Spring 2004 Ichthyoplankton Recruitment to the Delta Nursery Areas of Nueces Bay, Texas

Publication CBBEP – 42
Project Number – 0406
August 2005

Principal Investigators

James M. Tolan, Ph.D.
Coastal Studies Program
Texas Parks and Wildlife Department
6300 Ocean Dr., NRC 2501
Corpus Christi, Texas 78412

and

David J. Newstead
Center for Coastal Studies
Texas A&M University-Corpus Christi
6300 Ocean Dr. NRC 3216
Corpus Christi, Texas 78412

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, TX 78401

TABLE OF CONTENTS

Section **Page**

LIST OF TABLES

LIST OF FIGURES

Acknowledgements

This project was performed with funding from the Coastal Bend Bays & Estuaries Program under contract No. 04-06. Texas Parks and Wildlife Department, Coastal Studies Program, Coastal Fisheries Division provided additional interagency cooperation in the form of equipment and field logistical support.

The authors would like to thank the following individuals from the Center for Coastal Studies at Texas A&M University-Corpus Christi; Brien A. Nicolau-Co-Project Manager, for writing the Quality Assurance Project Plan, overall contract administration, report review and editing; Erin Albert, for report reviewing and editorial comments; Jarrod Monroe and Shari Hanson for assistance in the field collecting ichthyoplankton samples and for assistance in the laboratory sorting, identifying, and measuring ichthyoplankton samples.

SPRING 2004 ICHTHYOPLANKTON RECRUITMENT TO THE DELTA NURSERY AREAS OF NUECES BAY, TEXAS

By James M. Tolan, Ph.D. and Crystal D. Sanders

EXECUTIVE SUMMARY

The objectives of this study are to quantify the spring seasonal recruitment of larval and juvenile fish and shrimp to the nursery areas of Nueces Bay, Texas, and to compare their distributions within the bay in relation to the discharge location of the major riverine input within this estuary, the Nueces River. Currently, the river discharges into the bay at a location away from the Nueces delta region - the marsh habitat complex that provides an important nursery area function for many finfish and shellfish species.

Numerous commercially and recreationally important finfish species are considered estuarine-dependent in their early-life-history stages, and as such, they must find suitable estuarine nursery habitats. For species that spawn in areas distant from these nursery areas, planktonic larvae face a wide variety of biotic and abiotic factors that can greatly influence their dispersal into estuaries. These factors can greatly influence larval survival and recruitment, and successful recruitment events can ultimately affect adult populations.

Sampling for this study conducted biweekly during the spring of 2004 (3 Mar to 23 Jun) at four fixed locations within the extreme western portions of Nueces Bay. Previous research has shown that the western (back-bay) portions of this estuarine system are preferentially sought out by immigrating fish larvae, and these areas are thought to serve as a nursery habitat for the early life stages of many species. Two stations were located within the open water parts of the back-bay, one directly in front of the river discharge zone across from White's Point, and another at the western-most end of the bay near the face of the delta. Two other stations were sampled bi-weekly, one located within the southern portion of the delta region approximately 5 km up the river, and the other located 2 km in a tidal channel within the delta complex. At each station, triplicate ichthyoplankton collections were taken during daylight hours, and collections were standardized to reflect larval densities (as numbers of individuals per 100 m^3 water filtered). Environmental water quality parameters (temperature, salinity, dissolved oxygen, pH, and turbidity) were recorded prior to ichthyoplankton sampling at each station.

All fish larvae and penaeid shrimp post-larvae were sorted from whole collections and identified to the lowest possible taxon, enumerated, and measured to the nearest 0.1 mm. Community structure of the ichthyoplankton among the stations was determined

by ordination techniques, including non-metric multidimensional scaling (MDS) and rank-based analysis of similarity (ANOSIM). For each technique, the Bray-Curtis coefficient was used as the similarity measure. Length frequencies of the most abundant ichthyoplankton were also tested for differences among stations with the ANOSIM, but Euclidean Distance was used as the similarity measure. Environmental water quality data was tested for differences among stations with a parametric one-way analysis of covariance.

An unusually large 'freshet', or a flooding event from the river that effectively replaces the volume of the bay with freshwater, greatly influenced the environmental water quality parameters recorded during the spring sampling period. This freshet event was extremely large, both in magnitude and duration, essentially turning the back-bay regions of the estuary into a 'lake' for the duration of sampling. Once the flooding event began in early April, all the environmental parameters (e.g., temperature, salinity, and dissolved oxygen) were nearly uniform throughout the study area because the bay took on the characteristics of the floodwaters coming down the river. No significant differences were detected in any of the environmental parameters among the four fixed sampling locations throughout the spring study period.

The eight sampling trips during the spring of 2004 resulted in the collection of 38,218 larval and juvenile fish representing at least 25 species from 20 families. Numerically, three families accounted for 90.3% of the total (Gobiidae 47.9%, Engraulidae 30.2%, and Clupeidae 12.2%). Ichthyoplankton abundance was bi-modal, with peaks in the early spring and early summer. The flooding event, recorded during April and May, dramatically decreased ichthyoplankton abundance in the back-bay regions of Nueces Bay. The greatest proportion of individuals were collected in June, well after the flood flows coming down the river had subsided. Additionally, a total of 2,781 postlarval and juvenile penaeid shrimps were also collected and they were most abundant in early March before the flood event in April.

Like the environmental parameters, springtime ichthyoplankton communities in Nueces Bay were dramatically affected by the freshet event. Based on their overall community compositions, stations were not well separated by the MDS procedure into the delta, river and open water zones. Only the community at the extreme end of the back-bay, the open-water station in front of the delta, was consistently unique from all other sampling locations. Prior to the flood, numerous estuarine-dependent taxa were collected in the river station, but after the onset of the freshet abundance levels of nearly all taxa were dramatically lower in the river. The highest abundance levels of many organisms, especially those estuarine-dependent taxa that are spawned offshore, were found in the back-bay and delta stations. Despite the flooding event, many taxa still appeared to be actively seeking out the back-bay portions of the study area. The rank-based ANOSIM test confirmed the spatial and temporal patterns of community structure seen with the MDS, with a great degree of overlap among stations, especially the stations most directly impacted by the flood waters (the river, the delta, and the river discharge zone).

The most abundant ichthyoplankton (Gobiidae, Engraulidae, and Clupeidae) and the penaeid shrimps were tested for differences in length frequencies among the stations in order to assess any partitioning of habitats by the recruiting taxa. Gobiidae larvae were unimodal (4-6 mm) and were most abundant in the open-water stations well after the relaxation of the freshet. Engraulids were more bimodal, with two main cohorts (4-8 mm and 16-22 mm) observed. The larger size classes were presumed to be a fall/winter cohort and the smaller individuals were presumed to be spring spawned. The spring spawned cohort were notably absent from the river and delta stations after the flood. Engraulids showed a partitioning of habitats, with the greatest proportion of juvenile-sized individuals being found in the back-bay and delta stations. Clupeids were primarily collected as juveniles (19-24 mm) and were also found in higher abundances in the delta and river locations prior to the flood. Post-larval penaeid shrimps were equally abundant in the delta and back-bay stations prior to the flood, although after the freshet juvenile penaeids again were abundant in the back-bay and delta stations. Few larval or juvenile fish or shellfish were collected in the river during or immediately after the flood event.

The larval abundance of many species found during this study (particularly those that spawn outside the bay or in the Gulf of Mexico) indicates that back-bay and delta regions of the Nueces estuary are preferentially sought out as nursery habitats. Many taxa appear to be recruiting to these highly productive areas. While the freshet event recorded during the spring of 2004 dramatically altered the biotic and abiotic character of the bay during the recruitment season, it showed that the current river discharge location (near White's Point, away from the historic river delta) does not appear to act as a recruitment barrier for most taxa seeking out the nursery areas within the estuary. Despite these extraordinary environmental conditions that took place during their normal spawning and recruitment season, most taxa showed little to no detrimental effects of the flood event. While some planktonic larvae and juveniles may have been displaced out of the back-bay and delta regions by the flood, these same taxa were collected, albiet later in the season, at densities typical of the spring-time recruitment levels encountered in Nueces Bay.

I. INTRODUCTION

The importance of estuaries as nursery grounds for a variety of marine organisms has been well documented (Knox 1986; Heck et al. 1989; Livingston 1997; Tolan et al. 1997; Beck et al. 2001; Le Pape et al. 2003). Experimental investigations into some of the mechanisms thought to make estuaries a preferred habitat include increased food availability, refuge from predation, increased living space, and habitat richness (Heck and Thoman 1981; Leber 1985; Jordan et al. 1996; Adams et al. 2004). High rates of primary production within estuaries are generally associated with nutrient loadings from freshwater input (Skreslet 1986), and overall high rates of productivity are maintained by a complex of emergent vegetation, benthic algae and phytoplankton which efficiently utilizes these inputted nutrients within the estuary (Schelske and Odum 1961).

Gulf of Mexico estuaries are typically shallow, turbid, and well mixed with predominantly wind-driven circulation. They are also characterized as having mixed tides with very small tidal amplitude (Lyczkowski-Shultz et al. 1990; Raynie and Shaw 1994). The Nueces River, the major riverine input into Nueces-Corpus Christi Bay estuarine system, currently discharges into the bay at a location isolated from the historic river delta complex. The current discharge point is isolated from the emergent marsh, submerged aquatic vegetation and intertidal flats that are thought to provide the primary nursery habitat function of this estuary. Despite this "hydrologic-disconnect," the Nueces delta is considered an important nursery area for many commercially important finfish and shellfish (Henley and Rauschuber 1981; Tolan and Newstead 2004).

Freshwater inflow into the Nueces Estuary is governed by the operation of a double-reservoir system on the Nueces, Frio, and Atascosa Rivers. This departure from the traditional riverine-estuarine structure may be affecting the habitat value of the delta area as a nursery for larval finfish and shellfish. The purpose of this study is to quantify larval fish recruitment into the delta region of Nueces Bay and determine if ichthyoplankton community structure within the bay is affected by freshwater inflow.

Purpose and Scope

The importance of freshwater inflows to the maintenance of estuarine function has been demonstrated by numerous studies (Grange et al. 2000: see Estevez 2002 for a review of methodologies; Montagna et al. 2002). Though interannual variability in flows and extended periods of floods or drought are natural features of estuaries, the addition of anthropogenic disruptions on the hydrology of estuarine systems (in the form of freshwater diversions, reservoir operations, etc.) forces these systems into artificial cycles, and consistent reduced inflow conditions can lead to degradation and loss of important nursery habitat (Powell and Matsumoto 1994, Pulich et al. 2002). The recommended freshwater inflow regime for the Nueces Estuary, consisting of a series of monthly inflow targets as determined by Pulich et al. (2002), shows that inflows would be most beneficial if delivered in proximity to the delta region in one or two pulsed events in the spring (the time of historical maximum flows), or, secondarily (in the case of persistent low flows in spring and summer), in the fall. The estuarine biota appear to respond most favorably to naturalized hydrologic events within this estuary (Pulich et al. 2002). As pointed out by Tolan and Newstead (2004), some of the components of the monitoring plan for the Rincon Bayou, Nueces delta that have yet to be implemented include:

- ► Construct and operate a pipeline with the capability to deliver up to 3,000 acre-feet per month from the Calallen Pool to Upper Rincon Bayou, and
- ► Implement a monitoring program to facilitate an "adaptive management" program for freshwater inflows into the Nueces Estuary.

This ongoing study provides additional baseline, pre-pipeline characterizations of larval recruitment by finfish and shellfish into the nursery areas of Nueces delta.

The objective of this study is to determine the extent of larval recruitment to the Nueces delta, and compare the distribution of fish larvae and shrimp post-larvae (PL) within Nueces Bay as related to discharge of the Nueces River. Specific objectives of the study are to (1) document the distribution of ichthyoplankton and shrimp PL within the back-bay regions of the estuary system (through the river discharge zone and into the estuarine nursery areas of the delta region); (2) to determine if the discharge of the Nueces River away from the delta region acts as a "recruitment barrier" for transport and recruitment of fish and shrimp into the Nueces delta; and (3) collect baseline information on fish and shellfish recruitment into upper Nueces delta in order to evaluate the effectiveness of monthly diversions of freshwater via the pipeline diversion project.

Description of the Study Area

The Nueces River watershed encompasses > 4.3 million ha within the Edwards Plateau and Gulf Coast Section of the Coastal Plains Province (HDR Engineering, Inc. 1991, see Fig. 1). The Frio River flows into the Choke Canyon Reservoir above the Nueces River, and downstream, the Atascosa River joins the Nueces River, which is impounded by the Lake Corpus Christi Reservoir. Beyond this lower reservoir, the river empties into Nueces Bay.

Nueces Bay is a secondary bay of the Corpus Christi Bay system, with a combined surface area of 518 km^2. It is a shallow, well-mixed, wind-driven bay located in a semi-arid zone. Mean precipitation of 71.9 cm yr^{-1} is exceeded by mean evaporation of 100 cm yr^{-1}. Precipitation is bimodal, with peaks in the spring and fall. Mean summer and winter air temperatures are 33.3 and 8.3°C, respectively. Prevailing winds are southeasterly to south-southeasterly throughout most of the year, with strong northerly frontal systems occurring intermittently throughout the winter (Texas Department of Water Resources 1982). Salinity may vary from near fresh (<2 PSU) during heavy flood

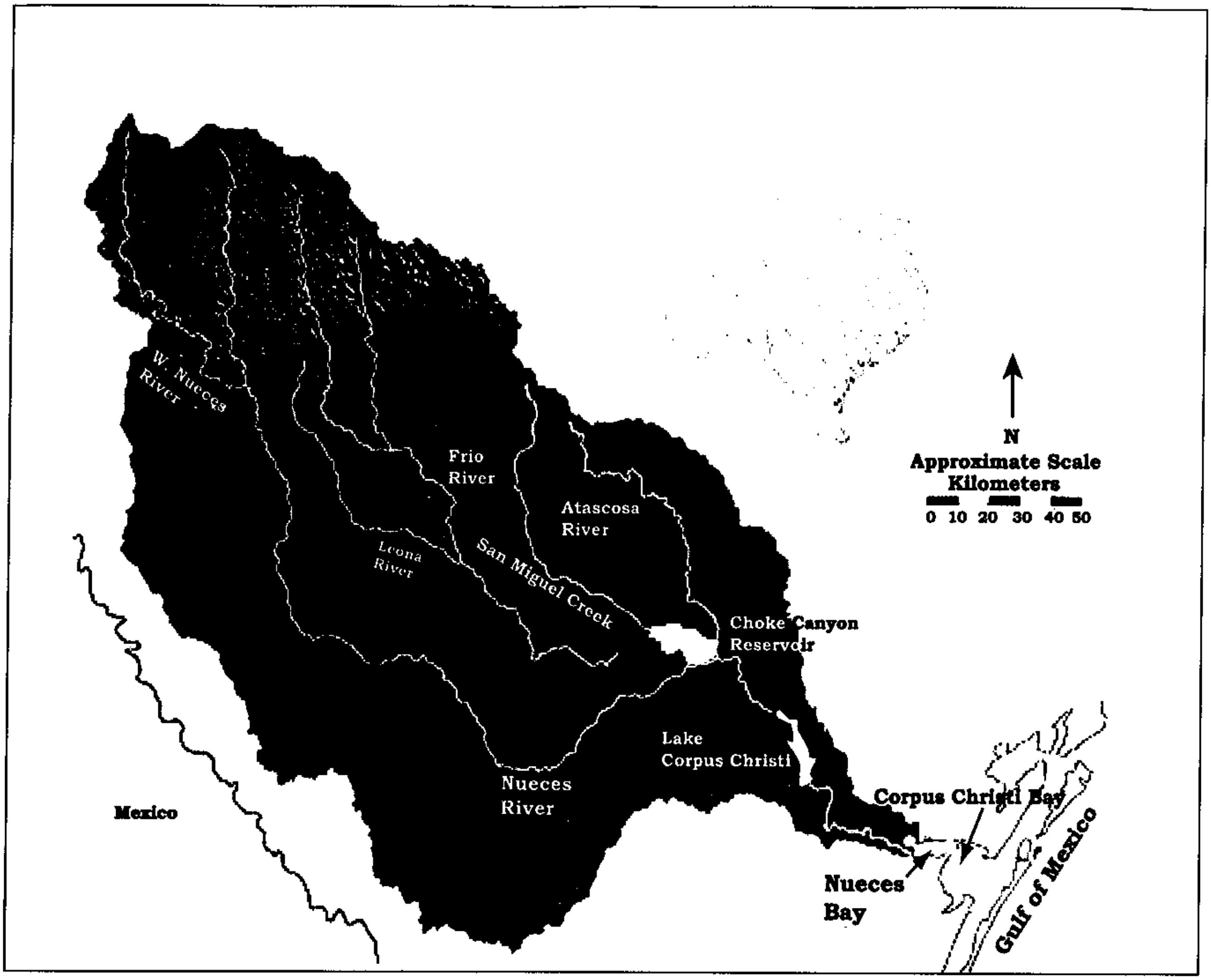

Figure 1. The Nueces River Drainage, including the two reservoirs (Modified from Bureau of Reclamation 2000).

events ("freshets") to hypersaline (>45 PSU) during prolonged periods of low inflow. Mean annual salinity is reported as 25 PSU (HDR Engineering, Inc. 1991). Tides are primarily diurnal with amplitude averaging on the order of 10 cm, and seasonal water levels creating a range of approximately 0.1 m. Tidal range is controlled primarily by the wind (Ruth 1990).

The Nueces River currently flows along the southern edge of the Nueces delta complex and empties directly into Nueces Bay away from the delta (Fig. 2). The delta is an expansive area of middle- to high-marsh that is bypassed by the main river flow except during the highest flood flow events (Bureau of Reclamation 2000). Rincon Bayou, the historical river channel, conveys floodwaters from the river immediately south of Interstate Highway 37 (IH 37) into the delta during these events. The combined reservoir operations have resulted in a 54.9% decrease in mean annual river flow into the Nueces Estuary, and a 99.6% decrease in annual flow into Nueces delta (Bureau of Reclamation 2000). These decreased flows, coupled with high evaporation rates in the shallow delta area, resulted in the formation of a negative estuary with salinity increasing upstream (into the delta) instead of downstream (Palmer et al. 2002).

The Nueces delta consists of approximately 5,850 ha of middle and high marsh, with 35 ha of smooth cordgrass (*Spartina alterniflora*) distributed along the fringes of tidal channels (Espey, Huston & Associates 1981). Drift algae (*Gracilaria* sp.) is the dominant submerged aquatic vegetation in the bay (Tom Wagner personal communication). Seagrasses (*Halodule beaudettii* and *Ruppia maritima*) are concentrated in small patches along the northern edge of the study area. Relict (and some extant) oyster reefs (*Crassostrea virginica*) are scattered in the western and northern portions of the bay, with a concentrated area of reefs located near White's Point, directly across from the river discharge.

II. LITERATURE AND HISTORICAL DATA REVIEW

Recruitment can be defined as the addition of a new cohort of young individuals to a population (Sale 1990). The process of settlement or transfer of individuals from planktonic to demersal populations is a major event in the recruitment process. Various biotic and abiotic factors interacting during these early life history stages can ultimately affect dispersal and successful settlement. Numbers of larvae surviving dispersal and settling out of the planktonic phase may be one of the determinants in adult population sizes (Richards and Lindeman 1987). Variability in planktonic dispersal processes have great influence on larval supply, which can be manifested in considerable seasonal variation in community structure (Underwood and Fairweather 1989; Roberts 1991).

Physical transport mechanisms responsible for circulation are important in the dispersal of larvae. Major influences on circulation in estuaries include tide, river flow, wind,

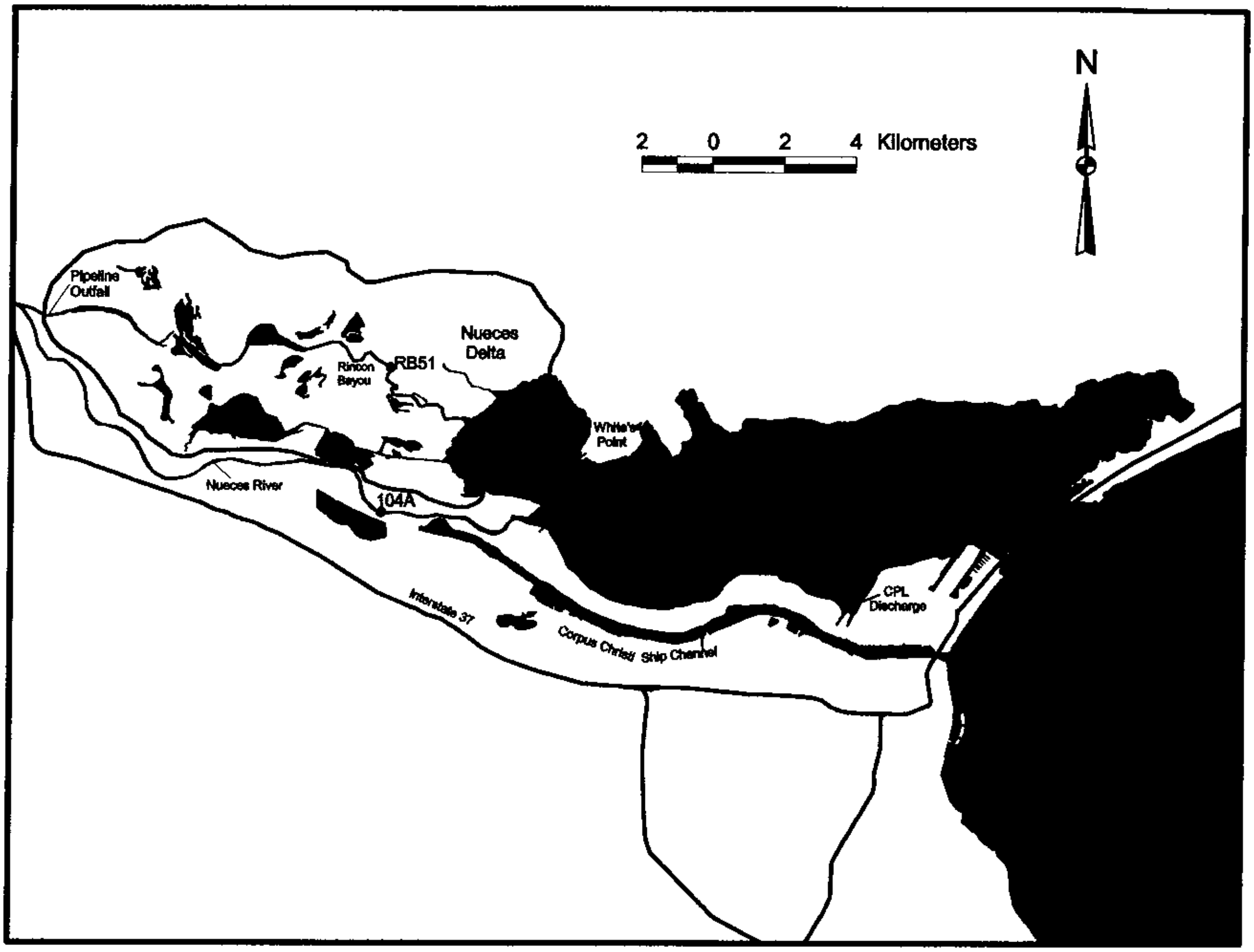

Figure 2. Study area with relevant surrounding features and sampling stations for this study (Modified from United States Geological Survey 1984).

nontidal forcing from the coastal ocean, and topographically induced circulation (Norcross and Shaw 1984). The presence of two-layered, vertically stratified current flow has been proposed as one of the recruitment mechanisms linking offshore spawning grounds with estuarine nursery areas in some Atlantic coastal systems (Weinstein et al. 1980; Hettler et al. 1997). Tidal stream transport of larvae may play an important role as a mechanism linking offshore spawning grounds with estuarine nursery areas (Shaw et al. 1988). Distribution and population structure of fishes are also indirectly related to the estuarine environment through food web dynamics that can be modified by changes in river flow (Livingston 1997).

Fish that utilize estuaries as nursery areas employ a range of life history strategies in order to settle into favorable habitat. A major problem encountered by these fishes is the net seaward flow of estuarine waters combined with tidal flux, which may affect transport into, or away from, estuaries (Boehlert and Mundy 1988). For those species residing in estuaries through their entire life cycle (estuarine residents), the problem of export of early life history stages is sometimes counteracted by production of large, demersal eggs and short early life history stages (Hildebrand and Schroeder 1928; Kneib 1997). Some species brood their young within a pouch (Syngnathidae) or mouth (Ariidae) (Dando 1984), or seek more protected habitats near the margins of estuaries. Estuarine-dependent species require estuarine habitat only during a particular life history stage. Many of these fishes are spawned offshore or near passes and face the problem of locating and entering estuarine areas in spite of the net seaward movement of water (Valesini et al. 1997). These fishes [including several that are commercially and recreationally important such as black drum (*Pogonias cromis*), Atlantic croaker (*Micropogonias undulates*), spot (*Leiostomus xanthurus*), spotted seatrout (*Cynoscion nebulosus*), flounder (*Paralichthys* spp.), and others] generally have an extended larval phase and experience a wide range of physical processes before potentially being delivered to an estuarine area.

The spawning of many temperate fish species is in phase with the onset of seasonal production cycles. Spring and fall phytoplankton blooms are often closely followed by increases in zooplankton abundance (Riley 1967). The "match-mismatch" hypothesis suggests that the strength of the spatial and temporal correlation between the production of zooplankton (food source) and the production of fish eggs can have significant effects on larval survival and subsequent recruitment, and thus serve as another significant source of interannual variability (Cushing 1975).

III. METHODS OF ANALYSIS

Sample Collection

Sampling was conducted approximately biweekly during the spring recruitment period in 2004. Biweekly sampling began in March and extended until late June. Four fixed stations located in the western margins of the bay (i.e., the back-bay) were sampled along a transect from the bay mouth through the river discharge zone and into the delta and river regions. Station RB51 was located on Rincon Bayou within the delta complex, approximately 6.5 km east of the proposed pipeline outfall point (Fig. 2). Station NB1 was at westernmost margin of the bay, immediately outside of Rincon Bayou; Station 313 was located at the river discharge zone directly across from White's Point; and Station 104A was located within Nueces River, 4.8 km upstream of the current river discharge location.

Triplicate ichthyoplankton samples were collected at each station during daylight hours using a 60 cm diameter pull-net with 500 μm mesh. Except for RB51, the net was pulled in an arc in order to minimize the influence of motor wash from the boat. At RB51, the width of the channel was too narrow to pull the net as described, so it was fixed to the starboard side of the boat and used as a pushnet down the channel. A mechanical flowmeter was attached to the net allowing for a calculation of the volume of water filtered in each sample. Collections are standardized to reflect fish density (fish 100 m^{-3}). Collections were initially preserved in 10% seawater formalin. After 48 h, all collections were transferred to 95% ethanol for final storage and preservation.

In the laboratory, all fish larvae and shrimp PL were sorted from whole collections, enumerated and measured to the nearest 0.1 mm with dial calipers. Lengths recorded are notochord length for pre-flexion larvae, and standard length (SL) for flexion and post-flexion larvae and juveniles. Shrimp lengths are total lengths, straight-line distance from rostrum to the telson. For samples containing large numbers of individuals from a particular taxa, a Folsom Plankton Splitter was used to divide whole samples in half, and this process was repeated until a reasonable number of individuals was present in the subsample. A whole count was then extrapolated from the fraction for that species, and the entire sample was searched for all other taxa. Fifteen individuals of each taxa were measured for each replicate sample. If more than fifteen individuals were present, a random subsample of 15 individuals from each taxa was measured. Ichthyoplankton identification followed published descriptions (Fritzsche 1978; Hardy, Jr. 1978;; Johnson 1978; Jones et al. 1978; Martin and Drewery 1978; Holthuis 1980; Hoese and Moore 1992; Ditty and Shaw 1994; Farooqi et al. 1995). A description and relative quantification of zooplankton abundance was also noted during sample processing.

At each station prior to ichthyoplankton collections, water quality parameters [temperature (°C), salinity (PSU), dissolved oxygen (D.O. mg l^{-1}, and % saturation), pH (SU)] were measured with a YSI 6920 sonde. Turbidity was measured by secchi depth (m). Continuous water temperature and salinity data were also collected near station 313 by a salinity monitoring station operated by the Conrad Blucher Institute for Surveying and Science.

Daily freshwater discharge volumes were obtained from the USGS water level monitoring station at Calallen (USGS 08211500; upriver from the Pipeline Outfall identified in Fig. 2) and these data were used as an approximation of inflow into the bay.

Statistical Tests

Ordination

The PRIMER v5.0 (Plymouth Routines in Multivariate Ecological Research) software program was used for analysis of the ichthyoplankton collection. Community structure was analyzed using a non-metric Multidimensional Scaling procedure (MDS), and a non-parametric randomization Analysis of Similarity (ANOSIM) procedure. Fish densities were $\text{Log}_{(10)}(x + 1)$ transformed and similarities between each pair of samples were calculated using the Bray-Curtis similarity measure:

$$S_{jk}(i) = 100 \left\{ 1 - \frac{\Sigma_{i=1}^{p} |y_{ij} - y_{ik}|}{\Sigma_{i=1}^{p} (y_{ij} + y_{ik})} \right\} \qquad \text{Eq. 1}$$

where y_{ij} is density of the i^{th} species in the j^{th} sample, and y_{ik} is the density of the i^{th} species in the k^{th} sample. In the Bray-Curtis measure, $S = 0$ if the two stations have no species in common, and $S = 1$ if the community composition is identical, because $| y_{ij} - y_{ik} | = 0$ for all i.

Non-metric MDS seeks to compute coordinates for a set of points in a unit-less space such that the distances between the pairs of points fit as closely as possible to the measured similarity between a corresponding set of objects (SYSTAT 1992). MDS is a graphical representation of the sample patterns, built on the ranks of the similarity matrix. The data set contains two main factors, sample date and Station, so the MDS patterns were plotted twice, once using the Station name as the symbol and once using the sample date as the symbol. Second stage MDS (Clarke and Warwick 2001) is a time-series technique incorporating the Spearman Rank (ρ) correlations between the underlying similarity matrices calculated for each sample date-Station two-way layout. Second stage MDS concentrates only on whether the community pattern among the stations is similar temporally across sample dates.

Differences among stations were further evaluated using a one-way ANOSIM (Clarke and Warwick 2001) on the *a priori* groups of samples. The procedure constructs a test statistic (R) based on the ranks of the similarities within and between stations. This value is then tested for significant differences against a null distribution constructed from random sampling of all possible permutations of the sample labels (Clarke and Warwick 2001). Values of the R-statistic close to unity show that the compositions of the samples are very different, whereas those close to zero demonstrate that there are very similar.

The SIMPER (SIMilarity PERcentages – PRIMER v5.0) routine was used to examine the contribution of individual species (i) to the community structure seen at each Station (see Eq. 1). Values of $S_{jk}(i)$ are averaged over all pairs of samples (j,k) between fish assemblages to give the average contribution. The ratio of $Savg_{(i)}$ to its standard deviation indicates how consistently a species discriminates among the assemblages. If a species is found at consistent levels (i.e., densities) across all samples at a Station, then the standard deviation of its contribution is low, and the ratio is high (Clarke and Warwick 2001). Such a species will contribute more to the intra-group similarity, and can be thought of as typifying that group.

Length-frequencies of abundant ichthyoplankton

In previous years of this study, length-frequencies of abundant organisms (e.g., larval and juvenile Gobiidae, Engraulidae, Clupeidae, and Penaeidae) were tested for differences among stations with Pearson's Chi-square test statistic. This procedure relies on a null hypothesis of homogeneity of length-frequency among stations. As pointed out in Alldredge and Ratti (1986), the Chi-square test is recommended only in situations where there is ≥1 expected observation in each category (i.e., length-frequency bin size) and that ≤20% of all categories contain <5 expected observations. In each family of interest for this study, cell frequencies were commonly <5 observations in greater than 20% of the length-frequency categories. Clarke and Warwick (2001) point out that the ANOSIM procedure can be used for many other kinds of data, including length-frequency data, to test for differences in *a priori* designated samples. For this test, the station-sampling date designation was treated as the sample and the length class bins (in 1 mm increments for all families) were treated as the variables. The frequency counts in each 1 mm length class were used as the basis for the similarity matrix. Instead of the Bray-Curtis index (Eq. 1) as the similarity measure, Euclidean distance was used. A pair-wise comparison of length-frequencies by station was carried out with an ANOSIM for each family of interest. In addition to the ANOSIM test not being affected by sparse cell counts, it also better captures the temporal nature of the differences in the length-frequencies among the stations over the entire spring season.

Abiotic data

An analysis of covariance (ANCOVA) was used to detect differences in the abiotic data measurements among the stations. Sampling date (julian day) was used as a covariate in order to adjust each station dependent variable mean for the temporal nature of sampling over the spring season. In each test, the assumption of parallel slopes of the regression lines was accepted. Homogeneous subsets were delineated using Tukey's honestly significant difference (HSD) multiple comparison method, which tests for differences among all pair-wise comparisons of means while controlling the maximum experiment-wise error rate ($\alpha = 0.05$ for all comparisons). There was no significant covariate term in the tests involving dissolved oxygen % saturation and turbidity, therefore differences among stations for these tests was compared with a simple one-way analysis of variance.

IV. RESULTS

Abiotic Data

Hydrological parameters were measured at each site during each sampling event. Descriptive values for these abiotic variables [temperature (°C); salinity (PSU); pH (SU); D.O. (mg l^{-1} and % saturation); turbidity (secchi depth in m)] are reported by station in Table 1. Differences in abiotic variables between stations were tested with a one-way ANCOVA and these results are presented in Table 2.

Table 1. Descriptive statistics of the abiotic water quality parameters recorded at each fixed sampling location within Nueces Bay, Texas during the 2004 spring recruitment period.

	Station	N	Mean	Std. Dev.	Min.	Max.
Temperature (°C)	104A	8	25.1	3.9	19.5	30.1
	313	8	24.4	3.4	19.8	29.3
	NB1	8	24.7	2.9	21.0	28.8
	RB51	8	25.6	2.8	21.1	29.1
Salinity (PSU)	104A	8	1.2	1.9	0.3	5.8
	313	8	6.2	8.1	0.5	22.8
	NB1	8	7.7	8.3	0.8	23.8
	RB51	8	6.8	8.8	0.6	23.4
pH (SU)	104A	8	8.1	0.3	7.6	8.7
	313	8	8.2	0.3	7.9	8.6
	NB1	8	8.3	0.2	8.0	8.3
	RB51	8	8.4	0.2	8.1	8.7
D.O. (mg l$^{-1)}$	104A	8	8.7	1.6	6.2	11.7
	313	8	7.7	0.5	6.8	8.6
	NB1	8	8.0	0.7	6.8	9.1
	RB51	8	8.4	1.0	6.8	10.2
D.O. (% saturation)	104A	8	105.9	19.2	73.0	131.5
	313	8	95.6	5.6	90.3	107.9
	NB1	8	100.8	8.5	88.5	114.1
	RB51	8	107.4	12.8	90.3	129.9
Secchi Depth (m)	104A	8	0.26	0.13	0.05	0.40
	313	8	0.24	0.13	0.01	0.43
	NB1	8	0.23	0.11	0.08	0.44
	RB51	8	0.25	0.12	0.06	0.25
Flow (cubic ft/sec)	08211500	115	1963.5	1967.4	3.2	7570.0

Table 2. Analysis of covariance results of the abiotic water quality parameters among stations in Nueces Bay, Texas, during spring 2004. Station means are arranged from highest to lowest values. Means joined by a line indicate a non-significant difference (Tukey's HSD test, $P < 0.05$).

Dependent Variable	df	F-Value	$P > F$	Homogeneous subset
Temperature	3, 27	1.07	0.397	RB51 104A NB1 313
pH	3, 27	2.45	0.085	RB51 NB1 313 104A
Salinity	3, 27	2.34	0.096	NB1 RB51 313 104A
D.O. mg l^{-1}	3, 27	1.70	0.191	104A RB51 NB1 313
D.O. % sat.	3, 28	1.43	0.255	RB51 104A NB1 313
Turbidity	3, 28	0.09	0.964	104A RB51 313 NB1

While water temperature showed a typical seasonal increase with time throughout the study period, the influence of the flood flows in April are clearly seen in the depressed temperature records of April and May (Fig. 3a). While there appeared to be some early spring differences between the river / river discharge zone and the delta face / delta complex (temperature was lower in and around the river, i.e., stations 104A and 313), temperature was not significantly different among stations over the spring recruitment season. By the end of the study, water temperature was slightly warmer in the river and delta than in the open-water bay stations (NB1 and 313, see Fig. 3a).

Salinity values in Nueces Bay were markedly different in the spring 2004 season as compared to any other spring sampling season to date (see Figure 17). Flooding conditions that began in April essentially replaced the entire bay volume with freshwater during the early parts of the spring (Fig. 4) and this "freshet" condition extended throughout the entire spring sampling season (Fig. 3b). Despite a clear difference between the river (104A) and the other stations at the beginning of the sampling period, mean salinities were not significantly different between the river, the open water, and the delta locations during the spring of 2004 (Table 2). By the time sampling concluded

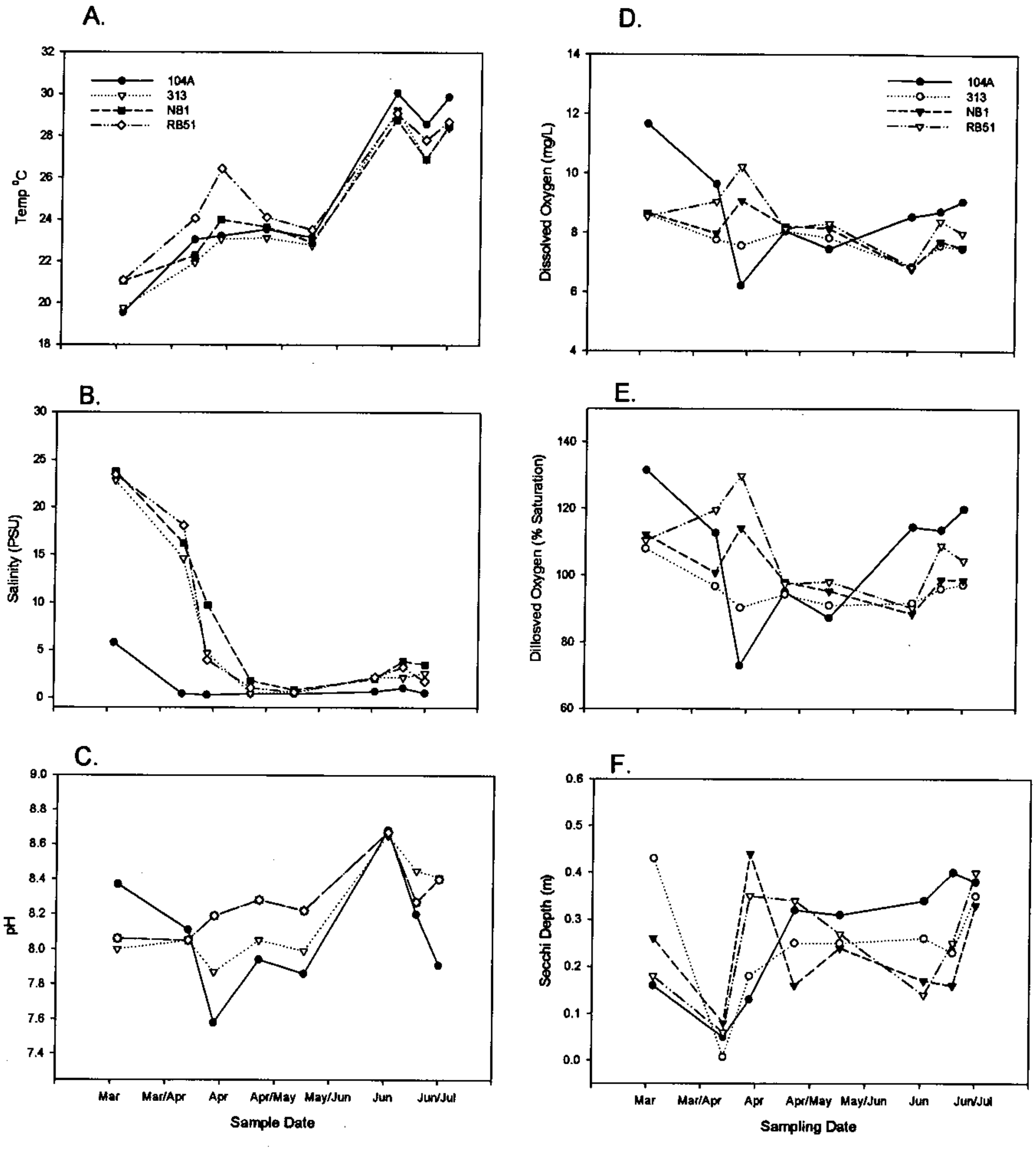

Figure 3. Time-series of the abiotic water quality parameters from Nueces Bay during spring 2004. A). Temperature; B). Salinity; C). pH; D). Dissolved Oxygen; E). Dissolved Oxygen Percent Saturation; and F). Turbidity (as measured by secchi depth). Station designation legend for each plot is given in A and D.

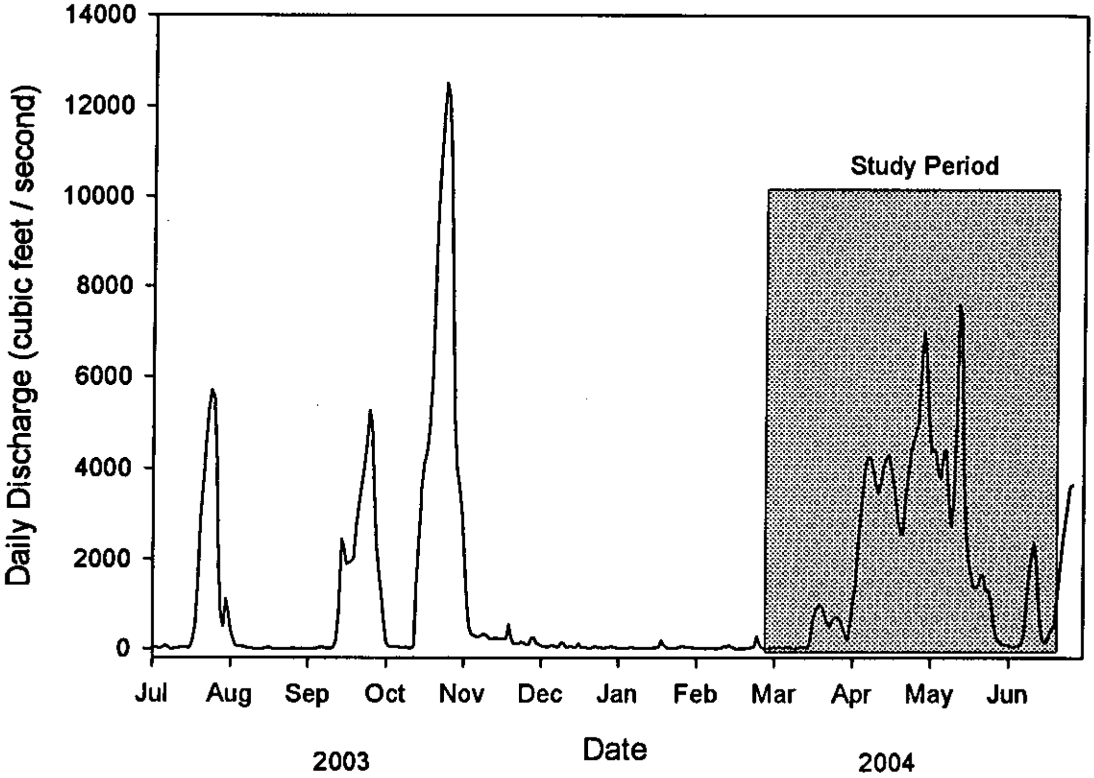

Figure 4. Surface inflow, measured as daily discharge at the Calallen gauge (USGS 08211500), preceding and during the spring 2004 ichthyoplankton recruitment study.

in late June, bay-wide salinities were still under 5 PSU, well below the average salinity of 25 PSU identified for this estuary.

In general, pH measurements were well within normal ranges for estuarine waters, with values identical for the open-water stations in 2004 (NB1 and 313; see Fig. 3c). The low pH values recorded in the river (104A) and delta (RB51) stations in April coincided with the onset of the flooding conditions, with a secondary low in pH also coinciding with increased flow conditions in the late part of June. No significant differences in pH were found among the stations during the spring recruitment period (Table 2).

Dissolved oxygen levels were highest in the early part of the spring prior to the flooding conditions, especially in the river station (Fig. 3d). When adjusted for temperature and salinity, mean D.O. percent saturation levels were near or above the 100% level throughout the spring of 2004 (Fig 3e and Table 1), indicating good water quality throughout the study area for the immigrating larvae and juveniles. No significant differences in either D.O. or % saturation were detected among any of the sampling stations (Table 2).

The flooding conditions of April and May are most evident in the turbidity readings, with the highest turbidity (and hence, the lowest secchi depth readings) recorded in the river, delta, and river discharge locations (Fig 3e).

Ichthyoplankton Community

Eight sampling trips were conducted over the spring 2004 recruitment period, resulting in 96 plankton samples. A total of 38,218 larval and juvenile fishes, representing at least 25 species from 20 families, were collected during this study. Additionally, a total of 2,781 postlarval and juvenile penaeid shrimp were also collected. Numerically, three families accounted for 90.3% of the total number of individuals (Gobiidae 47.9%, Engraulidae 30.2%, and Clupeidae 12.2%). A complete taxonomic list, with mean densities collected from each station, is given in Appendix 1. Graphical representations of larval densities across stations through time are given for all larvae and juveniles combined (Fig. 5); the families Gobiidae (Fig. 6), Engraulidae (Fig. 7) Clupeidae (Fig. 8), and Penaeidae (Fig. 9). Overall spring ichthyoplankton abundance was bimodal in 2004, with the majority of recruitment taking place in March (before the flooding conditions) and June (Fig. 5). Before the onset of the flood in April, clupeids (primarily *Brevoortia partonus*) and postlarval penaeids were very abundant in early part of the spring season, with highest densities found in the river and the delta (Figures 8 and 9). Both of these families were well represented in the river before the flood, although after the onset of the very high flows of the flooding period, no taxa was recorded in great abundance at the river station. The smaller, later season increase of clupeids was attributed to a different species, finescale menhaden (*B. gunteri*), which has a later spawning season than *B. patronus.* Larval anchovies were not found in high densities until mid-June, and these size fractions of the engraulids were found primarily in the open-water portions of the bay (stations 313 and NB1, see Fig. 7). Larger juveniles

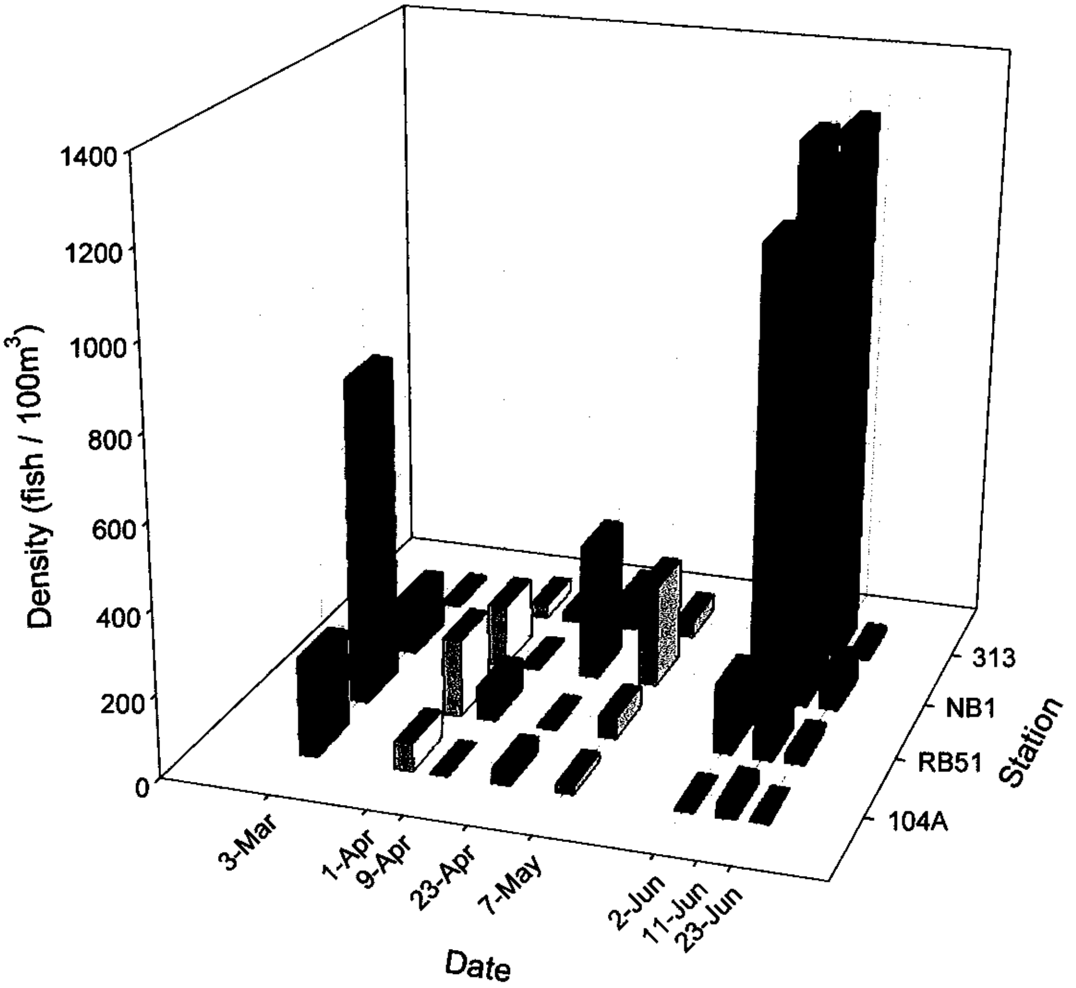

Figure 5. Total fish densities (fish 100 m^{-3}) by station for all sampling events in Nueces Bay during 2004.

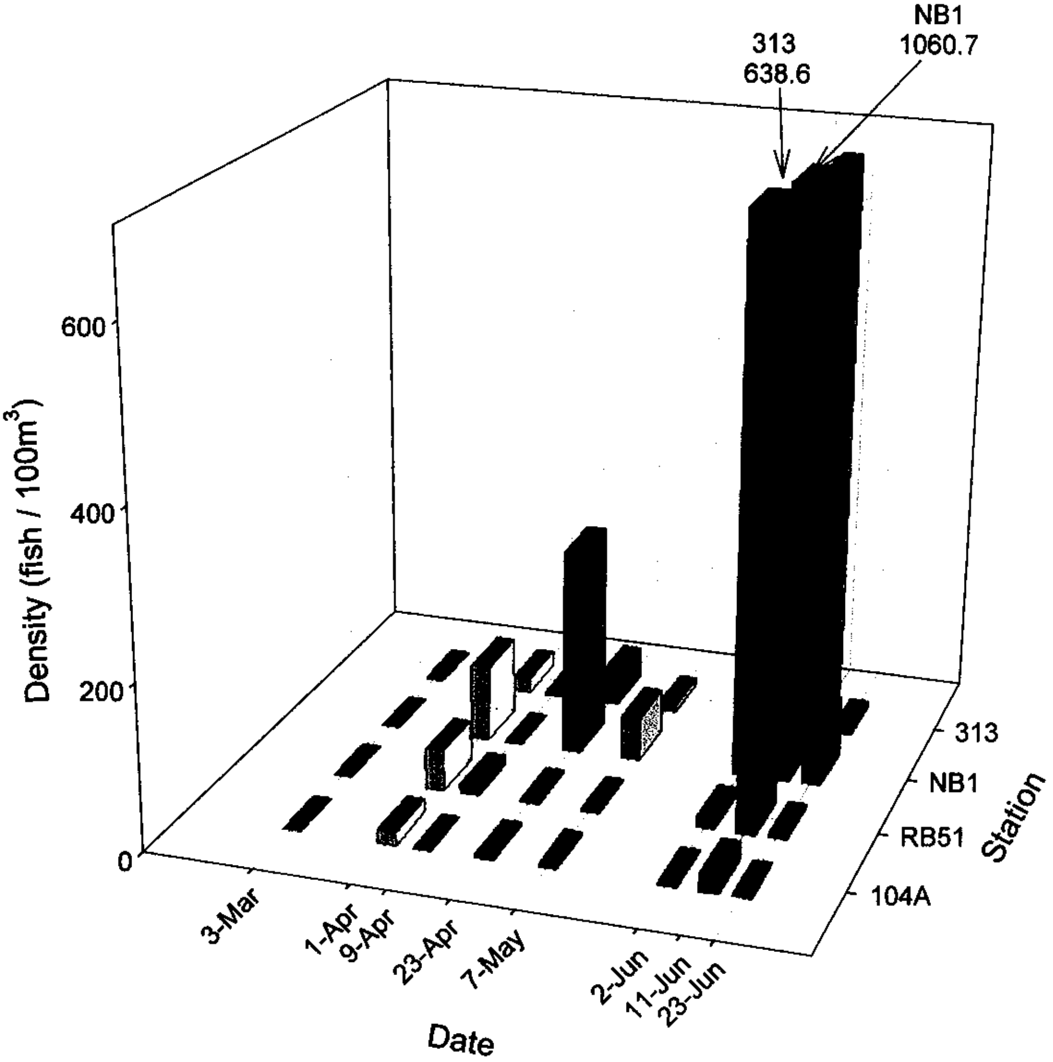

Figure 6. Total densities (fish 100 m^{-3}) of Gobiidae by station for all sampling events in Nueces Bay during 2004.

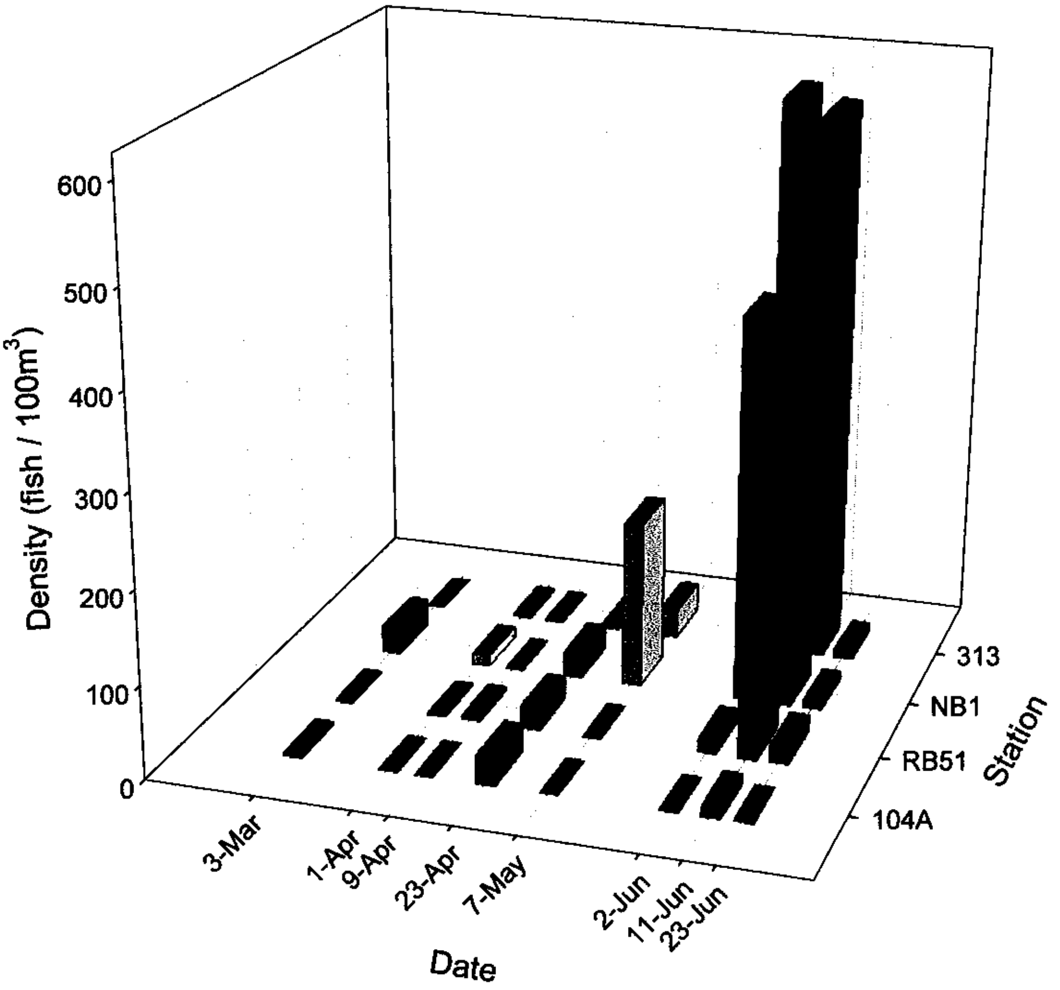

Figure 7. Total densities (fish 100 m^{-3}) of Engraulidae by station for all sampling events in Nueces Bay during 2004.

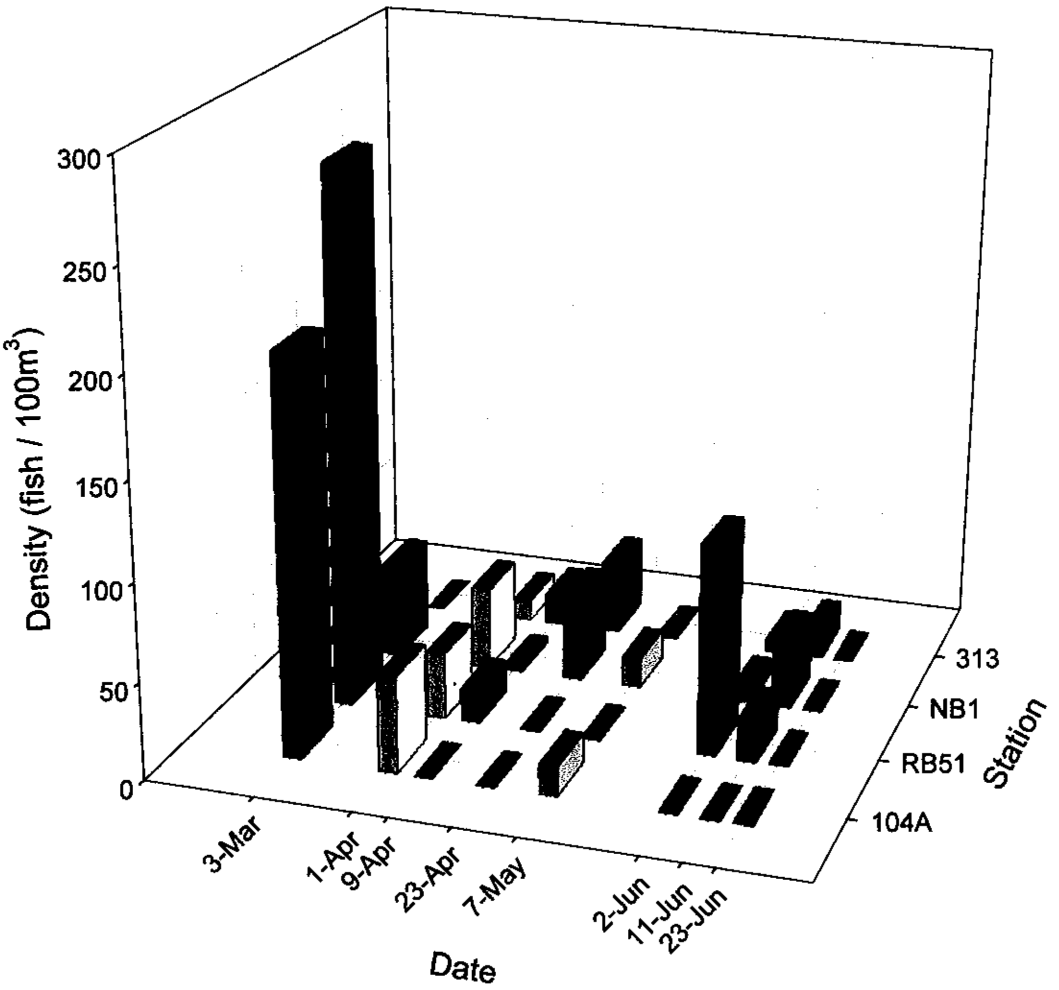

Figure 8. Total densities (fish 100 m^{-3}) of Clupeidae by station for all sampling events in Nueces Bay during 2004.

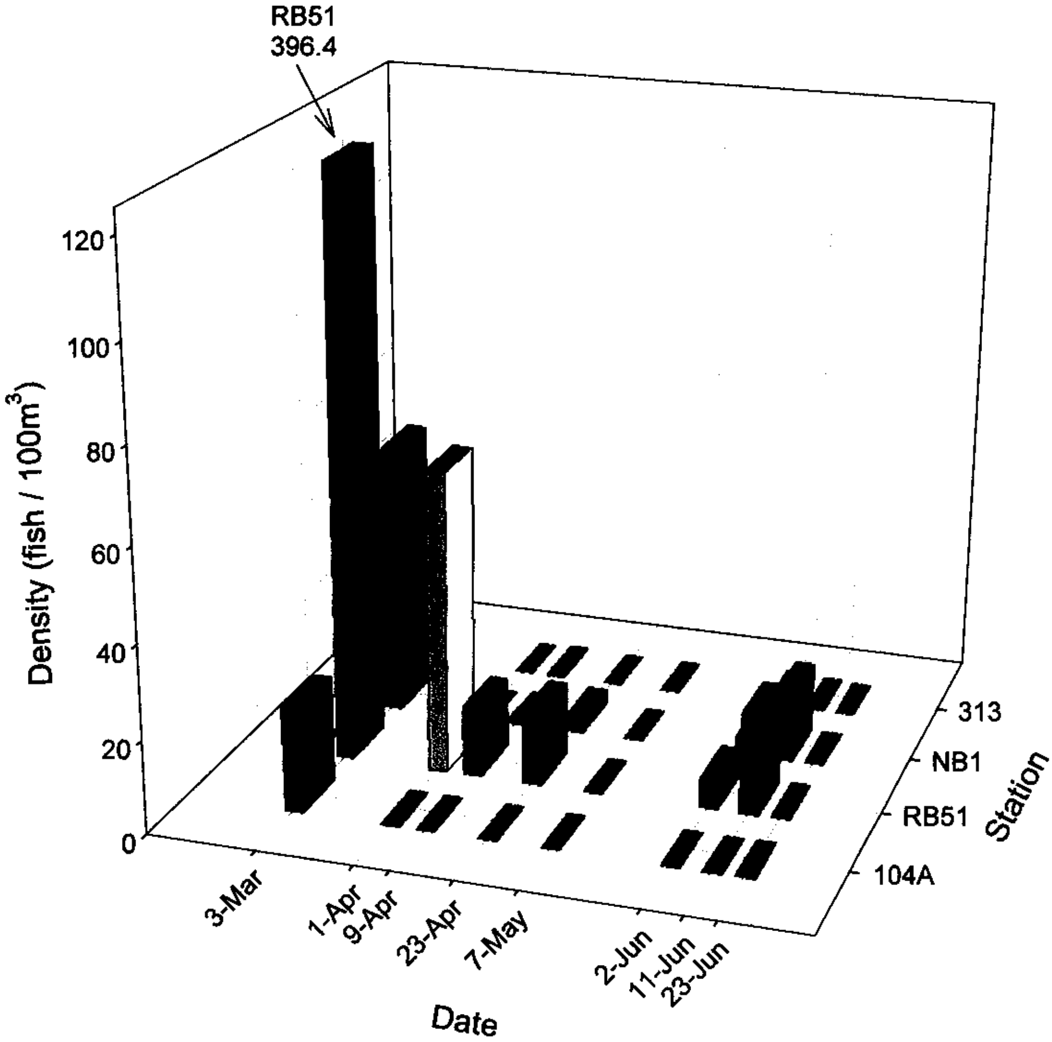

Figure 9. Total densities (shrimp PL 100 m^{-3}) of Penaeidae by station for all sampling events in Nueces Bay during 2004.

(mainly *A. mitchilli*) occurred mostly at the delta and back-bay stations (RB51 and NB1). Like the engraulids, larval gobiids and larger *Gobisoma bosc* individuals were also not collected in great numbers until early to mid-June (Fig. 6). Gobiids appeared to begin recruiting in the early part of April before the flood event, but they were most likely displaced from all the sampling stations by the flood event that began during the second April sampling trip (Fig. 6). When they did show maximal recruitment in early to mid-June, this family was found predominantly in the open-water stations at 313 and NB1.

Ordination

The flood event within Nueces Bay beginning in April 2004 was clearly revealed by the community-structure based MDS procedure (Fig. 10). The period of peak flow down the river effectively transported all of the estuarine-resident, estuarine-transient, and estuarine-dependent larvae and juveniles completely out of the river station. The community seen in the river during this flood was composed strictly of freshwater species (family Cyprinidae) and this taxa was not found at any other sampling station during the spring recruitment period (see Appendix 1). In order to reveal any temporal or spatial patterns in the community structure of the springtime ichthyoplankton, it was necessary to exclude the peak flood period sampling at station 104A (Fig. 11a). As was the case with the abiotic environmental structure of the bay, the ichthyoplankton community composition during the spring recruitment period did not separated the stations into readily identifiable groups.

The general gradient within the MDS can be read as the most diverse communities (based on species diversity as well as abundance levels) found in the lower left quadrant of the plot, and the least diverse communities seen in the in the upper right quadrant of the plot. The temporal sequence of samples clearly shows the influence of the flooding event that began in early April (Fig. 11b). The main shift in the temporal progression of the communities occurs here, where the centers of the MDS configurations show the greatest degree of among-station variability (the river [104A] and delta [RB51] stations are farthest removed from the bay stations [313 and NB1] during the post flood sampling trips in late April through May; see Fig. 11). The flooding event that displaced many of the larvae and juveniles outside of the study area, which is shown in the reduced densities of the most abundant taxa in Figures 6-9, is also reinforced by the shift of the centers of the MDS configurations to the upper right quadrant of the plot during these same sampling trips. By mid to late June, the amount of among-station variability of each temporal cluster seen in the MDS is reduced to that seen in the pre-flood period. Additionally, the progression of the centers of the station configurations in the MDS plot in the latter part of June is towards the right or lower diversity region of the plot, signifying the end of the recruitment period.

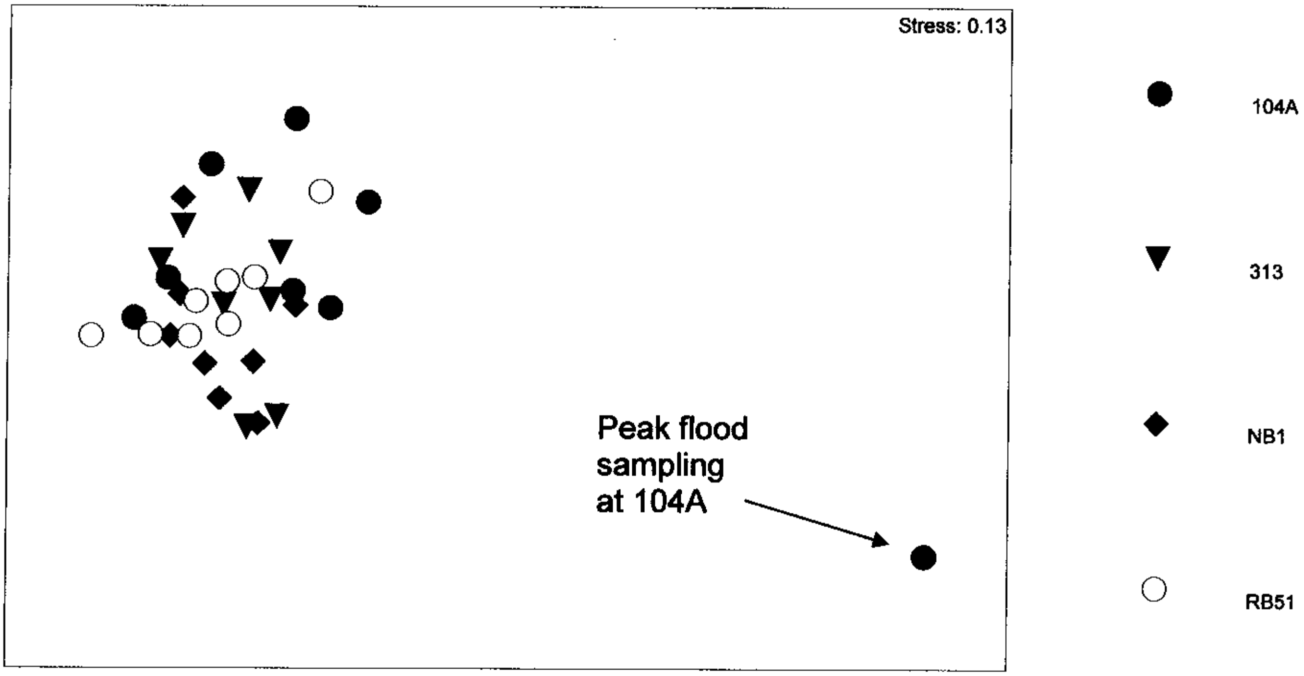

Figure 10. MDS configuration of spring 2004 ichthyoplankton sampling in Nueces Bay, Texas, plotted with stations as the symbols. Flood sampling at the river Station (104A) during the 9 Apr 04 collections is indicated by the arrow.

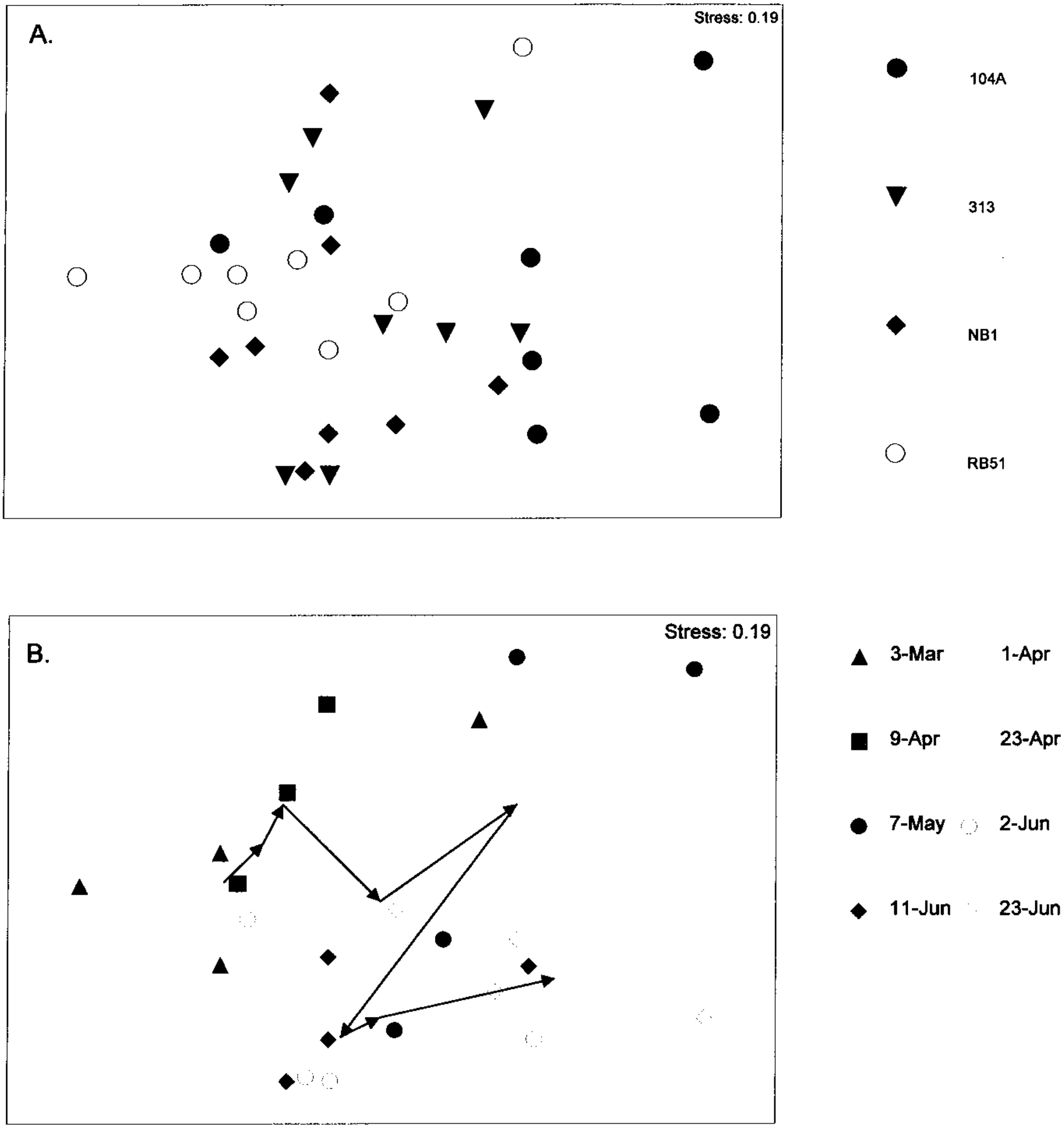

Figure 11. MDS configuration of spring ichthyoplankton sampling in Nueces Bay, Texas excluding the flood sampling in the river on 09 Apr 04. A). Plotted using stations as the symbols. B). Plotted using sample date as the symbols, with an arrow through the center of each sample date space indicating sample sequence through the spring season.

SIMPER analysis was used to determine which taxa were most responsible for the station configurations seen in the spatial and temporal MDS plots. Before the flood, the plankton community in the river (104A) was dominated by juvenile clupeids (*Brevoortia patronus*), larval engraulids and gobiids, as well as numerous penaeid shrimps (Table 3). A few other estuarine-dependent taxa were also noted from the river prior to the onset of the flood (e.g., *Elops saurus and Lagodon rhomboids*) although their densities were typically very low. Some estuarine-resident taxa, such as syngnathids (*Syngnathus scovelli*) and atherinids (*Menidia* sp.) were also present in low densities before the flood event, yet after the high flows only freshwater taxa (Cyprinidae) were collected from the river until late June when larval gobiids showed their peak abundance throughout the entire study area. At the river discharge and open bay stations (313 and NB1), the density levels of gobiids and engraulids showed a very similar pattern, with greatest densities occurring in the final weeks of the spring recruitment season, well after the flood event. Menhaden (*B. patronus*) abundance increased from the open bay to the front of the delta region (313 to NB1), and this pattern of increased density up into the delta also held true at RB51 (Table 3). Juvenile-sized anchovies (*Anchoa mitchilli*) were especially numerous at these two stations, and like the gobiids, maximal densities were not encountered well after the flood event. Taxa found at high abundance levels in the river discharge/back-bay area included estuarine-dependent penaeid shrimps, sciaenids (*Cynoscion arenarius*), and elopidae (*Elops saurus*), as well as estuarine-resident atherinids, syngnathids, and blenniids.

The highest abundance levels, by orders of magnitude in some cases, for all estuarine-dependent and many estuarine-resident taxa (e.g., antherinids, cyprinodontids, and the sciaenid *Leiostomus xanthurus*) were found at the delta Station (RB51; see Table 3). The larger juvenile clupeids, engraulids, and especially penaeids, as well as larval *Menidia* sp. and *L. xanthurus* were all found at greatly increased abundance levels in the delta.

The spatial structure of these communities over time, combined with the results of the ANOSIM test, is shown in Figure 12. Based on 1,716 possible permutations of the sample labels, the Global *R* value for this one-way test was 0.104 (p = <0.046). Pair-wise comparison *R* values for each sampling station are presented in Table 4. Based on their ichthyoplankton communities, the river (104A), river discharge (313) and delta (RB51) stations were identified as being a temporally consistent group of stations. This result is confirmed by the second stage MDS which shows station NB1 as being significantly different from the river and the delta stations, but not the adjacent river discharge location (each is connected by 2 lines to other stations, see Fig. 12). Within the areas immediately impacted by the flood waters (104A, 313, and RB51), there was a high degree of overlap in the ichthyoplankton communities found at these stations over the spring 2004 recruitment season.

Table 3. SIMPER analysis mean densities (fish per 100 m^{-3}), and average similarity (*Si*, within-group) of the spring 2004 ichthyoplankton communities at each station. Life History (LH) designation follows those presented in Patillo et. al (1997) and McEachran and Fechhelm (1998): ED – Estuarine Dependent, ER – Estuarine Resident, MR – Marine Resident, FW – Freshwater.

		Station			
Taxa	LH	104A	313	NB1	RB51
Penaeidae	ED	3.75	1.88	13.13	52.50
Ophichthidae					
Myrophis punctatus	ER	-	-	0.25	-
Elopidae					
Elops saurus	ED	0.63	0.38	1.13	4.13
Engraulidae					
Anchoa mitchilli	ER	16.63	382.25	236.13	22.63
Clupeidae					
Brevoortia gunteri	ER	-	-	1.25	-
Brevoortia patronus	ED	66.75	19.13	42.75	60.25
Cyprinidae	FW	0.38	-	-	-
Mugilidae					
Mugil cephalus	ED	-	-	-	4.38
Atherinopsidae					
Menidia sp.	ER	0.50	1.38	0.75	13.00

Table 3. (cont.)

		Station			
		104A	313	NB1	RB51
Belonidae					
Strongylura marina	ER	-	-	-	0.25
Fundulidae					
Adenia xenica	ER	-	-	-	0.38
Fundulus grandis	ER	-	-	-	1.00
Cyprinidontidae					
Cyprinodon variegatus	ER	-	-	-	0.75
Syngnathidae					
Syngnathus scovelli	ER	1.88	1.00	1.50	0.38
Sparidae					
Lagodon rhomboides	ED	0.25	-	0.38	2.38
Sciaenidae					
Cynoscion arenarius	ED/ER	-	0.25	0.25	-
Leiostomus xanthurus	ED	-	-	-	2.50
Blenniidae	ER/MR	-	-	1.25	-
Gobiesocidae					
Gobiesox strumosus	ER	-	-	0.25	-
Gobiidae	ER	12.88	247.00	289.75	26.88
Gobiosoma bosc	ER	0.63	132.75	204.25	8.13
Average Similarity (S_i)		9.81	17.67	17.36	29.72

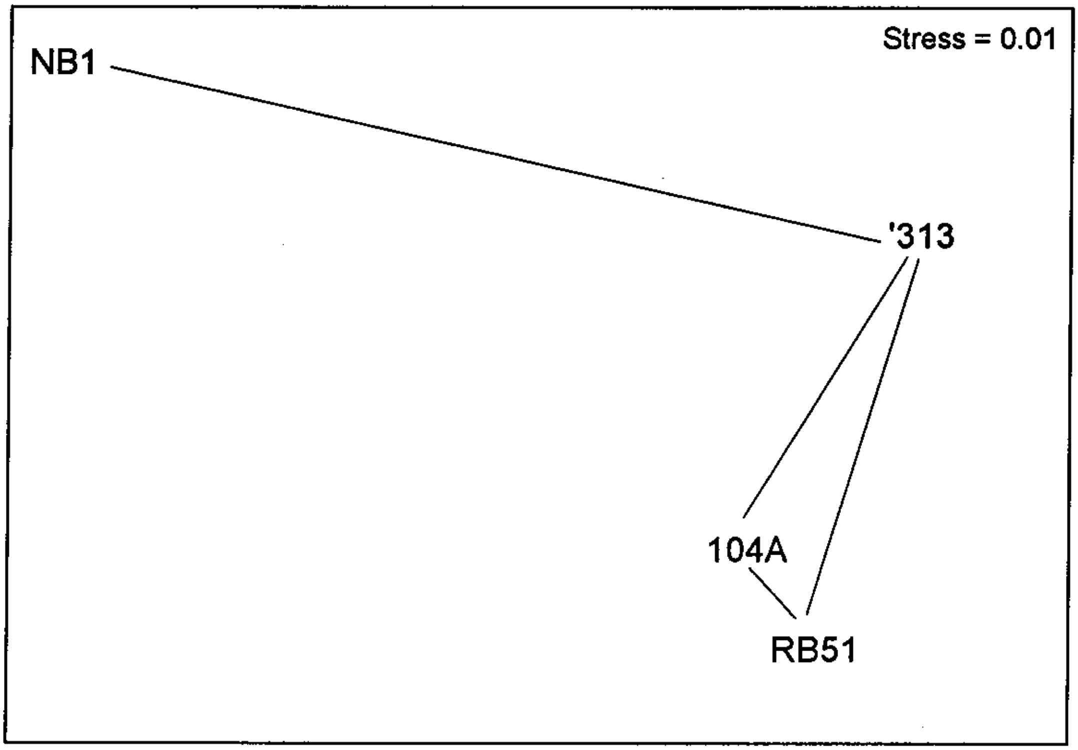

Figure 12. Station configuration (second stage MDS) produced by species similarities (Bray-Curtis similarity measure of the entire community over the spring 2004 sampling season) over each sample date-Station combination. Stress = 0.01. Stations connected by a line are not significantly different based on ANOSIM pair-wise comparisons.

Table 4. Analysis of Similarity (ANOSIM) *R*-statistic values of the stations pair-wise comparisons, based on 1,716 random permutations of the sample labels (all possible permutations). Significant *R* values ($p < 0.05$) identified in bold.

Station	104A	313	NB1
313	-0.052	.	.
NB1	***0.243***	0.004	.
RB51	0.150	0.095	***0.235***

Length-Frequency Distributions

The most abundant ichthyoplankton (the families of Gobiidae, Engraulidae, and Clupeidae numerically accounted for 90.3% of the total) were tested for differences in length-frequencies among stations. Additionally, post-larval shrimp (Penaeidae) were also tested for differences in their length-frequencies. Median size of gobiid larvae throughout Nueces Bay was 5.6 mm SL, with the greatest numbers of larvae collected in the back bay at NB1 (Table 5). Length-frequencies were unimodal in the river and delta, but far more uniform in the open-water stations (Fig. 13). Only the comparison between the river (104A) and river-discharge station (313) was significant, with a greater proportion of the smallest larval gobies (< 4 mm SL) collected in the river station. The largest individuals were typically found in the open-water and back-bay stations (313 and NB1).

Engraulids were generally discernible to the species level by approximately 15-18 mm SL, and the majority of the juvenile engraulids were *Anchoa mitchilli.* The overall median size for this family was 18.6 mm, with the greatest proportion of juvenile sized individuals increasing from the open water to the back-bay and into the delta complex. Based on the bimodal distribution seen at each of the study area locations, it appears that multiple cohorts of engraulids were encountered during spring-time sampling (Fig. 14). Based on the ANOSIM test, only the river (104A) and the back-bay station (NB1) were significantly different in their length frequencies of the engraulids.

For comparisons involving clupeids, only *B. patronus* was used. The other clupeoids collected (i.e., *B. gunteri*, *Dorosoma* spp, and *Opisthonema oglinum*) were not collected in sufficient numbers to enable analysis. Clupeids were collected at all stations at a much larger size, with an overall median size of 23.7 mm SL. This family was found predominantly in the river and at the back-bay / delta stations (NB1 and RB51, see Fig. 15) prior to the flood event. Clupeids were similar in their size distributions at all stations (Table 6).

Based on the early spring season, the post-larval penaeid shrimps collected in this study are most likely brown shrimp, *Farfantepenaeus aztecus* (Patillo et. al, 1997). Relative to the numbers of finfish encountered in the spring, penaeids were collected in the plankton at far lower total numbers (Table 6), yet they were found in relatively high densities in the delta location. Post-larval size shrimp (< 20 mm) were encountered at all the study locations prior to the flood event, while after the flood nearly all the penaeids were collected from the either the delta or back-bay stations (Fig. 16). Only the river (104A) and the delta (RB51) stations differed in their size distributions of shrimp, with more juvenile sized (> 20 mm) individuals collected in the delta after the flood event (Table 6).

Table 5. Total numbers and median (mm) length by Station for length-frequencies of the most abundant ichthyoplankton families and taxa of particular interest (Penaeidae) collected in spring 2004, Nueces Bay, Texas.

	Gobiidae		Engraulidae		Clupeidae		Penaeidae	
Station	Median	*N*	Median	*N*	Median	*N*	Median	*N*
104A	4.7	309	17.9	291	21.4	1,500	11.6	124
313	5.9	7,752	17.6	6,926	23.5	523	12.5	13
NB1	6.0	10,911	18.8	4,622	26.3	1,085	17.9	414
RB51	4.9	670	20.5	526	30.3	1,910	28.4	2,191

Table 6. Analysis of Similarity (ANOSIM) *R*-statistic values of the stations pair-wise comparisons, based on 999 permutations of the sample labels, to detect length-frequency differences for families of interest collected during spring 2004, Nueces Bay, Texas. Significant differences among stations are identified in bold.

A.	Gobiidae Station				Engraulidae Station			
	104A	313	NB1	RB51	104A	313	NB1	RB51
104A	.				.			
313	***0.210***	.			0.094	.		
NB1	0.086	0.010	.		***0.210***	-0.075	.	
RB51	0.006	-0.023	0.007	.	0.077	0.027	-0.023	.

B.	Clupeidae Station				Penaeidae Station			
	104A	313	NB1	RB51	104A	313	NB1	RB51
104A	.				.			
313	-0.042	.			0.053	.		
NB1	-0.063	-0.037	.		-0.005	0.007	.	
RB51	-0.064	-0.058	-0.047	.	***0.105***	0.060	-0.103	.

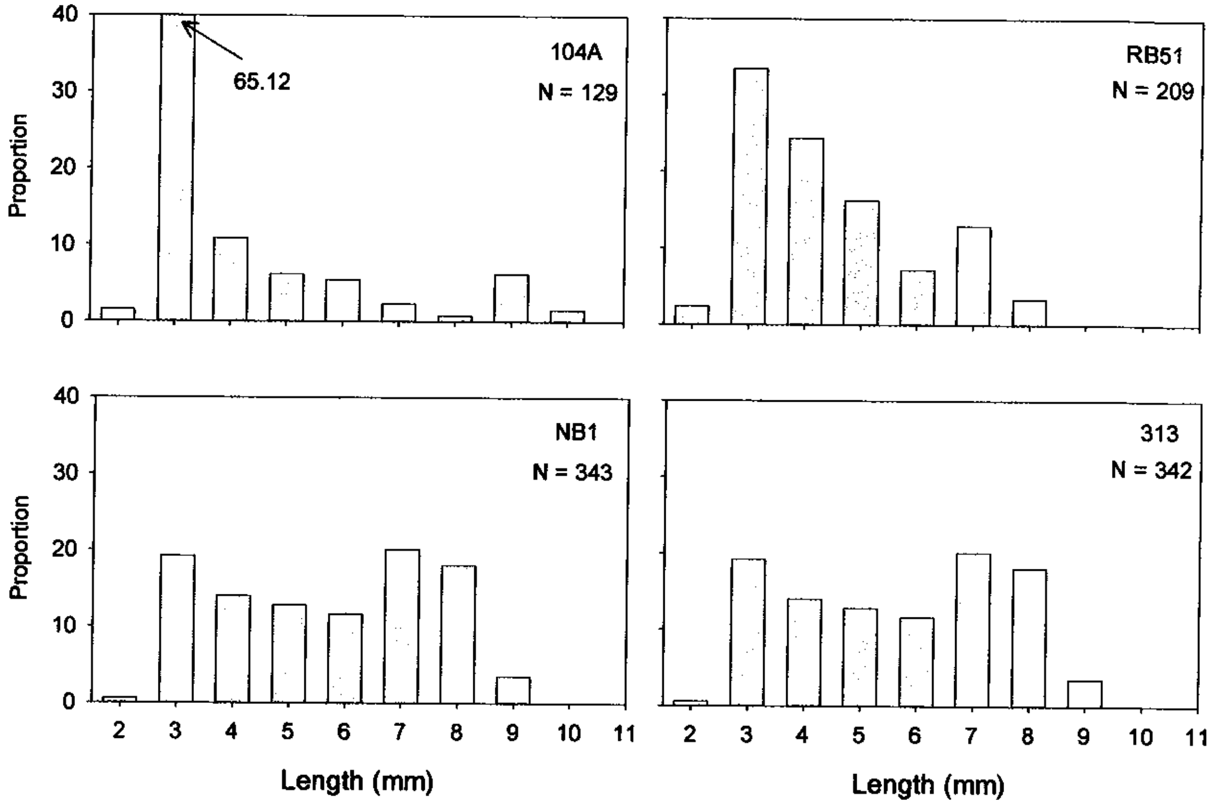

Figure 13. Length frequencies, arranged by Station, of gobiid larvae collected in Nueces Bay during spring 2004.

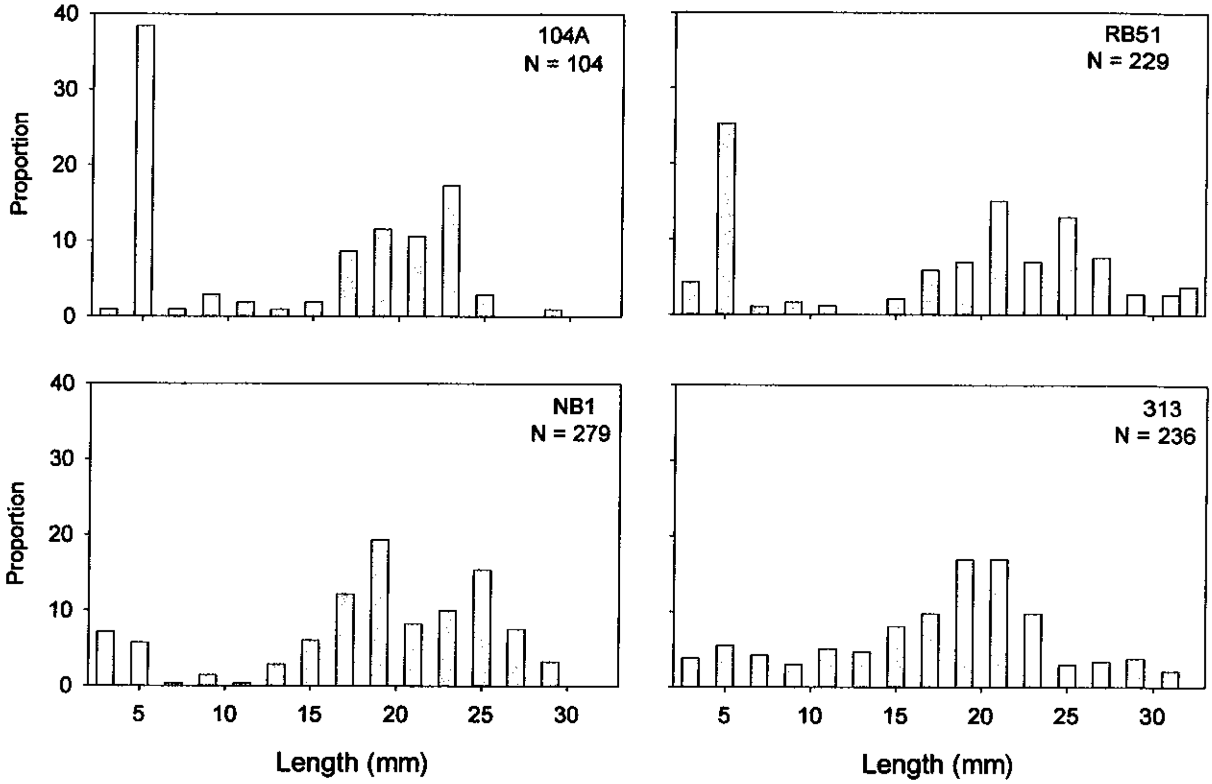

Figure 14. Length frequencies, arranged by Station, of engraulid larvae and juveniles collected in Nueces Bay during spring 2004. All individuals >31 mm are included within the final bin.

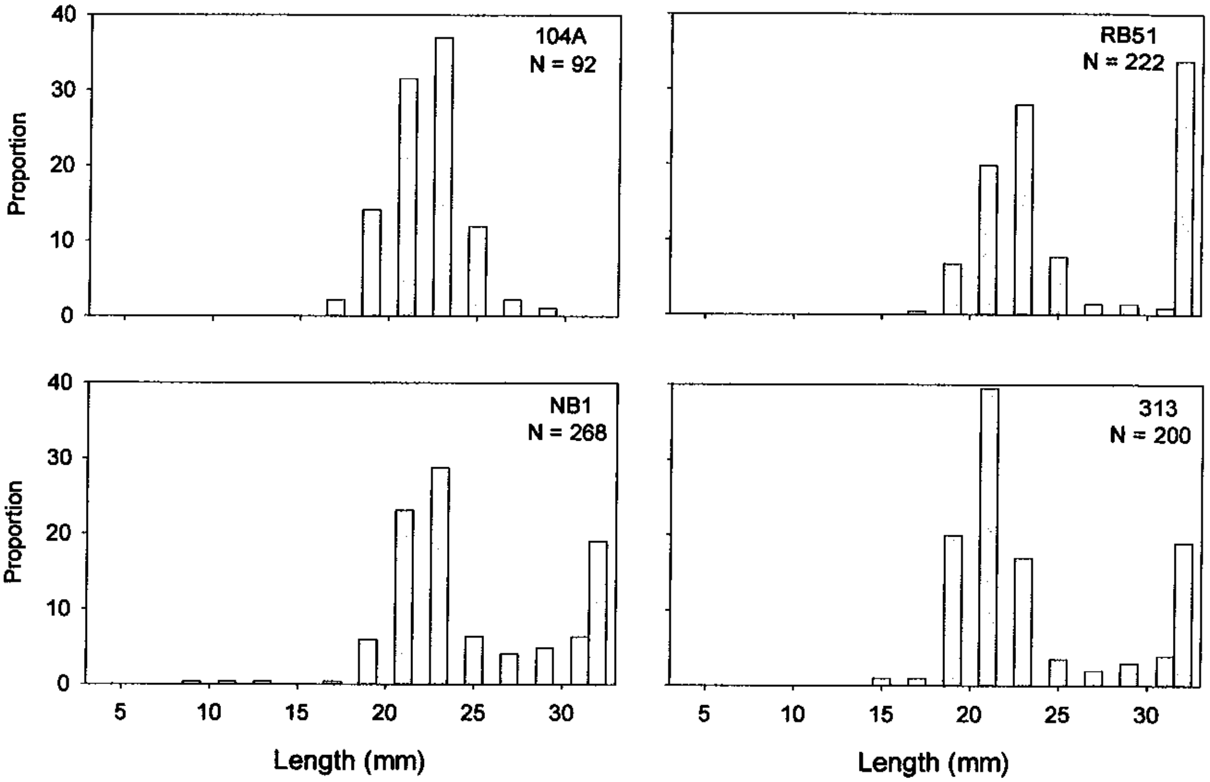

Figure 15. Length frequencies, arranged by Station, of clupeid larvae juveniles collected in Nueces Bay during spring 2004. All individuals > 31 mm are included within the final bin.

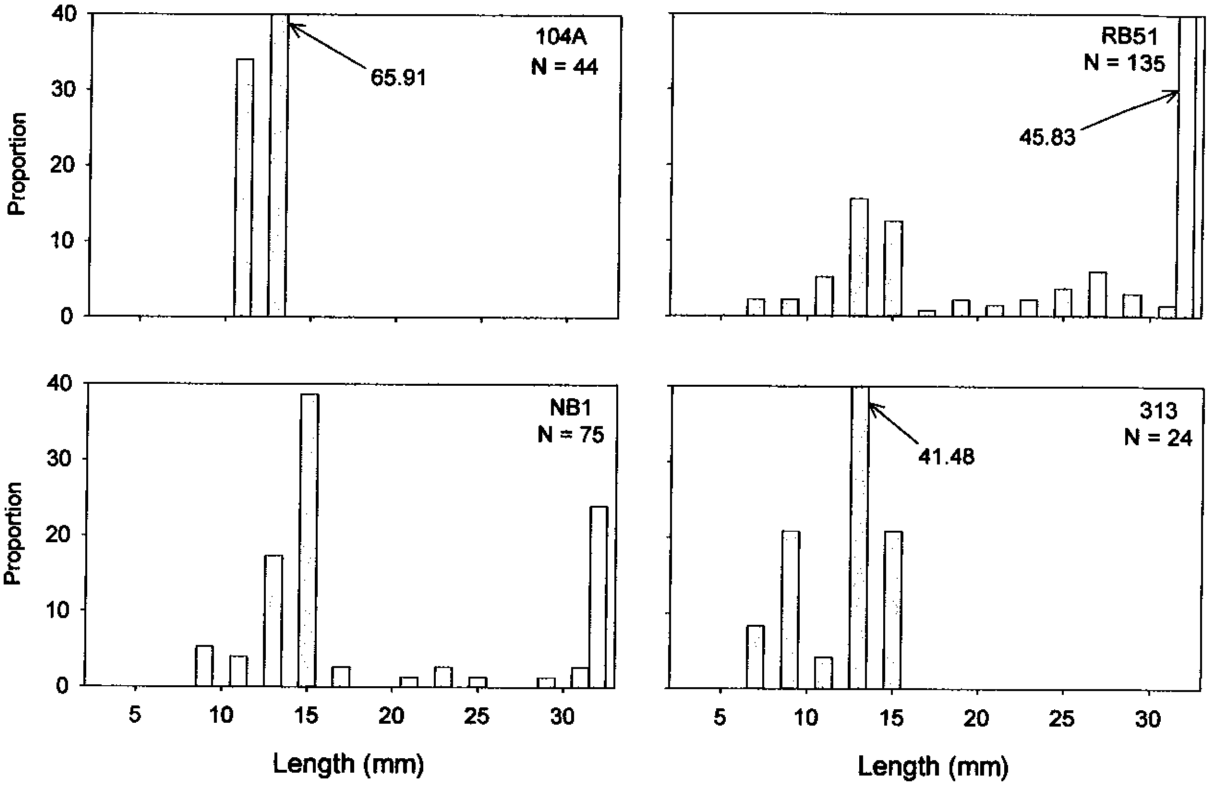

Figure 16. Length frequencies, arranged by Station, of penaeid post-larvae and juveniles collected in Nueces Bay during spring 2004. All individuals > 31 mm are included within the final bin.

V. DISCUSSION

Estuarine-dependent fishery species require estuaries as nursery habitats for at least some portion of their life history stages (Weinstein and Brooks 1983; Worthington et al. 1992, Beck et al. 2001), and many of these species spawn far offshore and face numerous problems locating and entering estuarine nursery areas (Blaber and Blaber 1980; Valesini et al. 1997). Several environmental factors (e.g., prevailing winds, astronomical tides, local rainfall, and circulation patterns) can directly affect the distribution of many of these young organisms, and these same abiotic factors may be affected by or work synergistically with freshwater inflows (Longley 1994). Physiological and behavioral mechanisms related to salinity and (indirectly) to freshwater inflow have been reported to affect the transport of these early life history stages within an estuary (Darnell and McEachran 1989; Wilber and Bass 1998; Tsou and Matheson 2002).

Salinity within Nueces Bay is highly and immediately affected by freshwater inflow, especially the large inflow events typical of the Nueces River. These large events, or freshets, quickly drop salinity levels to 10 PSU or less, with salinities recovering by approximately 10 PSU in the month following the freshet event (Bureau of Reclamation 2000). A continuation of this recovery (to a final salinity of 25-30 PSU in the following months, assuming no additional large inflows) is typically completed within 2-3 months (Freund and Dodson 1995). Newstead (2003) showed that large inflow events taking place during the spring recruitment period, either during the spring or preceding it by 2-3 months, produces a temporary decline in ichthyoplankton abundance in the early spring and delays the majority of recruitment until later in the season. In the spring of 2004 the primary recruitment period for many estuarine-dependent species was interrupted by an extremely large, in magnitude and equally large in duration, inflow event (Fig. 4). This extended 'freshet' depressed salinity values estuary-wide for the entire spring recruitment season. Compared to bay-wide salinity patterns recorded in previous years of similar ichthyoplankton sampling, the salinity structure of Nueces Bay was dramatically affected by the flooding events of April and May of 2004 (Fig. 17).

Tolan and Newstead (2003) point out that the majority of recruitment for many species has been shown to be delayed until later in the season as a result of large inflow events prior to the spring recruitment season. Maximal larval abundance in the plankton has been shown to be recorded between the middle of April and the middle of May, depending upon when the majority of the inflow was received into the estuary. The 'freshet' of 2004 appears to support this theory, with maximal abundance in the plankton, and hence recruitment for these estuarine-dependent and estuarine-resident species, not recorded until much later in the season in June. They also point out that when average salinity across the bay system was lower than the expected 25 PSU, species that prefer lower salinity conditions might be afforded an environmentally-induced advantage. As evidence for this hypothesis, Tolan and Newstead (2003) showed that numerically, gobiids outnumbering all other dominant families within the plankton for the first time in Nueces Bay in 2003 when a large 'freshet' impacted the estuary in the months preceding the spring recruitment season. Because of the flood

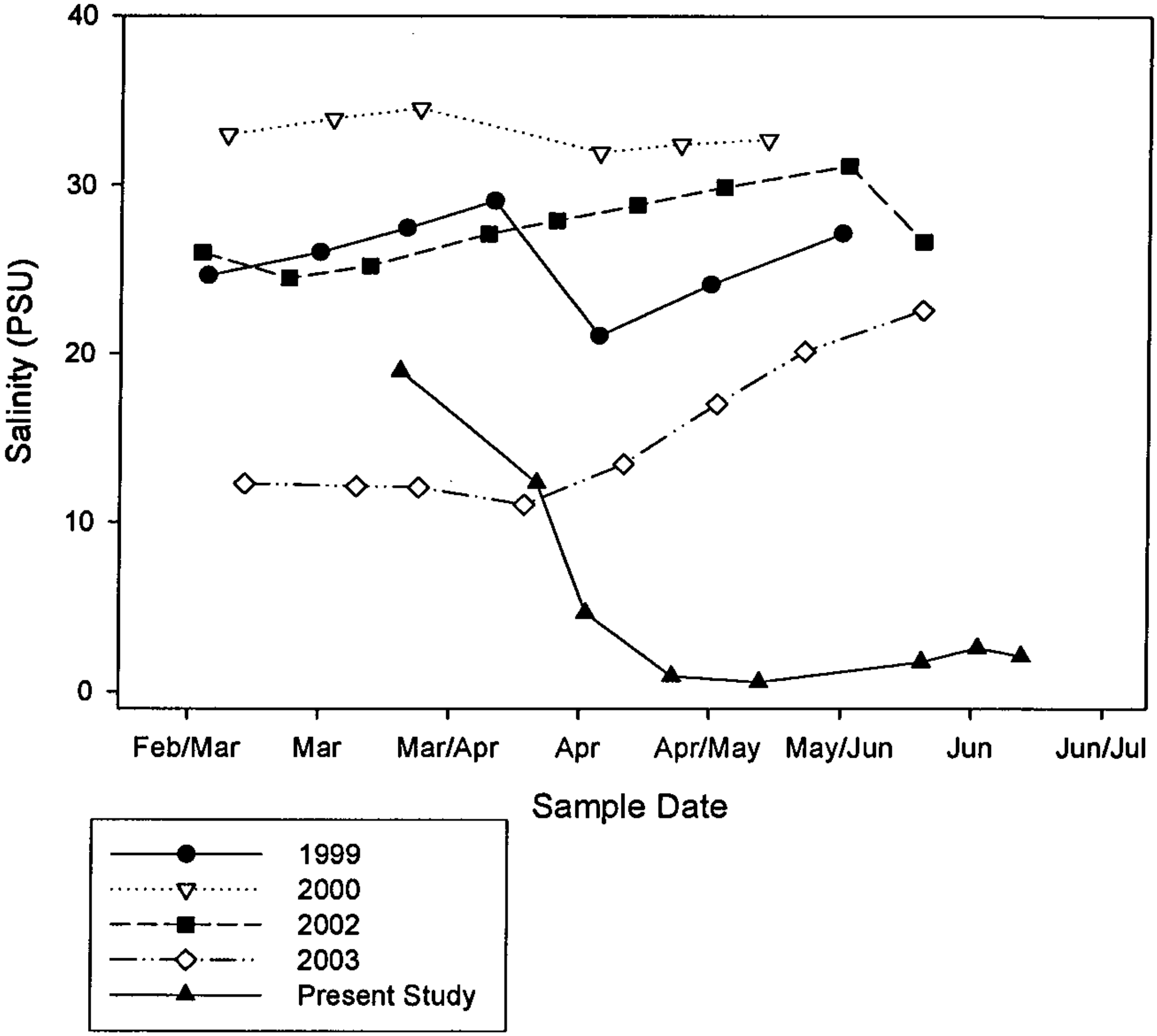

Figure 17. Average bay-wide salinity recorded during the spring recruitment period (1999-2004).

event of 2004 and the subsequent low salinity conditions that were found throughout the study area, gobiids were again the dominant ichthyoplankton found in Nueces Bay.

An alternative explanation for the much-delayed recruitment pattern seen in 2004 could be the result of the mid-season flooding events physically displacing most of the volume of estuary, and along with it moving nearly all the larvae and juveniles that were present in the water column in the early and middle parts of the recruitment season to other locations outside of the extreme western margins of the study area. As the flow from the river subsided and the saltwater began to move back into the back-bay regions of the estuary, estuarine-dependent larvae and juveniles entrained in this water mass could have been brought back to the study locations. If, instead of salinity, spawning and recruitment are more highly governed by other external environmental factors (such as temperature, photoperiod, moon phase, etc.), then the delay in maximal ichthyoplankton abundance might have be the result of the larvae and juveniles being simply displaced from the sampling locations during the flooding periods. This appears to be the case for many taxa that utilized the river station, as densities were similar to previous studies (Tolan and Newstead 2004) before the flood, but because the flow never subsided enough to fully allow the intrusion of saltwater back to this station, densities for nearly all estuarine-dependent and estuarine-resident taxa continued to be low after the flood.

Other taxa that could have benefited from the lower salinity conditions produced by the flood included *Synodus foetens*, *Mugil cephalus*, *Menidia* sp., and *Elops saurus*. Ladyfish (*E. saurus*) spawn year-round offshore (with a possible peak in the fall; Jones et al. 1978) and this species was found in highest abundance in the delta. While most of the *E. saurus* specimens captured in this study were Stage I leptocephali (elongate, ribbon-like, transparent to semi-translucent larvae with a long fin-fold and forked tail) they appear to be actively seeking out the river, back-bay, and delta stations farthest from their source. Inshore lizardfish (*S. foetens*) and striped mullet (*M. cephalus*) are also known to actively seek out brackish water conditions (Hoese and Moore 1992), and like *E. saurus*, they too are spawned well offshore and appear to be actively seeking out the back-bay and delta regions as a preferred nursery habitat. Silversides (family Atherinidae), an estuarine-resident taxa that prefers shallow bay-margin regions (Hoese and Moore 1992), was collected in far higher densities (by an order of magnitude) in the delta than from any other station in Nueces Bay.

As a result of the flood replacing the volume of the bay with freshwater, none of the abiotic variables showed any significant differences among the stations throughout Nueces Bay in 2004. Although average water temperature at the beginning of spring sampling period was comparable to previous years (19-21 °C; see Newstead 2003), the flood flows depressed bay-wide temperatures uniformly across the study area in April and May. Dissolved oxygen concentrations ranged from 6.2 – 11.7 mg l^{-1} at all stations and these values indicate no potential problems associated with low D.O. levels during the spring recruitment period.

The community-level analysis of similarity (ANOSIM) and multidimensional scaling showed that over the spring recruitment period, the back-bay station (NB1) was biologically distinct from the river and the delta, but similar in composition to the river-discharge zone (see Fig. 12 and Table 4). Unlike previous years (see Tolan and Newstead 2004), consistent geographically-based groupings of stations were not seen throughout the spring recruitment period of 2004. This is undoubtedly associated with the extraordinary flooding event that took place. The river, river-discharge zone, and delta regions, all locations that were immediately and substantially impacted by the flood flows, were all very similar in their community compositions. Their spatial configurations in the second-stage MDS plot showed that while environmental gradients were generally lacking throughout the spring, biological community-based patterns were also very similar among these stations. The second stage MDS plot in Figure 12 reinforces the influence of the flood on the communities most directly affected; the river (104A) and the delta (RB51) are closest in the MDS space based on their community compositions.

The greatest degree of species diversity was found in the back-bay and the delta stations (see Table 3). Additionally, the length frequencies of each taxa under investigation showed that the largest individuals (i.e., those with the most advanced morphological and physiological development) were found within the delta or the back-bay stations (RB51 or NB1; see Figures 13-16). It has been hypothesized that this increase in larger-sized individuals in the back-bay and delta stations is in response to increased food availability associated with the high turbidity zone of the back-bay areas (Tolan and Newstead 2004). They also postulate that the current river discharge location, in the relatively constricted portion of the bay across from White's Point and completely removed from the delta nursery grounds (see Fig. 2), could be acting as a recruitment barrier for the smallest larvae. This river discharge barrier could effectively limit the passage of small larvae trying to recruit to the back-bay and delta nursery areas, allowing only the largest and most physiologically developed individuals to pass. Based on the spatial distribution of estuarine-dependent planktonic larvae within the study area, especially after the flood event, shows that the any constriction associated with the current location of the river discharge does not act as any recruitment barrier for estuarine-dependent taxa. Further, many taxa appear to actively seek out the back-bay and delta areas, and this portion of the estuary system appears to be the preferred nursery habitat portion of Nueces Bay.

The April / May flood event of 2004 was one of the longest duration 'freshet' events ever recorded in Nueces Bay. For a large portion of the spring recruitment period, this estuarine system was converted into a brackish water "lake" after nearly all of the volume of the back-bay was replaced with the freshwater flowing down the river. The estuarine-resident species that reside here must be physiologically adapted to withstand these low salinity conditions for extended periods of time. Despite these extraordinary environmental conditions that took place during their normal spawning and recruitment season, these taxa showed little to no detrimental effects of the flood event. While some planktonic larvae and juveniles may have been displaced out of the back-bay and delta regions by the freshet event (see Figures 6-9), these taxa were collected, albiet later in the season, at densities typical of the spring-time recruitment levels encountered in Nueces Bay (see Newstead 2003). Estuarine-dependent taxa also showed no ill effects of the flood event, with density levels in the back-bay and delta region similar to, or in some cases greater than, levels seen in previous sampling seasons. Penaeid shrimps, for example, recruited to the delta region before and after the flood event at density levels nearly 4 times the level that was seen in 2003 (Tolan and Newstead 2004). The same taxa that accounts for the majority of the ichthyoplankton in normal and dry years (e.g., Engraulidae, Clupeidae, and Gobiidae) were just as abundant in the back-bay and delta region even after the estuary had been essentially converted to a lake during this unusually wet spring. This study shows the back-bay and delta regions of Nueces Bay appear to be the preferentially utilized by many different fishery species, especially those taxa identified as estuarine-dependent.

VI. CONCLUSIONS

The spatial distribution of many of the species collected during this study (particularly those that spawn outside the bay and in the Gulf) were unaffected by the freshet event that dramatically changed the salinity structure of Nueces Bay. Under these extraordinary environmental conditions, most taxa still appeared to be selectively recruiting to the more productive areas of the estuary associated with the delta. The current river discharge location does not appear to act as a recruitment barrier for estuarine-dependent taxa seeking out nursery habitats located in the back-bay.

CITED REFERENCES

Ahrenholz, D.W. 1991. Population biology and life history of the North American menhadens, *Brevoortia* spp. *Marine Fisheries Review* 53(4)3-19.

Alldredge, J.R., and J.T. Ratti. 1986. Comparison of some statistical techniques for analysis of resource selection. *Journal of Wildlife Management* 50(1):157-165.

Allshouse, W.C. 1983. The distribution of immigrating larval and postlarval fishes into the Aransas-Corpus Christi Bay complex. M. S. Thesis. Corpus Christi State University. 120 pp.

Armstrong, N.E. 1981. Responses of Texas estuaries to freshwater inflows, p. 103-120. In V. S. Kennedy (ed.), Estuarine Comparisons: Proceedings of the Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oregon.

Beck, M.W., K.L. Able, D.L. Childers, and 9 others. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience* 51:633-641.

Boehlert, G.W. and B.C. Mundy. 1988. Roles of behavioral and physical factors in larval and juvenile fish recruitment to estuarine nursery areas. *American Fisheries Society* 3:51-67.

Boesch, D. and R. Turner. 1984. Dependence of fishery species on salt marshes: The role of food and refuge. *Estuaries* 7:460-468.

Bureau of Reclamation. 2000. Concluding Report: Rincon Bayou Demonstration Project. Volume II: Findings. United States Department of the Interior, Bureau of Reclamation, Oklahoma-Texas Area Office, Austin, Texas.

Buskey, E.J. 1993. Annual pattern of micro- and mesozooplankton abundance and biomass in a subtropical estuary. *Journal of Plankton Research* 15:907-924.

Christmas, J.Y., J.T. McBee, R.S. Waller and F.C. Sutter III. 1982. Habitat suitability index models: Gulf menhaden. U. S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.23. 23 pp.

Clarke, K.R. and R.M. Warwick. 2001. Changes in Marine Communities: An Approach to Stastical Analysis and Interpretation, 2nd edition. PRIMER-E. Plymouth Marine Laboratory.

Cushing, D.H. 1975. Marine Ecology and Fisheries. Cambridge University Press, Cambridge, Massachusetts.

Dando, P.R. 1984. Reproduction in Estuarine Fish, p. 155-170. In G. Potts and R. Wootton (eds.), Fish Reproduction: Strategies and Tactics. Academic Press, Orlando, Florida.

Darnell, R.M. and J.D. McEachran. 1989. Larval recruitment of estuarine-related fishes and invertebrates of the Texas coast. Report to Texas Parks and Wildlife Department, by Department of Oceanography and Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX. 107 pp.

Ditty, J.G. and R.F. Shaw. 1994. Preliminary guide to the identification of the early life history stages of sciaenid fishes from the western central Atlantic. NOAA Tech. Mem. NMFS-SEFSC-349. 118 pp.

Espey, Huston & Associates. 1981. Nueces marsh development: A feasibility study of the introduction of river flows. Document #81328. EH&A, Austin, Texas.

Estevez, E.D. 2002. Review and assessment of biotic variables and analytical methods used in estuarine inflow studies. *Estuaries* 25(6B):1291-1303.

Farooqi, T., R.F. Shaw, and J.G. Ditty. 1995. Preliminary guide to the identification of the early life history stages of anchovies (Family Engraulidae) of the western central Atlantic. NOAA Tech. Mem. NMFS-SEFSC-358. 65 pp.

Freund, R.A. and J.A. Dodson. 1995. Freshwater releases and salinity monitoring in Nueces Bay, Texas, p. 43-52. In Texas Water '95. Proceedings of the Texas Section of the American Society of Civil Engineers, San Antonio, Texas (USA), 16-17 August 1995.

Fritzsche, R.A. 1978. Development of Fishes of the Mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Volume V. Chaetodontidae through Ophidiidae. U.S. Department of the Interior, Biological Services Program. 340 pp.

Gamble, J.C. and S.J. Hay. 1989. Predation by the scyphomedusan Aurelia aurita on herring larvae in large enclosures: Effects of predator size and prey starvation, p. 366-375, In The Early Life History of Fish. The Third ICES Symposium, Bergen (Norway), 3-5 October 1988.

Grange, N., A.K. Whitfield, C.J. de Villiers and B.R. Allanson. 2000. The response of two South African east coast estuaries to altered flow regimes. *Aquatic Conservation: Marine and Freshwater Ecosystems* 10:155-177.

Hardy, Jr., J.D. 1978. Development of Fishes of the Mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Volume II. Anguillidae through Syngnathidae. U.S. Department of the Interior, Biological Services Program. 458 pp.

Heck, Jr., K.L., M.P. Fahay, and C.T. Roman. 1989. Fishes and decapod crustaceans of Cape Cod eelgrass meadows: Species composition, seasonal abundance patterns, and comparisons with unvegetated substrates. *Estuaries* 12(2):59-65.

HDR Engineering, Inc. 1991. Regional Wastewater Planning Study – Phase I, Nueces Estuary. Austin, Texas.

Henley, D.E. and D.G. Rauschuber. 1981. Freshwater needs of fish and wildlife resources in the Nueces-Corpus Christi Bay area, Texas: a literature synthesis. FWS/OBS-80/10. U.S. Fish and Wildlife Service, Washington, D.C.

Hettler, W.F., Jr., D.S. Peters, D.R. Colby, and E.H. Laban. 1997. Daily variability in abundance of larval fishes inside Beaufort Inlet. *Fishery Bulletin* 95:477-493.

Hildebrand, S.F. and W.C. Schroeder. 1928. Fishes of Chesapeake Bay. *U.S. Bureau of Fisheries Bulletin*, Vol. 43:1-388.

Hoese, H.D. and R.H. Moore. 1992. Fishes of the Gulf of Mexico. Texas, Louisiana, and Adjacent Waters. Texas A&M University Press. College Station.

Holthuis, L.B. 1980. FAO species catalogue. Vol.1. Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries. FAO Fish.Synop. (125) Vol.I:271 p.

Johnson, G.D. 1978. Development of Fishes of the Mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Volume IV. Carangidae through Ephippidae. U.S. Department of the Interior, Biological Services Program. 314 pp.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of Fishes of the Mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Volume I. Acipenseridae through Ictaluridae. U.S. Department of the Interior, Biological Services Program. 366 pp.

Kneib, R.T. 1997. Early life stages of resident nekton in intertidal marshes. *Estuaries* 20:214-230.

Knox, G.A. 1986. Estuarine Ecosystems, Vol. I. CRC Press, Boca Raton, Florida.

Lange, U. and W. Greve. 1996. (How) Does temperature determine the spawning time and the distribution of fish? Council Meeting of the International Council for the Exploration of the Sea, Reykjavik (Iceland), 27 Sep-4 Oct 1996.

Laprise, R. and P. Pepin. 1995. Factors influencing the spatio-temporal occurrence of fish eggs and larvae in a northern, physically dynamic coastal environment. *Marine Ecological Progress Series* 122:73-92.

Lee, W.Y., P.E. Eldridge, D. Buzan, and W.M. Pulich. 2001. Freshwater Inflow Recommendation for the Trinity-San Jacinto Estuary of Texas. Technical Report. Texas Parks and Wildlife Department, Resource Protection Division, Coastal Studies Program, Austin, Texas.

Livingston, R.J. 1997. Trophic response of estuarine fishes to long-term changes of river runoff. *Bulletin of Marine Science* 60:984-1004.

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, TX. 386 pp.

Lowe, J.A., D.R.G. Farrow, A.S. Pait, S.J. Arenstam and E.F. Lavan. 1991. Fish Kills in Coastal Waters 1980-1989. National Oceanic and Atmospheric Administration, Rockville, Maryland. 69 pp.

Lyczkowski-Shultz, J., D.L. Ruple, S.L. Richardson, and J.H. Cowan, Jr. 1990. Distribution of fish larvae relative to time and tide in a Gulf of Mexico barrier island pass. *Bulletin of Marine Science* 46:563-577.

Martin, F.D. and G.E. Drewery. 1978. Development of Fishes of the Mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Volume VI. Stromateidae through Ogcocephalidae. U.S. Department of the Interior, Biological Services Program. 416 pp.

McEachran, J.D. and J.D. Fechhelm. 1998. Fishes of the Gulf of Mexico. Volume 1: Mxyiniformes to Gasterosteiformes. University of Texas Press, Austin, TX. 1112 pg.

Montagna, P.A., R.D. Kalke and C. Ritter. 2002. Effect of freshwater inflow on macrofauna and meiofauna in upper Rincon Bayou, Texas, USA. *Estuaries* 25(6B):1436-1447.

NEAC, 2002. Nueces Estuary Advisory Council. Recommended Monitoring Plan for Rincon Bayou, Nueces delta. Monitoring Subcommittee. July 17, 2002. Unpublished Document. 21 pp.

Newstead, D. 2003. Larval fish recruitment to isolated nursery grounds in Nueces Bay, Texas. M. S. Thesis, Texas A&M-Corpus Christi University. 61 pp.

Norcross, B.L. and R.F. Shaw. 1984. Oceanic and estuarine transport of fish eggs and larvae: a review. *Transactions of the American Fisheries Society* 113:153-165.

Palmer, T.A., P.A. Montagna and R.D. Kalke. 2002. Downstream effects of restored freshwater inflow to Rincon Bayou, Nueces delta, Texas, USA. *Estuaries* 25:1448-1456.

Pattillo, M.E., T.E. Czapla, D.M. Nelson and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries, Volume II: Species life history summaries. ELMR Rep. No. 11. NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, MD. 377 pp.

Powell, G.L. and J. Matsumoto. 1994. Texas estuarine mathematical programming model: a tool for freshwater inflow management, p. 401-406. In K. R. Dyer and R. J. Orth (eds.), Changes and Fluxes in Estuaries. Olsen & Olsen: Fredensborg, Denmark.

_________, J. Matsumoto, W.L. Longley, and D.A. Brock. 1997. Effects of Structures and Practices on the Circulation and Salinity Patterns of the Corpus Christi Bay National Estuary Program Study Area. Corpus Christi Bay National Estuary Program Publication No. 19. 169 pp.

Pulich, W.M., Jr., W.Y. Lee, P.E. Eldridge, C.L. Loeffler, and J.M. Hinson. 1998. Freshwater Inflow Recommendation for the Guadalupe Estuary of Texas. technical Report 98-01. Texas Parks & Wildlife Department, Resource Protection Division, Austin, TX. 101 pp.

_________, J.M. Tolan, W.Y. Lee and W. Alvis. 2002. Freshwater Inflow Recommendation for the Nueces Estuary. Technical Report. Texas Parks and Wildlife Department, Resource Protection Division, Coastal Studies Program, Austin, Texas.

Raynie, R.C. and R.F. Shaw. 1994. Ichthyoplankton abundance along a recruitment corridor from offshore spawning to estuarine nursery ground. *Estuarine, Coastal and Shelf Science* 39:421-450.

Richards, W.J. and K.C. Lindeman. 1987. Recruitment dynamics of reef fishes: planktonic processes, settlement and demersal ecologies, and fishery analysis. *Bulletin of Marine Science* 41:392-410.

Riley, G.A. 1967. The plankton of estuaries, pp. 316-326. In G. H. Lauff (ed.) Estuaries. American Association for the Advancement of Science Publication No. 83. Washington, D. C.: AAAS.

Roberts, C.M. 1991. Larval mortality and the composition of coral reef fish communities. *Trends in Ecology and Evolution* 6:83-87.

Ruth, B.F. 1990. Establishment of estuarine faunal use in a salt marsh creation project, Nueces River delta, Texas. Center for Coastal Studies. Corpus Christi State University, Corpus Christi, Texas. CCSU-9001-CCS.

Sale, P.F. 1990. Recruitment of marine species: Is the bandwagon rolling in the right direction? *Trends in Ecology and Evolution* 5:25-27.

SAS. 2000. SAS Online Doc., Version 7.1. Chapter 28. The GLM Procedure. 162 pp.

Schelske, C.L. and E.P. Odum. 1961. Mechanisms maintaining high productivity in Georgia estuaries, p. 75-80. In Clean Water for the Nation's Estuaries. Proceedings of the Georgia Public Meeting, Jekyll Island, Georgia.

Shaw, R.F., B.D. Rogers, J.H. Cowan, Jr., and W.H. Herke. 1988. Ocean-estuary coupling of ichthyoplankton and nekton in the northern Gulf of Mexico. *American Fisheries Society Symposium* 3:77-89.

SYSTAT. 1992. SYSTAT for Windows: Statistics, Version 5 Edition. SYSTAT Inc., Evanston, Ill. 750 pp.

Taggart, C.T. and W.C. Leggett. 1987. Wind-forced hydrodynamics and their interaction with larval fish and plankton abundance: A time-series analysis of physical and biological data. *Canadian Journal of Fisheries and Aquatic Sciences* 44:438-451.

Texas Department of Health. 2002. 2001-2002 Red Tide Event in Texas. Texas Department of Health, 1100 W. 49th Street, Austin, Texas 78756.

Texas Department of Water Resources. 1982. Nueces and Mission-Aransas Estuaries: An Analysis of Bay Segment Boundaries, Physical Characteristics, and Nutrient Processes. (LP-83) Texas Department of Water Resources, Austin, Texas.

Tolan, J.M., S.A. Holt and C.P. Onuf. 1997. Distribution and community structure of ichythyoplankton in Laguna Madre seagrass meadows: Potential impact of seagrass species change. *Estuaries* 20(2):450-464.

__________ and D.A. Newstead. 2004. Spring 2003 ichthyoplankton recruitment to the delta nursery areas of Nueces Bay, Texas. Report to the Coastal Bend Bays and Estuaries Program. 49 pg.

Tsou, T.S. and R.E. Matheson, Jr. 2002. Seasonal changes in the nekton community of the Suwannee River estuary and the potential impacts of freshwater withdrawal. *Estuaries* 26(6B):1372-1381.

Underwood, A.J. and P.G. Fairweather. 1989. Supply-side ecology and benthic marine assemblages. *Trends in Ecology and Evolution* 4:16-20.

United States Geological Survey. 1984. Corpus Christi, Texas Quadrangle Map. 27097-E1-TB-100.

Valesini, F.J., I.C. Potter, M.E. Platell, and G.A. Hyndes. 1997. Ichthyofaunas of a temperate estuary and adjacent marine embayment. Implications regarding choice of nursery area and influence of environmental changes. *Marine Biology* 128: 317-328.

Weinstein, M.P., S.L. Weiss, R.G. Hodson, and L.R. Gerry. 1980. Retention of three taxa of postlarval fishes in an intensively flushed tidal estuary, Cape Fear River, North Carolina. *Fishery Bulletin* 78:419-435.

_________ and H.A Brooks. 1983. Comparative ecology of nekton residing in a tidal creek and adjacent seagrass meadow: Community composition and structure. *Marine Ecology Progress Series* 12:15-27.

Whitledge, T.E. 1993. Enhanced hydrographic survey for CPL discharge in Nueces Bay. Technical Report No. TR/93-008. The University of Texas Marine Science Institute, Port Aransas, Texas.

Wilber, D.H. and R. Bass. 1998. Effect of the Colorado river diversion on Matagorda Bay epifauna. *Estuarine, Coastal and Shelf Science* 47:309-318.

Worthington, D.G., D.J. Ferrell, S.E. McMeill, and J.D. Bell. 1992. Effects of the shoot density of seagrass on fish and decapods: Are correlations evident over large spatial scales? *Marine Biology* 112:139-146.

SOURCES OF UNPUBLISHED INFORMATION

United States Geological Survey. USGS discharge data for station #08211500 Nueces River at Calallen, Texas (June 2003 – July 2004).

Website: http://tx.waterdata.usgs.gov/nwis/uv/?site_no=08211500.

Wagner, T. personal communication. Texas Parks and Wildlife Department, Coastal Fisheries Division, Corpus Christi Bay Ecosystem Office, 702 Navigation Circle, Rockport, Texas 78382.

APPENDIX

Taxonomic list of species collected (total number collected by Station) during spring 2004 ichthyoplankton sampling in Nueces Bay, Texas.

Taxa	STATION			
	104A	313	NB1	RB51
F. Penaeidae	124	52	414	2191
O. Elopiformes				
F. Elopidae				
Elops saurus	11	6	13	157
O. Anguilliformes				
F. Ophichthidae				
Myrophis punctatus		1	2	1
O. Clupeiformes				
F. Engraulidae				
Anchoa mitchilli	291	6926	4622	526
F. Clupeidae		1		
Brevoortia gunteri			10	1
Brevoortia patronus	1404	509	1074	1903
Dorosoma cepedianum		13		
Opisthonema oglinum	96		1	6
O. Cypriniformes				
F. Cyprinidae	7			
O. Aulopiformes				
F. Synodontidae				
Synodus foetens			7	2
O. Mugiliformes				
F. Mugilidae			1	
Mugil cephalus		4		201
O. Atheriniformes				
F. Atherinopsidae				
Menidia sp.	4	19	15	399
O. Beloniformes				
F. Belonidae				
Strongylura marina	16		1	2

Appendix (cont.)	104A	313	NB1	RB51
F. Hemiramphidae				
Hyporhamphus unifasciatus		1		
O. Cyprinidontiformes				
F. Fundulidae				
Adinia xenica				6
Fundulus grandis				12
Lucania parva				1
F. Cyrpinidontidae				
Cyprinidon variegatus			1	34
O. Gasterosteiformes				
F. Syngnathidae				
Syngnathus scovelli	31	13	22	3
O. Perciformes				
F. Sparidae				
Lagodon rhomboides	5		4	112
F. Sciaenidae				
Cynoscion arenarius				
Leiostomus xanthurus	2	1	1	45
Micropogonias undulatus				1
F. Blenniidae		6	10	
F. Gobiesocidae				
Gobiesox strumosus		1	2	
F. Gobiidae	310	5041	5820	605
Gobiosoma bosc	8	2710	5090	65
Microgobius thalassinus		1	1	
O. Pleuronectiformes				
F. Achiridae				
Trinectes maculatus		1		
O. Tetraodontiformes				
F. Diodontidae		1		
TOTAL	2,300	15,310	17,115	6,274