EFFECT OF FRESHWATER INFLOW ON MACROBENTHOS PRODUCTIVITY IN THE GUADALUPE ESTUARY

by

Paul A. Montagna, Ph.D.
Terry A. Palmer M.S.

Texas A&M University – Corpus Christi
Harte Research Institute for Gulf of Mexico Studies
6300 Ocean Drive, Unit 5869
Corpus Christi, Texas 78412
Phone: 361-825-2040
Fax: 361-825-2050
Email: paul.montagna@tamucc.edu

TEXAS A&M UNIVERSITY
CORPUS CHRISTI

Final report to:

Texas Water Development Board
P.O. Box 13231
Austin, TX 78711-3231

Contract # 1104831133
December 2011

CONTRACT ADMINISTRATION
2012 JUN 19 AM 10:15

EFFECT OF FRESHWATER INFLOW ON MACROBENTHOS PRODUCTIVITY IN THE GUADALUPE ESTUARY

by

Paul A. Montagna, Ph.D.
Terry A. Palmer M.S.

Texas A&M University – Corpus Christi
Harte Research Institute for Gulf of Mexico Studies
6300 Ocean Drive, Unit 5869
Corpus Christi, Texas 78412
Phone: 361-825-2040
Fax: 361-825-2050
Email: paul.montagna@tamucc.edu

Final report to:

Texas Water Development Board
P.O. Box 13231
Austin, TX 78711-3231

Contract # 1104831133
December 2011

Cite as:

Montagna, P.A., and T.A. Palmer. 2011. Effect of Freshwater Inflow on Macrobenthos Productivity in the Guadalupe Estuary 2010-2011. Final Report to the Texas Water Development Board, Contract # 1104831133. Harte Research Institute, Texas A&M University-Corpus Christi, Corpus Christi, Texas, 16 pp.

INTRODUCTION

Since the early 1970's, Texas Water Development Board (TWDB) sponsored freshwater inflow studies focused on the major bay systems of the Texas coast. These bay systems, which are influenced primarily by river inflow and exchange with the Gulf of Mexico, are now subject to greater scrutiny because of recent legislative changes. In recognition of the importance that the ecological soundness of our riverine, bay, estuary, and riparian areas has on the economy, health, and well-being of our state, the 80th Texas Legislature enacted Senate Bill 3 in 2007, which calls for creation of Basin and Bay Area Expert Science Teams (BBEST) to establish environmental flow recommendations for bay and estuary inflows, and Basin and Bay Area Stakeholder Committees (BBASC) charged with balancing environmental needs with the need for water for human uses. In the past, the State methodology depended on modeling inflow effects on fisheries harvest in Texas estuaries (Longely 1994). SB 3 however, requires an ecosystem management approach to provide environmental flows "adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats." Thus, BBEST and BBASC groups will need information on freshwater inflow effects on water quality and biological indicator communities (Montagna et al. 2009, 2010).

Since 1986, researchers led by Dr. Montagna have been studying the effect of freshwater inflow on benthic communities and productivity (Kalke and Montagna 1991; Kim and Montagna 2009, Montagna 1989, 1999, 2000; Montagna et al. 2007; Montagna and Kalke 1992, 1995; Montagna and Li 1996, 2011; Montagna and Palmer 2009, 2010; Montagna and Yoon 1991; Pollack et al. 2009). These studies have demonstrated that long-term hydrological cycles affect water quality and regulate benthic abundance, productivity, diversity, and community structure. Benthos are excellent bioindicators of environmental effects because they are very abundant and diverse, are sessile, and long-lived relative to plankton (Montagna et al. 2010). Therefore, benthos are good biological indicators of freshwater inflow effects because they integrate changes in temporal dynamics of ecosystem factors over long time scales and large spatial scales.

The benthic studies performed as part of the long-term monitoring of benthos (i.e., those listed above) have elucidated some general trends. The Texas estuaries lie in a climatic gradient where those in the northeast receive more rainfall than those in the southwest. Consequently inflow and nutrient loading decreases along the climatic gradient and salinity increases. In addition there is year-to-year variation in rain and inflow that results in wet and dry years. This combination of the climatic gradient and temporal variability drives variability in estuarine communities and secondary production. Among Texas estuaries, increased salinity (and thus decreased inflow) benefits deposit feeders (increased abundance and species richness), while suspension feeders are reduced (decreased abundance and species richness); thus there is a decrease in functional diversity when salinity is increased because of loss of a trophic guild. Within estuaries, the upstream benthic community is reduced by reduced inflow, whereas, the downstream community increases with reduced inflow and higher salinities. This is because lower salinity regimes are required to support food production for suspension feeders, and polyhaline deposit feeding species increase during marine conditions. Overall, these studies demonstrates that freshwater inflow is important in to maintain secondary productivity and functional diversity in estuaries, which is required to maintain estuarine health and sustainability.

The ultimate goal of the current project is to use the data to assess ecosystem health as it relates to change in freshwater inflow by assessing benthic habitat health, and benthic productivity. However, inflow itself does not affect ecosystem dynamics; it is the change in estuarine condition primarily salinity, nutrients, and chlorophyll, which drives change in biological resources (SAC 2009). Thus, the goal is to relate changes in water column dynamics with change in benthic dynamics. The benthic data set has proven useful to date. For example, it has been used to model productivity based on seven years (1988 – 1995) of data in four Texas estuaries: Lavaca-Colorado, Guadalupe, Nueces, and Laguna Madre (Montagna and Li 1996, 2010). The model was used to support inflow criteria development for Matagorda Bay in the Lavaca-Colorado Estuary (Kim and Montagna 2009). Recently, the adjusted model was rerun on 20 years (1988 - 2008) of benthic and water column data and it was shown that salinity and nutrient changes (which are caused by inflow changes) drives benthic productivity and functional diversity (Kim and Montagna 2010). In order to perform similar analyses and provide an understanding of the long-term ecosystem dynamics the San Antonio Bay system, data is needed, and the data collected during this study will support these efforts.

METHODS

Four stations were sampled for macrofauna and water quality in the Guadalupe Estuary (San Antonio Bay; Figure 1, Table 1). Sampling occurred four times: October 2010, and January, April, and July 2011.

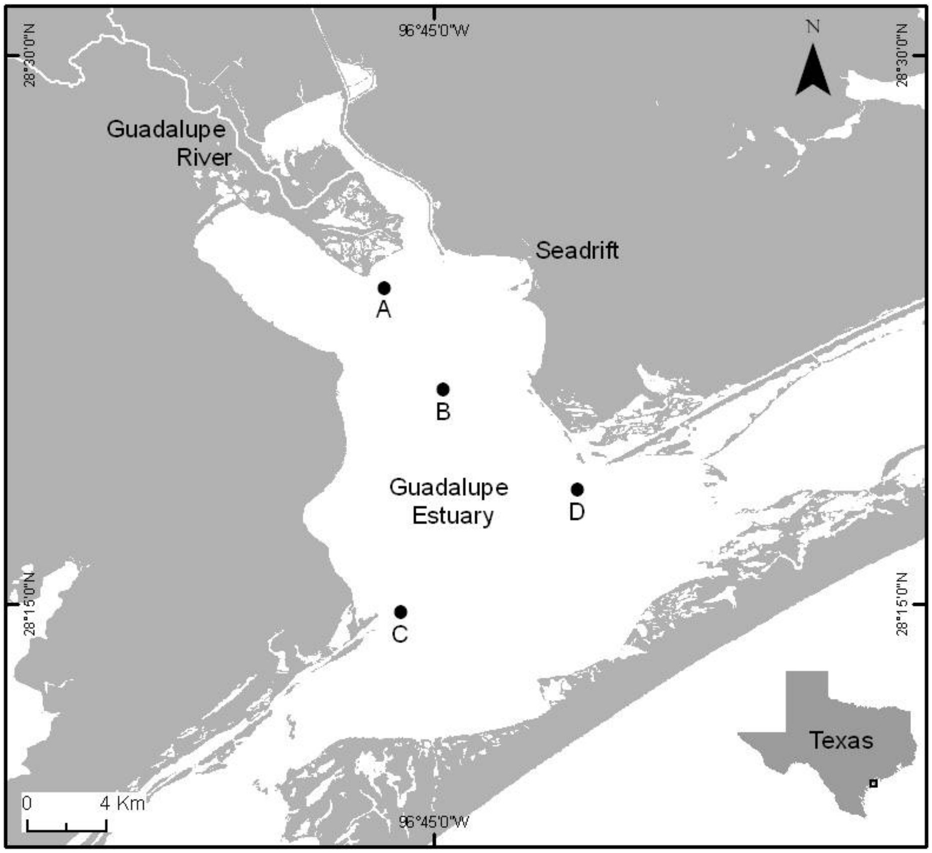

Figure 1. Map of sampling stations in Guadalupe Estuary / San Antonio Bay

Table 1. Station Locations.

Station	Latitude	Longitude
A	28.39352	-96.77240
B	28.34777	-96.74573
C	28.24618	-96.76488
D	28.30210	-96.68435

Water Quality

Physical water quality measurements in addition to chlorophyll and nutrients were sampled in duplicate just beneath the surface and at the bottom of the water column at all four stations on each sampling date.

Hydrographic measurements were made at each station with a YSI 6600 multi parameter instrument. The following parameters were read from the digital display unit (accuracy and units): temperature (± 0.15 °C), pH (± 0.1 units), dissolved oxygen (± 0.2 mg l^{-1}), depth (± 1 m), and salinity (ppt). Salinity is automatically corrected to 25 ^{o}C.

Chlorophyll samples were filtered onto glass fiber filters and placed on ice (<4.0 °C). Chlorophyll is extracted overnight and read fluorometrically on a Turner Model 10-AU using the non-acidification technique (Welschmeyer, 1994; EPA method 445.0).

Nutrient samples were filtered to remove biological activity (0.45 μm polycarbonate filters) and placed on ice (<0.4 °C). Water samples were analyzed at the Harte Research Institute using a OAI Flow-4 autoanalyzer with computer controlled sample selection and peak processing. Chemistries are as specified by the manufacturer and have ranges as follows: nitrate+nitrate (0.03-5.0 μM; Quikchem method 31-107-04-1-A), silicate (0.03-5.0 μM; Quikchem method 31-114-27-1-B), ammonium (0.1-10 μM; Quikchem method 31-107-06-5-A) and phosphate (0.03-2.0 μM; Quikchem method 31-115-01-3-A.

Multivariate analyses were used to analyze how the physical-chemical environmental changes over time. The water column structure was each analyzed using Principal Component Analysis (PCA). PCA reduces multiple environmental variables into component scores, which describe the variance in order to discover the underlying structure in a data set (Clarke and Warwick 2001). In this study, only the first two principal components were used.

Macrofauna

Sediment samples were collected using cores deployed from small boats. The position of all stations is established with a Global Positioning System (GPS) with an accuracy of ±3 m. Macrofauna were sampled with a 6.7-cm diameter core tube (35.4 cm^2 area). The cores were sectioned at 0-3 cm and 3-10 cm depths to examine vertical distribution of macrofauna. Three replicates are taken per station. Organisms are enumerated to the lowest taxonomic level possible, and biomass is determined for higher taxonomic groupings.

Community structure of macrofauna species was analyzed by non-metric multidmensional scaling (MDS) and cluster analysis using a Bray-Curtis similarity matrix (Clarke 1993, Clarke and Warwick 2001). Prior to analysis, the data was $\log_{10}$ transformed. Log transformations improve the performance of the analysis by decreasing the weight of the dominant species. MDS was used to compare numbers of individuals of each species for each station-date combination. The distance between station-date combinations can be related to community similarities or differences between different stations. Cluster analysis determines how much each station-date combination resembles each other based on species abundances. The percent resemblance can then displayed on the MDS plot to elucidate grouping of station-date combinations. The group average cluster mode was used for the cluster analysis.

RESULTS

Principal Components Analysis explained 73 % of the variation within the water quality data set (Figure 2). Principal Component (PC) 1 explained 42 % of the variation while PC2 explained 31 % of the variation.PC1 represents spatiotemporal changes in water quality. Along the PC1 axis, salinity is inversely proportional to pH, Chlorophyll and silicate concentrations (Figure 2A). The lowest salinity values and highest chlorophyll concentrations occur in Stations A and B nearest the Guadalupe River mouth and in October 2010(Figure 2C). PC2 represents seasonal changes in water quality with high temperatures being inversely proportional to dissolved oxygen and Nitrite+Nitrate concentrations (Figure 2A and 2C). In particular, the lowest temperatures occurred in January 2011 (Figure 2C).

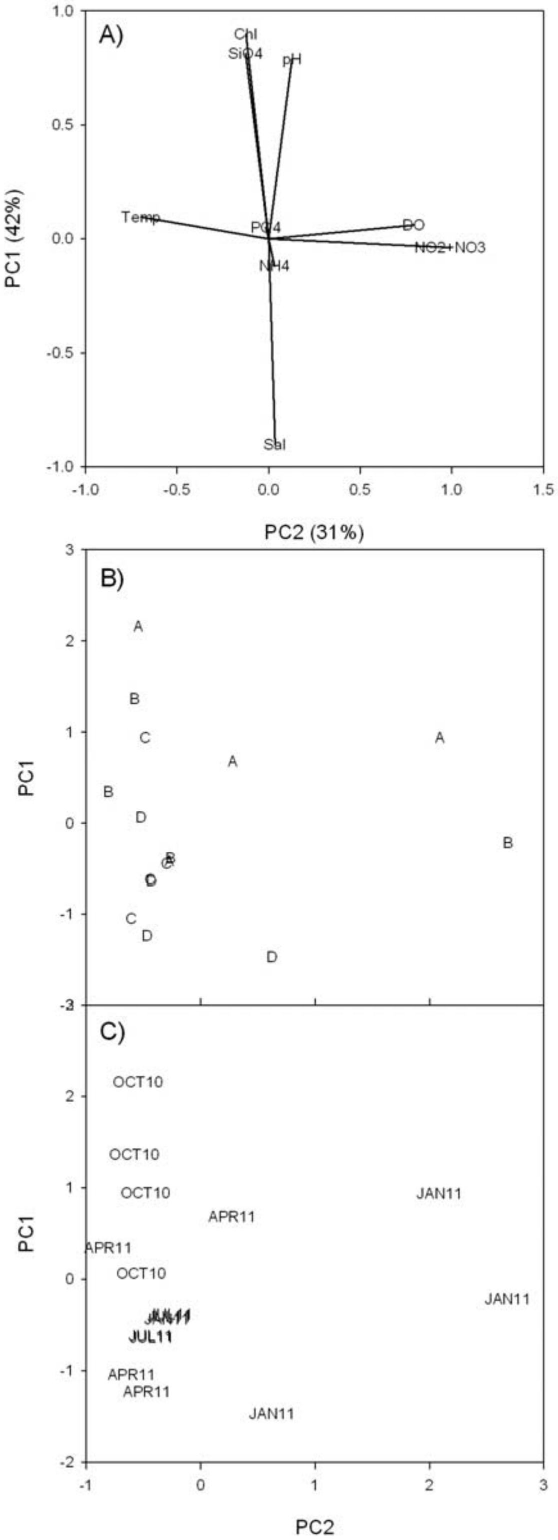

Figure 2. Principal Components Analysis of water quality. Variable loading plot (A) and station-scores labeled by station (B) and month(C) stating in October 2010 through to July 2011.

The lowest salinity and highest concentrations of silicate and nitrate+nitrite occur at Stations A and B, and this is an indicator of river flow from the Guadalupe River into San Antonio Bay (Table 2). Ammonium concentrations are below detection limits for many samples, so the overall average is only 1 umol/L. Mean chlorophyll concentrations are the highest at station A, and decrease along the salinity gradient to Station D, as do silicate concentrations. Mean dissolved oxygen concentrations are also highest at station A, however they are similar at other stations.

Table 2. Overall (for both top and bottom and over the sampling period) mean water quality values for each station. Standard deviation for all samples at each station are in parentheses.

	Station (n)				
Variables	**A (18)**	**B (23)**	**C (20)**	**D (20)**	**Mean**
DO (mg/l)	8.5 (1.40)	7.5 (1.72)	7.6 (1.10)	7.4 (1.42)	7.8
Salinity (psu)	14.4 (7.08)	19.5 (6.97)	20.5 (6.95)	22.9 (5.78)	19.3
Temperature (°C)	24.0 (6.36)	23.8 (6.07)	23.8 (5.96)	23.5 (5.91)	23.8
pH	8.4 (0.17)	8.2 (0.09)	8.2 (0.07)	8.2 (0.10)	8.2
NH4 (umol/L)	1.4 (0.74)	0.8 (0.51)	0.8 (0.68)	1.0 (1.30)	1.0
NO2+NO3 (umol/L)	5.1 (7.20)	8.1 (13.82)	0.4 (0.22)	1.0 (1.28)	3.6
P04 (umol/L)	0.8 (0.33)	1.0 (0.28)	1.1 (0.53)	0.9 (0.35)	0.9
SI04 (umol/L)	123.4 (54.36)	113.5 (49.29)	106.1 (54.47)	84.5 (41.12)	106.9
Chlorophyll (ug/l)	18.0 (6.99)	15.3 (6.99)	10.5 (4.52)	6.9 (2.35)	12.7

The sampling year was characterized by decreasing inflows throughout the year (Figure 3). In fact, this was a very dry period overall. The dry conditions are reflected by increasing salinity throughout the year (Figure 3). In contrast average overall chlorophyll decreased overall throughout the year.

The four stations (A through D) lie along a gradient from river to marine end at the Gulf Intracoastal Waterway and that is reflected in the differences in salinity among the stations as well where salinity increases from A to B, B to C, and C to D (Figure 4A). Station A, closest to the river had the highest abundance (Figure 4B) during the driest times, and highest biomass earlier in the period (Figure 4C). The other stations along the river-gradient had similar abundance and biomass. Typically, there is higher diversity in the more saline stations because of invasion by marine species (Figure 4D), and this was generally true except for April 2011. When salinity increased during the drier spring and summer,, abundance increased only at the freshest stations (Figures 4A and 4B).

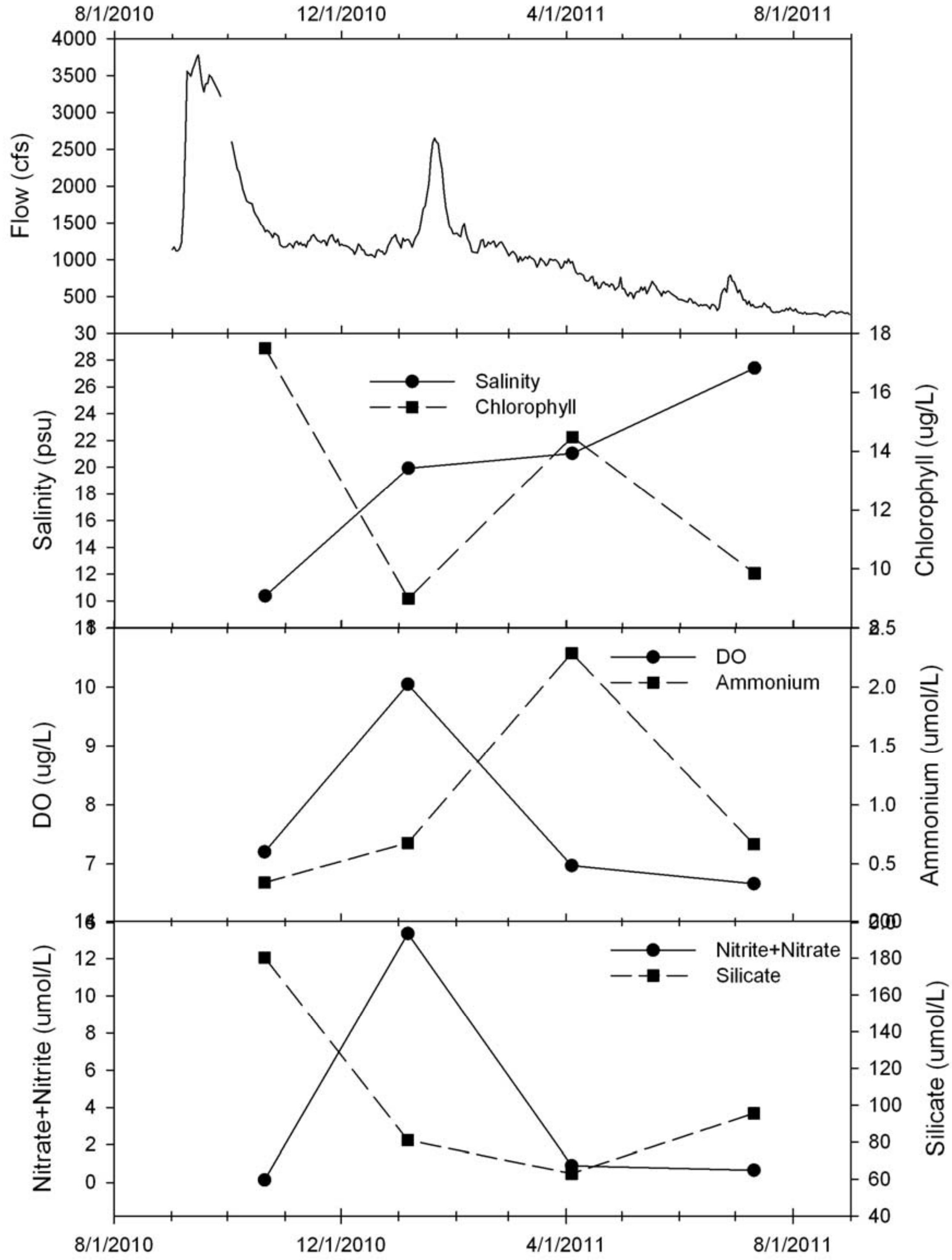

Figure 3. Flow and water quality during sampling year. Inflow at gage USGS 08188800 Guadalupe River near Tivoli, TX and water quality parameters during sampling periods.

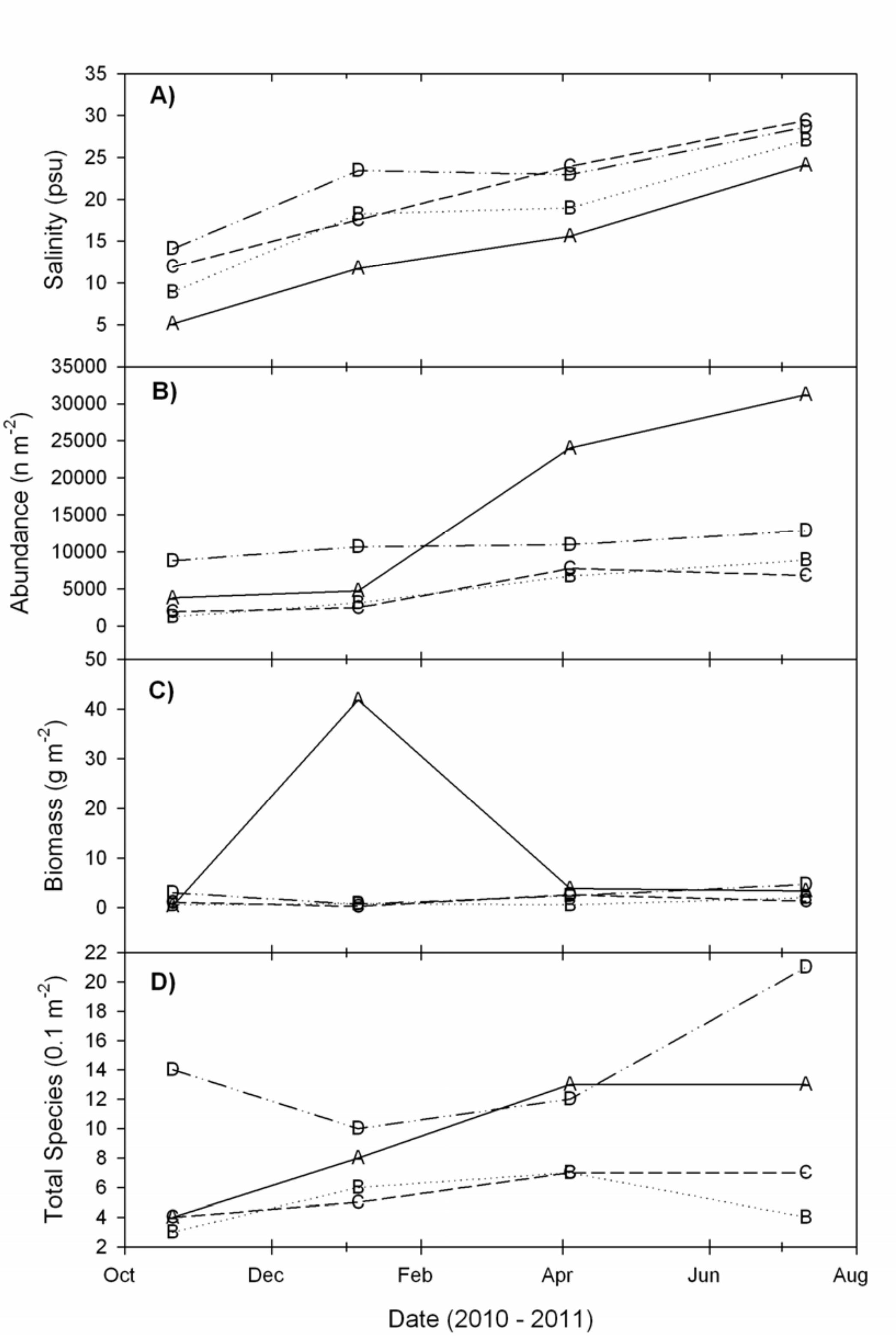

Figure 4. Macrofauna characteristics by station over the sampling period. Subfigures: A) Salinity, B) Abundance, C) Biomass, and D) Diversity.

There were a total of 48 species found over the year (Table 3). The capitellid polychaete *Mediomastus ambiseta* was the most abundant species overall and especially dominant at stations A and D. Overall, *M. ambiseta* made up 64.6 % of the total number of organisms found. Another polychaete *Streblospio benedicti* was the second most dominant species and it made up 18% of the organisms. The bivalve *Mulinia lateralis* was the third most abundant species, but made up only 2.9% of organisms found. In contrast, *M. lateralis* made up 20% of the organisms during a wetter period in 2009-2010 (Montagna and Palmer 2011). Together the six most dominant species made up 90% of all organisms found. The high diversity found in San Antonio Bay is made up of rare organisms or organisms found primarily in the marine parts of the bay, especially station D.

Macrofauna communities for each station-date combination were depicted in a multidimensional scaling plot (MDS, Figure 5). Significant clustering of communities are represented by similarity contours that are overlaid on the MDS plot. Macrofauna communities at Station D in July 2011 were significantly different from any other communities. In general, there is a gradation of communities from the fresher stations A and B from the bottom right to the saltier stations to the upper left. Three macrofauna communities occur at 50% similarity level. These represent changes in salinity over time and space. For example, the freshest station at the freshest time (Station A in October 2010 and January 2011 is furthest to the right, but station A moves to the left during the drier periods of April and July 2011.

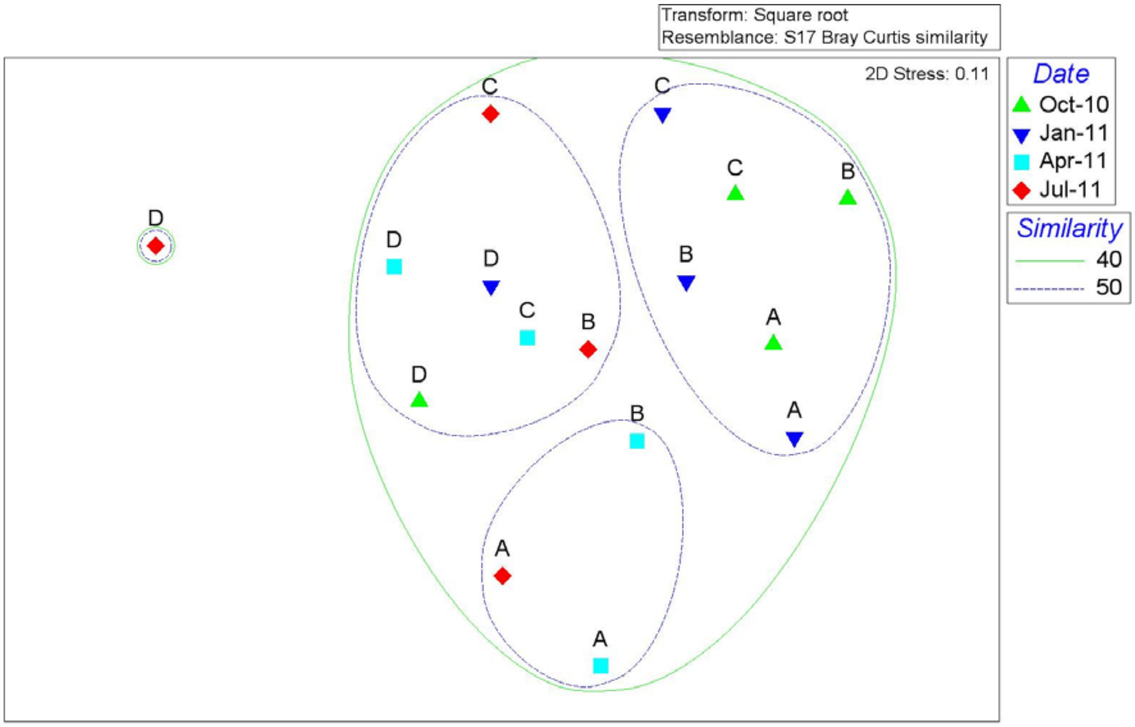

Figure 5. Multidimensional Scaling plot of macrofaunal community structure symbolized by date and labeled by station. Lines indicate percent similarity of samples from a cluster analysis.

Table 3. Species abundance and occurrence at stations in Guadalupe Estuary. Average abundance (n m^{-2}) over the period October 2010 to July 2011 period.

	Stations					Mean %
Species Name	A	B	C	D	Mean	of Total
Mediomastus ambiseta	8,604	3,049	3,853	8,084	5,897	64.6
Streblospio benedicti	4,940	1,087	260	284	1,643	18.0
Mulinia lateralis	213	260	118	473	266	2.9
Texidina sphinctostoma	402	331	0	0	183	2.0
Oligochaeta unidentified	496	0	0	0	124	1.4
Capitella capitata	402	24	0	0	106	1.2
Glycinde solitaria	71	47	47	165	83	0.9
Nemertea unidentified	71	118	24	118	83	0.9
Parandalia ocularis	189	0	24	24	59	0.6
Acteocina canaliculata	0	0	71	142	53	0.6
Cossura delta	0	0	0	213	53	0.6
Haploscoloplos foliosus	0	0	71	142	53	0.6
Axiothella mucosa	0	0	0	189	47	0.5
Eteone heteropoda	165	0	0	0	41	0.4
Macoma mitchelli	24	24	47	47	35	0.4
Paraprionospio pinnata	0	0	71	47	30	0.3
Hemicyclops sp	0	0	0	95	24	0.3
Oxyurostylis sp	0	0	71	24	24	0.3
Rangia cuneata	95	0	0	0	24	0.3
Turbonilla sp	0	0	0	95	24	0.3
Branchioasychis americana	0	0	0	71	18	0.2
Hobsonia florida	71	0	0	0	18	0.2
Microprotopus sp	0	0	0	71	18	0.2
Pectinaria gouldii	0	0	0	71	18	0.2
Pseudodiaptomus pelagicus	24	47	0	0	18	0.2
Ampelisca abdita	0	0	0	47	12	0.1
Cyclaspis varians	0	0	0	47	12	0.1
Diopatra cuprea	0	0	0	47	12	0.1
Gyptis vittata	24	0	0	24	12	0.1
Melinna maculata	0	0	0	47	12	0.1
Mysidopsis sp	24	0	24	0	12	0.1
Neanthes succinea	0	0	0	47	12	0.1
Pandora trilineata	0	0	24	24	12	0.1
Xenanthura brevitelson	0	0	0	47	12	0.1
Clibanarius vittatus	0	0	0	24	6	0.1
Corophium louisianum	0	0	0	24	6	0.1
Fargoa cf gibbosa	0	0	0	24	6	0.1
Haploscoloplos fragilis	0	0	24	0	6	0.1
Isolda pulchella	0	0	0	24	6	0.1
Magelona pettiboneae	0	0	0	24	6	0.1
Megalomma bioculatum	0	0	0	24	6	0.1
Monoculodes sp	24	0	0	0	6	0.1
Mytilidae unidentified	0	0	0	24	6	0.1
Ostracoda unidentified	24	0	0	0	6	0.1
Polydora websteri	24	0	0	0	6	0.1
Rictaxis punctostriatus	24	0	0	0	6	0.1
Scolelepis texana	24	0	0	0	6	0.1
Spiochaetopterus costarum	0	0	0	24	6	0.1
Total	15,931	4,987	4,727	10,873	9,130	100.0

Benthic data has been collected in the Guadalupe Estuary since 1987 (Figure 6). The period from October 2010 through July 2011 was the driest period in the record as indicated by highest estuary-wide average salinities, reaching an average of around 35 psu. The other periods when salinities were also high were 1988-1991, and 1997-1998, and 2008-2009. There has been a long-term decline in abundance over the entire range of sampling dates, and this continued during the current sampling period. Biomass has fluctuated, generally being high biomass during high salinity periods. The biomass was relatively low over the sampling period compared to the long-term trends. Diversity fluctuates with salinity, being higher during high salinity periods, but was uncharacteristically low during the current high salinity period.

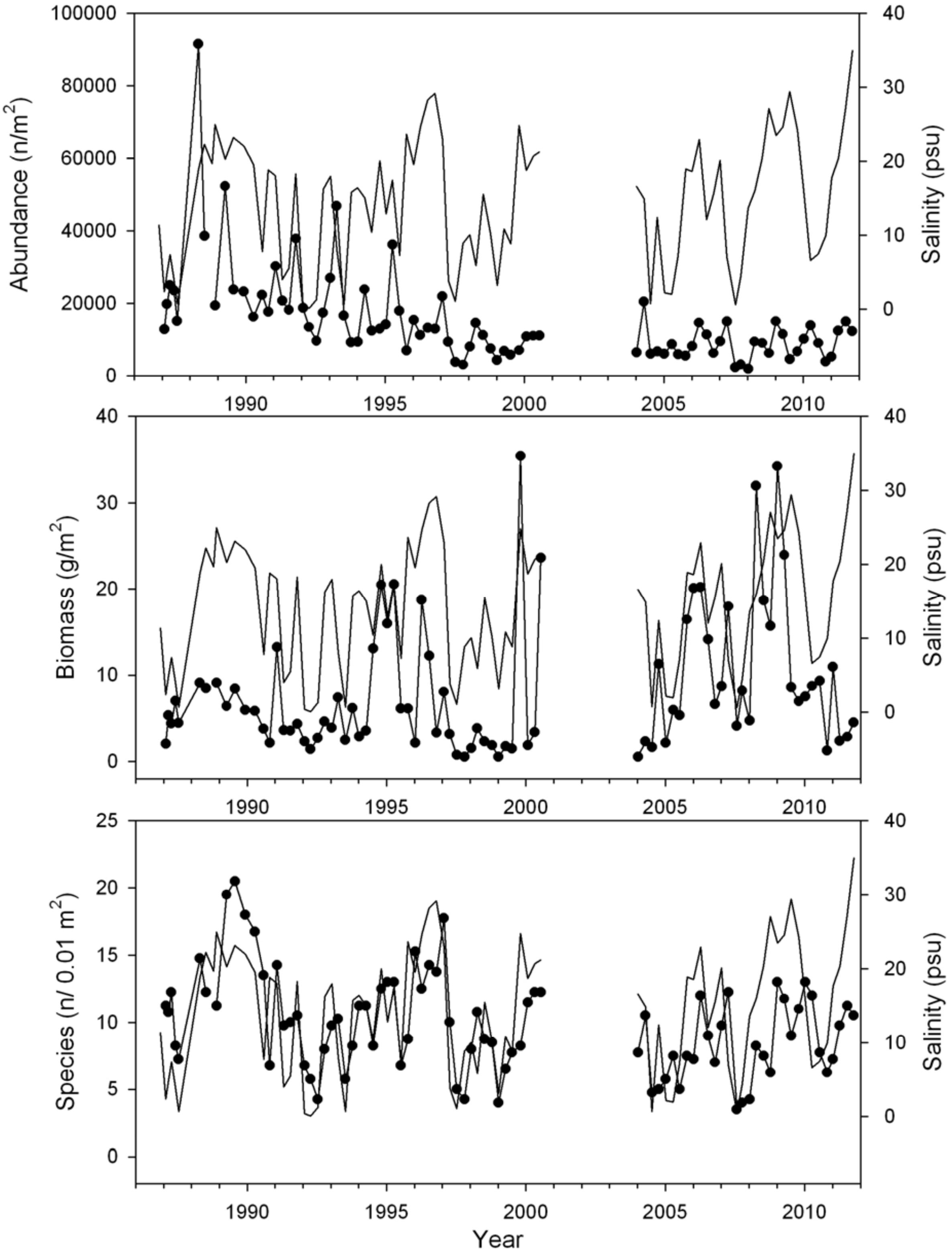

Figure 6. Long-term change in estuary-wide, average, biomass (with dots for each sample) and salinity (continuous line).

DISCUSSION

Overall water quality trends of station-date combinations separate stations both by season and by amount of freshwater inflow that each station receives (Figures 2 and 3). Temperature is inversely proportional to dissolved oxygen and the separation of the station-date combinations along this gradient represents seasonal changes in water quality. The spatial difference in freshwater inflow that each station receives is represented by the inverse relationship between salinity and nutrients. Station A is the closest of the stations to the Guadalupe River mouth so had the highest nutrient concentrations and lowest salinity values. The most important trend during the current sampling period was a transition from a wet period to a dry period.

There is a clear difference between macrofauna communities in environments with low salinities (Station A) and macrofauna communities at stations with high salinities(Station D). In many years, there are gradients where Stations A and B are similar and Stations C and D are similar, but during the current period, all stations exhibited marine influence. Freshwater inflow into Guadalupe Estuary travels southwest along the western side of the estuary allowing lower salinities on the southwestern side to be lower than salinities on the northeastern side resulting in long-term lower salinities at station C than D (Table 2). The macrofauna community at station C is an intermediate community between the communities of the upper stations (A and B) and the community at station D because station C is located on the southwestern side of the estuary whereas station D is located on the southeastern side. This intermediate community occurs at station C despite station D being closer to the Guadalupe River mouth than station C.

It is also apparent that macrofauna abundance and biomass reacted positively with salinity after the large freshwater event in September and October 2010. When salinities reached the highest levels in April and July 2011, the abundance in Station A, closest to the river with the lowest salinity, was the highest. Biomass was high only at Station A, and only in January 2011. Species richness typically increases during high salinity periods because of invasion by marine species, thus it increased during period of study at Station A. However, richness stayed relatively constant at stations B and C throughout the sampling period.

There has been a decline in macrofauna abundance since 1987, however there is no associated decrease in macrofauna biomass or species richness. Biomass follows a pattern of increasing when salinity increases and decreasing when salinity decreases. Estuary-wide salinity has changed from being more sporadic before 2005 to a state of gradual change after 2005. Mean estuary-wide salinity in July 2011 (35 psu) is the highest it has been since 1987.

REFERENCES

Bedford W.B.and J.W. Anderson. 1972. The physiological response of the estuarine clam *Rangia cuneata* (Gray) to salinity. I. Osmoregulation, Physiological Zoology 45: 255–260.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18: 117-143.

Clarke, K.R. and R.M Warwick. 2001. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd Edition. PRIMER-E: Plymouth, United Kingdom.

Kalke, R.D. and P.A. Montagna. 1991. The effect of freshwater inflow on macrobenthos in the Lavaca River Delta and Upper Lavaca Bay, Texas. *Contributions to Marine Science* 32:49-72.

Kim, H-C., and P.A. Montagna. 2009. Implications of Colorado River freshwater inflow in the benthic ecosystem dynamics and bay health: a modeling study. *Estuarine, Coastal and Shelf Science* 83:491-504.

Kim, H.-C. and P.A. Montagna. 2010. Effect of Climatic Variability on Freshwater Inflow, Benthic Communities, and Secondary Production in Texas Lagoonal Estuaries. Final report to the Texas Water Development Board, contract number 08-483-0791. Harte Research Institute for Gulf of Mexico Studies, Texas A&M University-Corpus Christi, Corpus Christi, Texas. 119 pages.

Longley, W.L. (ed.). 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, Texas. 386 p.

Montagna, P.A. 1989. Nitrogen Process Studies (NIPS): the effect of freshwater inflow on benthos communities and dynamics. Technical Report No. TR/89-011, Marine Science Institute, The University of Texas, Port Aransas, TX, 370 pp.

Montagna, P.A. 1999. Predicting long-term effects of freshwater inflow on macrobenthos and nitrogen losses in the Lavaca-Colorado and Guadalupe Estuaries. Final Report to Texas Water Development Board. Technical Report No. TR/99-001, Marine Science Institute, The University of Texas, Port Aransas, TX, 68 pp.

Montagna, P.A. 2000. Effect of freshwater inflow on macrobenthos productivity and nitrogen losses in Texas estuaries. Final report to Texas Water Development Board, Contract No. 2000-483-323, University of Texas Marine Science Institute Technical Report Number TR/00-03, Port Aransas, Texas. 78 pp.

Montagna, P.A., E.D. Estevez, T.A. Palmer, and M.S. Flannery. 2008. Meta-analysis of the relationship between salinity and molluscs in tidal river estuaries of southwest Florida, USA. American Malacological Bulletin 24(1-2):101-115.

Montagna, P.A. and R.D. Kalke. 1992. The effect of freshwater inflow on meiofaunal and macrofaunal populations in the Guadalupe and Nueces Estuaries, Texas. *Estuaries* 15:266-285.

Montagna, P.A. and R.D. Kalke. 1995. Ecology of infaunal Mollusca in south Texas estuaries. *American Malacological Bulletin* 11:163-175.

Montagna, P.A, E.M. Hill, and B. Moulton. (2009). Role of science-based and adaptive management in allocating environmental flows to the Nueces Estuary, Texas, USA. In: Brebbia, C.A. and E. Tiezzi (eds.), Ecosystems and Sustainable Development VII, WIT Press, Southampton, UK, pp. 559-570.

Montagna, P.A., and J. Li. 1996. Modeling and monitoring long-term change in macrobenthos in Texas estuaries. Final Report to the Texas Water Development Board. University of Texas at Austin, Marine Science Institute, Technical Report No. TR/96-001, Port Aransas, Texas, 149 pp.

Montagna, P.A. and J. Li. 2010. Effect of Freshwater Inflow on Nutrient Loading and Macrobenthos Secondary Production in Texas Lagoons. In: Coastal Lagoons: Critical Habitats of Environmental Change, M. J. Kennish and H. W. Paerl (eds.), CRC Press, Taylor & Francis Group, Boca Raton, FL, pp. 513-539.

Montagna, P.A., and T.A. Palmer. 2009. Effect of Freshwater Inflow on Macrobenthos Productivity in the Guadalupe Estuary 2008-2009. Final Report to the Texas Water Development Board, Contract # 0904830893. Harte Research Institute, Texas A&M University-Corpus Christi, Corpus Christi, Texas, 12 pp.

Montagna, P.A., and T.A. Palmer. 2011. Effect of Freshwater Inflow on Macrobenthos Productivity in the Guadalupe Estuary 2009-2010. Final Report to the Texas Water Development Board, Contract # 1004831015. Harte Research Institute, Texas A&M University-Corpus Christi, Corpus Christi, Texas, 17 pp.

Montagna, P.A., T.A. Palmer, and J. Beseres Pollack. 2007. Effect Of Freshwater Inflow On Macrobenthos Productivity In Minor Bay And River-Dominated Estuaries - Synthesis. Final Report to the Texas Water Development Board, Contract No. 2006-483-026.

Montagna, P., G. Ward and B. Vaughan. 2010. The importance and problem of freshwater inflows to Texas estuaries. In: Water Policy in Texas: Responding to the Rise of Scarcity, R.C. Griffin (ed.). The RFF Press, London.

Montagna, P.A. and Yoon, W.B. 1991. The effect of freshwater inflow on meiofaunal consumption of sediment bacteria and microphytobenthos in San Antonio Bay, Texas USA. *Estuarine and Coastal Shelf Science* 33:529-547.

Pollack, J.B., J.W. Kinsey, and P.A. Montagna. 2009. Freshwater Inflow Biotic Index (FIBI) for the Lavaca-Colorado Estuary, Texas. *Environmental Bioindicators* 4:153-169.

Science Advisory Committee. 2009. Methodologies for Establishing a Freshwater Inflow Regime for Texas Estuaries Within the Context of the Senate Bill 3 Environmental Flows Process. Report # SAC-2009-03-Rev1., June 5, 2009. Available at http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/eflows/fwi20090605.pdf

Swingle, H. A. and D. G. Bland. 1974. Distribution of the estuarine clam *Rangia cuneata* Gray in the coastal waters of Alabama. *Alabama Marine Resource Bulletin* 10: 9-16.

Welschmeyer, N. A. 1994. Fluorometric analysis of chlorophyll a in the presence of chlorophyll b and pheopigments. *Limnology and Oceanography* 39:1985-1992.

Texas Water
Development Board

P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

May 10, 2012

Paul Montagna, Ph.D.
Texas A&M University at Corpus Christi
Harte Research Institute for Gulf of Mexico Studies
6300 Ocean Drive, Unit #5844
Corpus Christi, Texas 78412

RE: Research and Planning Fund Grant Contract between the Texas Water Development Board (TWDB) and Texas A&M University at Corpus Christi (TAMU-CC); TWDB Contract No. 1104831133, Draft Report Comments

Dear Dr. Montagna:

Staff members of the TWDB have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT I provides the comments resulting from this review. As stated in the TWDB contract, TAMU-CC will consider incorporating draft report comments from the EXECUTIVE ADMINISTRATOR as well as other reviewers into the final report. In addition, TAMU-CC will include a copy of the EXECUTIVE ADMINISTRATOR'S draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. **Please further note, that in compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report must comply with the requirements and standards specified in statute. For more information, visit** http://www.sos.state.tx.us/tac/index.shtml**.** If you have any questions on accessibility, please contact David Carter with the Contract Administration Division at (512) 936-6079 or David.Carter@twdb.texas.gov.

TAMU-CC shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

If you have any questions concerning the contract, please contact Dr. Carla Guthrie, the TWDB's designated Contract Manager for this project at (512) 463-4179.

Sincerely,

Robert E. Mace, Ph.D., P.G.
Deputy Executive Administrator
Water Science and Conservation

Enclosures
c: Carla Guthrie, Ph.D., TWDB

ATTACHMENT I

Effect of freshwater inflow on macrobenthos productivity in the Guadalupe Estuary

P.I. Paul Montagna
Contract # 1104831133
TWDB comments to Final Report

REQUIRED CHANGES

General Draft Final Report Comments:

This study scope of work focused on collecting and assessing benthic community data in the Guadalupe Estuary. The goal of this effort is to relate changes in water column dynamics with changes in benthic community dynamics. The continued data collection and information about benthic community trends, water quality data, and nutrient data in this estuary will allow for the analysis of estuarine productivity and understanding of long-term ecosystem dynamics in the San Antonio Bay system.

Please check the document for grammar, spelling, and typographical errors.

Please be sure that the report meets new accessibility requirements as noted in TWDB's cover letter.

Specific Draft Final Report comments:

1. Introduction, page 1 3rd ¶: This paragraph discusses general trends in the deposit feeders, suspension feeders, upstream benthic community, and downstream benthic community with respect to inflows. Please add wording to clarify whether the increasing and decreasing trends are a result of changes in species number, the abundances of individual species, or a combination of both.

2. Results, page 5, 1st ¶: The data results described in the results section do not match the data presented in Figure 2a. Specifically, the text states that PCA explained 81% of the variation, with PC1 explaining 56% and PC2 explaining 25% of the variation. However, the data presented in Figure 2 show that PCA explained 71% of the variation, with PC1 explaining 42% and PC2 explaining 31% of the variation. Furthermore, the description of the principal component axes is reversed. It is stated that PC1 represents seasonal changes in water quality with high temperatures being inversely proportional to dissolved oxygen and Nitrate+Nitrite concentrations, but Figure 2 indicates that PC2 represents this gradient. Similarly, the description of the PC2 axis is reversed as well. Please make the necessary corrections.

3. Discussion, page 14, 2nd ¶: There is a reference to Table 4 in the text, but there is no Table 4 in the report. Please correct.

4. Discussion, page 14, 2nd ¶, 3rd sentence: The text describes the travel of inflow through the estuary as "southeast along the western side of the estuary". Inflow tends to travel southwesterly; this sentence may need to be corrected.

5. Discussion, page 14, 3rd ¶, 1st sentence: Please consider re-phrasing the statement that "*It is also apparent that macrofauna abundance and biomass reacted positively to increases in inflow as indicated by decreases in salinity*", along with the supporting information in this paragraph. Data presented in the report suggest that salinity increased during the study period as inflows decreased. Data do not show any appreciable inflow events. Station A reports the highest abundance of all stations during the high salinity period, but this is not necessarily due to an inflow event. Also, Figure 6 shows long-term trends that indicate abundance and biomass are highest when salinities are highest. Diversity measures were not reported in the study; only abundance and richness.

Figures and Tables Comments:

1. Table 3, page 11: The table caption describes "species dominance and occurrence", a more accurate description is "species abundance and occurrence". Additionally, it will be helpful to clarify that these values are total abundance at a given station for *all* sampling events. Mean abundance of a species at these four sites in the bay is useful when the species is recorded at all stations. However, when a species is recorded at only one station, mean abundance seems less relevant. It may be more useful to report total abundance and mean abundance for each station.

SUGGESTED CHANGES
Specific Draft Final Report Comments:

1. Results, page 1: Please consider including a citation to reference the Principal Component Analysis, non-metric Mutli-Dimensional Scaling ordination, and Cluster Analysis.

2. Results, page 10, 1st ¶: Please consider adding a citation from a previous report to the statement "In contrast, *Mulinia* made up 20% of the organisms during a wetter period in 2009-2010."

3. Discussion, page 14: Please consider including a discussion or summary of the long-term trends observed in water quality, abundance and biomass since data collection began in 1987.

Figures and Tables Comments:

1. Table 3. Please consider adding another column in the table to show percent abundance of the total for each species found.