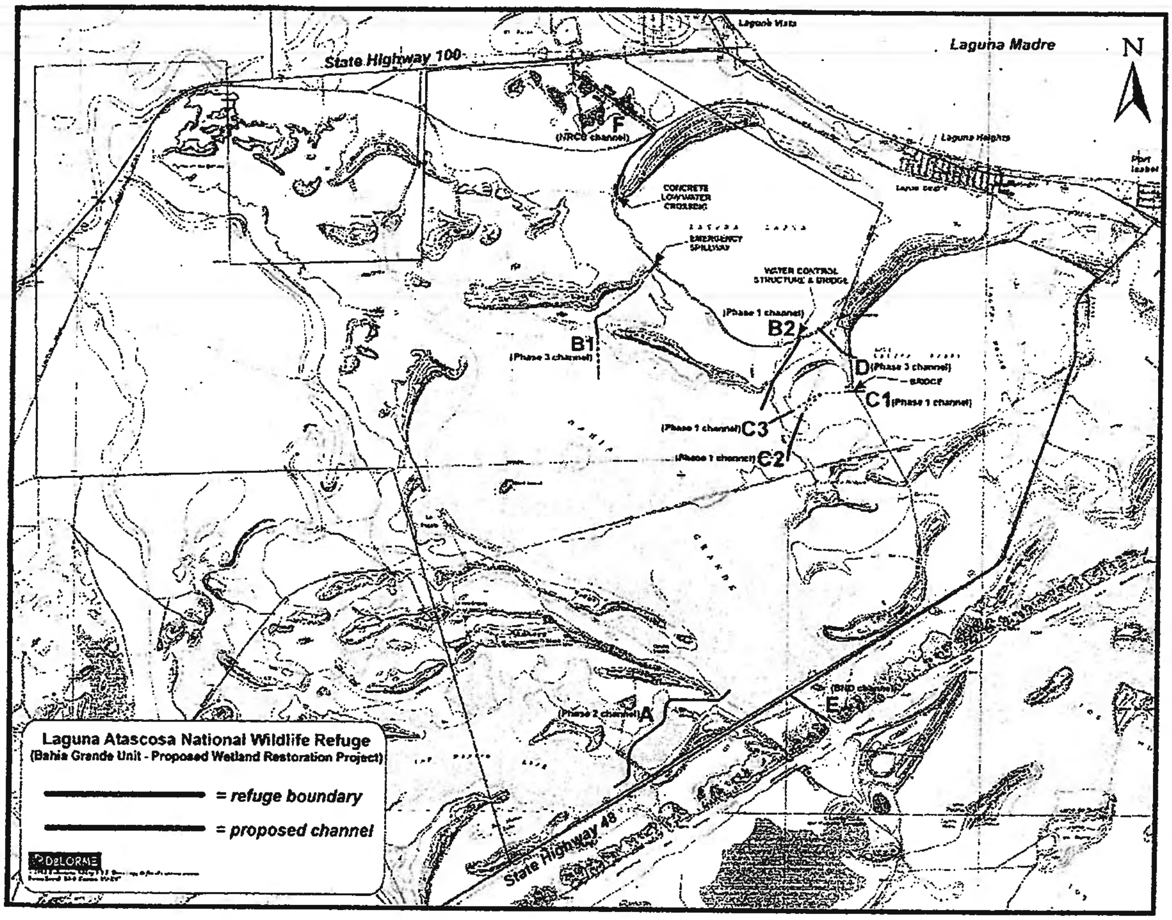

Fig. 1. Map of Bahia Grande depicting the location of the pilot (marked as channel "E") and internal channels.

System-Level Monitoring Program

The long-term goal of the Bahia Grande restoration project is to restore the wetland complex to historical function. Accordingly, the goal of the biological monitoring program is to provide the USFWS supplementary data for evaluating the ecological successes of restoration efforts thereby allowing for adaptive management of restoration and enhancement actions and associated programs. Physical, chemical, and biological features are being used to evaluate the function and restoration effects of the reintroduction of water to the Bahia Grande system including:

- water levels & hydrodynamics
- water quality
- geochemical sediment parameters
- establishment of the marine algal community including the phytoplankton, microphytobenthos (microalgae associated with sediment), seagrass epiphytes, drifting macroalgae and wind-tidal algal mats;

- establishment of a seagrass and mangrove habitats; and
- development of benthic, epibenthic, and nektonic communities

Community Education & Outreach Program

This venture has a strong community outreach component that promotes a sense of local ownership, establishing an emotional bond between the area participants and the restoration project. The JASON Project at UTB/TSC improves the quality of life for area residents by providing dynamic leadership for students, teachers, and family members from local elementary, middle, and high schools. These stakeholders have been involved in the propagation and planting of black mangroves (*Avicennia germinans*) and Gulf cordgrass (*Spartina alterniflora*) along the shores of Bahia Grande. A permanent part of JASON Project materials is a Field Study component, a curriculum for watershed studies, complete with digital labs, field work, and experiments, all of which compliment Bahia Grande restoration efforts

MATERIALS & METHODS

Sampling Design for Biological & Sediment Parameters

The sampling design for water quality, biological and sediment monitoring was based upon the overall objective of collecting sufficient physical and biological data necessary to quantitatively assess the recovery of the Bahia Grande. All data taken for assessing the development of the biological community were considered critical measurements in meeting the program's objectives. Site selection followed the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) for estuarine systems systematic and random sampling (probabilistic sampling design; U.S. EPA, 2001). Accordingly, the Bahia Grande basin was divided into three sectors (BG-S, BG-NE, BG-NW) to ensure adequate sampling of the entire system (i.e., stratified) (Fig. 2). The area south of the abandoned railroad trestle, which includes the tidal inlet from the Brownsville ship channel, was designated as sector BG-S. The area north of the abandoned railroad was divided into east and west sectors (BG-NE, BG-NW). Sampling stations were established by overlaying a one second latitude-longitude grid on a map of the Bahia Grande and randomly selecting intersecting points of latitude and longitude from each of the three sectors identified above. This method was used each quarter to randomly select new sampling sites. Additional site locations within each of the three sampling regions were generated for use in the event that the primary sites were inaccessible. All site locations were established prior to each sampling event and entered into a GPS unit prior to field sampling.

Biological Monitoring

Algae & Seagrass

Quarterly sampling occurred in August 2006, November 2006, March 2007 and May 2007 and August 2007. Data for the following parameters are reported: water temperature, salinity, dissolved oxygen, total suspended solids, nitrate-nitrite nitrogen, ammonium

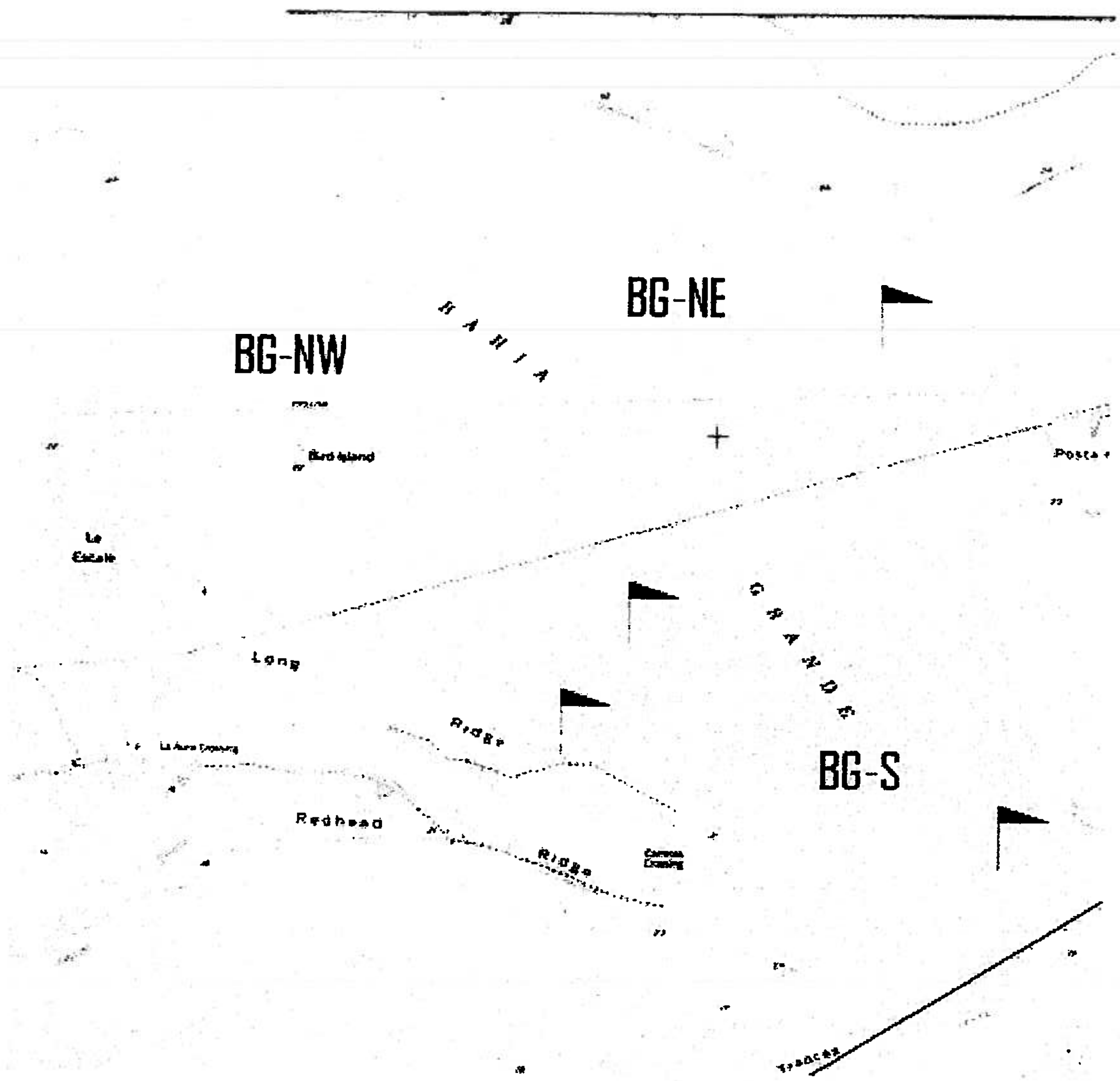

Fig. 2. Environmental data is recorded every 30 minutes and downloaded to worldwide web site for public access and retrieval every 24 hours (see http://lighthouse.tamucc.edu/BahiaGrande). Also shown are the three major sampling divisions: Bahia Grande South (BG-S), Bahia Grande Northwest (BG-NW), and Bahia Grande Northeast (BG-NE). The pilot channel opens into BG-S.

nitrogen, soluble reactive phosphate, water column chlorophyll, sediment chlorophyll and phytoplankton. No seagrass sampling or epiphyte monitoring occurred during this reporting period since no significant seagrass was present in the basin. In addition, no drift algal monitoring occurred during the project period since none was present in the basin.

The sampling design described above was used each quarter to randomly select new sampling sites except for August 2006 and November 2006 when a modified sampling scheme was performed. Additional site locations within each of the three sampling regions were randomly generated for use in the event that the primary sites are inaccessible. The sampling points were entered into a field GPS unit prior to field sampling. The August 2006 sampling was an extra (and therefore voluntary) sampling event included to maintain the continuity of the data set. At the time of the November 2006 sampling, no contract was in effect so this was considered a voluntary sampling event. One site was sampled in each sector by wading in November. All samples for each quarter were collected within a 1-2 day period. This sampling design was used for all biological data collection, with the exception of edge-of-basin sites (tidal flat algal mat sampling and bag seine sampling).

Water Quality Monitoring – Water quality indicators were recorded at nine sites each quarter. At each site measurements of dissolved oxygen (DO), salinity, temperature, specific conductivity, pH, depth and Secchi depth were measured using a HydroLab Quanta. Triplicate water samples were collected in 250 mL plastic bottles for laboratory analysis of nitrate-nitrite nitrogen, ammonium nitrogen, dissolved reactive phosphorus, and TSS. If salinity values exceeded the measuring capacity of hand-held equipment, a water sample was collected for laboratory analysis. In the laboratory, two subsamples were drawn from the original sample and diluted with an appropriate volume of de-ionized water. The salinity of the mixture was measured with a refractometer.

Four analyses were performed on water samples- nitrate-nitrogen, ammonium-nitrogen, soluble reactive phosphorus and total suspended solids. All analyses are EPA Methods (nitrate- EPA Method 0353.2, ammonium- EPA Method 0350.2, soluble reactive phosphorus- EPA Method 0365.2, total suspended solids- EPA Method 160.2). Within 24 hrs of collection, water samples were filtered through Whatman GF/C filters and frozen for later analysis of nitrate, ammonium and phosphate. TSS samples were refrigerated until analysis which was generally completed within two days of collection.

Phytoplankton and Water Column Chlorophyll Monitoring – At each water quality sampling site, one subsurface 100 ml whole water sample was collected quarterly and preserved with 1% Lugol's solution for phytoplankton analysis. Triplicate water samples for phytoplankton and chlorophyll analysis were collected in amber 250 mL plastic bottles. Phytoplankton samples were transported back to the lab in a cooler containing ice and filtered within 24 hrs onto Whatman GF/C filter and then frozen. Chlorophyll *a* analysis was performed according to EPA Method 0445.

Microphytobenthos Monitoring – At each site, four 33 cm^2 sediment cores were collected. The cores were collected one meter apart along a transect extending away from the sample site. From each core, the top one cm of sediment was collected, put in a labeled plastic bag and placed in a cooler containing ice. Three samples were homogenized and frozen upon return to the lab while the remaining sample was preserved 2% formalin and archived for possible algal composition analysis. Chlorophyll *a* analysis was performed based on the method of Porra et al. (1989).

Cyanobacterial Mat Sampling – To monitor possible development of tidal flat cyanobacterial mats, four edge-of-bay sampling locations were randomly selected. At each site, four 289 cm^2 surface sediment samples (1 cm deep) were collected along a transect one meter apart using a paint scraper. The sediment was transferred to a labeled plastic bag and placed in a cooler containing ice.

Sediment samples were analyzed for chlorophyll a using the method of Porra et al. (1989). This method employs N,N dimethylformamide (DMF) for extraction of chlorophyll, spectrophotometric measurement of absorbance at selected wavelengths and use of simultaneous equations developed by Porra et al. (1989). If sediment was completely dry, water was added up to 5% of sample weight to maintain the extraction efficiency of the DMF.

Statistical Analyses – Prior to statistical analysis, data were routinely assessed for normality using the Shapiro-Wilks statistic, skewness and kurtosis. If appropriate, data were transformed to achieve normality. If data were not normally distributed, comparisons were made using the Kruskal-Wallis ANOVA, otherwise ANOVA was used to make comparisons. SYSTAT version 11.00.01 was used for statistical analyses.

Benthos & Nekton

The objectives of this component included: 1) monitoring the physiochemical parameters of water column habitats (i.e., structural monitoring); 2) monitoring the redevelopment of fishery-relevant components of the Bahia Grande system (i.e., benthic and nekton communities); and 3) characterizing baseline conditions and their variability as the system organizes and sustains itself in time (i.e., to index the seasonal and annual changes in the conditions of the ecosystem). The biological monitoring program utilized four survey approaches to achieve the objectives: 1) water quality measurement systems; 2) benthic community surveys; 3) epibenthic community surveys; and 4) nekton community surveys. Data generated by these surveys were analyzed to determine community development, abundance, spatial distribution, and habitat use. Quarterly sampling occurred in

Water Quality – Water quality indicators were obtained from the three in-basin water quality stations provided by the Division of Nearshore Research's (DNR-Texas A&M Corpus Christi) which monitor dissolved oxygen (DO), pH, salinity, conductivity, depth, and temperature (Fig. 2). Basic water quality parameters were also collected by field personnel during sampling events including DO, salinity, specific conductivity, and temperature using a hand-held multi-parameter water quality probe (e.g., YSI 85) suspended from the side of the boat at each station. All water quality parameter measurements were collected in duplicate by field personnel. Water depth was determined using a 2-meter staff marked in centimeter increments. Secchi depth was determined by using a standard 20-cm diameter black and white secchi disc. When salinity values exceeded the measuring capacity of hand-held equipment (> 80 ppt), water samples were collected in a 100 ml plastic bottle for laboratory analysis. In the laboratory, two subsamples were drawn from the original sample and diluted with equal volumes of deionized water. The salinity of the mixture was measured with hand-held multi-probe or refractometer.

Benthic Habitat Surveys – A total of 24 sampling stations were randomly selected as described in the sampling design section (eight primary stations and four alternates within each of the three sampling areas) for quarterly sampling interval. All sites were located using Global Positioning Satellite System (GPS).

A PVC cylindrical push corer, 8.3 cm diameter, was used to sample benthic habitats to a depth of 10 cm. Cores were placed into 500µm nylon mesh bags and field washed by gently homogenizing the samples by hand. Four replicate samples (53.5 cm^2) were taken at each station yielding a total sampling station area of 214 cm^2. Core samples were stored in ambient seawater while in the field and during transportation to the laboratory where they were transfer to a 10% formalin and seawater mixture containing the protein stain Rose Bengal. All benthic samples were allowed a minimum of one 1-2 weeks for fixation and then preserved in 45% isopropyl alcohol. Abundance of benthic organisms was expressed as average number of individuals per square meter of sea bottom and forms the basis of comparisons between sampled areas and sampling intervals. A reference collection, consisting of representative specimens of taxa identified in core samples, is maintained at the University of Texas Brownsville.

Epibenthic habitat surveys – Sampling design and site selection criteria for sampling of epibenthic habitats followed Texas Parks & Wildlife Department (TPWD) standard operating procedures (SOPs). Nine edge-of-bay sampling locations were randomly selected for each quarterly sampling interval as described above (three locations within each of the three sampling areas). Two additional site locations within each sampling area were randomly generated for use in the event that any of the three primary sites were inaccessible.

An 18.3 m (60 ft) long, 1.8 m (6 ft) deep bag seine was used to sample epibenthic habitats. The net was constructed according to TPWD specifications with 19 mm (0.75 in) stretched nylon #5 multifilament mesh in the wings and 13 mm (0.50 in) stretched nylon #5 multifilament mesh in the bag. At each sampling site, the net was pulled parallel to shore for a distance of 15.2 m (50 ft) long with the shoreward pole positioned at a minimum depth of 10 cm. A net width of 12.2 m (40 ft) was maintained by attaching a pre-measured line between the net poles resulting in a 186 square meter sampling area at each station.

Fish and invertebrates captured in bag seine samples were identified and enumerated in the field. The first 19 haphazardly selected specimens of each species collected were measured for size. Crab size was represented by carapace length, shrimp by total length, and fish by fork length. For samples in which fewer than 19 individuals of a species were collected, all individuals were measured. Abundance of epibenthic organisms was expressed as average number of individuals per square meter of sea bottom and forms the basis of comparisons between sampled areas and sampling intervals. A reference collection, consisting of representative specimens of each species identified in bag seine samples, is maintained at the University of Texas Brownsville.

Water column habitat surveys – Sampling of water column habitats followed Texas Parks & Wildlife Department SOPs. Gill net sampling was employed to target mainly larger fish species (e.g., > 100-mm fork length; FL). Sampling utilized experimental gill nets with dimensions of 61 m (200 ft) long, 0.9 m (3 ft) deep, with 15.2 m (50 ft) sections of 76 mm (3 in), 102 mm (4 in), 127 mm (5 in), and 152 mm (6 in) stretched monofilament mesh. The original net height of 1.2 m (4 ft) was modified to accommodate realized depth of the basin after flooding.

Net deployment was limited to the deepest part of each of the three sampling areas (one net in each of the three sampling areas). Nets were deployed at dusk and retrieved at dawn. The first 19 haphazardly selected individuals of each species, in each mesh panel were measured to the nearest mm FL in the field. The remainder of the sample was identified and counted. Catch per unit effort (CPUE) was expressed in terms of the average number of fish captured per 100 h of gill netting and forms the basis of comparisons between the relative abundance of fishes between areas and sampling intervals.

Sediment Geochemistry

Samples were collected quarterly at locations and dates shown in Table 1. Short gravity cores were collected using pvc coring equipment. Cores were transported back to the laboratory, split and sub-sampled. The upper 5 cm was sectioned from the top of the core. The other half was sent to UTB for grain size analysis. The upper section was dried at 95°C for 12-15 hours, ground with a mortar and pestle, homogenized, and further divided into 3 sub-samples, for analysis of a) organic carbon, b) carbonate carbon and 3) metals.

Laboratory Analysis

The procedures outlined by Loring and Rantala (1992) are used with some modifications. Metallic elements were digested and processed using the procedures given in the USEPA SW 846-3050B manual for analysis of solids. This procedure is not a complete digestion for silicate and aluminosilicate minerals and hence will not give 100% yields for most metals. This procedure is however, reproducible and yields critical information for environmentally available metals. Complete sediment digestion requires HF and $HClO_4$ acids and was not deemed necessary for metals characterization of the Bahia Grande basin.

Specific geochemical laboratory analysis and modifications are given below.

Organic Carbon – The procedure given in Loring and Rantala (1992) was followed with some modifications. The procedure is basically a Walkely-Black potassium dichromate/sulfuric acid oxidation of organic material followed by a back titration with ferrous ammonium sulfate. According to the procedure, a factor of 3 is used to convert organic matter to organic carbon. Each sample was vacuum filtered prior to titrating enabling a clearer end point. The indicator was changed to ferroin solution. A standard sediment (PAC) was used as the SRM.

Carbonate Minerals – Loring and Rantala's procedure was followed without modification. The variability was determined by analyzing replicates and using pure reagent grade $CaCO_3$ as a calibration standard.

Table 1. Coring locations and water depths for 2007 sediment sampling.

Collection Date	Site ID	Latitude (N)	Longitude (W)	Water Depth (m)
3/24/2007	SA	26 2' 09.96"	97 16' 54.84"	0.5
	SC	26 1' 50.16"	97 17' 59.99"	0.5
	NW A	26 2' 58.2"	97 18' 59.96"	0.28
	NW C	26 2' 59.96"	97 18' 45.00"	0.42
	NE A	26 2' 30.12"	97 18' 10.08"	0.49
	NE C	26 3' 00.00"	97 18' 20.16"	0.41
5/15/2007	SA	26 1' 48.00"	97 16' 40.08"	0.31
	SC	26 2' 07.44"	97 17' 48.84"	0.35
	NW A	26 2' 23.64"	97 18' 17.28"	0.40
	NW C	26 2' 49.56"	97 19' 18.84"	0.27
	NE B	26 2' 57.12"	97 19' 00.84"	0.45
	NE C	26 3' 02.52"	97 18' 01.14"	0.33
8/8/2007	SA	26 2' 04.92"	97 17' 25.08"	0.53
	S B	26 1' 57.24"	97 17' 20.04	0.60
	NW A	26 2' 20.04"	97 19' 09.84"	0.60
	NW B	26 2' 20.04"	97 18' 39.96"	0.42
	NE B	26 2' 54.96"	97 17' 35.16"	0.52
	NE C	26 3' 00.00"	97 17' 60.00"	0.45

Major metallic ions – Major cations include calcium, magnesium, sodium and potassium. Digested samples were diluted from 50 to 100 fold and analyzed by flame atomic absorption spectroscopy. Lanthanum was added to suppress ionization in calcium. Sodium and potassium were also diluted from the digested sample according to their concentration in the digestate.

Essential Trace Metals – Iron, manganese, zinc and copper were also measured in acid digested samples. Flame atomic absorption spectroscopy was also used to determine the concentration of these metals. Fe was analyzed by diluting the original digested sample 50 fold.

Non-Essential Trace Metals – Arsenic, lead and chromium were determined by graphite furnace atomic absorption techniques. Each sample was diluted appropriately to accommodate the calibration for each element.

Sediment Grain Size – Cores from each sample were dried and 50 g of material was processed for total organic carbon, total carbonate. Then samples were dry sieved for course fractions and wet sieved for the fines. After wet sieving, then using the pipette method the fines were fractionated. Prior to statistical analysis, data were routinely assessed for normality using the Shapiro-Wilks statistic, skewness and kurtosis. If appropriate, data were transformed to achieve normality. If data were not normally distributed, comparisons were made using the Kruskal-Wallis ANOVA, otherwise ANOVA was used to make comparisons.

Water Levels and Hydrodynamics

Hydrologic data obtained during 2007 consisted of flow measurements in channels within the system.

Mean Channel Velocity Measurements

Point measurements of water velocity at low and high tides, timed to coincide with spring / neap tides, were collected at various channels. Manual mean channel velocities were collected weekly over the summer of 2007 by Mr. William Cortez for Channel E. Standard USGS river velocity measurement techniques were utilized for measuring flow rates in the initial or "pilot" channel that now connects the Bahia Grande with the Brownsville Ship Channel (see Channel 'E' in Fig. 3). Additional flow measurements were taken at internal channels C2 and B2 when conditions permitted.

RESULTS & DISCUSSION

Biological Monitoring

Algae and Seagrass

Water Quality – The highest water temperatures were found in August 2006 and 2007 with a basin average of 31.2 and 30.2°C, respectively with the coldest temperatures in November 2006 having an average of 21.6°C (Fig. 4). Temperature differences among the sectors for any sampling date were generally not significant. There was no consistent spatial pattern to water temperature.

Salinities in the Bahia Grande were always hypersaline (>35 PSU) (Fig. 5). Highest salinities were noted in May 2007 when salinities were at least 70 PSU or greater. There were salinity differences among the sectors with the South sector generally having the lowest salinities of the three sectors.

Basin salinity is a function of tidal exchange processes, precipitation, air temperature, evaporation rate and water exchange among the sectors. The south sector generally had the lowest salinity values likely due to its direct connection to the pilot channel. Salinities above 60 PSU inhibit growth and survival of *Halodule wrightii* which is the seagrass most likely to succeed in the basin (McMillian and Moseley, 1967). Average basin salinity was below 60 PSU in March and August 2007. If, after August 2007, salinity stays below 60 PSU, we expect to find *Halodule* in the basin in 2008.

Dissolved oxygen values in the Bahia Grande exceeded 4 mg/L except for August 2006 (average 3.7 mg/L) (Fig. 6). Percent saturation values were generally higher than 75% and were frequently above 100%. There was no consistent pattern in dissolved oxygen related to season or sector.

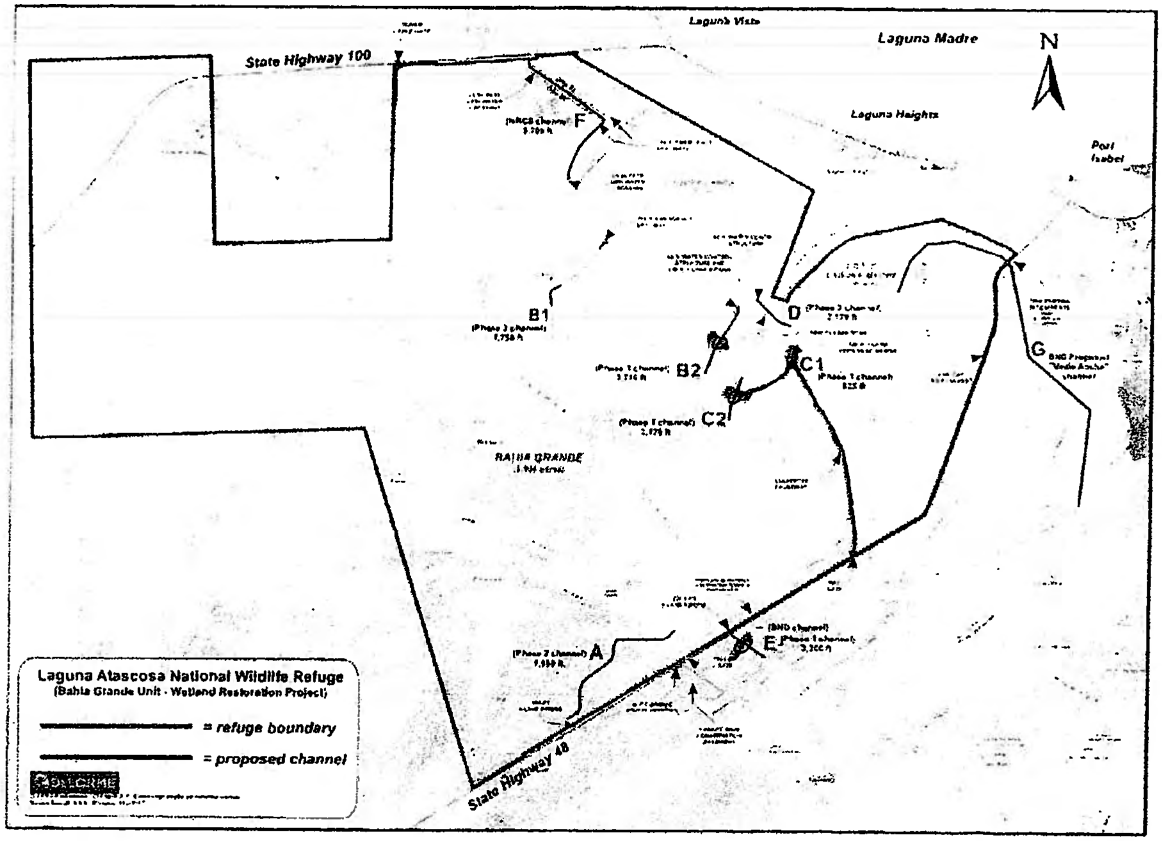

Fig. 3. Map illustrating the extent of Laguna Atascosa National Wildlife Refuge, the Bahia Grande Wetland Complex inside the refuge boundary, and planned or completed channels connecting neighboring bodies of water. Channel E is the "pilot" channel that hydraulically re-connected the Bahia with tidal influences via the Brownsville Ship Channel. Channels B2, C1, C2, and D were also completed recently and serve to connect the Bahia Grande (proper) with the Laguna Larga pool to the North-Northwest and the Little Laguna Madre to the Northwest. Channel D was dug but remains plugged at the northwest end. Channels F, B1, and A have either been scrapped or are on hold. Channel E will be widened starting January of 2009. (Data Source: NRCS)

Water column ammonium values varied widely within the basin and seasonally. Patterns were not evident. Highest average ammonium value (7.0 µM NH_4^+) occurred in November 2006 (Fig. 7). Nitrate-nitrite values were low (<4 µM) during each sampling (Fig. 8). No pattern among the basin sectors was noted. Soluble reactive phosphate values were also low (<2 µM) throughout the sampling period.

Total suspended solids levels varied significantly among sampling dates and among the basin sectors (Fig. 9). Highest average basin value occurred in March 2007 (>400 mg/L) while lowest values occurred in May 2007 (<50 mg/L). The fine and loose nature of the sediments makes them highly susceptible to wind suspension.

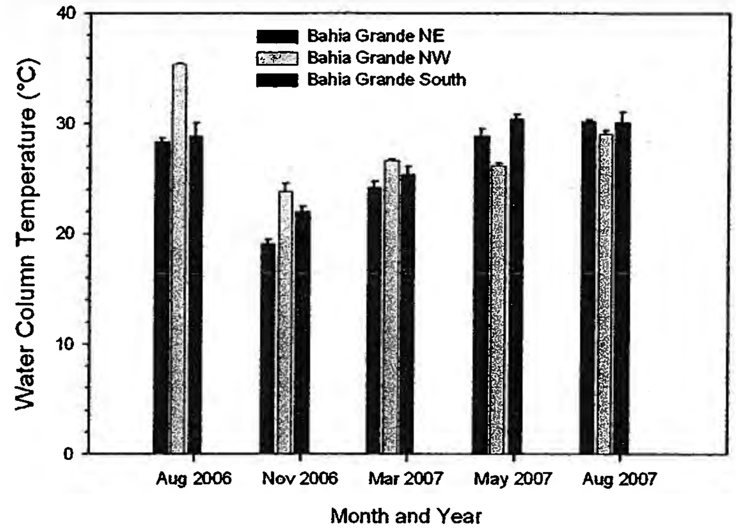

Fig. 4. Quarterly water column temperatures for the Bahia Grande, Aug. 2006-Aug. 2007.

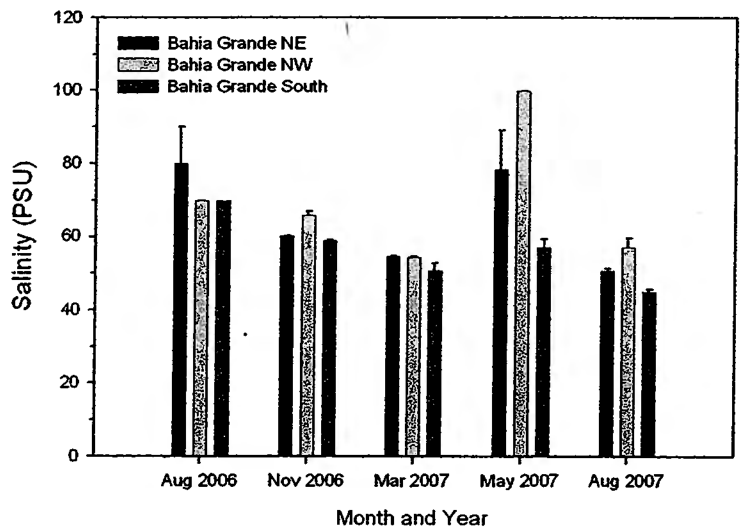

Fig. 5. Quarterly water column salinities for the Bahia Grande, Aug. 2006-Aug. 2007.

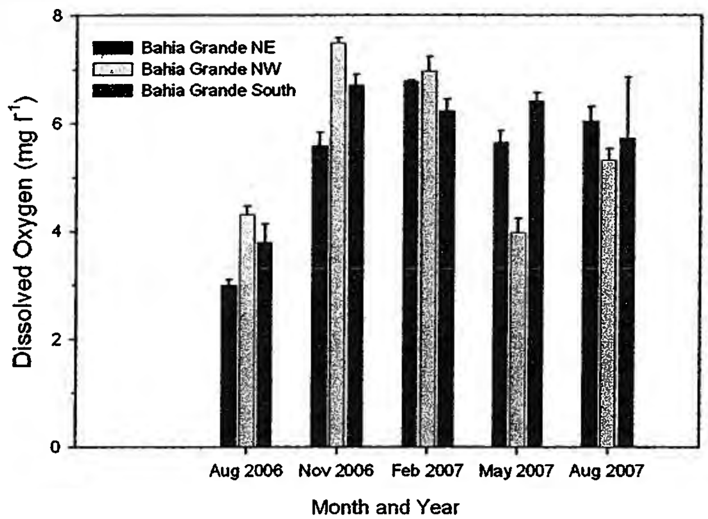

Fig. 6. Quarterly water column dissolved oxygen for the Bahia Grande, Aug. 2006-Aug. 2007.

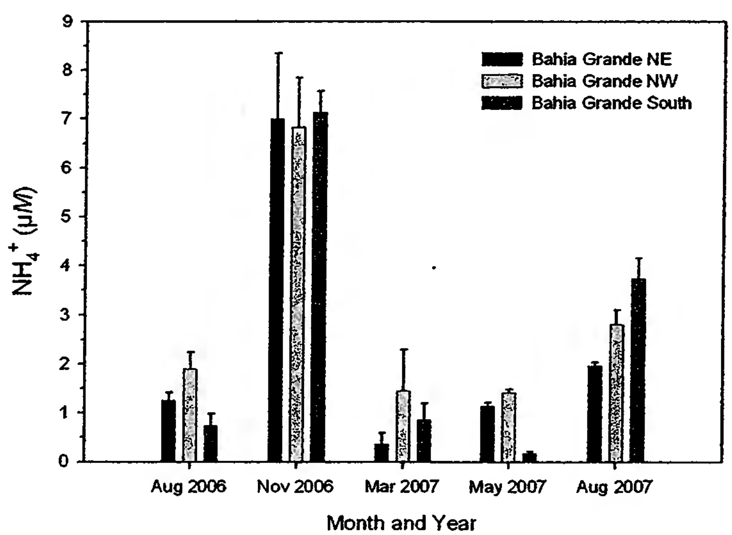

Fig. 7. Quarterly water column ammonium for the Bahia Grande, Aug. 2006-Aug. 2007.

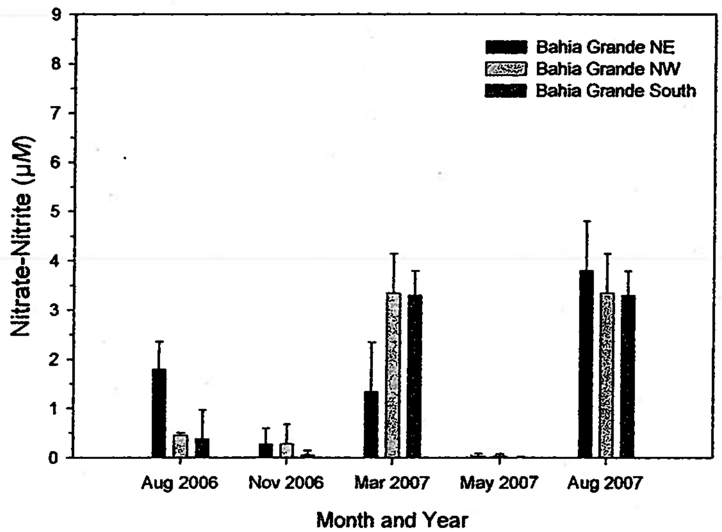

Fig. 8. Quarterly water column nitrate-nitrite for the Bahia Grande, Aug. 2006-Aug. 2007.

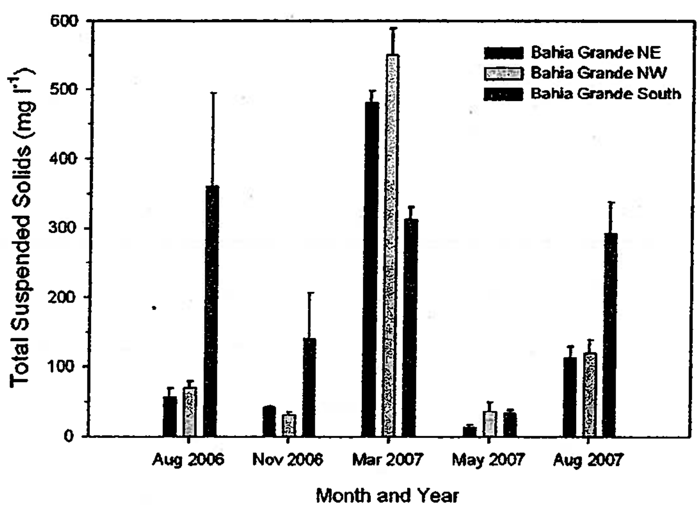

Fig. 9. Quarterly water column total suspended solids for the Bahia Grande, Aug. 2006-Aug. 2007.

<u>Phytoplankton and Water Column Chlorophyll</u> – Water column chlorophyll *a* values were <10 mg/L from August 2006 to May 2007 (Fig. 10). The highest values occurred in August 2007 (74 mg/L) which coincided with the highest phytoplankton abundance (Fig.11). No consistent pattern was evident among the basin sectors.

Phytoplankton largely consisted of indeterminate coccoid microalgae ranging in diameter from 2-5 microns. Microalgal abundance was generally below 200,000 units/mL but reached algal bloom levels (>1 million units/mL) in August 2008. Pennate diatoms and cyanobacteria were the next most common groups. There was no pattern among the sectors. The high August phytoplankton and water column chlorophyll values indicate that a microalgal bloom occurred for the first time in the Bahia Grande. The bloom may have been transported into the basin through the pilot channel which is supported by the highest chlorophyll values occurring in the south sector. It is not known how long this bloom was sustained. Dead cells from the bloom will contribute to the sediment organic matter which may help stimulate development of the benthic faunal community.

<u>Microphytobenthos</u> – Sediment chlorophyll values ranged from 2 to 26 µg chl *a*/g with the highest values occurring in March 2007 and the lowest values in August 2007 (Fig. 12). There was no notable pattern among the sectors.

<u>Cyanobacterial Mat Survey</u> – Edge-of-basin samples were collected for sediment chlorophyll analysis in June 2007 and October 2007. Mean sediment chlorophyll *a* values for the June collection ranged from 3.54 to 28.0 µg chl *a*/g while average October values ranged from 0.11 to 3.20 µg chl *a*/g (Table 2). Cyanobacterial mats typical of the Laguna Madre wind tidal flats were found for the first time at one non-sampled site in June 2007.

<u>Interannual Comparisons</u> – Comparing August 2005, 2006 and 2007, average basin salinity was highest in 2006 (70 PSU) while 2005 and 2007 values were about the same (Fig. 13). The basin was reconnected to tidal flow in July 2005. If it is assumed that the salinity of the inflow water was about 35 PSU, the August 2005 salinity indicates how rapidly salinity can increase in the basin but residual salt in the basin sediments may have contributed to this salinity increase. In 2007, precipitation levels were higher than normal especially in the 2^{nd} half of the year and basin salinity decline reflects that meteorological effect (Fig. 14). Basin water temperatures were typical (Fig. 15).

Phytoplankton (water column) chlorophyll is a good general indicator of water quality. Phytoplankton growth is strongly tied to light, salinity, temperature, pH, and nutrient levels. From fall 2005 to summer 2007, chlorophyll levels in the basin were modest (Fig. 16). Since algae and seagrass have many of the same requirements, the algal bloom that occurred in August 2007 may signal that conditions are suitable for seagrass development. In last year's annual report it was noted that in a short-term experiment, sediment from the Bahia did support *Halodule* growth. The key to development of a seagrass community in the Bahia Grande is stabilization of salinities at a tolerable level generally thought to be less than 60 PSU.

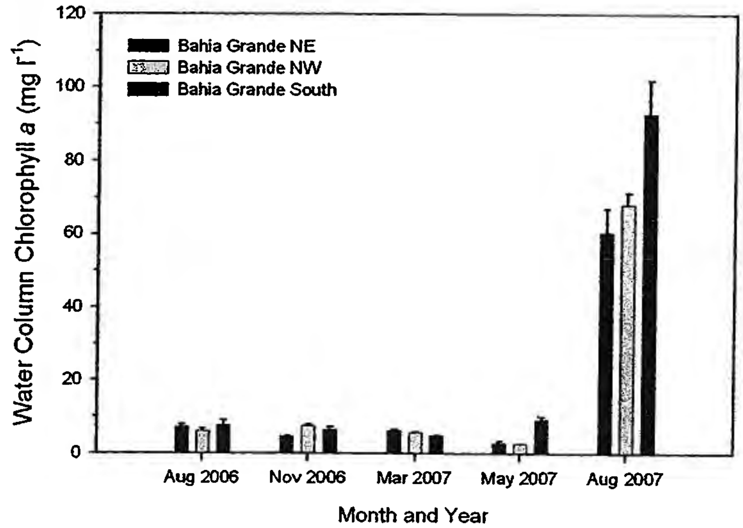

Fig. 10. Quarterly water column chlorophyll *a* for the Bahia Grande, Aug. 2006-Aug. 2007.

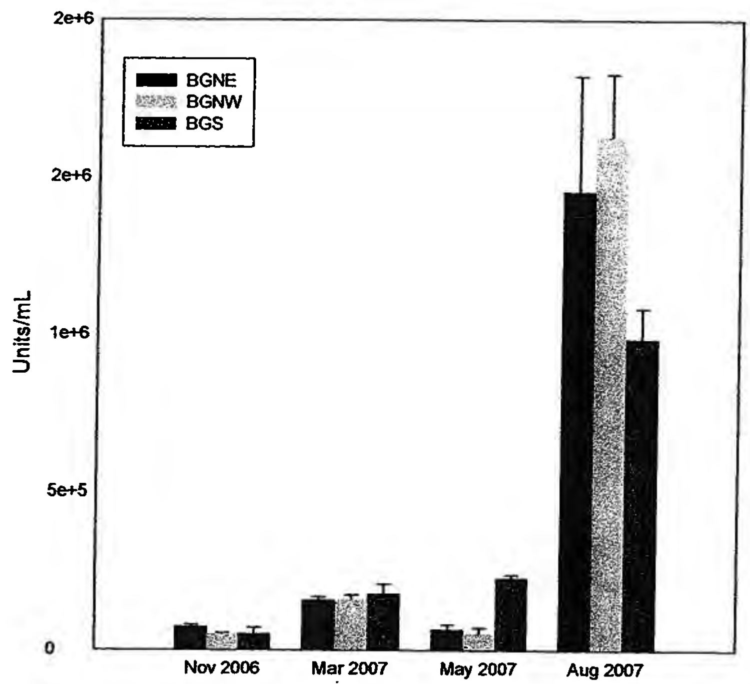

Fig. 11. Quarterly phytoplankton abundance for the Bahia Grande, Nov. 2006-Aug. 2007.

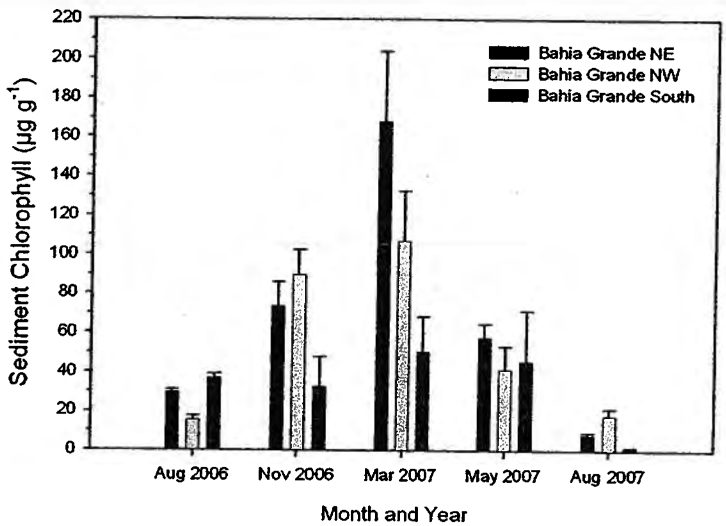

Fig. 12. Quarterly sediment chlorophyll *a* for the Bahia Grande, Aug. 2006-Aug. 2007.

Table 2. Bahia Grande edge of bay sediment chlorophyll *a* values for 2007.

Collection Date	Sector	Site	Mean ug/g	SD ug/g
6/21/2007	BGS	A	28.05	18.00
6/21/2007	BGS	B	11.67	4.73
6/21/2007	BGNW	C	12.48	9.93
6/21/2007	BGNE	D	3.54	2.09
10/30/2007	BGSE	A	1.34	0.41
10/30/2007	BGSW	B	0.11	0.08
10/30/2007	BGNE	C	3.20	1.22
10/30/2007	BGNW	D	2.08	1.55

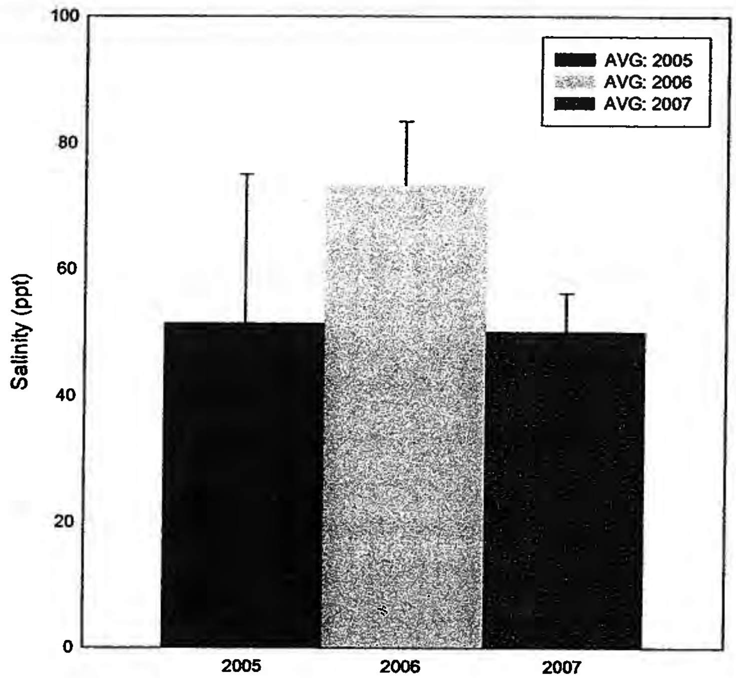

Fig. 13. Bahia Grande average basin salinity for August 2005-07

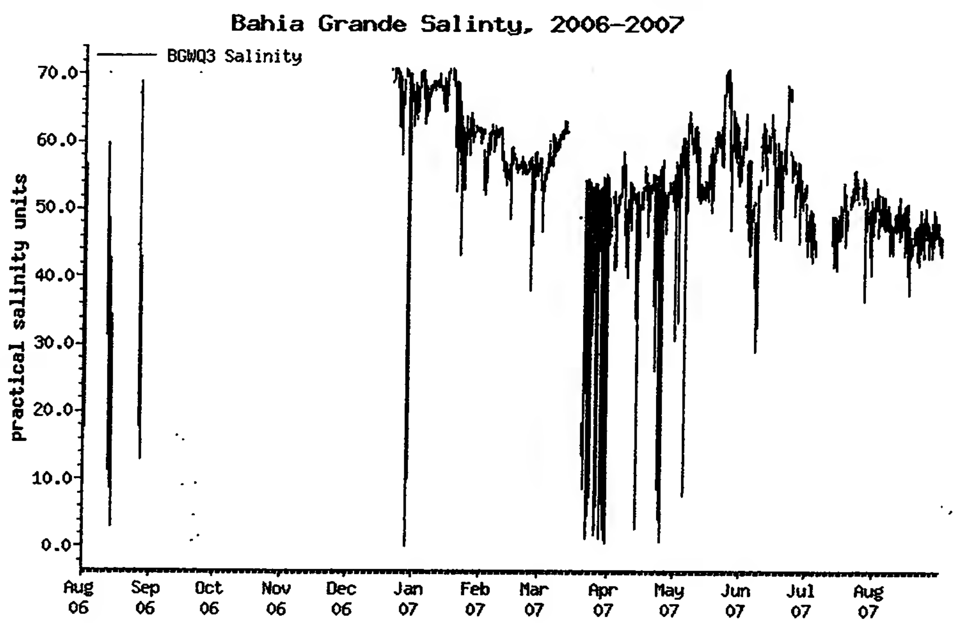

Fig. 14. Salinity at permanent monitoring station 1 in the Bahia Grande from August 2006 to August 2007.

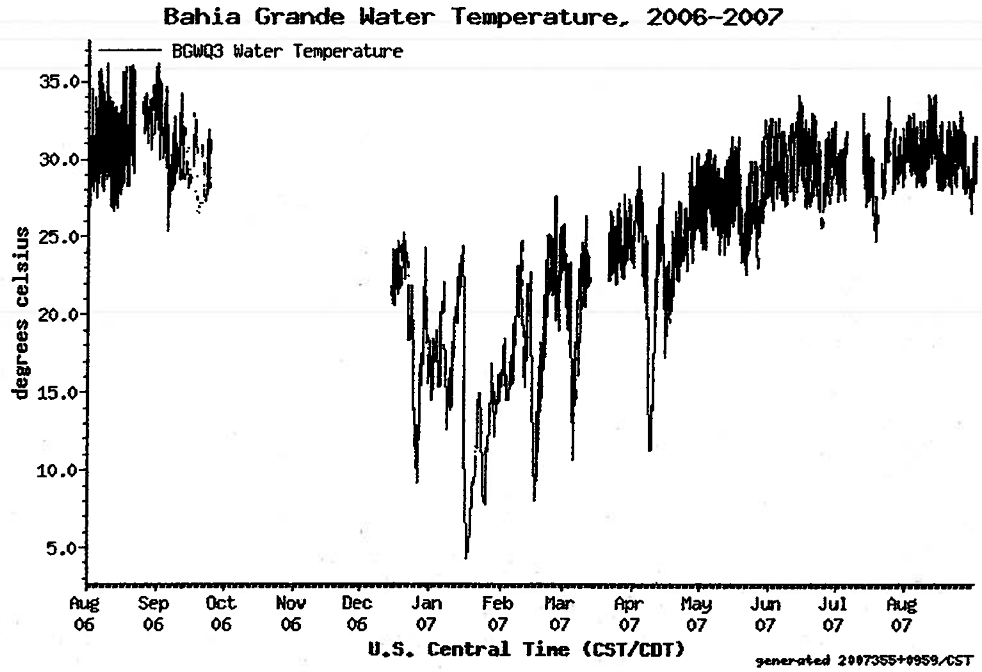

Fig. 15. Water temperature at permanent monitoring station 1 in the Bahia Grande from August 2006 to August 2007.

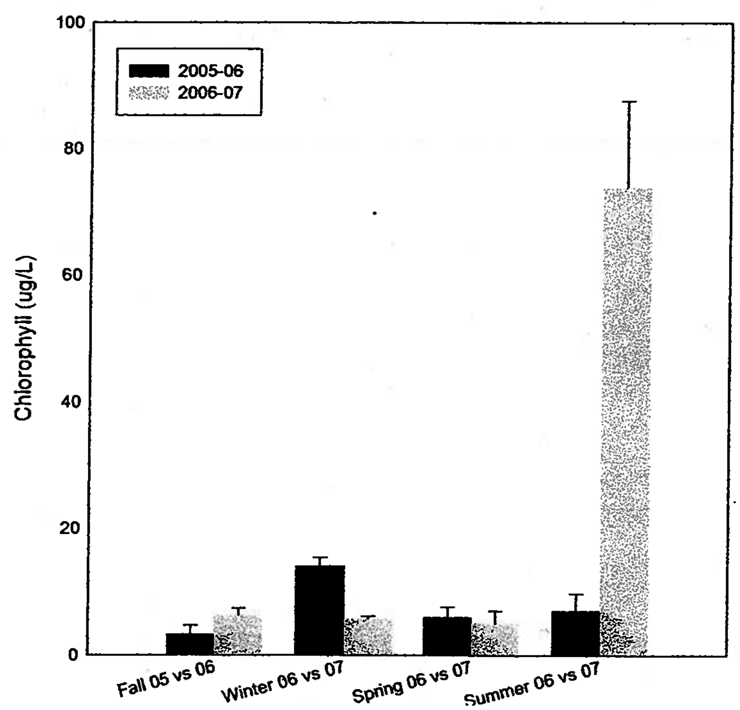

Fig. 16. Comparison of Bahia Grande quarterly water column chlorophyll values, 2006-07.

Benthos and Nekton

<u>Benthic habitat surveys</u> – Sampling of benthic habitats commenced during the February – April 2007 quarter, approximately 20 months following the July 2005 opening of the pilot channel. Sediment core samples and water quality data were collected from 24 randomly selected stations distributed across the three basin sectors (BG-S, BG-NW, and BG-NE). Water depths in some areas exceeded 0.7 m (averages for sampling sectors BG-S, BG-NW, and BG-NE were 0.64, 0.39, and 0.34 m, respectively). The average of salinity measurements of station grab samples from the southernmost area (BG-S) was 52 ppt. Northernmost area stations were more hypersaline averaging 58.5 and 63.1 ppt in BG-NW and BG-NE, respectively. Invertebrates were identified and enumerated from four replicate core samples collected at each station. Diversity of the benthic community was low (0.64, Fig. 17) as this was the first sampling interval following a three-month period (Summer 2007, Fig. 17) of extreme hypersalinity (>70 ppt) during which the benthic community had become dominated by salt-tolerant insects (Smith et al., 2006). Five macrobenthos species were collected: three were insect larvae (hydrophilids, dipterans, and ephydrids) and two were polychaete worms (*Polydora* and *Capitella*). When averaged over all stations in all areas, insect and polychaete densities averaged 15.6 and 7.8 individuals/m^2, respectively.

Moderate hypersalinity continued through the next sampling interval (May – July, 2007) as a result of increased precipitation (Brownsville reporting > 30.1 cm during this quarter). Sediment core samples and water quality data were collected from 24 stations. Salinity measurements of station grab samples were slightly lower compared with those of the previous sampling interval averaging 53.8 ppt (averages for sampling sectors BG-S, BG-NW, and BG-NE were 49.8, 56.3, and 55.2 ppt, respectively). Despite the moderate hypersalinity, benthic diversity decreased from 0.64 in the previous quarter to 0.28 (Fig. 17) as a result of a marked increase in dipteran larvae abundance (677 individuals/m^2). However, while diversity decreased, species richness increased from 5 in the previous sampling interval to 7 during the May – July sampling interval (Fig. 17B). Two additional polychaete worms (*Capitomastus* and Spionidae) were recorded. When averaged over all stations in all areas, polychaete densities increased to 110.9 individuals/m^2.

Above normal rainfall continued during the next sampling interval (August – October, 2007; Brownsville reporting 24.1 cm of precipitation) resulting in the lowest salinity values recorded since September 2005. Sediment core samples and water quality data were collected from all 24 stations. Salinity measurements of station grab samples averaged 45.6 ppt (averages for sampling sectors BG-S, BG-NW, and BG-NE were 46.2, 43.8, and 44.5 ppt, respectively). Polychaete densities continued to increase (373 individuals/m^2) while insect abundance decreased (9.7 individuals/m^{-2}). Further, the diversity and species richness values at 0.66 and 10 respectively were the highest recorded since the July, 2005 reflooding (Fig. 17).

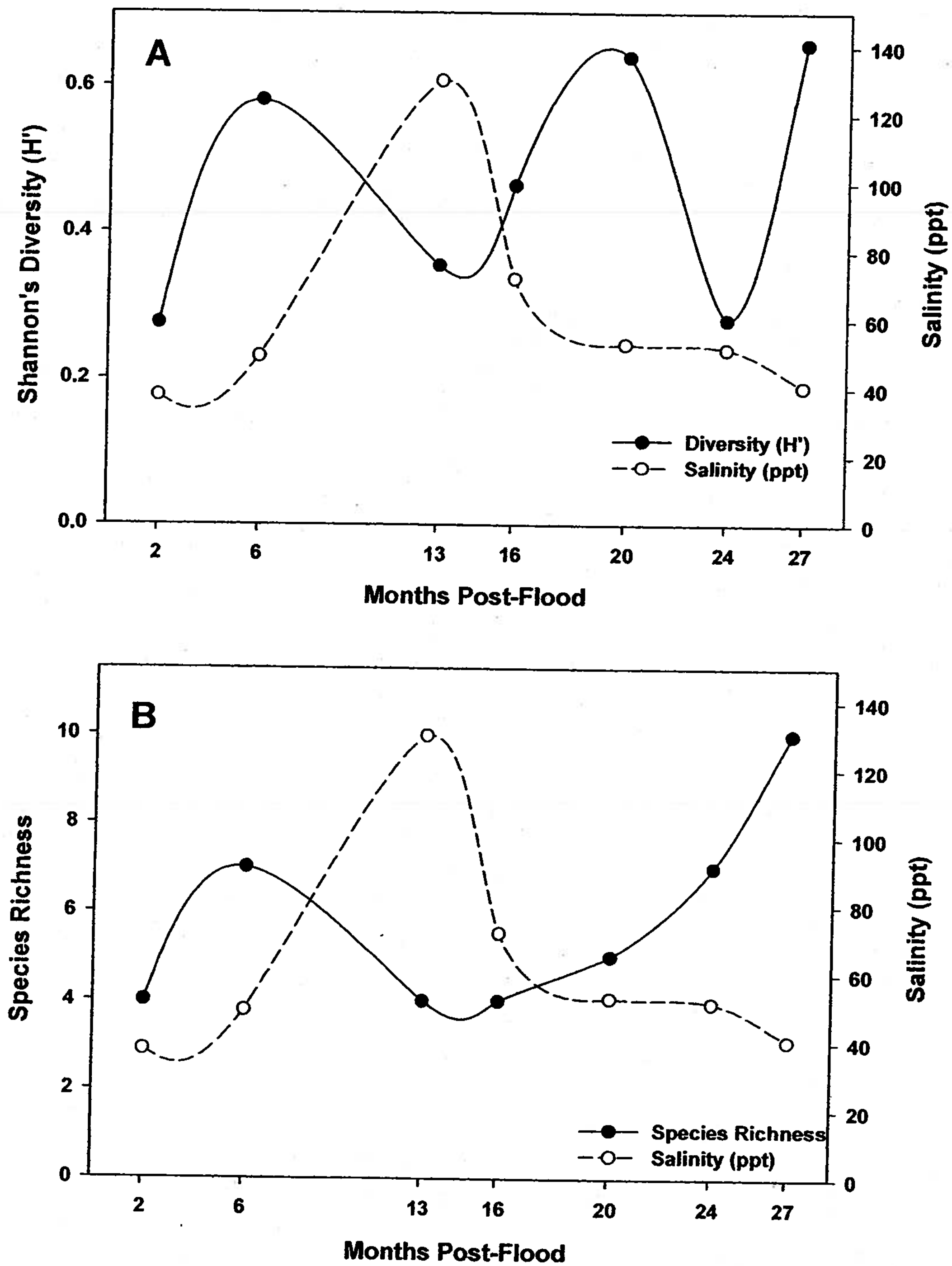

Fig. 17. Benthic habitat diversity values (A, Shannon's H', log 10), species richness (B), and mean salinity pooled over all stations in all areas by sampling interval (month). Data reported herein are from months 20, 24, and 27.

Epibenthic habitat surveys: Sampling of epibenthic habitats commenced during the February – April 2007 quarter (approximately 21 months following the July 2005 opening of the pilot channel). Bag seine samples and water quality data were collected from 9 randomly selected edge-of-the-bay stations distributed across the three basin sectors (BG-S, BG-NW, and BG-NE). Salinity values of station grab samples collected from shallow waters along the shoreline averaged 55.5 ppt (averages for sampling areas BG-S, BG-NW, and BG-NE were 48.2, 56.8, and 61.4 ppt, respectively). Nine fish species were recorded. The dominant fish species captured in bag seine samples was the sheepshead minnow (*Cyprinodon variegatus*). When averaged over all stations in all areas, sheepshead minnow densities averaged 14.3 individuals/m^2. Striped mullet (*Mugil cephalus*) was the second most abundant fish averaging 0.75 individuals/m^2. Five fish species including, Gulf menhaden (*Brevoortia patronus*), tidewater silverside (*Menidia peninsulae*), black drum (*Pogonias cromis*), Spot (*Leiostomus xanthurus*), and red drum (*Sciaenops ocellatus*) were recorded for the first time in Bahia Grande. Diversity (all samples combined) of fish species captured in bag seine samples during this quarter was 0.13 (Fig. 18). Penaeid shrimp were the only macroinvertebrates captured in bag seine samples. Brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) occurred at densities of 0.01 and 0.09 individuals/m^2, respectively.

Moderate hypersalinity continued through the next sampling interval (May – July, 2007) with salinity measurements similar to the previous sampling interval averaging 55.9 ppt (averages for sampling areas BG-S, BG-NW, and BG-NE were 55.3, 50.8, and 61.8 ppt, respectively). A total of nine fish species were recorded with the dominant species being sheepshead minnow (*Cyprinodon variegatus*), tidewater silverside (*Menidia peninsulae*), and striped mullet (*Mugil cephalus*) averaging densities of 4.6, 1.8, and 0.99 individuals/m$^-$ respectively. Three fish species including, Atlantic croaker (*Micropogonias undulates*), Florida pompano (*Trachinotus carolinus*), and pinfish (*Lagodon rhomboids*) were recorded for the first time. The latter is particularly interesting as it generally inhabits seagrass beds. Despite similar species richness, the more even densities among the species collected resulted in a greater diversity index (0.53) compared to the previous sampling interval (Fig 18). Penaeid shrimp were the only macroinvertebrates captured in bag seine samples. Brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) occurred at densities of 0.31 and 0.17 individuals/m^2, respectively.

Moderate hypersalinity continued through the next sampling interval (August – October, 2007) as a result of increased precipitation. Salinity values of station grab samples averaged 51.2 ppt (averages for sampling areas BG-S, BG-NW, and BG-NE were 41.6, 59.5, and 52.4 ppt, respectively). A total of 11 fish species were recorded with the dominant species being striped mullet (*Mugil cephalus*) and sheepshead minnow (*Cyprinodon variegatus*) averaging densities of 0.28 and 0.20 individuals/m^2 respectively. The density of sheepshead minnow was the lowest value recorded since the 2005 reflooding. Five fish species including lined sole (*Achirus lineatus*), bay anchovy (*Anchoa mitchilli*), white mullet (*Mugil curema*), flagfin mojarra (*Eucinostomus melanopterus*), and bay whiff (*Citharichthys spilopterus*) were recorded for the first time. Penaeid shrimp were the most abundant macroinvertebrates captured in bag seine samples. Brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) occurred at densities of 0.12 and 1.23 individuals/m^2, respectively.

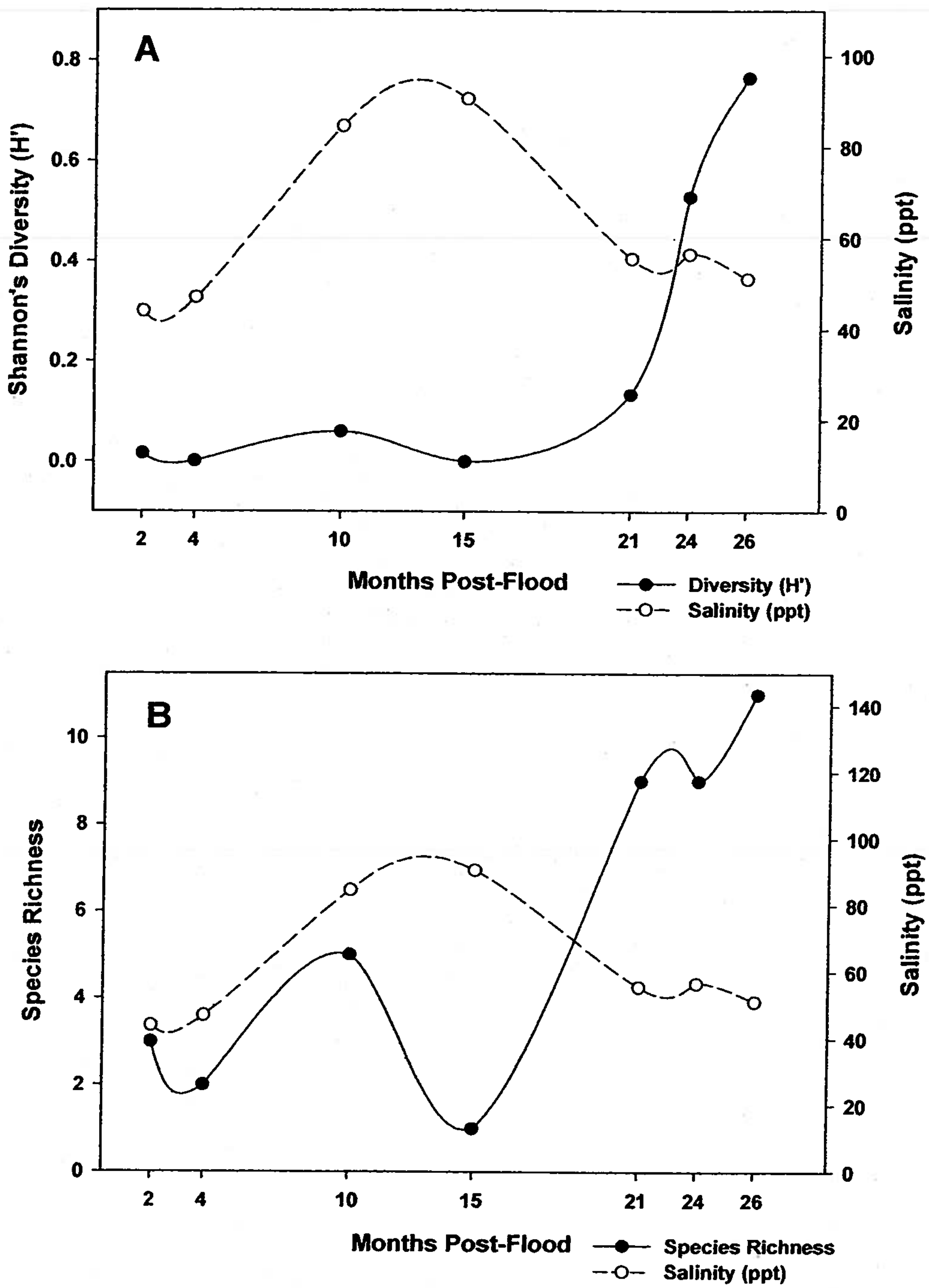

Fig. 18. Epibenthic habitat diversity values (A, Shannon's H', log 10), species richness (B), and mean salinity pooled over all stations in all areas by sampling interval (month). Data reported herein are from months 21, 24, and 26.

Portunid crabs, (blue crab [*Callinectes sapidus*] and lesser blue crab [*C. similis*] were recorded for the first time since September 2005. No other macroinvertebrate species were captured.

Water column habitat surveys: Gill net sampling commenced during the February – April 2007 quarter (approximately 21 months following the July 2005 opening of the pilot channel) to survey water column habitats for larger fish species. A single net was deployed and water quality data collected within each of the three sectors (BG-S, BG-NW, and BG-NE). During the February – April 2007 sampling interval, twelve striped mullet (*Mugil cephalus*) were collected in the south sector (BG-S). Total length (TL) of striped mullet ranged 29 – 39 mm. No other fish were captured (i.e., species diversity = 0).

During the May – July, 2007 sampling interval, a single black drum (*Pogonias cromis*), 9 ladyfish (*Elops saurus*), and 30 striped mullet (*Mugil cephalus*) were collected. The majority of fishes were captured in the south sector (BG-S). The black drum had a total length of 34.9 cm, lady fish ranged from 18.2 – 24.3 cm, and striped mullet ranged from 30.2 – 37.6 cm. Species diversity for the May – July sample was 0.28 (Fig. 19)A total of 8 fish species were captured in gill nets during the August – October, 2007 sampling interval. This included 9 ladyfish (*Elops saurus*, TL = 21.6 – 38.9 cm), 12 striped mullet (*Mugil cephalus*, TL = 31.8 – 41.3 cm), 3 black drum (*Pogonias cromis*, TL = 22.4 – 23.1 cm), 7 Hardhead catfish (*Arius felis*, TL = 29.4 – 36.8 cm), 3 Spanish mackerel (*Scomberomorus maculates*, TL = 37.3 – 43.8 cm), 1 Gulf menhaden (*Brevoortia patronus*, TL = 22.0 cm), 2 pinfish (*Lagodon rhomboids*, TL = 12.7 & 13.8 cm), and 2 spotted seatrout (*Cynoscion nebulosus*, TL = 35.8 & 40.0 cm). This was the first record for hardhead catfish, Spanish mackerel, and spotted seatrout in Bahia Grande. Species diversity for the August – October sample was 0.78 (Fig. 19).

Discussion – The study period, February - October 2007, was characterized by above normal rainfall with Brownsville, Texas, reporting 72 cm (annual rainfall average < 75 cm, Britton and Morton, 1989). The net result is that an extreme hypersalinity condition (> 70ppt) failed to develop in Bahia Grande as it did during the previous summer (Figs. 17-19). Under these moderate hypersalinity conditions, diversity of species in all examined habitats (benthic, epibenthic, and water column habitats) increased (Figs. 17-19).

The relationship between salinity and species diversity was analyzed further using linear regression models for benthic ($F = 16.2$; $df = 1, 153$; $P < 0.001$) and epibenthic ($F = 5.0$; $df = 1, 67$; $P = 0.029$) habitats. The model-predicted species diversity values were used to generate diversity contours across the basin dependent upon spatial variations in salinity (intersecting seconds of latitude and longitude) for two mean salinity regimes: 40 and 70 ppt. For benthic habitats, diversity is predicted to be much higher under an average basin salinity of 40 ppt compared to 70 ppt (Fig. 20). Under both the 40 and 70 ppt mean salinity regimes, diversity increases along the salinity gradient which increases south-to-north and east-to-west north of the railroad trestle (Fig. 20). A similar pattern is depicted for epibenthic habitats along the bay margins (Fig. 21).

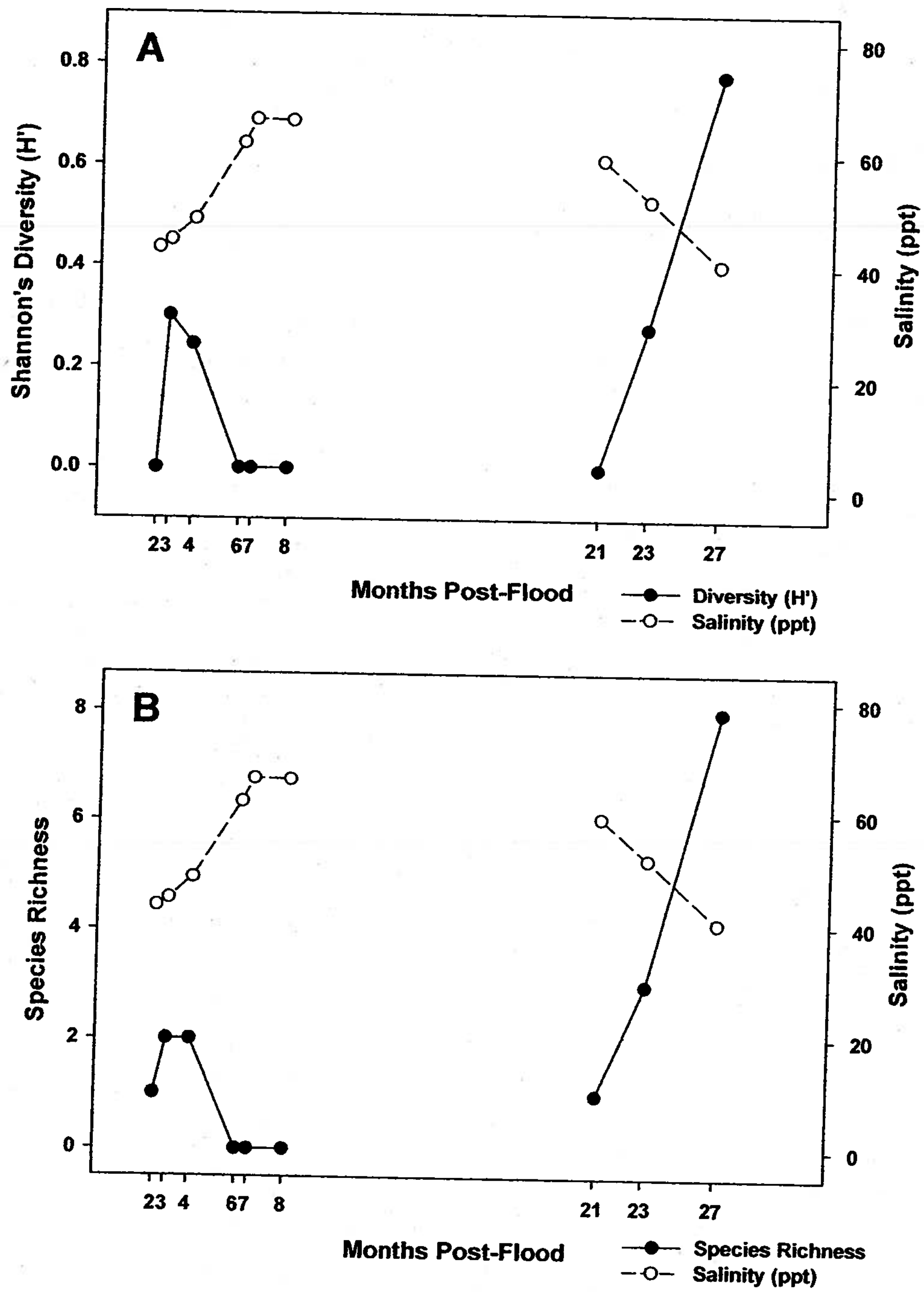

Fig. 19. Water column habitat diversity values (A, Shannon's H', log 10), species richness (B), and mean salinity pooled over all stations in all areas by sampling interval (month). Data reported herein are from months 21, 23, and 27.

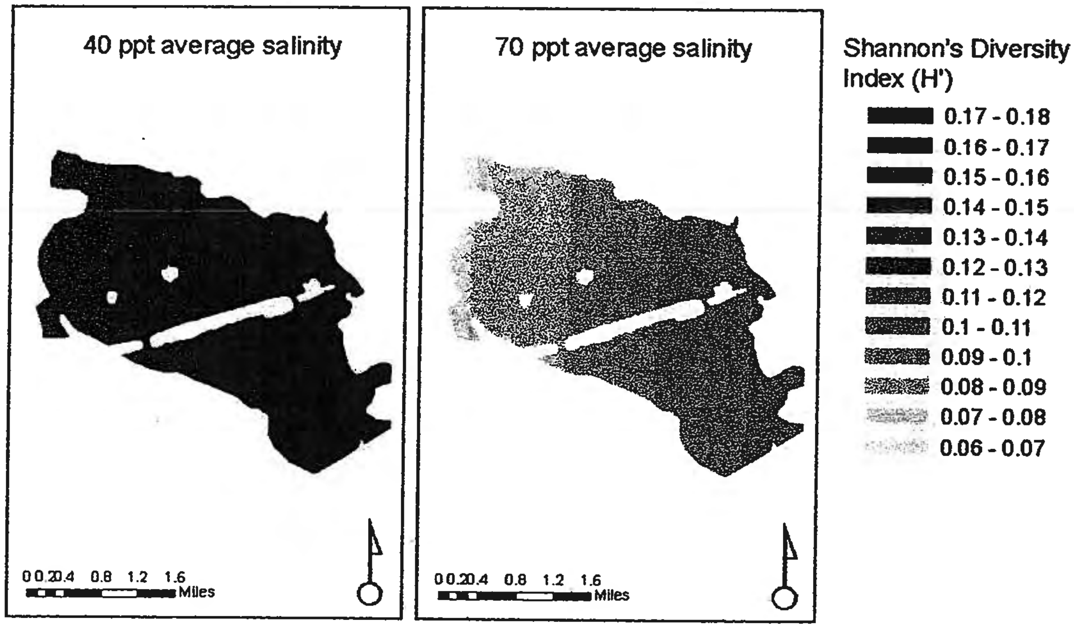

Fig. 20. Estimated Shannon's diversity values (H', base 10) for benthic macroinvertebrate assemblages across the Bahia Grande basin based upon salinity regimes of 40 and 70 ppt.

The hypersaline condition that periodically affects Bahia Grande since its reflooding is due to many interrelated factors, particularly, current pilot channel being too small to allow for adequate tidal exchange. This situation is exacerbated by the very large surface area relative to the volume of water at Bahia Grande making it very susceptible to high evaporation rates, particularly during prolonged droughts as occurred throughout the Spring and Summer of 2006. This hypersalinity has both direct and indirect effects on the direction of species succession in Bahia Grande. The extreme salinity levels directly controls which species can inhabit the area. For example only those species able to tolerate the extreme hypersaline conditions (e.g., salt-tolerant insects and sheepshead minnows) can utilize the system.

The Bahia Grande's anticipated value as nursery habitat for juveniles of important commercial species (finfish and shellfish) will be diminished under the current widely fluctuating salinity regime. While some adult species may have the capacity to withstand the harsh conditions, it is unlikely that juveniles, eggs, or larvae of desirable estuarine species will. Hypersalinity also impacts the water quality by influencing the amount of dissolved oxygen the water store. Hot, hypersaline waters hold very little oxygen. Therefore, the

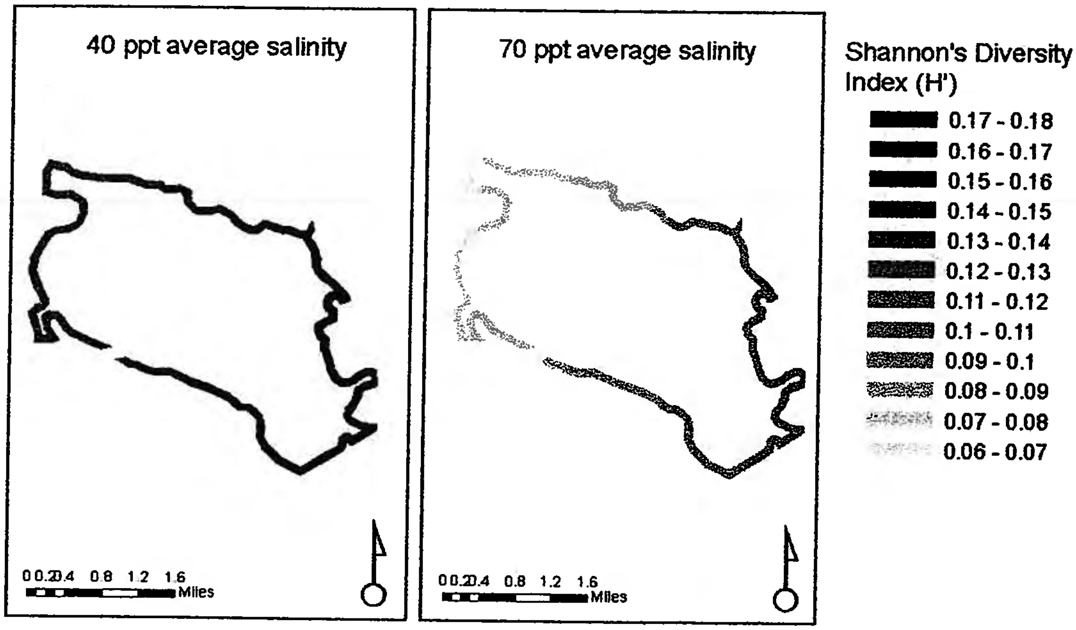

Fig. 21. Estimated Shannon's diversity values (H', base 10) for nearshore epibenthic assemblages at Bahia Grande basin based upon salinity regimes of 40 and 70 ppt.

findings reported herein continue to support the need for future manipulations and enhancement actions for increasing circulation throughout the system. Under a moderate hypersalinity regime as occurred during the current sampling period (February - October 2007) diversity of all sampled habitat increased demonstrating the importance of managing salinity in the system.

<u>Recommendations</u> – Any recommendation would require knowledge of acceptable end-points for the restoration process. If a system supportive of community assemblages similar to those of the adjacent Laguna Madre and South Bay is desired, preventing the development of extreme hypersalinity must be addressed. Marked differences among community assemblages and salinity regimes were detected on either side of the abandon railway suggesting it as a formidable barrier to within-basin circulation. Opening up more sections of railway foundation will likely increase basin circulation and create more habitat for nesting shorebirds. The Bahia Grande's anticipated value as nursery habitat for juveniles of important commercial species (finfish and shellfish) will be diminished under the current widely fluctuating salinity regime. During periods of extreme hypersalinity the basin

community undergoes a drastic turnaround from a developing estuary to assemblage reminiscent to those of wind-tidal flats and coastal evaporative salt ponds.

Sediment Geochemistry

Results given in the following Tables and Figures are organized by date and sector. For example, replicate values for all NW sectors are listed by date i.e. March, May and August. Listed below each set of replicates are averages and standard deviations. Plots are given only for the average values for each of the sub-samples in each sector. For example, total carbonate and organic values are plotted for 6 south sector locations for March, May and August. Each class of metal is organized the same way. For example, essential metals in the NE sector contain average values for Cu, Fe, Mn, and Zn for each sampling period (March, May and August).

Organic Carbon

Organic carbon values ranged between 0.4 to 1.37 % (dry weight) and are tabulated in Table 3 and shown graphically in Fig. 22. These data indicate a general geographic pattern showing statistically higher organic carbon in the NW sector. In May the values were the lowest in the south and NE sectors and inconclusive for the NW. Organic carbon distributions are variable and show no statistically significant trend with season. It is possible that some benthic cyanobacterial populations that bloomed on the surface sediments, could contribute to the elevated organic carbon data for this reporting period

Carbonate Minerals

Carbonate content is also highly variable between season and space. Values range from about 30 % in March for the NE sector to a low value of 12 % also in the second March NE sector. As shown by the graphical representation given in Fig. 23, sector S contains the lowest overall values. These data are tabulated in Table 4. Precipitation of carbonate minerals or the sequestration of carbonate particles by cyanobacteria-diatom mats could contribute to the higher overall values relative to 2006.

Non-Essential Metals

Figure 24 and Table 5 list results from all non-essential metals. Arsenic is a toxic metalloid and was used in agricultural chemicals for many years before it was banned. Arsenic was especially effective as a cotton defoliant and may still be used in Mexico today. If this is so, southeast and south winds can carry sediment laden arsenic to the Bahia Grande. The data in Figure 3 show arsenic levels condensed over space and time. Average arsenic is 7.91 ug/g. This result is significantly higher than the average for the upper 2 cm sediments in the Lower Laguna Madre (3.4 ± 1.3) reported by Whelan et. al (2005). Thus the upper sediment layer may be important in knowing if the Bahia contains mildly toxic levels of arsenic. Mean lead is 12.3 ug/g. This is also enriched slightly since lead was used in agricultural chemicals in the US and likely still used in Mexico. Chromium is the most enriched non essential metal, with a mean value of 13.6 ug/g. If the upper layers of recent sediment are depositional, we might

Table 3. Organic carbon by sector and date.

Organic Carbon 2007 (weight %)					
March		**May**		**August**	
SA-1	1.27	S-A1	0.62	S A1	1.10
SA 2	1.74	S-A2	1.02	S A2	1.15
SA-3	0.95	S-A3	0.89	S A3	0.80
AVE	**1.32**	**AVE**	**0.84**	**Ave**	**1.01**
STD	**0.40**	**STD**	**0.20**	**STD**	**0.18**
SC-4	0.74	S-C1	0.40	SB 1	1.05
SC-5	1.25	S-C2	0.79	SB 2	0.95
SC-6	0.83	S-C3	0.29	SB 3	0.92
AVE	**0.94**	**AVE**	**0.49**	**AVE**	**0.97**
STD	**0.27**	**STD**	**0.26**	**STD**	**0.07**
NEA-1	1.12	NE-C1	1.08	NE B1	1.19
NEA-2	0.48	NE-C2	0.49	NE B2	1.17
NEA-3	0.69	NE-C3	0.08	NE B3	1.10
AVE	**0.76**	**AVE**	**0.55**	**AVE**	**1.15**
STD	**0.33**	**STD**	**0.51**	**STD**	**0.05**
NEC-4	1.20	NE-B1	0.60	NE C1	0.93
NEC-5	0.87	NE-B2	0.95	NE C2	0.83
NEC-6	1.25	NE-B3	1.07	NE C3	0.88
AVE	**1.10**	**AVE**	**0.87**	**AVE**	**0.88**
STD	**0.21**	**STD**	**0.24**	**STD**	**0.05**
NWA-1	1.00	NW-A1	1.11	NW-A1	1.05
NWA-2	1.02	NW-A2	1.37	NW A2	1.12
NWA-3	1.55	NW-A3	1.14	NW A3	1.14
AVE	**1.19**	**AVE**	**1.20**	**Ave**	**1.10**
STD	**0.31**	**STD**	**0.14**	**STD**	**0.05**
NWC-1	1.03	NW-C1	0.80	NW B1	1.05
NWC-2	0.94	NW-C2	1.34	NW B2	0.98
NWC-3	1.00	NW-C3	1.22	NW B3	0.96
AVE	**0.99**	**AVE**	**1.12**	**AVE**	**1.00**
STD	**0.05**	**STD**	**0.28**	**STD**	**0.05**

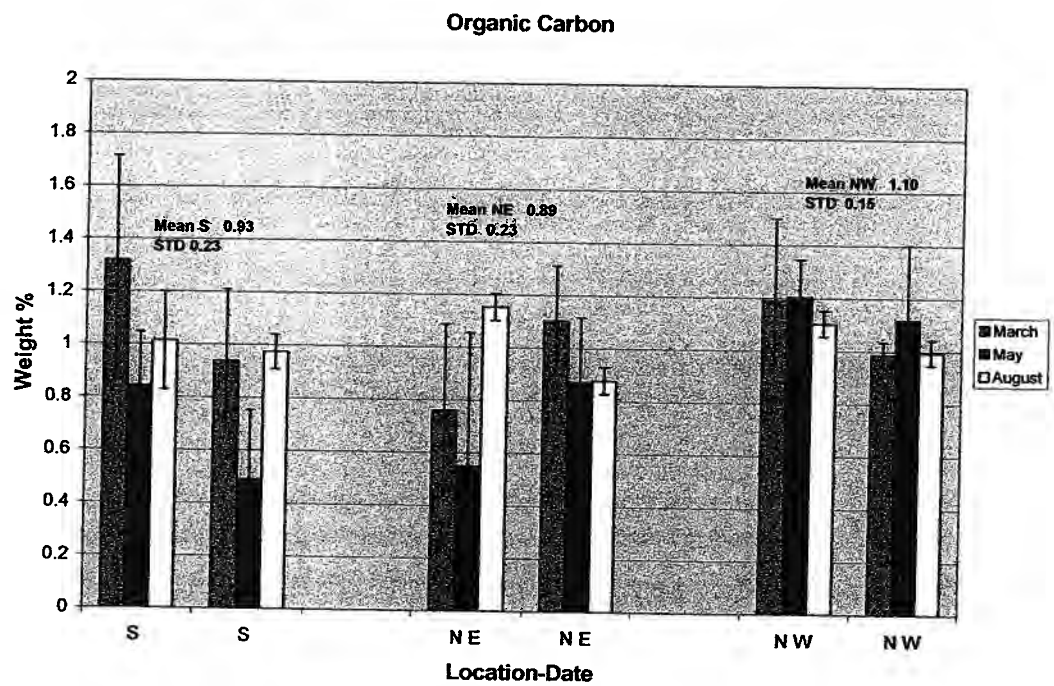

Fig. 22. Organic carbon by sector and date.

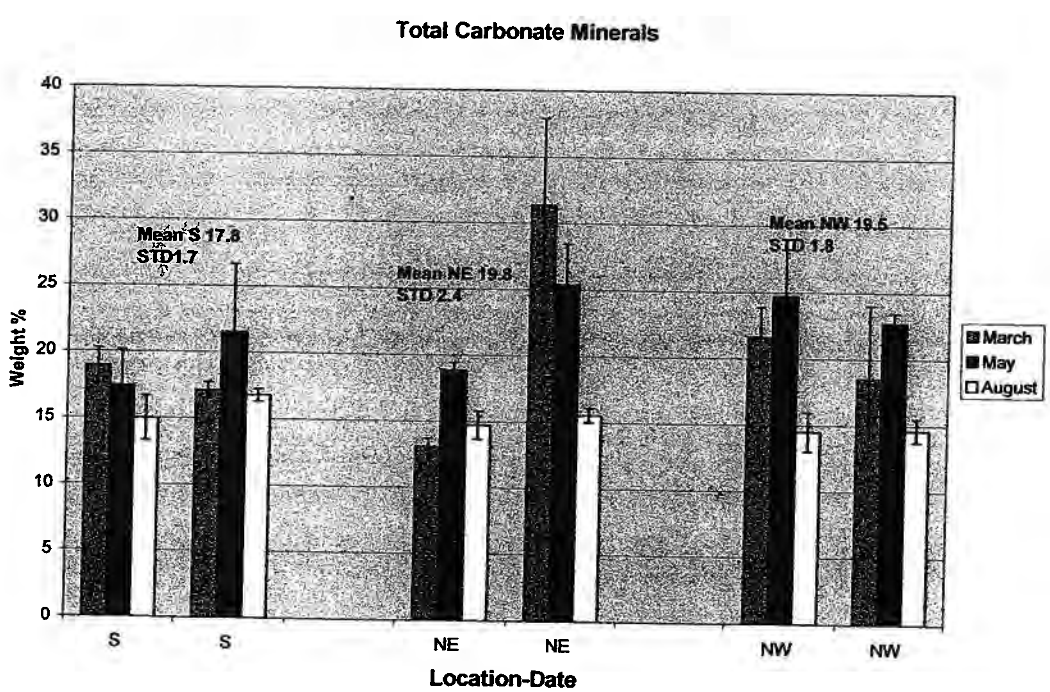

Fig. 23. Plot of total carbonate minerals by date and sector.

Table 4. Carbonate minerals by date and sector.

Carbonate Minerals 2007 (weight %)					
March		**May**		**August**	
SA-1	17.7	SA-1	15.6	SA-1	14.2
SA-2	20.3	SA-2	16.2	SA-2	16.9
SA-3	18.8	SA-3	20.5	SA-3	13.8
Ave	**18.9**	**Ave**	**17.4**	**Ave**	**15.0**
STD	**1.3**	**STD**	**2.7**	**STD**	**1.7**
SC-1	16.5	SC-1	17.0	SB-1	16.5
SC-2	17.7	SC-2	20.6	SB-2	17.3
SC-3	17.2	SC-3	27.1	SB-3	16.5
Ave	**17.1**	**Ave**	**21.5**	**Ave**	**16.8**
STD	**0.6**	**STD**	**5.1**	**STD**	**0.5**
NEA-1	13.1	NEC-1	18.6	NEC-1	14.7
NEA-2	13.7	NEC-2	18.5	NEC-2	15.8
NEA-3	12.5	NEC-3	19.5	NEC-3	13.7
Ave	**13.1**	**Ave**	**18.9**	**Ave**	**14.7**
STD	**0.6**	**STD**	**0.6**	**STD**	**1.1**
NEC-1	33.0	NEB-1	22.1	NEB-1	15.4
NEC-2	24.1	NEB-2	26.1	NEB-2	15.1
NEC 3	37.0	NEB-3	28.1	NEB-3	16.1
Ave	**31.4**	**Ave**	**25.4**	**Ave**	**15.5**
STD	**6.6**	**STD**	**3.1**	**STD**	**0.5**
NWA-1	24.1	NWA-1	21.1	NWA-1	15.0
NWA 2	21.0	NWA-2	28.1	NWA-2	12.8
NWA-3	19.8	NWA-3	25.0	NWA-3	15.6
Ave	**21.6**	**Ave**	**24.7**	**Ave**	**14.5**
STD	**2.2**	**STD**	**3.5**	**STD**	**1.5**
NWC-1	13.0	NWC-1	23.5	NWB-1	14.7
NWC-2	18.5	NWC-2	22.1	NWB-2	15.4
NWC-3	24.0	NWC-3	22.5	NWB-3	13.7
Ave	**18.5**	**Ave**	**22.7**	**Ave**	**14.6**
STD	**5.5**	**STD**	**0.8**	**STD**	**0.9**

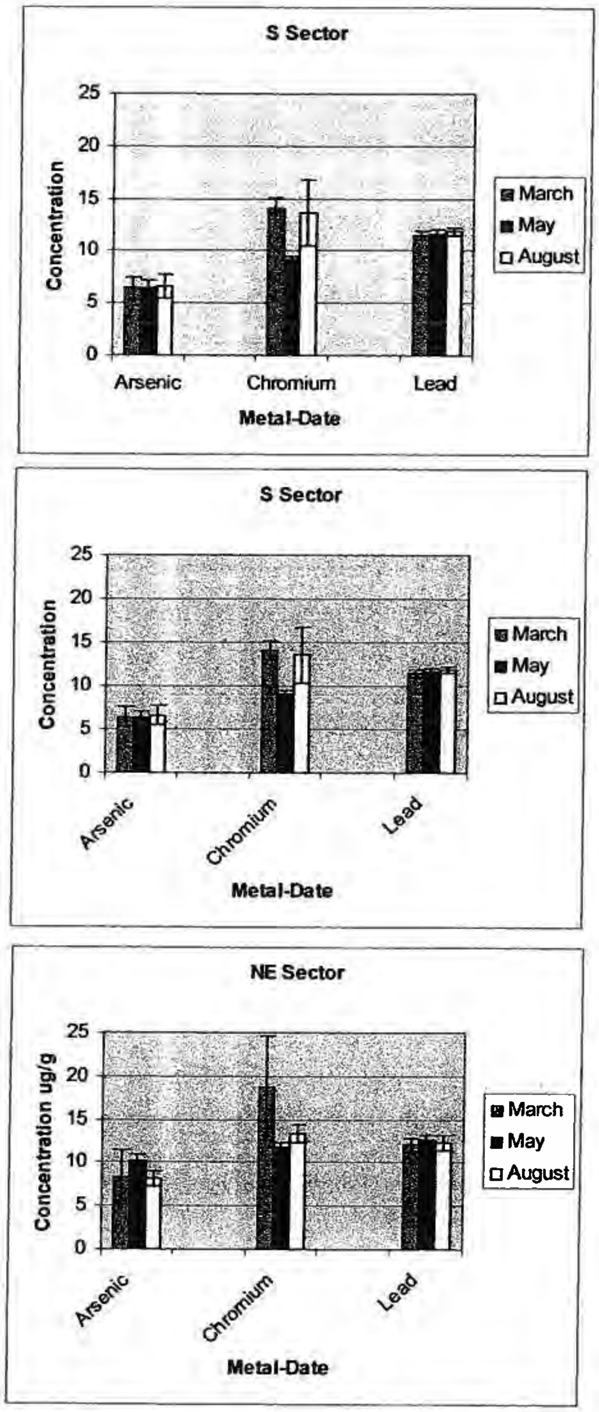

Fig. 24. Plot of non-essential metals by date and sector.

Table 5. Listing of non-essential metals by date and sector.

Non-Essential Metals – Summary (ug/g)	Arsenic			Chromium			Lead		
	March	May	August	March	May	August	March	May	August
NW A1	7.16	8.80	7.10	13.0	12.7	16.2	9.4	11.6	10.5
NW A2	7.08	8.25	8.62	13.4	13.7	14.5	9.5	12.3	12.5
NW A3	6.18	9.42	8.31	12.6	12.1	15.0	8.5	12.2	11.6
Ave	**6.81**	**8.82**	**8.01**	**12.99**	**12.85**	**15.23**	**9.13**	**12.01**	**11.54**
STD	**0.54**	**0.59**	**0.80**	**0.43**	**0.79**	**0.87**	**0.53**	**0.40**	**1.02**
NW B1	9.96	6.32	7.50	17.0	12.6	13.0	8.8	30.5	11.3
NW B2	10.33	7.11	10.5	16.1	11.3	14.9	8.9	23.2	11.2
NW B3	11.20	6.68	9.27	15.3	9.7	16.0	9.5	19.9	11.7
Ave	**10.50**	**6.70**	**9.09**	**16.11**	**11.19**	**14.63**	**9.06**	**24.55**	**11.40**
STD	**0.64**	**0.39**	**1.51**	**0.86**	**1.47**	**1.52**	**0.37**	**5.44**	**0.29**
NE C1	9.33	9.20	8.04	32.1	11.4	13.0	12.0	11.4	11.5
NE C2	8.19	10.55	8.46	16.8	11.9	13.3	12.1	11.9	11.7
NE C3	9.62	10.28	8.52	15.0	12.2	13.8	10.6	12.6	12.5
Ave	**9.04**	**10.01**	**8.34**	**21.27**	**11.82**	**13.41**	**11.58**	**11.95**	**11.88**
STD	**0.75**	**0.71**	**0.26**	**9.38**	**0.44**	**0.40**	**0.85**	**0.60**	**0.51**
NE B1	1.18	10.40	7.64	13.1	11.9	11.6	12.2	13.3	11.4
NE B2	10.79	11.34	6.84	17.7	11.2	13.3	13.5	13.7	12.8
NE B3	10.65	10.05	9.48	17.5	12.5	15.1	12.3	13.7	14.1
Ave	**7.54**	**10.60**	**7.98**	**16.08**	**11.86**	**13.31**	**12.70**	**13.55**	**12.78**
STD	**5.50**	**0.67**	**1.36**	**2.58**	**0.63**	**1.76**	**0.73**	**0.25**	**1.37**
S A1	7.20	6.45	7.72	15.5	9.4	12.6	12.4	11.9	
S-A2	5.82	7.24	5.47	15.5	9.5	12.1	13.3	11.6	11.7
S-A3	5.72	5.61	6.83	13.8	9.8	22.7	11.8	12.2	11.4
Ave	**6.25**	**6.43**	**6.67**	**14.94**	**9.58**	**15.78**	**12.51**	**11.87**	**11.57**
STD	**0.83**	**0.81**	**1.14**	**0.97**	**0.22**	**5.97**	**0.74**	**0.30**	**0.20**
S-B1	8.13	6.30	6.29	14.0	8.2	11.9	10.6	11.1	11.8
S B2	5.65	6.03	5.51	13.9	9.0	11.3	10.5	11.0	12.6
S-B3	6.13	7.06	7.67	12.1	9.0	11.2	10.3	12.1	12.1
Ave	**6.64**	**6.46**	**6.49**	**13.32**	**8.72**	**11.44**	**10.47**	**11.42**	**12.16**
STD	**1.32**	**0.53**	**1.10**	**1.08**	**0.48**	**0.41**	**0.17**	**0.61**	**0.40**

expect recent lead and arsenic exposure to show elevated levels relative to the Laguna Madre.

Essential Metals

The essential metals are shown in Table 6 and Fig. 25. These elements are deemed essential since they are required for various metabolic functions. Generally, May data was the lowest, with a few exceptions. Iron is the most abundant metal in this category followed my Mn, Zn and Cu. This is the same order for the earth's crust and for Rio Grande deltaic sediments. In general, the NE sector showed the greatest abundance of essential metals.

Major Cations

Major cations include Ca, Mg, Na and K and occur in Bahia sediments in order of concentration listed above. Calcium has the highest concentration of any metal studied in this project (Table 7). Average Ca in the NE sector for March contained 63,033 ug Ca/g. This is equivalent to about 6.3 % Ca. Generally, it is expected that surface sediments would reflect the salinity of the surface waters. However, the highest salinities occurred in May (Fig. 26) but in most cases, major cations were lowest in May. Na showed higher levels in May only for the South sector.

Sediment Grain Size

Inorganic sediment grain size analysis shows that all 3 sections of the basin are dominated by fine sand (1-0.0625 mm) with a range of 67.40-78.21%. The next size fraction is the clay fraction (0.0625-0.0039 mm) with a range of 11.59-26.98%. The S section has more clay and less fine sand than the two northern sections. This is probably due to the limited water exchange in the basin through the small channel and the blockage crated by slight rise in the basin formed by the railroad trestle. Fine sediment is introduced to the system through the pilot channel, but it isn't being distributed to north of the railroad. The distribution of clay and probably silt is controlled by the blockage created by the railroad trestle.

Discussion

In order to assist in evaluation and understanding of optimum environmental conditions conducive to seagrass, benthos and mangrove development, knowledge of sediment characteristics in the Bahia Grande is of primary importance. We currently know little about the sediment variability in space and season within this basin. For instance, localized areas within the Bahia Grande containing fine grain sediments will disturb easily (especially during windy periods, high tidal movement and rain), creating low light conditions. Low light conditions will slow seagrass (Onuf, 1994; Lee and Dunton, 1997) and mangrove growth and consequently slow fauna development. In addition, fine grain sediments usually contain

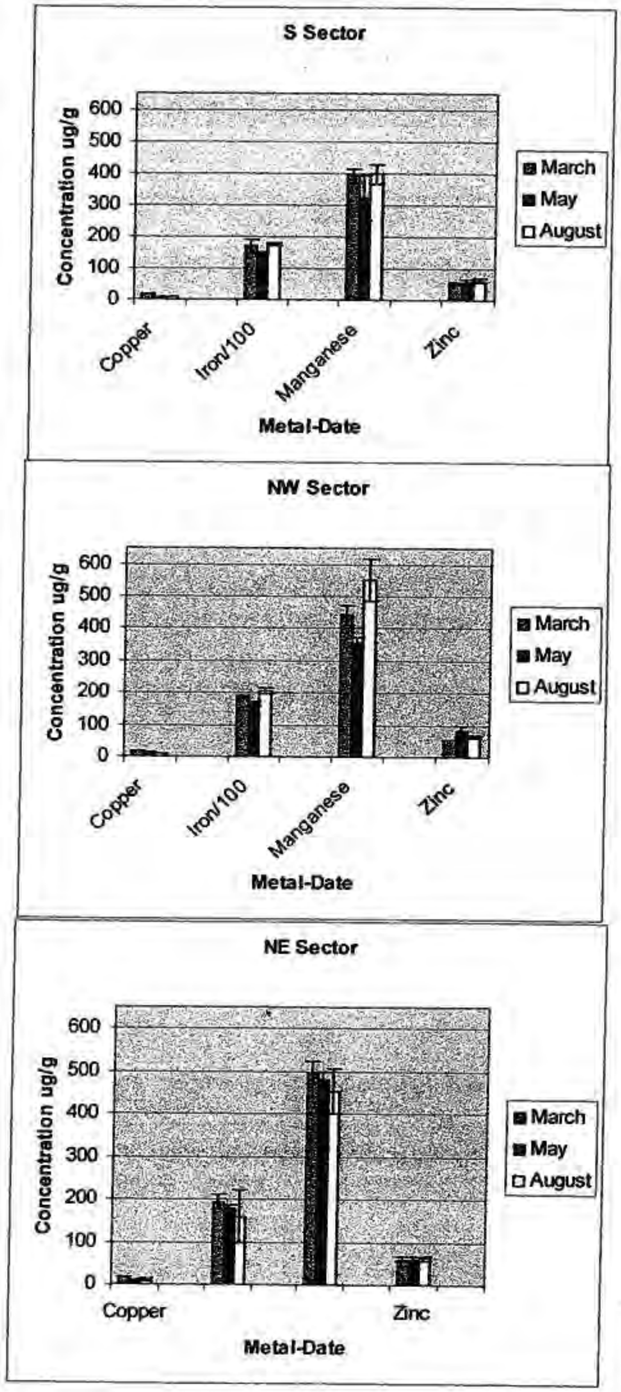

Fig. 25. Plot of essential metals by date and sector. Note that Fe values are divided by 100.

Table 6. Listing of essential metals by date and sector.

	Iron			Manganese			Copper			Zinc		
	March	May	August	March	May	August	March	May	August	March	May	August
NW A1	17033	16816	20627	384	396	556	15.7	9.78	11.0	52.1	115.0	64.6
NW A2	18311	16653	19880	424	351	700	16.5	9.80	11.8	56.0	69.2	69.5
NW A3	16873	16790	19726	375	385	660	17.0	9.57	11.0	52.9	75.1	63.9
Ave	**17406**	**16753**	**20078**	**394**	**377**	**639**	**16.39**	**9.71**	**11.25**	**53.7**	**86.4**	**66.0**
STD	**788**	**87**	**482**	**26**	**23**	**74**	**0.66**	**0.13**	**0.46**	**2.1**	**24.9**	**3.0**
NW B1	20038	17829	19056	457	337	401	19.9	13.9	8.2	58.1	88.0	56.4
NW B2	20111	16926	21113	524	324	517	20.2	12.2	10.8	59.5	78.3	63.7
NW B3	19499	14640	21792	495	344	478	20.7	9.75	11.2	57.3	67.1	65.4
Ave	**19882**	**16465**	**20654**	**492**	**335**	**466**	**20.27**	**11.96**	**10.04**	**58.3**	**77.8**	**61.8**
STD	**334**	**1644**	**1424**	**33**	**10**	**59**	**0.40**	**2.10**	**1.63**	**1.1**	**10.5**	**4.8**
NE C1	20725	17178	826	444	528	467	16.6	11.2	11.1	58.1	56.9	55.5
NE C2	20525	18015	18982	423	524	483	19.2	11.4	17.8	61.5	55.6	61.1
NE C3	18056	16939	18770	470	490	506	15.7	11.2	11.2	56.1	59.0	62.8
Ave	**19769**	**17377**	**12859**	**446**	**514**	**485**	**17.16**	**11.23**	**13.37**	**58.6**	**57.2**	**59.8**
STD	**1487**	**565**	**10422**	**23**	**21**	**19**	**1.80**	**0.12**	**3.81**	**2.7**	**1.7**	**3.8**
NE B1	19839	18109	16667	519	435	366	16.9	10.8	7.6	60.9	63.6	53.4
NE B2	20265	17940	19420	577	462	378	19.0	11.4	10.2	69.9	71.6	64.6
NE B3	16262	19676	20313	549	447	518	17.9	13.1	11.5	60.9	56.1	72.7
Ave	**18789**	**18575**	**18800**	**548**	**448**	**420**	**17.93**	**11.76**	**9.77**	**63.9**	**63.8**	**63.6**
STD	**2199**	**957**	**1900**	**29**	**13**	**84**	**1.07**	**1.23**	**2.02**	**5.2**	**7.7**	**9.7**
S A1	18463	15270	17986	418	260	412	15.7	8.20	9.2	67.6	61.2	60.8
S-A2	18708	14764	17051	399	439	396	16.5	7.20	9.6	60.7	48.6	69.2
S-A3	12237	15331	17026	402	239	401	17.0	7.58	8.8	50.7	62.0	56.6
Ave	**16469**	**15122**	**17354**	**406**	**313**	**403**	**16.39**	**7.66**	**9.18**	**59.7**	**57.3**	**62.2**
STD	**3668**	**311**	**547**	**11**	**110**	**8**	**0.66**	**0.51**	**0.38**	**8.5**	**7.5**	**6.5**
S-B1	18157	13350	16892	409	347	398	19.9	5.00	9.0	47.9	47.8	72.2
S B2	17443	14015	17628	346	297	336	20.2	7.38	7.0	48.3	66.6	58.1
S-B3	16195	14552	18238	381	357	435	20.7	7.17	5.8	48.9	60.4	58.1
Ave	**17265**	**13972**	**17586**	**379**	**334**	**390**	**20.27**	**6.52**	**7.23**	**48.3**	**58.2**	**62.8**
STD	**993**	**602**	**674**	**31**	**32**	**50**	**0.40**	**1.32**	**1.61**	**0.5**	**9.6**	**8.2**

Table 7. Listing of major cations by date and sector.

-	Magnesium			Potassium			Sodium			Calcium		
	March	May	August	March	May	August	March	May	August	March	May	August
NW A1	21968	27166	30461	6916	6427	7668	14655	14441	15805	58086	56667	54360
NW A2	23894	26529	31816	7406	6717	8034	15630	17113	15998	59539	55708	58204
NW A3	22597	28358	32311	7140	6527	8010	15158	14667	16380	63642	53886	59389
Ave	**22819**	**27351**	**31530**	**7154**	**6557**	**7904**	**15148**	**15407**	**16061**	**60422**	**55420**	**57317**
STD	**982**	**928**	**958**	**245**	**147**	**205**	**487**	**1482**	**293**	**2881**	**1412**	**2629**
NW B1	35173	23865	27270	7806	7012	6989	17005	15129	14944	53311	56145	55337
NW B2	38060	21803	36001	7715	6605	7924	16680	15118	16377	51289	50809	54357
NW B3	38908	21666	35413	8108	5762	8091	16454	12201	17507	52835	54618	51435
Ave	**37380**	**22444**	**32895**	**7876**	**6460**	**7668**	**16713**	**14150**	**16276**	**52479**	**53858**	**53709**
STD	**1958**	**1232**	**4880**	**206**	**637**	**594**	**277**	**1687**	**1284**	**1057**	**2748**	**2030**
NE C1	35447	31855	31290	7781	7012	6469	15641	14747	13973	49630	47011	58071
NE C2	33690	32513	32096	7751	5762	7006	15801	14697	16267	48622	47280	62186
NE C3	32780	33041	27340	7730	6277	6210	20483	14697	14100	55750	48874	48740
Ave	**33972**	**32470**	**30242**	**7754**	**6351**	**6562**	**17309**	**14714**	**14780**	**51334**	**47722**	**56332**
STD	**1356**	**594**	**2545**	**26**	**628**	**406**	**2751**	**29**	**1290**	**3858**	**1007**	**6889**
NE B1	28742	33177	22867	9438	6691	6150	29317	15447	13477	61562	59553	59021
NE B2	34529	31502	27950	7617	6043	6870	15571	14639	15330	56716	59832	54770
NE B3	33639	33340	34017	7703	7046	7235	16212	15655	17317	70820	60032	64749
Ave	**32303**	**32673**	**28278**	**8253**	**6594**	**6752**	**20367**	**15247**	**15375**	**63033**	**59806**	**59513**
STD	**3116**	**1018**	**5582**	**1028**	**509**	**552**	**7758**	**537**	**1920**	**7166**	**240**	**5008**
S A1	15813	9990	20454	7002	5360	6005	14260	15520	13379	58841	58900	59313
S-A2	16996	10996	16962	7469	5228	5462	14365	20122	12177	58805	58657	58605
S-A3	13031	10417	19195	6545	5682	5695	12594	18032	11591	49702	58543	55266
Ave	**15280**	**10467**	**18870**	**7005**	**5423**	**5721**	**13740**	**17891**	**12382**	**55783**	**58700**	**57728**
STD	**2035**	**505**	**1768**	**462**	**233**	**273**	**993**	**2304**	**912**	**5266**	**183**	**2161**
S-B1	19383	14870	18613	6102	4470	5641	12193	11330	11470	48131	51710	53372
S B2	17404	15451	17089	6422	4805	5696	13562	11154	11612	54016	51535	56953
S-B3	16917	16524	20605	5778	4781	5171	13939	10289	12878	58063	50388	59000
Ave	**17901**	**15615**	**18769**	**6100**	**4685**	**5503**	**13232**	**10924**	**11987**	**53403**	**51211**	**56442**
STD	**1306**	**839**	**1763**	**322**	**187**	**289**	**919**	**557**	**775**	**4994**	**718**	**2848**

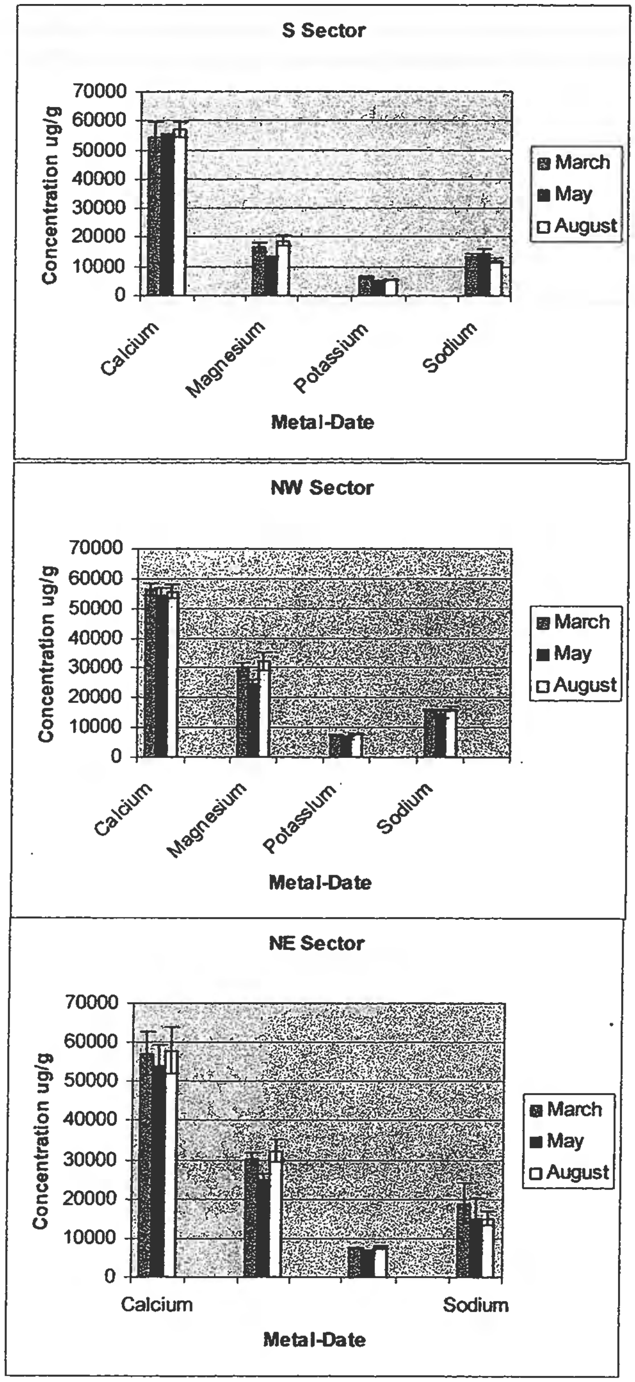

Fig. 26. Plot of major cations by date and sector.

elevated levels of organic carbon and result in an affinity for trace metals and other potential pollutants. Hydrogen sulfide can reach toxic levels in sediments containing increased oxygen consumption resulting from rapid decomposition of organic matter (Lee and Dunton, 2000). Salinity gradients in the water body can be influenced by the ambient salt content of sediment. Conversely, high salinity seawater can diffuse into the sediment column creating an expanded sediment grains and changes in chemical and physical properties. For these reasons we are analyzing sediment characteristics after seawater flooding.

Channel Velocities

Prior to the summer of 2007, flow in the channel E (see Fig. 3) was largely limited by three culverts (2 – 24 inch and 1- 48 inch) that permitted water to flow under Texas Highway 48. During 2007, these culverts were replaced by a bridge that effectively increased flow rates from the 0.5 ft/sec – 0.8 ft/sec mean channel velocity that existed prior to culvert removal to 1.5 – 2.0 ft/sec mean channel velocity after the bridge was completed.

The data gathered by point samples are not considered sufficient to accurately describe the complex inflow and outflow velocities dictated by both wind patterns and tidal fluctuations. Significant variation was observed in the data and interference stemming from bridge construction, internal channel excavation, and even unrelated seismic testing done by an oil exploration company prevented more frequent sampling. Monthly point measurements were completed from September 2007 through May of 2008. Point samples using a hand-held velocity probe will continue as necessary to supplement the new continuous flow meter and will additionally serve as calibration of the meter. Detailed sampling reports and summary tables of flow data will be provided with the final report submitted after Year 2 of this study.

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DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM DATABASE FRAMEWORK FOR THE BAHIA GRANDE

A GIS for the collection, analysis, and display of spatial information collected by this and other investigators is critical for the successful monitoring of Bahia Grande restoration efforts. Toward that end, UTB/TSC GIS Laboratory personnel, lead by Dr. Jude Benavides and lab coordinator Mr. Anthony Reisinger, dedicated sufficient storage space and processing power for the storage and analysis of GIS data provided by all investigators.

Two computers, a 46-inch plotter, 300 square feet of lab space, and over 500 GB of storage space have been dedicated to this project. The storage space is via a virtual server accessible by all UTB/TSC investigators and is backed up continuously by Information Resources personnel at UTB/TSC.

Critical base map and supporting GIS data were identified early in project year one including the need for detailed topographic data, bathymetric data, recent and historical aerial photography, and a reliable coastline data layer. Work during 2006-2007 completed the following specific tasks related to GIS base map and supporting data: (Some tasks have a figure illustrating a brief sample of the data that has been obtained).

1. Seamless Light Detection and Ranging (LIDAR) data were obtained from the International Boundary and Water Commission. This high-resolution (10 foot x,y cells) topographic data was deemed critical for a variety of monitoring tasks including future hydrologic model development, shoreline stabilization efforts, GPS surveys, vegetation mapping, etc. The data arrived in ASCII format for over 300 quadrants including the entire Cameron County area. GIS lab personnel converted the ASCII formatted datasets into a seamless, readily usable elevation raster set. Figure 27 illustrates the seamless 10-foot raster dataset.
2. Historical aerial photographs and maps were collected, digitized when necessary, georeferenced to a common projection, and stored for future base map applications. Figures 28 and 30 show the georeferenced USGS quad maps for 1935, 1955 and 1983 respectively.
3. Established a common coordinate system for display, combination, and analysis of data collection by other researchers. The agreed upon projection was:
    a. Coordinate System: NAD1983 StatePlane Texas South FIPS 4205 Feet
    Projection: Lambert_Conformal_Conic
    False_Easting: 984250.000000
    False_Northing: 16404166.666667
    Central_Meridian: -98.500000
    Standard_Parallel_1: 26.166667
    Standard_Parallel_2: 27.833333
    Latitude_Of_Origin: 25.666667
    LinearUnit: Foot_US

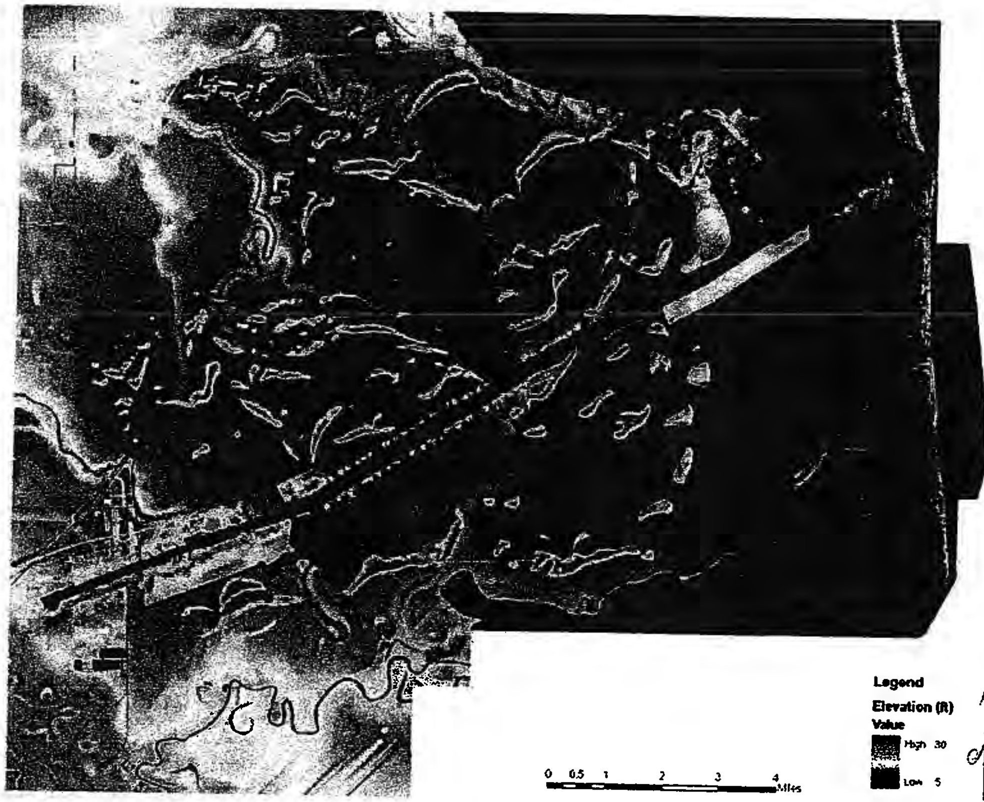

Fig 27. 10-foot resolution seamless LIDAR dataset for the Bahia Grande Wetland Complex and surrounding area. (Data Source: International Boundary and Water Comission)

4. A common coastal / shoreline delineation layer file was obtained and will be used in order to coordinate all research related to shoreline stabilization, modeling, water quality sampling, and biological sampling.

5. Bathymetry data for the main pool of the Bahia Grande system was obtained from the Natural Resources Conservation Service (NRCS). This data was georeferenced and merged with the LIDAR data discussed in item one above. (See Fig. 31) This data was considered critical to future work in the development of a bay circulation model.

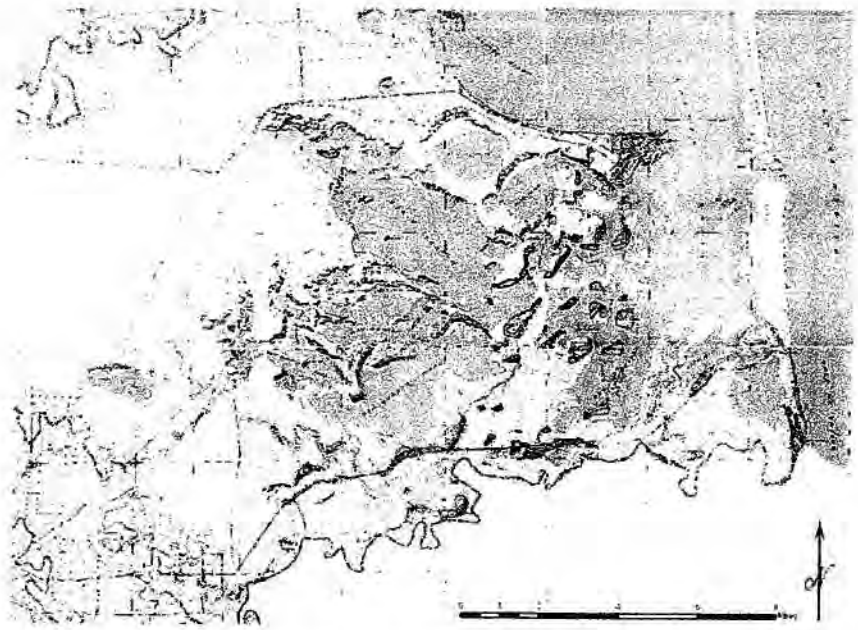

Fig 28. 1935 USGS quad map of the Bahia Grande Wetland Complex and surrounding area. The map was digitized and georeferenced for base map utilization and comparison of shoreline / geomorphologic changes over the 20th century.

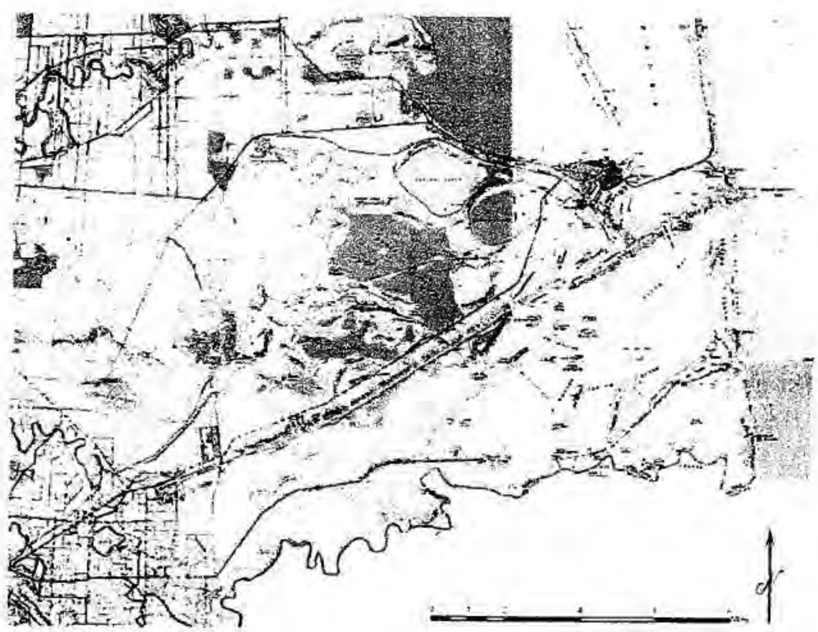

Fig. 29. 1955 USGS quad map of the Bahia Grande Wetland Complex and surrounding area. The map was georeferenced for base map utilization and comparison of shoreline / geomorphologic changes over the 20th century. Note the appearance of the Brownsville Ship Channel and subsequent isolation of the Bahia Grande from direct tidal influence. Observers should also notice the drastic reduction in the areal extent of San Martin Lake just southwest of the main Bahia Grande pool.

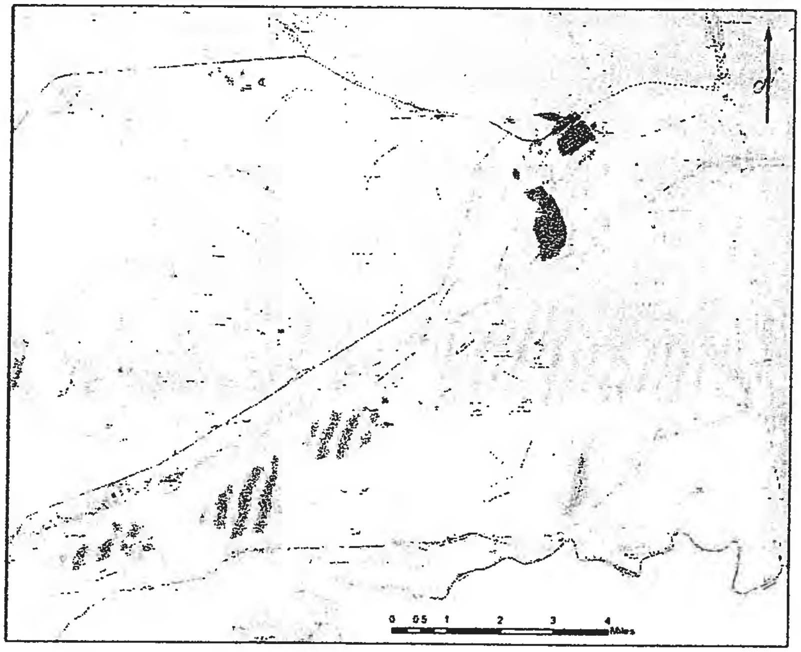

Fig. 30. 1983 USGS quad map of the Bahia Grande Wetland Complex and surrounding area.

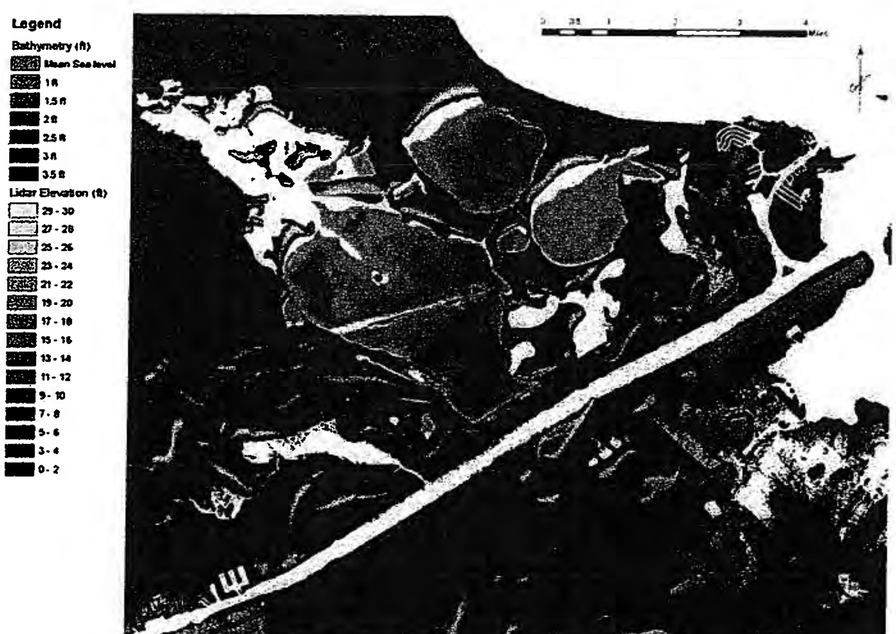

Fig. 31. NRCS bathymetry data superimposed on LIDAR data for the Bahia Grande Wetland Complex. Bathymetry data does not extend to the Brownsville Ship Channel and / or surrounding waters outside of the Bahia Grande system.

EDUCATION & OUTREACH

The JASON Project UTB/TSC has continued to provide a challenging science program for area K-12 students. In February 2007, we had our last professional development for teachers in the "Disappearing Wetlands" curriculum. We obtained posters, activities, maps, and videos from the Flower Gardens National Marine Sanctuary education office and the "Secrets of the Gulf" adventure curriculum from Immersion Presents, and distributed these materials to 90 teachers. We organized and hosted students, parents, and teachers from Laredo to Port Isabel for live-via-satellite broadcasts from the Flower Gardens Banks in the Immersion Presents program, March 5-6-7, at UTB/TSC. We delivered 5 hour-long professional development sessions via teleconference technology on January 30, February 27, March 22, and April 26, 2007. Schools continue to grow black mangrove seedlings and collect data about their growth.

On June 15, we retrieved 2,000 black mangrove seedlings which have been nurtured at Russell Elementary School in Brownsville for two years. JASON Project UTB/TSC donated the materials to construct a propagation pond, 8' x 16' x 8" on the school campus, then donated the mangroves in pots and trays for the students to monitor and tend. June 16, eighteen UTB/TSC students from Dr. Heise's geology class and about 7 other volunteers met at interior channel "C" where we planted the 2,000 black mangroves along two shorelines. June 22, there was an event at the Bahia Grande to celebrate the completion of all interior channels, at which there were approximately 200 attendees. The 65 partners of the Bahia Grande Restoration received the "Coastal America Partnership Award" from Virginia Tippie, Director, on behalf of the White House. I attended training in the new JASON Project curriculum, along with one other trainer, at a conference July 12, in Garden City, NY. We are currently recruiting schools for our 2007-2008 school year.

During June, we completed and submitted an application for "Gulf Guardian" award from the EPA, on behalf of the Bahia Grande Restoration Partnership. We were advised in late August that the Bahia Grande Restoration Partnership had won second place in the "Partnership" Division. On October 27, we retrieved 1,500 black mangrove seedlings which have been nurtured at Dr. Juliet V. Garcia Middle School in Brownsville for two years. JASON Project UTB/TSC donated the materials to construct a propagation pond, 8' x 16' x 8" on the school campus, then donated the mangroves in pots and trays for the students to monitor and tend. With twenty-five middle school students and six other adults, we planted the mangrove seedlings along 75m of shoreline on two sides of a small (13 acre) peninsula. We continnue recruiting schools for our 2007-2008 school year.

In November, December, and January we held five professional development sessions for JASON Project and Immersion Presents training and curricula distribution. Twenty teachers were trained from public and private schools in Brownsville, Harlingen, San Benito, Donna, and Port Isabel, Texas. Approximately 2,000 students are involved in our outreach program this year. We presented a 45-minute Power Point presentation on the current status of the Bahia Grande Restoration at the Winter Outdoor Wildlife Expo '08 on Feb. 2 at the South Padre Island Convention Center. We repeated the presentation on February 9 at the Valley Nature Center in Weslaco, Texas. Each audience was 50 to 60 attendees, mostly retired people and "Winter Texans". In mid-February, we purchased spades, shovels, and other gardening supplies with grant funds: $484.32. On February 22, we took 48 fifth-grade students from the Episcopal Day School (Brownsville) to the Bahia Grande, with 12 to 15 adults. Approximately 2,000 black mangroves were planted along the western shore, near the "yellow gate" off State Highway 48. These mangroves were planted as seeds by these same children when they were in third grade, monitored and tended for two years in a propagation pond (gift from JASON Project UTB/TSC). We organized and hosted students, parents, and teachers from Donna, TX, to Port Isabel for live-via-satellite broadcasts from the Monterey Bay National Marine Sanctuary in the Immersion Presents program, March 5-6-7, at UTB/TSC. We proposed the Bahia Grande Restoration Partnership for the Texas Environmental Excellence Award (Civic/Non-Profit Category), and we were advised in early April that we had won. Two of our partners, Cameron County Judge Carlos Cascos and Ocean Trust President Thor Lassen will attend the award ceremony in Austin. We are on schedule and are currently recruiting schools for the 2008-2009 school year.

PROJECT PRODUCTS

Presentations

Trevino, R., E. Cornejo, T. McWhorter, A. Reisinger, N. Matos, O. Sosa, and D. Hicks. Recolonization dynamics in the recently re-flooded Bahia Grande. Texas Bays and Estuaries Meeting, April 16-17, 2008, Port Aransas, Texas.

Trevino, R., T. McWhorter, O. Sosa, N. Matos, A. Reisinger, and D. Hicks. Macroinvertebrate recolonization dynamics of benthic habitats in the recently re-flooded Bahia Grande. 111th Annual Meeting of the Texas Academy of Science, March 6–8, 2008, Texas A&M University–Corpus Christi, Corpus Christi, Texas.

Cornejo, E., R. Trevino, T. McWhorter, A. Reisinger, and D. Hicks. Fish assemblage dynamics in the recently re-flooded Bahia Grande. 111th Annual Meeting of the Texas Academy of Science, March 6–8, 2008, Texas A&M University–Corpus Christi, Corpus Christi, Texas.