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 # 0904830893

November 2009
Revised February 2010

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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.

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, are now subject to greater scrutiny because of recent legislative changes. In recognition of the importance that the ecological soundness of our riverine, bay, and estuary systems and riparian lands has on the economy, health, and well-being of our state, the 80th Texas Legislature enacted Senate Bill 3, which calls for creation of Basin and Bay Area Stakeholder Groups. These groups will be responsible for establishing requirements for water for environmental needs for bay and estuary inflows. 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, Stakeholder Groups will need information on freshwater inflow effects on water quality and biological indicator communities.

Since 1986, researchers led by Dr. Montagna have been studying the effect of freshwater inflow on benthic productivity (Kalke and Montagna 1991; Montagna 1989, 1999, 2000; Montagna et al. 2007; Montagna and Kalke 1992, 1995; Montagna and Li 1996; Montagna and Yoon 1991). 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. 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 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 in models. The benthic productivity model was first developed by Montagna and Li (1996) to estimate productivity in four Texas estuaries (Lavaca-Colorado, Guadalupe, Nueces, and Laguna Madre). Recently, Kim and Montagna (2009) refined the model and used it to support inflow criteria development for the eastern arm of Matagorda Bay in the Lavaca-Colorado Estuary. The long-term goal is to rerun the original model, which was based on data from 1988 – 1995 on a much longer time scale. In order to calibrate the model, data is needed, and the data collected during this study will support that effort as well.

METHODS

Four stations were sampled for macrofauna and water quality in Guadalupe Estuary (San Antonio Bay; Figure 1). Sampling occurred four times in the first year of sampling; October 2008, and January, April, and July 2009.

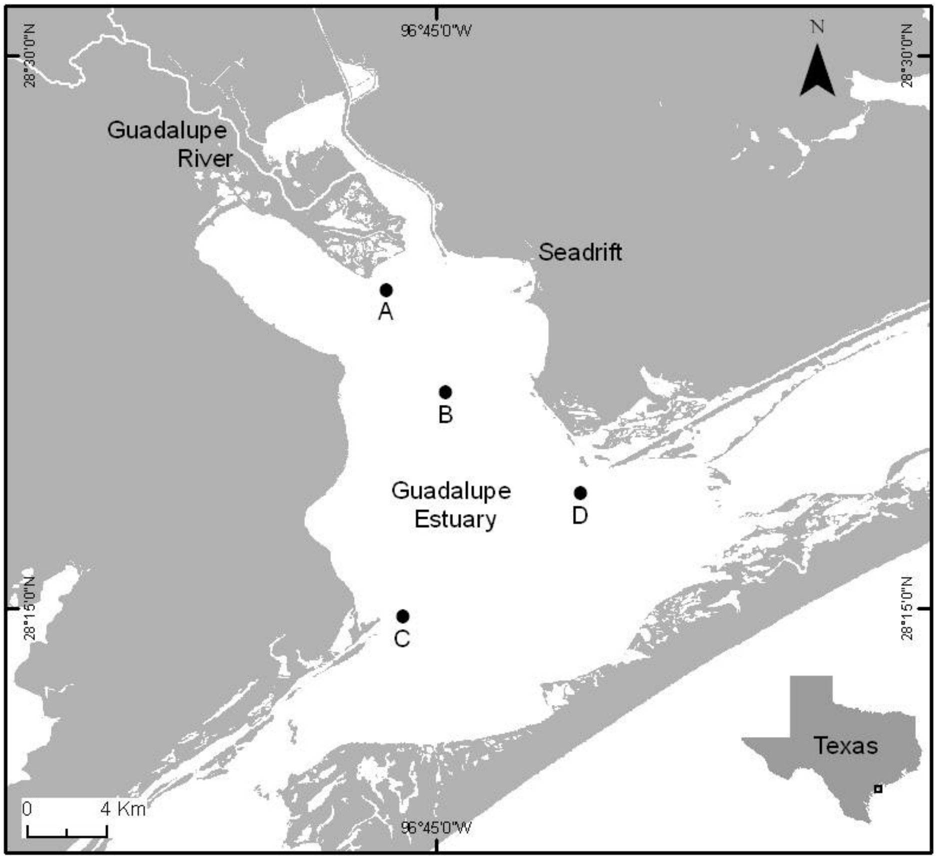

Figure 1. Map of sampling stations in Guadalupe Estuary / San Antonio Bay

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 ºC), pH (± 0.1 units), dissolved oxygen (± 0.2 mg l^{-1}), depth (± 1 m), and salinity (ppt). Salinity is automatically corrected to 25 ºC.

Chlorophyll samples were filtered onto glass fiber filters and placed on ice (<4.0 °C).). Chlorophyll will be extracted overnight and read fluorometrically on a Turner Model 10-AU using a 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). Both samples conducted at Harte Research Institute using a SmartChem autoanalyzer with computer controlled sample selection and peak processing. Chemistries are as specificed 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 environment 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. 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 nonmetric multidimensional scaling (MDS) and cluster analysis using a Bray-Curtis similarity matrix. Prior to analysis, the data was log10 transformed. 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 be displayed on the MDS plot to elucidate grouping of station-date combinations. The group average cluster mode was used for the cluster analysis.

RESULTS

Principle Components Analysis explained 86 % of the variation within the water quality dataset. Principal Component (PC) 1 explained 52 % of the variation while PC2 explained 33 % of the variation. PC1 represents seasonal changes in water quality with high temperatures and silicate concentrations being inversely proportional to pH and dissolved oxygen concentrations (Figure 2A). High temperatures and silicate concentrations occurred in October 2008 and July 2000, while the lowest temperatures and silicate concentrations occurred in January 2009 (Figure 2C). PC2 represents spatiotemporal changes in water quality. Along the PC2 axis, salinity is inversely proportional to phosphate and ammonium (Figure 2A). The lowest salinity values (20 to 21 ppt) and highest phosphate (3.2 - 3.3 mg l^{-1})and ammonium (9.9 - 10.5 mg l^{-1})concentrations occur in April 2009 at stations A and B (Figures 2B and C). The lowest salinity and highest phosphate concentrations occur at Stations A and B, however ammonium concentrations are below detection for all dates except for April at Station B (Table 2). Ammonium concentrations are below detection limits for all but one sampling date at Stations B and D, and for all dates at Station C. Mean chlorophyll concentrations are the highest and most stable at station B. Mean dissolved oxygen concentrations are also highest at station B, however they are more variable than any other station.

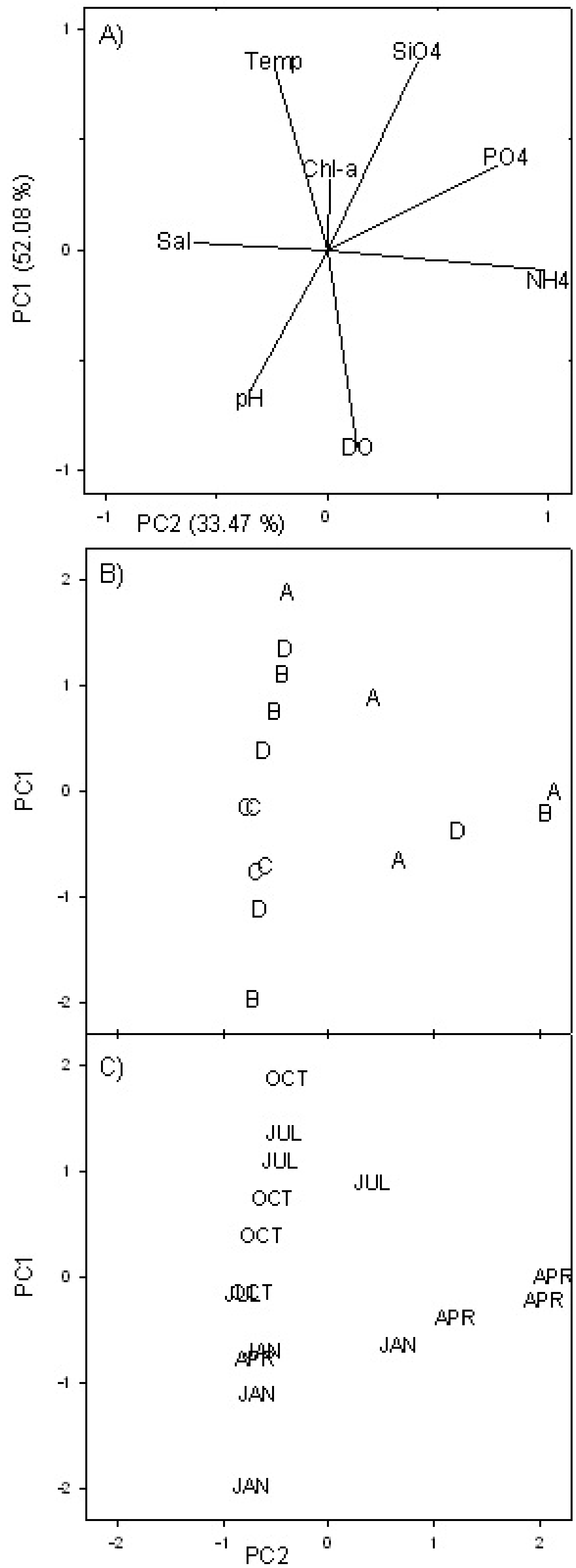

Figure 2. Principal Components Analysis of water quality. Variable loading plot (A) and station-scores labeled by station (B) and month(C) stating in October 2008 through to July 2009.

Table 2. Mean water quality values for each station. Standard deviation for the four sampling dates at each station are in parentheses.

		Station				
Variable	Units	A	B	C	D	Mean
Chlorophyll	mg l^{-1}	8.1 (5.7)	9.1 (2.4)	8.4 (6.2)	5.0 (3.0)	7.7 (4.5)
Dissolved Oxygen	mg l^{-1}	7.1 (3.0)	8.6 (3.1)	7.4 (1.3)	7.4 (1.4)	7.6 (2.2)
Ammonium	µmol l^{-1}	3.4 (4.8)	2.5 (5.0)	0.0 (0.0)	1.2 (2.4)	1.8 (3.5)
pH		8.1 (0.2)	8.2 (0.2)	8.1 (0.0)	8.1 (0.1)	8.2 (0.1)
Phosphate	µmol l^{-1}	2.6 (0.7)	1.7 (1.1)	0.7 (0.1)	1.2 (0.6)	1.6 (1.0)
Salinity	psu	21.6 (2.1)	24.3 (3.4)	31.3 (3.9)	29.0 (2.5)	26.5 (4.8)
Silicate	µmol l^{-1}	123 (55.7)	99.5 (44.6)	55.2 (17.6)	82.0 (41.7)	90.0 (45.7)
Temperatur						21.7 (6.1)

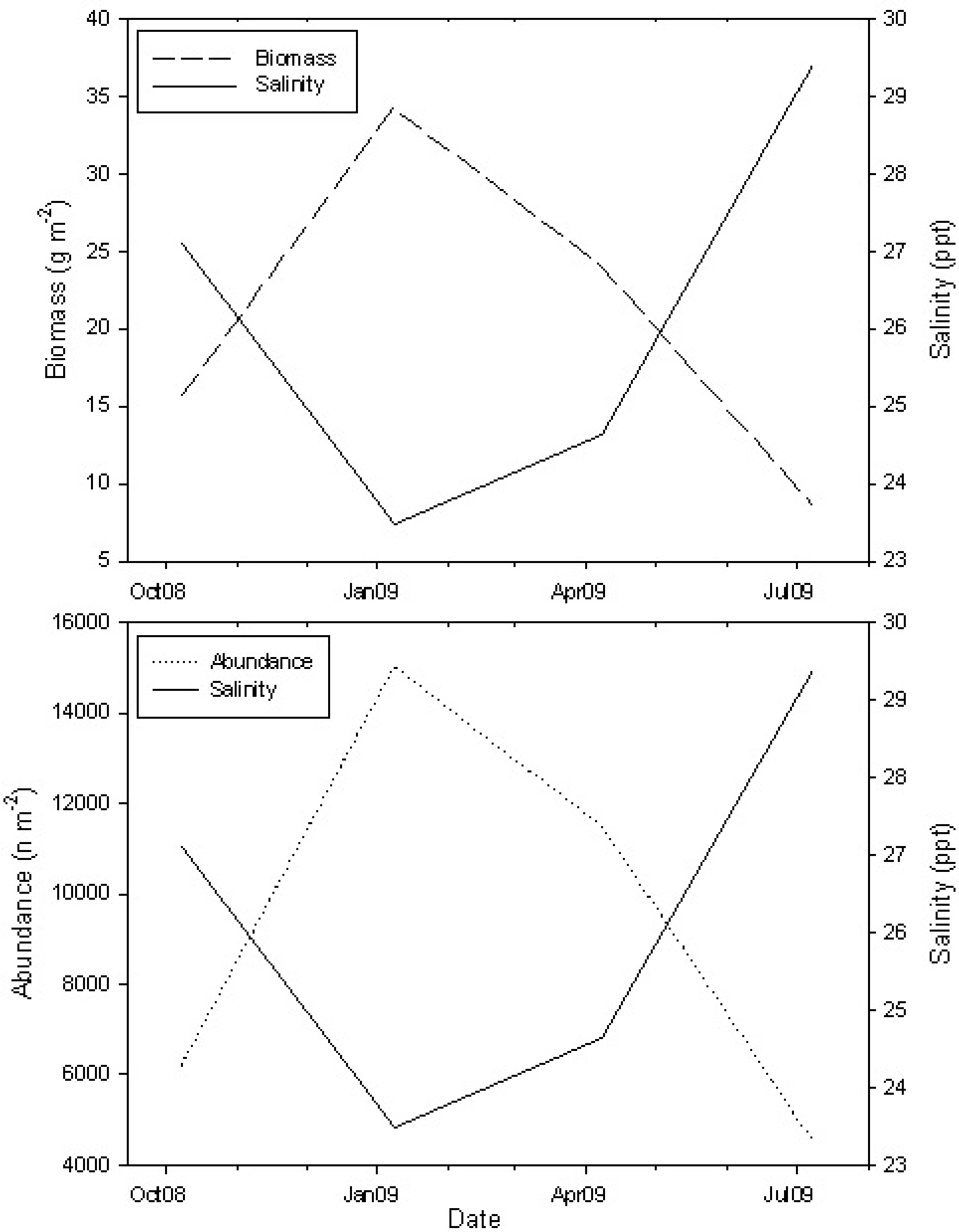

Figure 3. Macrofaunal biomass (top) and abundance (bottom) over time in relation to salinity

Mean macrofaunal abundance and biomass increased between October 2008 (6000 n m^{-2} and 16 g m^{-2}) and January 2009 (15000 n m^{-2} and 34 g m^{-2}) and then decreased for each quarter thereafter (Figure 3). The pattern of salinity change over time was opposite that of macrofaunal abundance and biomass. Salinity decreased from 27 to 23 ppt between October 2008 and January 2009 and then increased to a maximum of 29 ppt by July 2009 (Figure 3).

The capitellid polychaete *Mediomastus ambiseta* was the most abundant species at all stations except for at station C, where the bivalve *Mulinia lateralis* was the most abundant (Table 2). Overall, *M. ambiseta* made up over 60 % of the total number of organisms found. Another polychaete *Streblospio benedicti* was the second most abundant species att all stations except for station C. *S. benedicti* was the third most abundant species at station C.

Macrofaunal communities for each station-date combination were depicted in a Multidimensional Scaling plot (MDS, Figure 4). Significant clustering of communities are represented by similarity contours that are overlaid on the MDS plot. Macrofaunal communities at Station B in July were significantly different from any other communities. Macrofauna communities that occur at Stations A and B (top of MDS plot) are different from communities that occur at Stations C and D (bottom of MDS plot) regardless of the date sampled. The community at station C actually represents an intermediate between the community at station D and the communities at station A and B. In general, salinities in Stations A and B are lower than salinities in Stations C and D. All communities in October 2008 are clearly different from all communities in the other three months sampled. The separation of October 2008 and other communities confirms large scale temporal variation over the entire estuary.

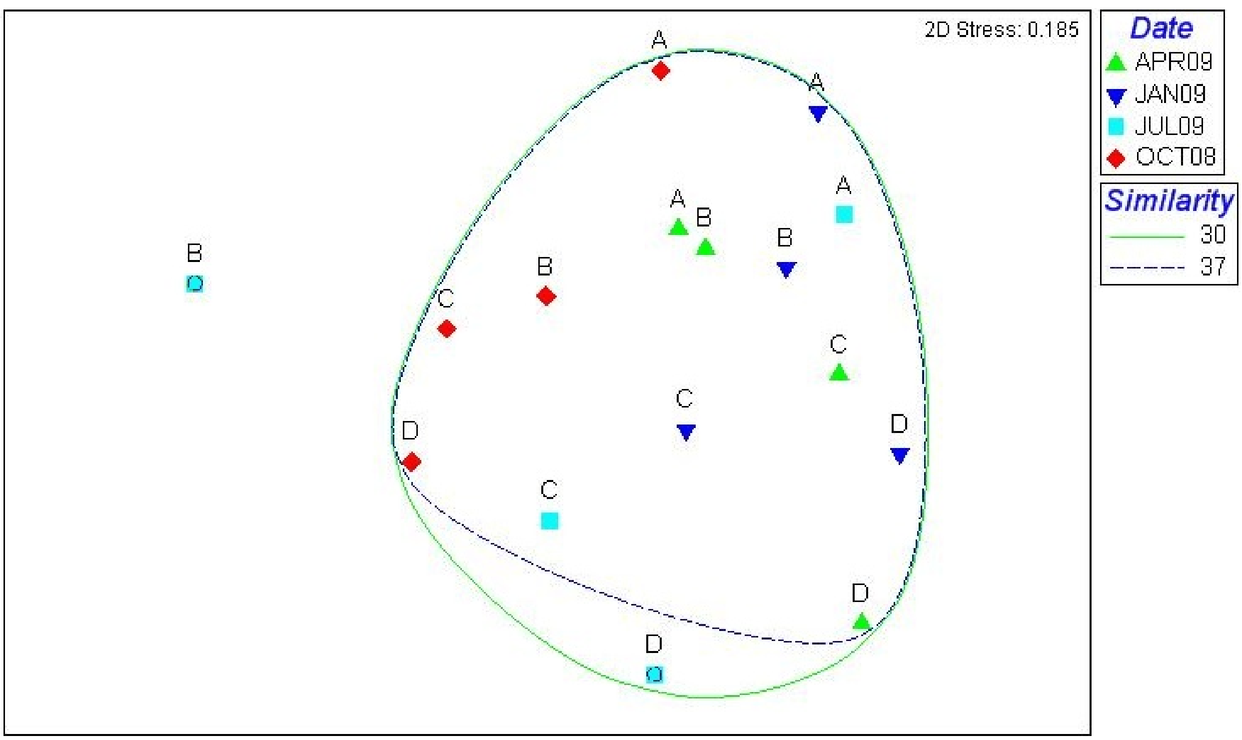

Figure 4. Multidimensional Scaling plot of macrofaunal community structure symbolized by date and labeled by station.

Table 2. Species occurrence at stations in Guadalupe Estuary

Species	Abundance (n m^{-2}) A	B	C	D	Mean	Percent of Mean
Mediomastus ambiseta	14253	5862	1040	2056	5803	62.2
Streblospio benedicti	3238	1489	213	402	1335	14.3
Mulinia lateralis	473	615	1915	24	756	8.1
Glycinde solitaria	95	213	71	236	154	1.6
Macoma mitchelli	47	378	47	95	142	1.5
Cyclaspis varians	284	142	24	24	118	1.3
Oxyurostylis sp.	95	189	118	24	106	1.1
Nemertea (unidentified)	95	0	71	189	89	0.9
Polydora ligni	284	24	0	0	77	0.8
Paraprionospio pinnata	0	24	142	142	77	0.8
Rangia cuneata	307	0	0	0	77	0.8
Oligochaeta (unidentified)	95	142	0	71	77	0.8
Ampelisca abdita	24	0	24	142	47	0.5
Parandalia ocularis	142	24	0	0	41	0.4
Pectinaria gouldii	47	0	24	71	35	0.4
Microprotopus sp.	24	71	24	24	35	0.4
Spiochaetopterus costarum	0	0	0	142	35	0.4
Texidina sphinctostoma	24	47	47	0	30	0.3
Gyptis vittata	0	24	24	47	24	0.3
Acteocina canaliculata	0	71	0	24	24	0.3
Hemicyclops sp.	0	0	0	95	24	0.3
Capitella capitata	71	0	0	0	18	0.2
Molgula manhattensis	0	0	0	71	18	0.2
Haploscoloplos foliosus	0	0	0	71	18	0.2
Fabriciola trilobata	0	0	0	47	12	0.1
Monoculodes sp.	24	24	0	0	12	0.1
Turbonilla sp.	0	0	0	47	12	0.1
Diastylis sp.	24	0	24	0	12	0.1
Aligena texasiana	0	0	0	47	12	0.1
Hobsonia florida	47	0	0	0	12	0.1
Balanus eburneus	47	0	0	0	12	0.1
Ogyrides limicola	0	0	0	24	6	0.1
Clymenella torquata	0	0	0	24	6	0.1
Nudibranchia (unidentified)	0	0	0	24	6	0.1
Mysidopsis almyra	24	0	0	0	6	0.1
Chironomidae (larvae)	24	0	0	0	6	0.1
Eulimastoma sp.	0	0	24	0	6	0.1
Turbellaria (unidentified)	0	24	0	0	6	0.1
Texidina barretti	24	0	0	0	6	0.1
Sigambra tentaculata	0	0	24	0	6	0.1
Scolelepis texana	0	0	0	24	6	0.1
Cyclopoida (commensal)	0	0	24	0	6	0.1

Species	Abundance (n m^{-2})					Percent of
	A	B	C	D	Mean	Mean
Maldanidae (unidentified)	0	0	0	24	6	0.1
Schizocardium sp.	0	0	0	24	6	0.1
Pseudodiaptomus pelagicus	0	0	24	0	6	0.1
Pinnixa sp.	0	0	0	24	6	0.1
Cossura delta	0	0	0	24	6	0.1
Total	19808	9360	3900	4278	9337	100.0
Total Number of Species	24	17	19	30	47	

The period from 2008 through 2009 was a high biomass and high salinity period compared to data collected between 1987 and 2000 (Figure 5).

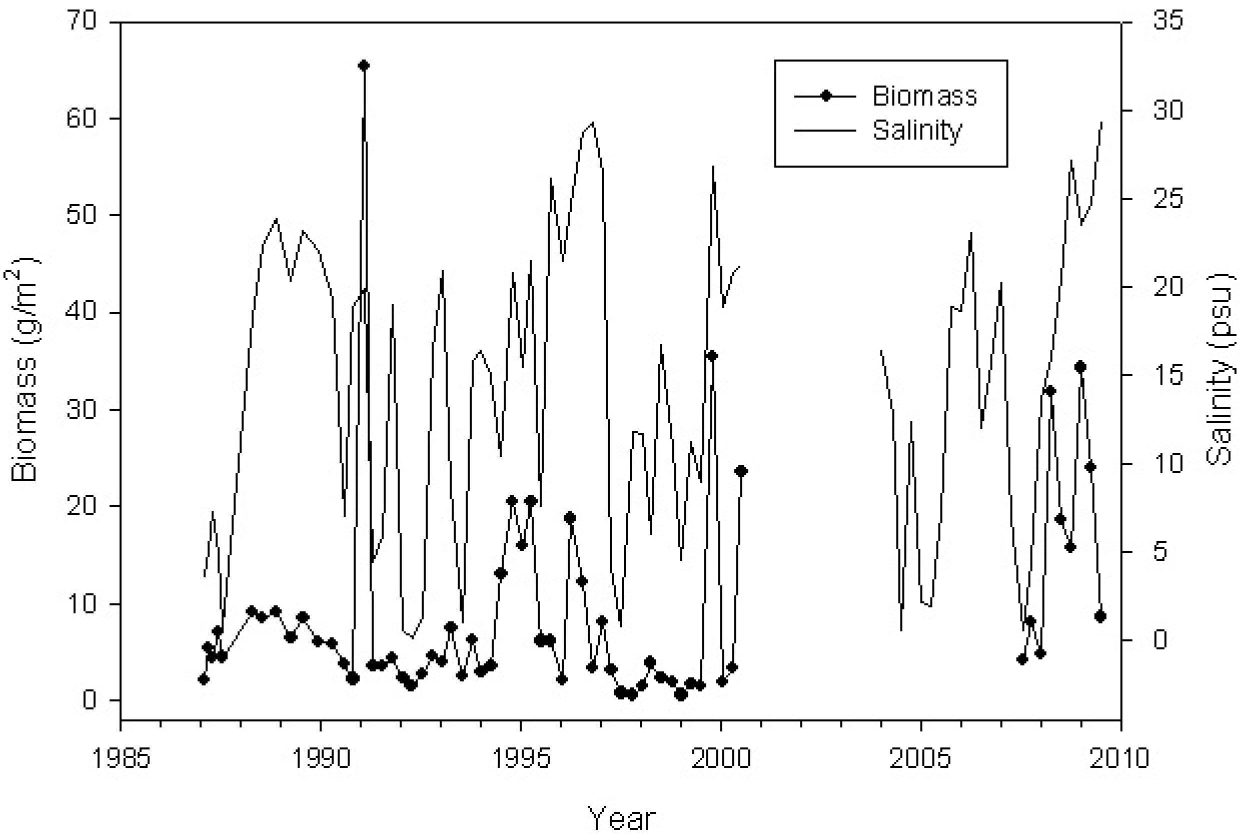

Figure 5. Long-term change in estuary-wide, average, biomass and salinity

DISCUSSION

Overall water quality trends of station-date combinations separate stations both by season and by amount of freshwater inflow that each station receives (Figure 2). Temperature is inversely proportional to dissolved oxygen and the separation of the station-date combinations along this gradient (PC1) 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 (ammonium and phosphate; PC2). Station A is the closest of the stations to the Guadalupe River mouth so had the highest nutrient concentrations and lowest salinity values (highest PC2 scores). It is unknown why there are high ammonium concentrations at stations B and D in April 2009 because salinities are not low nor are phosphate levels high.

There is a clear difference between macrofauna communities in environments with low salinities and high phosphate concentrations (Stations A and B) and macrofaunal communities at stations with higher salinities and lower phosphate concentrations (Stations C and D). Freshwater inflow into Guadalupe Estuary travels southward along the western side of the estuary allowing lower salinities on the western side to be lower than the rest of the estuary (Slack et al. 2009). 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.

In other words, estuarine macrofauna communities with a greater river influence were different from estuarine macrofauna communities with a greater marine influence. It is also clear that macrofaunal abundance and biomass during the October 2008 - July 2009 period reacted negatively to increases in salinity and positively to decreases in salinity when salinities are between 23 and 30 ppt. The reaction of biomass to salinity over this October 2008 to July 2009 period has to be treated with caution because this was during a high salinity period relative to long-term trends. Biomass actually increased with a long-term increase in salinity in 2008 and 2009. Other high salinity periods have been recorded between 1987 and 2001 but not all have had corresponding periods of high biomass. The recent increase in biomass is partially attributable to the growth of an age cohort of *Rangia cuneata* clams at station A (Kalke R.D., unpublished data). *R. cuneata* usually occurs at lowers salinities (0- 15 psu; Montagna et al. 2008, Swingle and Bland 1974) but is known to tolerate salinities up to 33 psu in the laboratory (Bedford and Anderson 1972). Salinities above 25 psu appear to be negatively correlated with macrofaunal biomass in the 2008-2009 period in Guadalupe Estuary.

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January 15, 2010

Paul Montagna, Ph.D.
Endowed Chair for Ecosystems Studies and Modeling
Texas A&M University - Corpus Christi
6300 Ocean Drive, Unit #5869
Corpus Christi, Texas 78412-5869

Re: Research Contract between the Texas Water Development Board (TWDB) and Texas A&M University - Corpus Christi (TAMUCC), TWDB Contract No. 0904830893, Draft Final 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, TAMUCC will consider incorporating draft report comments from the EXECUTIVE ADMINISTRATOR as well as other reviewers into the final report. In addition, TAMUCC 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. TAMUCC 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

Effect of Freshwater Inflow on Macrobenthos Productivity In The Guadalupe Estuary

PI Paul Montagna, PhD
Contract number #0904830893

TWDB comments to final draft

REQUIRED CHANGES

General Draft Final Report Comments:

The contract scope of work outlined a quarterly sampling program for benthic organisms, sediments, water quality, chlorophyll, and nutrients. The draft report does not include a presentation or discussion of the results for most of these factors. The primary results are based on an analysis of how the benthic community responds to salinity and other parameters, but the parameters themselves are not discussed. It would be helpful to describe these results by showing a basic statistical summary (plus table or graph), along with a species list for the organisms found. Diversity and abundance for the documented species also would be useful.

Specific Draft Final Report Comments:

Please add an Executive Summary to the report.

In looking at Figure 4, Communities from sites A and B are similar, but I notice that Community C is equally similar to A and B as it is to Community D. Is it possible this is related to the circulation of freshwater inflow within the estuary?

The discussion of Figure 5 highlights the high biomass/high salinity conditions during 2008 and 2009. Several other periods (1991, 1995, 2000) were similar, although other periods which had high salinity do not have high biomass. Any comments on why this might have been?

Specific changes also include:

1. Section “METHODS”, ¶1, first reference to Figure 4 should read “Figure 1”.
2. Section “METHODS”, ¶3, line 3, change mgl-1 ±0.2 to ±0.2 mgl-1.
3. Section “METHODS-Macrofauna”, the verb tense should be corrected to reflect past action.
4. Section “RESULTS”, ¶1, references to Figures 1A, 1B, and 1C should read “Figure 2” A, B, or C.
5. Section “RESULTS”, ¶1, line 5, change July 200 to July 2000
6. Section “RESULTS”, ¶1, line 6, change Figure 1C to Figure 2C
7. Section “RESULTS”, ¶1, line 8, change Figure 1A to Figure 2A
8. Section “RESULTS”, ¶1, line 10, change Figure 1B to Figure 2B

SUGGESTED CHANGES

General Draft Final Report Comments:

If feasible, it would be helpful to have the figures and graphs integrated into the text of the document, rather than attached at the end.