2003 Neches River Biological Survey
near Beaumont, Texas
for
Mobil Oil Corporation,
DuPont Beaumont
and
Lower Neches Valley Authority

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NONTECHNICAL SYNTHESIS

Overview and Rationale

The Academy's water quality surveys of the Neches River, conducted since 1953, assess the health of the river in the vicinity of Beaumont, Texas.

The Patrick Center for Environmental Research of the Academy of Natural Sciences has been conducting biological and water quality surveys of the Neches River since 1953. These surveys were originally conducted for the E.I. du Pont de Nemours Company, which operates a manufacturing facility near Beaumont, Texas. The present comprehensive study was carried out in October 2003 under the sponsorship of ExxonMobil Oil Corporation, the Lower Neches Valley Authority (LNVA), Jefferson County Waterway & Navigation District, and DuPont. Previous studies were undertaken in 1953 (comprehensive), 1956 (cursory), 1960 (cursory), 1973 (comprehensive) and 1996 (comprehensive). Comprehensive studies include all sampling stations and full sampling effort at each station; cursory studies include a reduced number of stations and reduced sampling effort per station. The Neches River surveys originally were designed to assess the general health of the river ecosystem in the vicinity of the DuPont facility. The 2003 investigation examined current conditions in relation to results primarily from the comprehensive surveys of 1953, 1973 and 1996.

Components of the surveys have included environmental chemistry (water and sediments), protozoans, plankton, attached algae, aquatic macrophytes (rooted or floating aquatic plants), macroinvertebrates and fish. Multiple levels of the aquatic food web are studied because no single group is reliably the best indicator of ecosystem health, and also because there is a broad consensus that maintaining the integrity of the entire system is important.

The study design employed in the Neches River surveys includes four sampling zones (see Fig. 1.1): three exposed to industrial and municipal influences originating in the vicinity of Beaumont and Port Neches (Stations 2, 3 and 4), and one upstream reference station (Station 1) that is not exposed to these influences (though it is exposed to municipal and agricultural influences originating upstream of the study area). These four stations lie in a continuum of increasing river salinity in the downstream direction, ranging from freshwater to moderately saline waters at Station 1 to a mix of moderately to highly saline conditions at Stations 2, 3 and 4. Spatial patterns in water quality and salinity are complicated by tidal influence, which causes the direction of river flow to reverse over the tidal cycle.

The Academy surveys assess potential impacts of industrial or other human activities on the river ecosystem by determining whether differences exist between the exposed and reference stations that are either greater or of a different character than would be expected if they were due merely to natural differences among sampling sites (e.g., differences in salinity or depth). For example, the character of differences among stations is judged, in part, by comparing the individual species collected. Evidence of impact exists if a station shows elevated abundances of species known to tolerate pollution and depressed abundances of species known to be sensitive to pollution. If this patterns is detected at the exposed stations but not at the reference station, then facilities or non-point sources along the Neches River downstream of Station 1 are implicated. If, however, the pattern is also seen at the reference station, then the impact is probably due to sources upstream from the study area.

Other types of evidence for impact include decreased species richness (number of species), decreased species abundance (numbers of individuals), decreased species evenness (higher numerical dominance by a small proportion of the species present), decreased species diversity (diversity is a combined measure of richness and evenness) and decreased individual growth rates of fish. These patterns arise because pollution tends to reduce population and individual growth rates in a majority of species, while a few tolerate or thrive in such conditions.

Another type of variation that the Academy surveys address is variation over time. Important components of temporal variation include seasonal trends, multiyear trends and trendless natural variability. As the Academy's Neches River surveys continue, it will eventually be possible to address most of these types of variation. Currently, however, the data record is too short to conduct a rigorous statistical assessment of temporal trends or natural temporal variability. The present study, therefore, primarily includes comparisons of the 2003 results with those from the 1953, 1973 and 1996 studies. The LNVA provided a fairly complete long-term data set for the period, 1981–2002 (from the Texas Commission on Environmental Quality data base), which permits trend analyses for several water-quality parameters. These data were analyzed for trends in dissolved oxygen, fecal coliforms and nitrogen and phosphorus nutrients.

Environmental Geochemistry

Station Comparisons in 2003

Water samples were collected by LNVA staff from each of the four sampling stations on four consecutive days (11-14 October 2003) and were analyzed by various contract laboratories for nutrients, solids, fecal coliforms, selected organic compounds and total recoverable trace metals and metalloids. Field measurements of dissolved oxygen, pH, temperature, salinity, and specific conductivity were also made. These data were used by the Academy to assess potential differences between reference and exposed stations and, where possible, to compare with applicable water-quality guidelines and standards. The results for 2003 were also compared with the Academy's data from previous studies of the Neches River conducted in 1953, 1956, 1973 and 1996. In addition, an assessment of long-term trends in several water-quality parameters (dissolved oxygen, fecal coliforms, and nutrients) was conducted, using data for 1981-2002 that were provided by LNVA (from the Texas Commission on Environmental Quality data base).

Nearly all chemical and water-quality parameters analyzed were found to be within acceptable limits. Roughly 12% of the measured dissolved oxygen levels were below the Texas standard of 3.0 mg/L. However, since all of these low levels occurred near the river bed, outside (below) the well-mixed surface layer of the water column, they do not constitute violations of the Texas water-quality standard for dissolved oxygen. All dissolved oxygen levels measured in the well-mixed surface layer (to which the Texas standard applies) were acceptable. Roughly 63% of the fecal coliform samples collected on 4 consecutive days exceeded 400 colonies per 100 ml, compared to the Texas standard of no more than 10% exceedance of 400 colonies per 100 ml in samples collected over a 30-day period. These elevated fecal coliform levels may be due at least in part to a high-flow event that occurred immediately prior to and during the October sampling period.

Comparison with Previous Academy Studies

Dissolved oxygen levels in 2003 were broadly similar to those in previous Academy studies, with no clear overall pattern of increase or decrease. Fecal coliform concentrations were similar to those in 1996 and, particularly at Stations 2 and 3, were well below those in 1973 and 1953. Concentrations of three forms of nitrogen (ammonia, dissolved nitrate, and total Kjeldahl nitrogen) were broadly similar to those in previous Academy studies, except that total Kjeldahl nitrogen was elevated at Station 1, where there appears to be a consistent pattern of increase since 1973. Concentrations of total phosphorus and dissolved inorganic phosphorus were consistently lower across stations in 2003 than in 1996.

Long-term Temporal Trends, 1981-2002

The long-term trend analysis assessed potential linear and polynomial trends in available water-quality data from river segment 601, stations 0100, 0300, 0500 and 0800, for years 1981-2002. Stations 0100 and 0300 are located roughly 6 river miles and 1 river mile (respectively) downstream from Academy Station 4, Station 0500 is less than 1 river mile downstream from Academy Station 2, and Station 0800 is roughly midway between Academy Stations 1 and 2. Data for many parameters were not adequate for trend analysis, due to infrequent sampling or problems with data quality in years prior to 1997. Near-surface dissolved oxygen saturation showed an increasing trend at most stations, with an overall increase of approximately 0.5 to 1% per year. Dissolved inorganic phosphorus showed a slightly increasing trend at most stations, while fecal coliform concentrations showed a decreasing trend at Stations 0300 and 0500.

Attached Algae

Attached algae were sampled at all four stations during 11-14 October 2003, using qualitative sampling methods. Specimens were identified to species and assessed for known ecological and pollution-tolerance properties. Comparisons among stations and years were based on apparent abundance of algae, prevalent major groups, number of species present (species richness), and the degree of dominance by one or a few species. Large algal growths, especially by blue-green algae (cyanobacteria), usually indicate nutrient enrichment. Algal assemblages are considered more balanced, and thus “healthier,” when species richness is high and dominance is low.

Station Comparisons in 2003

Diatom species richness consistently declined in the downstream direction from Station 1 through Station 4, and the diatom assemblage at Station 1 had a more even species distribution (i.e., less dominance) than at the three downstream stations. This trend probably reflects the fact that the number of species of attached algae in brackish waters is naturally lower than in fresh waters. As found in previous Academy studies, blue-green algal growths were evident at all stations, indicating nutrient enrichment throughout the study area.

Comparison with Previous Academy Studies

Algal assemblages at the four sampling stations in 2003 were broadly similar to those in 1996, though at Stations 2 and 3, diatom species richness was decreased and dominance was increased in 2003 compared to 1996, and richness at these stations was also reduced compared to 1973. Overall reductions in species dominance, prevalence of blue-greens compared to diatoms, and total abundance of algae in the study area all indicate improved conditions in 2003 compared to 1973 and 1953.

Macroinvertebrates

Macroinvertebrates were sampled qualitatively at all four stations during 11-14 October 2003. Specimens were identified to the lowest practical taxon (usually species) and were assessed for known ecological and pollution tolerance properties. Station and year comparisons were based mainly on species richness and salinity preferences of species.

Station Comparisons in 2003

Total macroinvertebrate species richness decreased consistently in the downstream direction from Stations 1 through 4, primarily due to a large number of freshwater insect species at the upper stations. Insect species richness showed a similar pattern of decrease, but species richness for non-insect macroinvertebrates was similar among stations.

Comparison with Previous Academy Studies

Total macroinvertebrate species richness in 2003 (119 species) was approximately double that in 1996 (58 species), mainly reflecting a much larger insect species richness in 2003. The lower richness in 1996 is probably due to elevated salinity throughout the study area as a result of drought conditions and reduced river flow. Non-insect macroinvertebrate species richness in 2003 was similar to that in 1996 at all stations. Based on the macroinvertebrate assemblages in 1953, Station 1 was polluted and Stations 2 through 4 were very polluted. A small improvement was noted in 1973 and a much greater improvement in 1996, particularly in species richness of total macroinvertebrates and of insects. In addition to pollution, salinity differences have been a significant contributor to between-year differences in species richness, especially for the high-flow year of 2003 versus the drought year of 1996.

Fish

Fish were sampled qualitatively and quantitatively at all four stations during 11-14 October 2003. Two different primary sampling techniques (seines and otter trawl) were employed, each appropriate for a different habitat or size class of fish. All specimens were identified to species, and station and year comparisons were based primarily on species richness and abundance.

Station Comparisons in 2003

A total of 28,567 fish of 51 species was caught, with 95 % of all fish being bay anchovy. A notable record is the collection of a single least killifish at Station 3, which may be the westernmost record for this species. The abundance of most species in seine samples varied among stations consistent with differences in salinity, with several freshwater species relatively common at Station 1 but not elsewhere, and several estuarine species found only at Stations 2 through 4. Bay anchovy was the only species common at all four stations in these samples, and it showed no statistically significant among-station difference in abundance. There was also a clear salinity-related gradient in trawl samples. The dominant species in these samples were bay anchovy and sand seatrout. Bay anchovy abundance tended to increase from Stations 1 to 4 and was significantly lower at Station 1 than at either Station 3 or 4. Sand seatrout abundance was significantly greater at Stations 2 and 4 than at Stations 1 and 3. None of these patterns appears to be related to pollution.

Comparison with Previous Academy Studies

Comparison of results from different study years is complicated by changes in collection techniques, which have included seines, otter trawls, gill nets, fyke (hoop) nets, wire basket traps, and Rotenone. The 2003 and 1996 surveys found higher numbers and a greater variety of estuarine species at Stations 2 through 4 than did the 1973 and 1953 surveys. Bay anchovy was uncommon in the early surveys but abundant in the 2003 and 1996 surveys. This difference probably reflects improved water quality rather than differences in sampling methods, since the seines used in the early surveys are effective in catching bay anchovy.

Conclusions

Compared with earlier Academy studies, the 2003 Lower Neches River study clearly indicates the system-wide improvement in the biological communities within the study area. The Neches estuary supports diverse algal, macroinvertebrate and fish populations, and serves as primary nursery habitat for numerous species of estuarine and marine fish.

Most chemical and water-quality parameters in 2003 were within acceptable limits and were similar to or better than levels in previous Academy studies, especially those in 1953 and 1973. As in previous Academy studies, however, there continues to be evidence of elevated fecal coliform levels.

Also as in previous Academy studies on the lower Neches River, blue-green algal growths were evident at all stations, indicating continued nutrient enrichment throughout the study area. However, overall reductions in algal species dominance, prevalence of blue-greens relative to diatoms, and total algal abundance all indicate improved conditions in 2003 compared to 1953 and 1973.

Total macroinvertebrate species richness in 2003 was by far the highest observed in any Academy study on the lower Neches River to date. Based on macroinvertebrate species richness as well as species characteristics, substantial improvements are evident in the health of the lower Neches River since 1953, with the greatest improvement occurring between 1973 and 1996.

The fish assemblage in the lower Neches River continues to be abundant and diverse. Increased abundance and variety of estuarine species at Stations 2 through 4 were evident in the 2003 and 1996 studies compared to the 1953 and 1973 studies. Bay anchovy was uncommon in 1953 and 1973 but was abundant at all stations in 2003 and 1996, at least partially reflecting improved water quality.

TABLE OF CONTENTS

Page

Page

1. INTRODUCTION

1.1 Overview

The Academy's surveys, conducted since 1953, characterize the health of the Neches River near Beaumont, Texas.

This report summarizes the findings of studies conducted on the Neches River, Jefferson and Orange counties, Texas, during 2003 by the Academy of Natural Sciences of Philadelphia for ExxonMobil, Lower Neches Valley Authority, Jefferson County Waterway & Navigation District and DuPont. Program elements were designed to characterize the biological conditions of the Neches River in areas previously surveyed by comprehensive studies by the Academy. The 2003 studies were conducted at a river reference station upriver from industrial sites on the Neches River in the Beaumont area and at three downriver station sites along the Neches River to the region of Port Neches, TX. Comprehensive studies of the Neches River were conducted by the Academy in August 1953 (ANSP 1954), August 1973 (ANSP 1974) and October 1996 (ANSP 1998), with cursory investigations in October 1956 (ANSP 1958) and December 1960 (ANSP 1961). The 1953 survey included chemical studies and biological surveys of ecological components (i.e., plankton, protozoans, attached algae, macroinvertebrates and fish). As in the 1953 comprehensive survey, the 1973 study included physical and chemical measures along with an examination of several biological groups (i.e., protozoans, algae and aquatic macrophytes, macroinvertebrates and fish). Additionally incorporated into the 1973 investigation was an analysis of selected metals in sediments. The primary purpose of the 1973 program was to measure trends by comparing and contrasting survey findings with those of the 1953 investigation. In the comprehensive surveys of 1996 and 2003, less sampling time was expended in the field than in the earlier comprehensive investigations of 1953 and 1973. Sampling

Cursory versus Comprehensive Surveys

Cursory
- Reduced Effort
- Fewer Sampling Stations

Comprehensive
- Full Effort
- All Sampling Stations

techniques for the algae were similar to previous comprehensive investigations with fewer sampling methods used for the macroinvertebrates and fishes. The 1953 and 1973 fish studies employed one or more active (e.g., seine or trawl) and passive (e.g., gill nets, traps or rotenone) collecting techniques. By comparison, the 1996 and 2003 fish sampling protocol differed by relying primarily on active collecting techniques utilizing a bag seine and otter trawl. Macroinvertebrate and fish studies benefitted each other from some of the same sampling methodologies (e.g., dip net, seine and trawl). The 1956 and 1960 surveys were cursory in terms of effort (survey time) and number of stations sampled (depending upon the biological group, Stations 2 through 4 or Stations 3 and 4). The cursory studies were intended to determine if improvements in water quality, observed in the Diatometer program (artificial substrates for measuring qualitative and quantitative aspects of algal biology), were reflected in other biological components. In 1956, a limited survey of the protozoa, plankton, algae, macroinvertebrates and fish along with a bioassay investigation and some chemical and physical measures of the Neches River was conducted. The 1960 cursory monitoring again examined some chemical and physical parameters and the same biological groups as in 1956.

In 1996 and 2003, some physical and chemical measures (dissolved oxygen, temperature, pH and salinity) were taken by the Academy to characterize basic aspects of water quality during the period of the field survey. The Lower Neches Valley Authority undertook a broader program of water chemistry analyses that included basic water quality measures (e.g., dissolved oxygen, salinity, temperature and pH) and whole water samples for total suspended solids, volatile suspended solids, dissolved nitrate, turbidity, fecal coliform, total phosphorous, dissolved ortho-phosphorus, total organic carbon, total Kjeldahl nitrogen, dissolved ammonia + ammonium, 1,3-butadiene, styrene, acetone, methanol, ethylene glycol and suites of phenols and metals. Most of the Neches River studies were carried out at a time when discharges entered at a potentially stressful time for the river (i.e., during a period of the year in which ambient river temperatures are higher and river flows are typically decreased).

The Neches River originates southeast of Dallas and flows generally southeastward 693 km (416 mi) to Sabine Lake. The Neches River and its principal tributary, the Angelina River, drains an area of approximately 25,900 km^2. The hydrology and general character of the lower Neches River is typical of an estuarine system where a salinity continuum from freshwater to polyhaline waters changes seasonally and annually and creates a dynamic range of environments. The water in the study area is tea-colored probably from dissolved tannins and lignins. The river in the area has low banks and cuts through a generally level plain of coastal prairies and marshes that permits flushing of these habitats during precipitation events. Manufacturing in the Beaumont area (city population approximately 114,000) is dominated by oil refining and petrochemical manufacturing with some paper, lumber and pulp products, food processing and synthetic rubber industries. Farming in the region includes crops (especially rice) and livestock.

The Neches River is dredged upriver to the Port of Beaumont to create a navigational channel, including digging new channels by cutting off several meanders. Upriver of the Port at Station 1 the wooded shoreline bears both depositional shallow muddy sand and cut bank areas. Softer muddy sediments are present in a large right bank (oriented downriver) backwater ringed primarily with bald cypress (*Taxodium distichum*). In this backwater, one important habitat for macroinvertebrates and fish was provided by a dense stand of the aquatic vascular plant, lake acanthus (*Hygrophila lacustris*), along a spit of land that separated the backwater from the main channel. In the dredged main channel regions, at Stations 2 through 4, the wooded, pasture or marshy shoreline areas were sampled along a narrow shelf that consisted primarily of sandy beaches, sand and clay banks and sandy/muddy/detrital backwaters. The navigational channel of the Neches River accommodates large oceangoing ships, and the draft of these ships creates a great deal of high energy wave activity along the narrow shelf and shoreline. The most conspicuous plants at these stations were the common reed (*Phragmites australis*) and California bulrush (*Scirpus californicus*), both emergents, with the latter providing habitat for macroinvertebrates and fish. Water hyacinth (*Eichhornia* *crassipes*), probably washed from tributaries by a recent rain event, was common in and along the main channel and also provided habitat for macroinvertebrates and fish. Indented backwater portions of the shoreline at Stations 2 and 4 contained sand and/or soft sediments of clay, mud and detrital matter. When field biologists walked in these areas in 1996, conspicuous brown oil deposits, with a strong petroleum odor, were released as blotches of oil sheen at the water surface. Oil in sediment samples coated the tray used for sorting macroinvertebrates. No oil was noted from these sites in 2003, although the oil was present in sediment and detrital material dredged by the otter trawl from along the right bank at Station 2.

1.2 Survey Sites

The same stations used during the 1953, 1973 and 1996 comprehensive surveys were investigated during the 2003 study (ANSP 1954, 1974, 1996) (Fig. 1.1). The limits of the four stations in 2003 were as follows:

Station 1: Located approximately 2.4 km (1.5 mi) upriver from the Beaumont Country Club in the downriver arm of a dextral (facing downriver) bend of the river. The right bank was marked by a large backwater near the lower end of the station. This backwater area was separated from the main channel by a dry spit of land (30° 08′ 20″ N, 94° 06′ 21″ W at the end of the spit) and was not sampled in 1996. In 2003, the spit of land was flooded, and the flooded vegetation on the backwater side of the spit was sampled as well as a deeper area for clams and mussels.

Station 2: A portion of the river just upriver from Light Number 56 and downriver to Light Number 54. Just beyond the downriver end of Station 2 lies Clark Island and an unnamed island created when a new channel segment of the Neches River was created. The latitude and longitude at midstation are 30° 03′ 07″ N, 94° 01′ 39″ W.

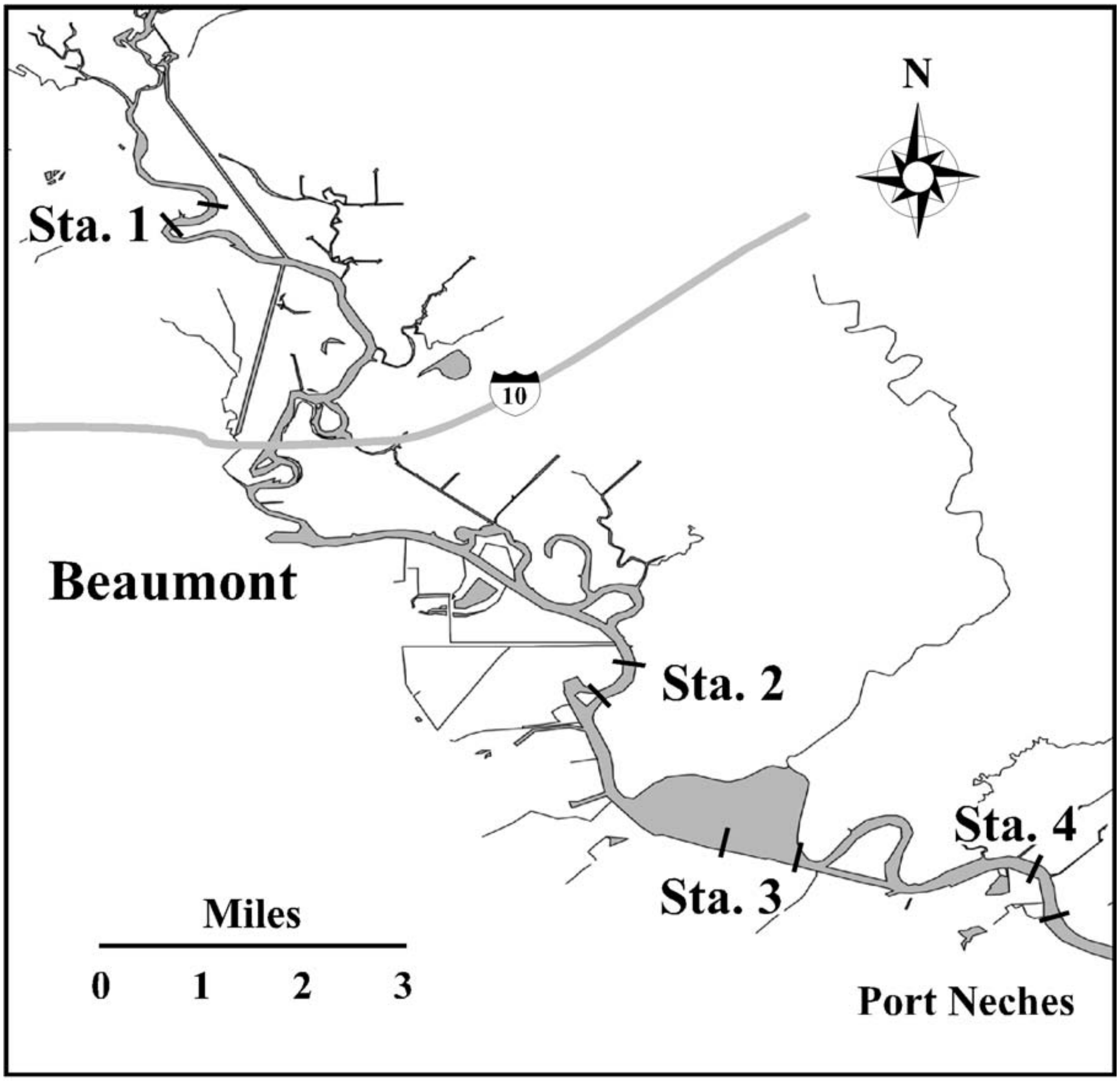

Figure 1.1. ANSP 2003 study areas on the Neches River, Jefferson and Orange counties, Texas. Showing Stations 1, 2, 3 and 4 in relation to the cities of Beaumont and Port Neches.

Station 3: From approximately the middle of the right bank of McFadden Bend Cutoff downriver to an indented right bank area marked with rip rap and lying in the region of Light Number 40. During earlier surveys, the left bank of the channel was marked by a series of low islands that separated the main channel from a large embayment (Reserve Fleet Area). These islands now exist as dredged mounts and no longer provide supratidal habitats. The Fleet Reserve Area, which is used for ship storage, had restricted access in 1996, and only one trawl sample was taken at that time. Access to this area in 2003 allowed trawling out of the main channel and seining and hand searches for molluscs along the east bank near the main channel. The latitude and longitude at the upper end of the station are 30°00′ 57″ N, 94°00′ 28″ W.

Station 4: From an area midway between lights numbered 28 and 30 downriver to an area at the level of the mouth of a canal to Block Bayou. The latitude and longitude of this station in the area of midstation are 30°00′ 38″ N, 93° 57′ 17″ W.

Broadly defined stations give individual investigators freedom to identify critical habitats for their particular study organisms, and because microhabitats occur sporadically throughout the study area, such stations provide a comprehensive view of the river ecosystem. Station 1 remains different from the other areas due to its upstream location in a zone draining a water oak-elm-hackberry forest, while the downriver channel is dredged and has more saline waters draining city, residential and industrial areas as well as marsh and pasture habitats.

1.3 River Discharge Patterns

Upriver from the study areas, the Neches River flow is partially regulated by dams of various sizes on the Neches and Angelina rivers. The largest of these is

Sam Rayburn Reservoir on the Angelina River. These impoundments were created for several purposes (e.g., to control floods, generate hydroelectric power and conserve water for municipal, industrial, agricultural and recreational uses). Rainfall, control of flow by dams and the Neches River Valley Saltwater Barrier, completed in 2003, near Beaumont are the most significant factors governing river discharge within the study area. The species composition has varied among years in part reflecting seasonal discharge patterns in the Neches River basin. In 2003, the Beaumont area experienced a large rainfall event on 9 October, two days prior to the start of field sampling (Fig. 1.2). As a result of these rains, water levels were slightly elevated during the survey, and increased flows of waters entered the river from low wet areas in marshes and pastures as did increased amounts of floating aquatic plants from tributaries.

Daily discharges recorded at Evadale for the 1953, 1973, 1996 and 2003 surveys are depicted in Figure 1.3. Discharge patterns among the study years differed with more periods of high discharges in the early portion of 1953 and high discharge rates for most of 1973. Low discharge rates throughout most of 1996 characterized it as a drought year. The 2003 discharge patterns were more similar to 1973, with higher flows in the first third of the year and lower flows thereafter, although in 1973 a late spring spike, absent in 2003, occurred. Like 1973, the generally higher discharges of 2003 favor certain species over those typical in low-flow years (e.g., 1996), dilute some of the chemical constituents of the river and increase others from terrestrial runoff.

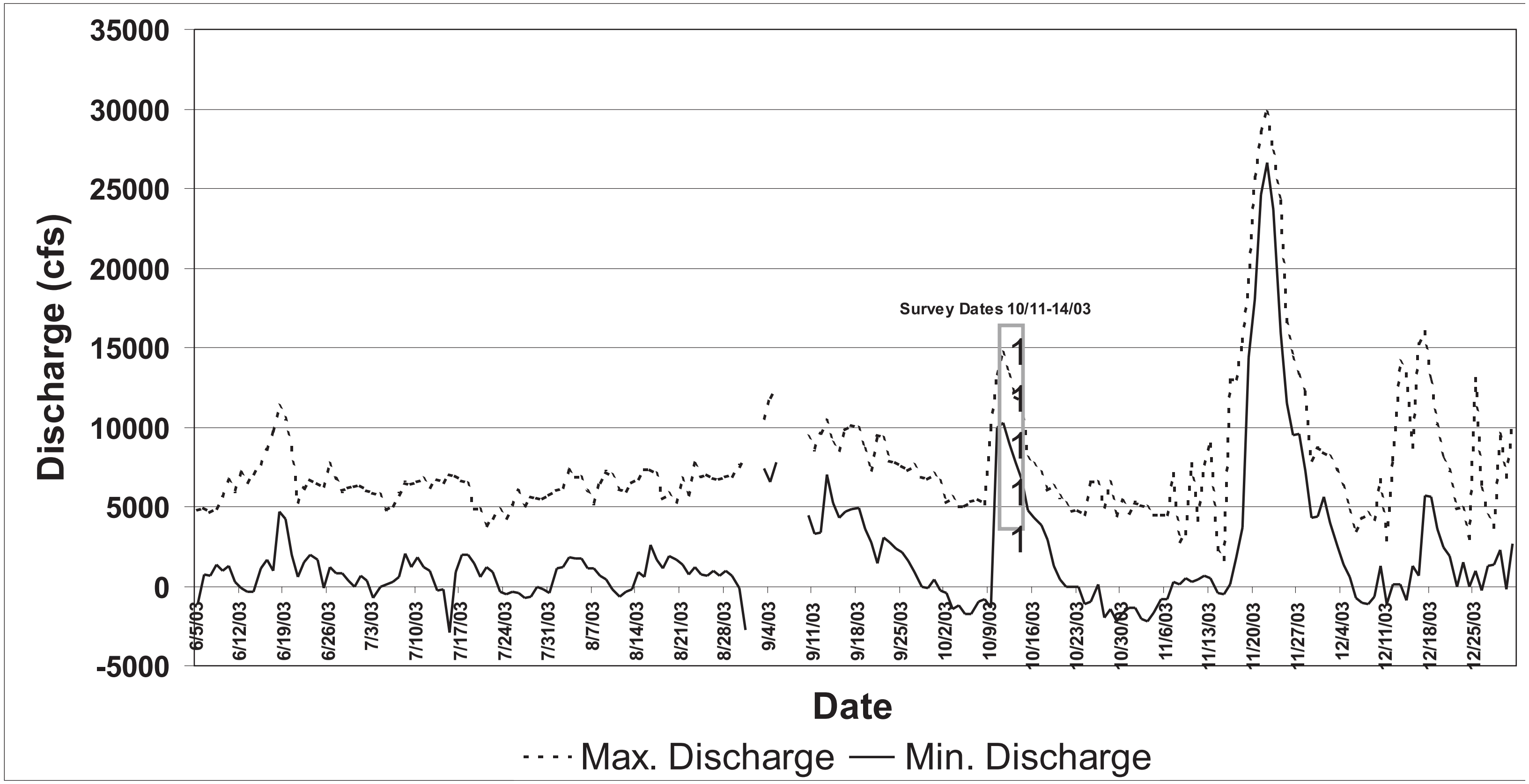

Figure 1.2. Maximum and minimum discharges (cfs) at the Neches River Saltwater Barrier for the second half of 2003. The survey dates of 11 to 14 October 2003 are delineated by an open bar.

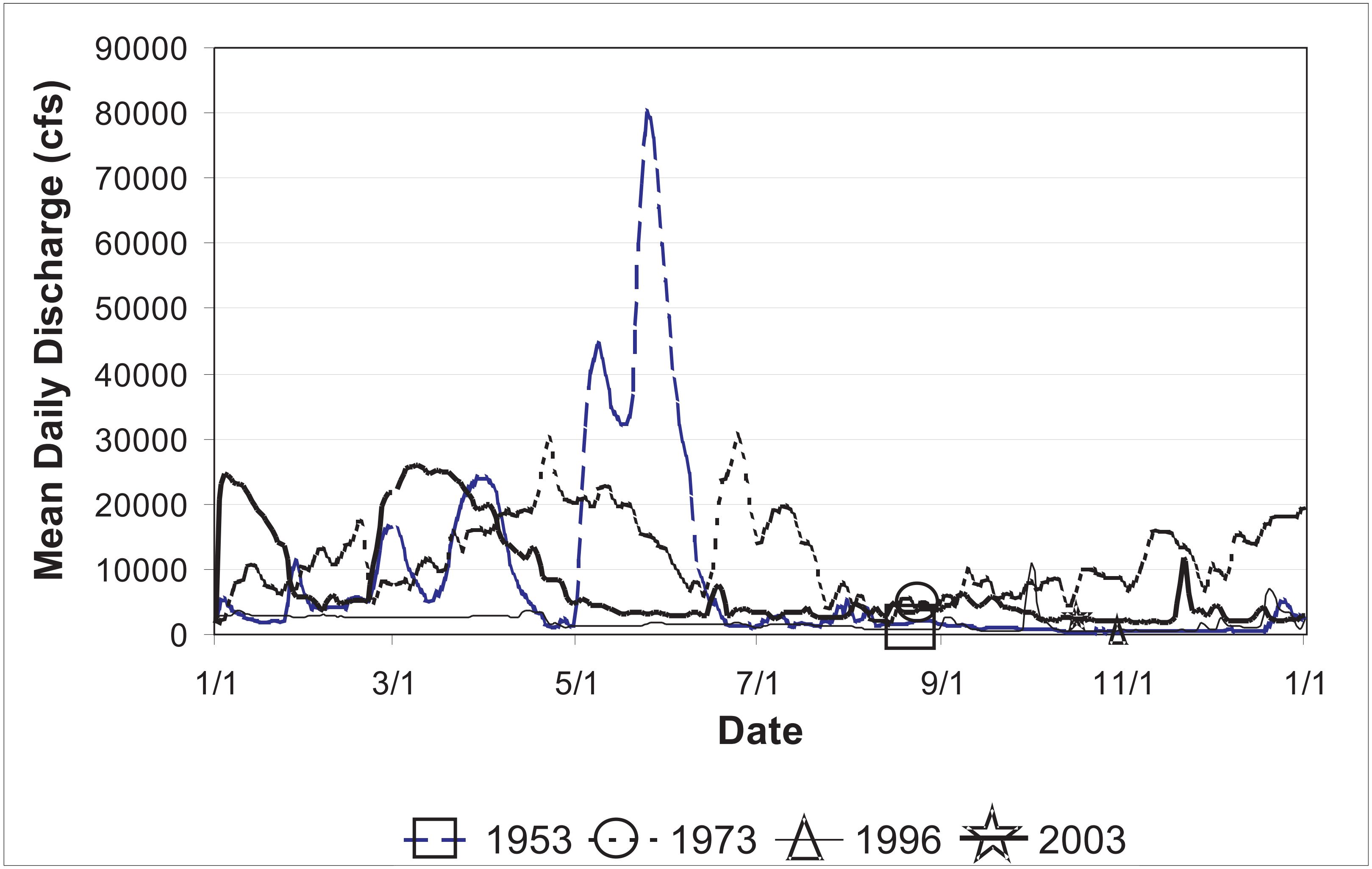

Figure 1.3. Neches River daily discharge (cfs) for 1953, 1973, 1996 and 2003. Icons for each study are proportional in width to the lengths, in days, of the field effort.

1.4 Personnel and Acknowledgments

These studies were performed under the supervision of Dr. David D. Hart, Director, the Patrick Center for Environmental Research of the Academy of Natural Sciences of Philadelphia. Dr. Raymond W. Bouchard, Senior Scientist, served as Project Manager for this study. Dr. Ruth Patrick, Francis Boyer Chair of Limnology, served as study director emeritus. The following personnel contributed to the study:

Algal Studies

Principal Scientific Investigators: Mr. Frank Acker, M.S. and Donald Charles, Ph.D.
Field Biologist: Frank Acker, M.S.
Laboratory Biologists: Frank Acker, M.S. , Diane Winter, M.S. and Erin Hagen

Macroinvertebrate Studies

Principal Scientific Investigator: Raymond Bouchard, Ph.D.
Field Biologists: Raymond W. Bouchard, Ph.D., Timothy Nightengale, M.S., and
Cody Helton (LNVA, assisted in the collection of bivalve molluscs from Station 1)
Laboratory Biologists: Raymond Bouchard, Ph.D. and David Funk (Stroud Water Research Center)

Fish Studies

Principal Scientific Investigator: Richard Horwitz, Ph.D.
Field Biologists: Paul Overbeck, Roger Thomas, Kevin O'Donnell
and from the LNVA Mike Darby, Cody Helton, Dennis Becker and Andrew Bruno
Principal Laboratory Biologists: Paul Overbeck and Amanda Kindt

Environmental Geochemical Studies

Principal Scientific Investigator: David Velinsky, Ph.D.

Field Chemists: Andrew Bruno, Jeannie Mahan and Jesse Caillier (LNVA)
Data Analyses and Report: David Velinsky, Ph.D. and Richard Horwitz, Ph.D.

Report

Scientific Editor: Robin Davis
Graphics: Roger Thomas

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2. ENVIRONMENTAL GEOCHEMISTRY

This section presents chemistry data collected in Fall 2003 as part of the Academy of Natural Sciences of Philadelphia's Patrick Center for Environmental Research (ANSP-PCER) biological survey. Water samples were collected by staff of the Lower Neches Valley Authority (LNVA) in support of the study by ANSP-PCER and analyzed by various contract laboratories. Additionally, the LNVA provided a fairly complete long-term data set for the period, 1981–2002 (from the Texas Commission on Environmental Quality data base), which permits trend analyses for several water-quality parameters. These parameters vary among stations and include dissolved oxygen, total phosphorus, and dissolved forms of ammonium, nitrate+nitrite, and inorganic phosphorus (e.g., ortho-phosphorus). Water samples were also analyzed for selected trace metals and organic contaminants. These data, presented below, were also analyzed for qualitative trends in concentrations.

2.1 Lower Neches River 2003 Survey

2.1.1 Sampling Methods

Water samples were collected at each of the four sampling stations (Stations 1, 2, 3 and 4) on four consecutive days (11 October to 14 October 2003). At each station, a water quality meter was used to collect basic water quality parameters (e.g., temperature, conductivity or salinity, pH, and dissolved oxygen) with depth, while surface grab samples were taken for solids, nutrients, selected organic compounds and total recoverable trace elements. Water samples for organic compounds and total recoverable trace metals were collected on 12 October only. Surface grab samples were taken by LNVA personnel for the parameters given in Table 2.1. All sample collection was performed by LNVA personnel using procedures outlined in TNRCC's SurfaceWater Quality Monitoring Procedures Manual (1996).

Table 2.1. Parameters determined in near-surface water samples from the Neches River 2003.

Field Measurements	
Dissolved Oxygen	pH
Salinity	Temperature
Conductivity	
Laboratory Measurements	
Dissolved Ammonia+Ammonium	Fecal Coliform
Dissolved Nitrate	Total Suspended Solids
Total Kjeldahl Nitrogen	Volatile Suspended Solids
Total Organic Carbon	Turbidity
Dissolved Ortho-phosphorus	Total Phosphorus
TR-Selenium	TR-Mercury
TR-Arsenic	TR-Aluminum
TR-Lead	TR-Nickel
TR-Copper	TR-Cadmium
TR-Silver	TR-Zinc
Ethylene Glycol	2,4-Dimethylphenol
Acetone	2,4-Dichlorophenol
Stryene	2,6-Dichlorophenol
1,3-Butadiene	4-Chloro-3-methylphenol
Methanol	2,4,6-Trichlorophenol
Phenol	2,4,5-Trichlorophenol
2-Chlorophenol	2,4-Dinitrophenol
2-Methylphenol	4-Nitrophenol
4-Methylphenol	2,3,4,6-Tetrachlorophenol
2-Nitrophenol	4,6-Dinitro-2-methylphenol
	Pentachlorophenol

TR-Total recoverable

2.1.2 Results and Discussion

The following presents the results from the sampling program between 11 and 14 October 2003 on the tidal Neches River. Results will be broken into four sections: basic water quality, solids and nutrients, organic compounds, and selected trace elements.

2.1.2.1 Basic Water Quality Parameters

As part of this sampling program, basic water quality parameters were measured with depth at all stations using calibrated meters. Parameters measured were: temperature, pH, dissolved oxygen concentration (DO), percent oxygen saturation (% Sat), and salinity or conductivity. Salinity and temperature ranged from <0.5 to 9.9 ppt and 23.3 to 25.1°C, respectively (Table 2.2). Temperature and salinity generally increased from Station 1 to Station 4. For example, surface and near bottom water temperature increased from 23.3 to 24.4°C and 23.3 to 25.1°C from upstream to downstream, respectively. Likewise, surface and bottom water salinity increased from <0.5 to 2 ppt and <0.5 to 8.3 ppt from upstream to downstream, respectively. At Station 1, temperature and conductivity were generally constant with depth (Fig. 2.1; note: conductivity was used for Station 1 only). There was a slight increase in temperature from 11 to 14 October, while conductivities (Table 2.2) were slightly higher on 11 and 12 October, however these changes were relatively small. At Stations 2 to 4, both temperature and salinity increased with depth (Figs. 2.2 to 2.4). Since salinity has a larger influence on water density than temperature, given the changes observed, this indicates that the system is a typical estuary with the water column normally stratified (i.e., low density water on top of high density water). The increase in salinity with depth at the downstream stations, especially the sharp halocline at Station 2, indicates that mixing of surface and bottom waters is limited.

For all stations and sampling periods, pH ranged from 6.4 to 7.2 (mean = 6.96). While there was substantial variability in pH, the lowest pH samples were associated with lower salinities (Table 2.2). There was no major trend of pH with depth in the water column. In all cases, pH was within the criteria range set by the State of Texas (i.e., 6.0 - 8.5; TCEQ 2000).

Table 2.2. Basic water quality measurements taken in October 2003.

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (μS)	TDS (mg/L)
			11 October 2003				
Station 1							
0.0	23.3	6.3	5.9	68.7	0.0	54	35
4.6	23.3	6.4	5.1	68.6	0.0	54	35
7.6	23.3	6.4	5.9	68.6	0.0	54	35
8.3	23.3	6.6	1.8	19.9	0.0	52	33
Station 2							
0.2	23.8	6.9	5.3	62.8	0.4	825	528
1.5	23.8	7.0	5.3	62.3	0.5	1088	696
4.6	23.8	7.2	5.2	61.7	0.7	1366	874
7.6	24.1	7.0	4.5	54.0	2.8	5253	3362
10.7	24.5	7.0	3.8	47.2	5.6	10000	6400
13.9	24.8	6.7	0.5	5.7	8.8	15231	9748
Station 3							
0.2	24.0	7.1	5.3	62.7	0.9	1789	1145
3.0	24.0	7.2	5.2	62.3	1.0	1924	1231
6.1	24.3	7.2	4.8	58.7	2.4	4410	2822
9.1	24.7	7.2	4.6	56.4	4.1	7420	4749
12.2	24.8	7.1	3.4	43.4	8.6	14900	9536
15.2	24.8	6.9	0.3	3.5	10.0	17064	10921
Station 4							
0.2	24.4	7.0	5.5	66.2	2.0	3819	2444
1.5	24.5	7.0	5.3	63.9	2.3	4302	2753
4.6	24.7	7.0	5.1	62.0	3.1	5643	3612
7.6	24.9	7.0	4.8	59.2	4.3	7608	4869
11.0	25.0	7.1	4.0	50.1	7.2	12538	8024
14.3	25.0	7.1	0.3	3.9	8.3	14367	9195

Dissolved oxygen (DO) concentrations ranged from approximately 0.3 to 5.9 mg O_2/L for all stations across all sampling dates and depths (Table 2.2). Near surface water concentrations ranged between 4.7 and 5.9 mg O_2/L (mean = 5.1) and decreased only slightly from Station 1 to 4. The largest change in DO was observed with depth at the various stations (Figs. 2.2 to 2.4). At Station 1, DO concentrations at depth only decreased on 11 October, otherwise the concentrations were almost uniform throughout the water column. At Stations 2 to 4, DO concentrations were fairly constant in the first 4.5 to 6 m, then steadily decreased to < 1 mg O_2/L near

Table 2.2 (continued). Basic water quality measurements taken in October 2003.

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (μS)	TDS (mg/L)
			12 October 2003				
Station 1							
0.2	23.4	6.4	5.6	65.6	0.0	57	37
3.0	23.3	6.4	5.6	65.6	0.0	58	37
6.1	23.3	6.4	5.6	65.7	0.0	60	38
9.1	23.3	6.4	5.7	66.1	0.0	58	37
Station 2							
0.2	23.8	6.6	5.2	61.1	0.3	539	345
1.5	23.8	6.8	4.8	56.8	0.3	543	348
4.6	23.8	7.0	4.7	56.0	0.4	718	460
7.6	23.9	6.8	4.3	51.4	1.3	2538	1624
10.7	24.5	6.8	4.2	51.6	3.8	6778	4338
12.2	24.7	6.7	3.4	42.3	6.6	11540	7386
Station 3							
0.2	23.8	6.8	4.8	56.7	0.4	819	524
3.0	23.8	6.9	4.8	56.3	0.4	887	568
6.1	24.1	7.0	4.7	56.3	1.2	2262	1448
9.1	24.4	7.0	4.7	55.7	2.4	4424	2831
12.2	24.7	7.1	3.4	42.5	6.5	11409	7302
15.9	24.8	6.9	1.7	21.1	9.4	16100	10304
Station 4							
0.2	24.0	6.9	5.0	59.9	1.1	2073	1327
3.0	24.3	7.0	4.9	58.5	1.2	2520	1613
6.1	24.5	7.1	4.6	56.0	2.5	4527	2897
9.1	24.8	7.1	4.2	51.9	4.7	8349	5343
12.2	24.9	7.1	3.6	47.0	6.0	11410	7302
15.8	24.9	7.1	3.3	41.2	7.0	12208	7813

the bottom. At Station 4, the concentrations of DO below 12 m did not remain low as at Stations 2 and 3, but fluctuated throughout the four-day sampling period (Fig. 2.4). Concentrations at the bottom of the river on 11 and 13 October were < 1 mg O_2/L and increased to approximately 4 mg O_2/L on 12 and 14 October. This may be due to the timing of sampling and tidal movement in the estuary, however, there was no relationship between salinity and dissolved oxygen in the bottom samples. Therefore it is not totally clear why these

Table 2.2 (continued). Basic water quality measurements taken in October 2003.

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (μS)	TDS (mg/L)
			13 October 2003				
Station 1							
0.2	23.6	6.4	5.7	67.6	0.0	62	40
7.1	23.6	6.7	5.8	68.1	0.0	61	39
Station 2							
0.2	23.9	6.7	4.8	56.6	0.2	365	234
3.0	23.9	6.9	4.6	55.0	0.3	518	331
6.1	23.9	6.9	4.5	53.6	0.5	897	574
9.1	24.0	6.8	4.1	48.6	1.6	3023	1935
12.2	24.8	6.9	3.4	41.7	5.4	9703	6203
14.3	24.7	6.7	1.7	21.0	8.0	13900	8896
Station 3							
0.2	23.9	6.8	4.7	55.6	0.3	618	396
3.0	23.9	7.0	4.6	54.9	0.4	710	454
6.1	24.0	7.0	4.4	52.3	1.0	1966	1258
9.1	24.4	7.2	4.3	51.9	2.1	3910	2502
12.2	24.8	7.1	3.2	40.3	5.7	10117	6475
14.9	24.8	7.0	1.4	24.5	9.0	15420	9869
Station 4							
0.2	24.4	6.9	4.7	57.0	1.3	2573	1647
3.0	24.5	7.0	4.5	54.3	2.3	4540	2906
6.1	24.6	7.0	4.4	53.6	2.7	5120	3277
9.1	24.7	7.0	4.3	52.7	3.1	6580	4211
12.2	24.7	7.0	4.3	52.8	3.8	7100	4544
14.4	25.0	7.3	0.3	3.4	6.0	10618	6796

changes in DO concentrations occurred. Dissolved oxygen concentrations were compared with the criterion set by the State of Texas (i.e., 3.0 mg O_2/L; TCEQ, 2000). This criterion pertains to samples in the mixed layer (i.e., surface to 6000 μS/cm). Overall, 10 out of 85 samples (12%) were below the criterion, however most of these samples were below the defined mixed zone on these dates. The one exception was on 11 October at Station 1 when the DO concentration within the defined mixed zone was < 2 mg O_2/L.

Table 2.2 (continued). Basic water quality measurements taken in October 2003.

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (µS)	TDS (mg/L)
			14 October 2003				
Station 1							
0.2	23.6	6.5	5.7	66.8	0.0	65	41
6.8	23.6	6.8	5.7	66.8	0.0	64	41
Station 2							
0.2	23.9	6.5	4.7	56.1	0.3	571	365
3.0	23.9	6.6	4.7	55.2	0.3	631	404
6.1	23.9	6.7	4.5	53.9	0.4	815	522
9.1	24.1	6.6	3.2	38.1	1.8	3419	2188
12.2	24.5	6.7	3.3	41.2	3.7	6500	4160
14.8	24.7	6.4	1.1	13.6	7.2	12418	7948
Station 3							
0.2	24.0	6.6	4.7	55.5	0.5	985	630
3.0	24.0	6.6	4.6	54.9	0.6	1136	727
6.1	24.1	6.7	4.3	51.2	1.1	2233	1429
9.1	24.3	6.8	4.1	49.9	1.7	3838	2456
12.2	24.7	6.7	3.6	44.3	4.2	7600	4864
14.3	24.7	6.5	2.3	23.8	6.6	11675	7472
Station 4							
0.1	24.2	6.7	4.9	58.4	0.8	1665	1065
3.0	24.2	6.8	4.8	57.0	1.0	1952	1249
6.1	24.3	6.9	4.6	55.6	1.5	2810	1798
9.1	24.7	7.0	4.4	53.7	3.5	6166	3946
12.2	25.1	7.0	4.8	61.1	8.7	14855	9507
14.0	25.1	6.7	4.9	62.5	9.0	15469	9900

To factor out changes in oxygen solubility due to temperature and salinity, dissolved oxygen saturation (% Sat) was measured. The % Sat ranged from approximately < 5 to 69 % (mean = 51%) for all stations and sampling dates (Table 2.2). Lowest % Sat was measured in the deeper samples from all stations. There was a slight decrease in surface water % Sat from Station 1 to Station 4 on all sampling dates except on 11 October when % Sat was fairly constant at all four stations (mean = 65%). Surface water % Sat decreased from an average of 65% to 59% from 11 to 14 October.

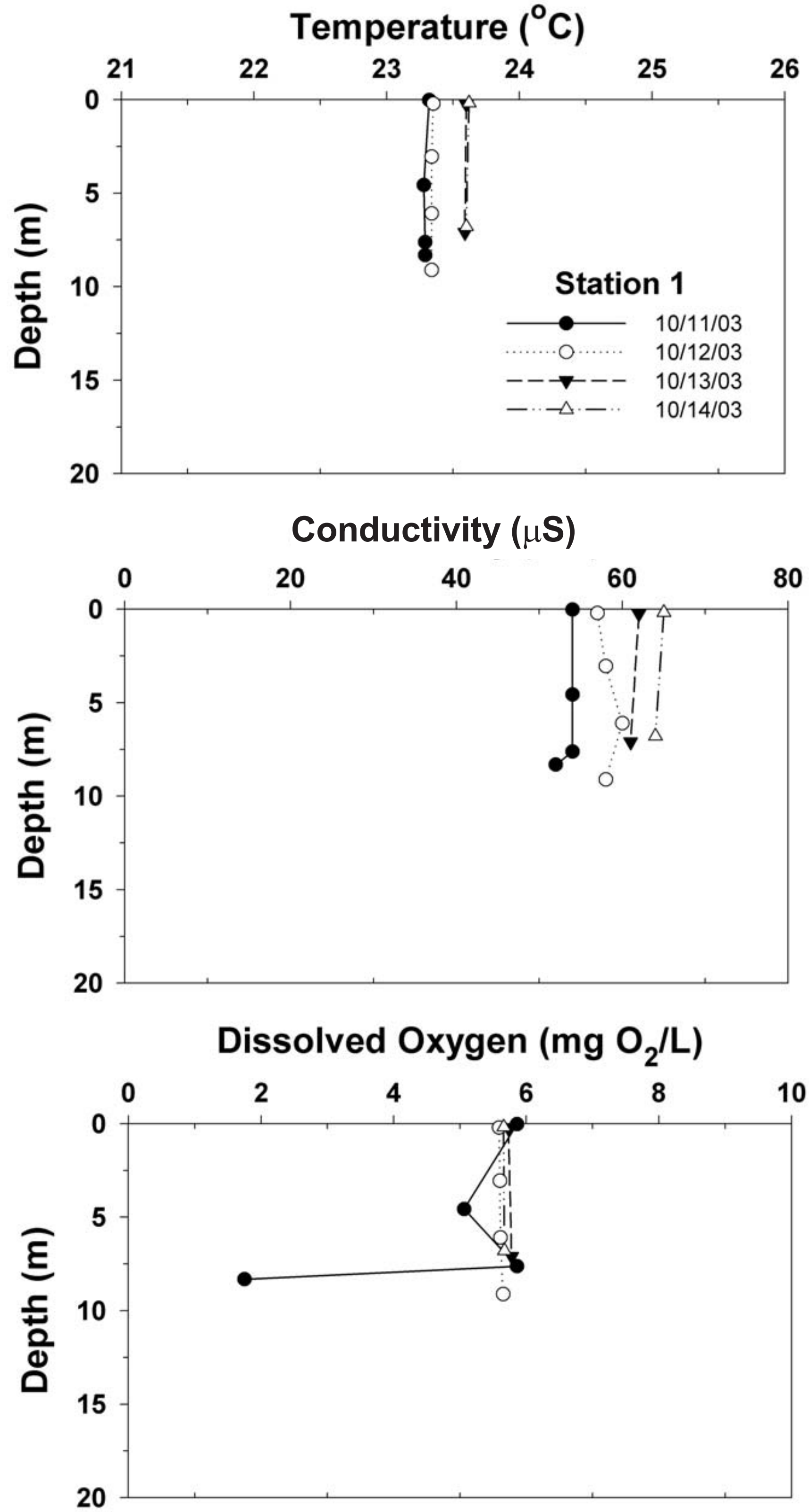


Figure 2.1. Depth profiles of temperature, conductivity and dissolved oxygen for Station 1 for the four sampling dates.

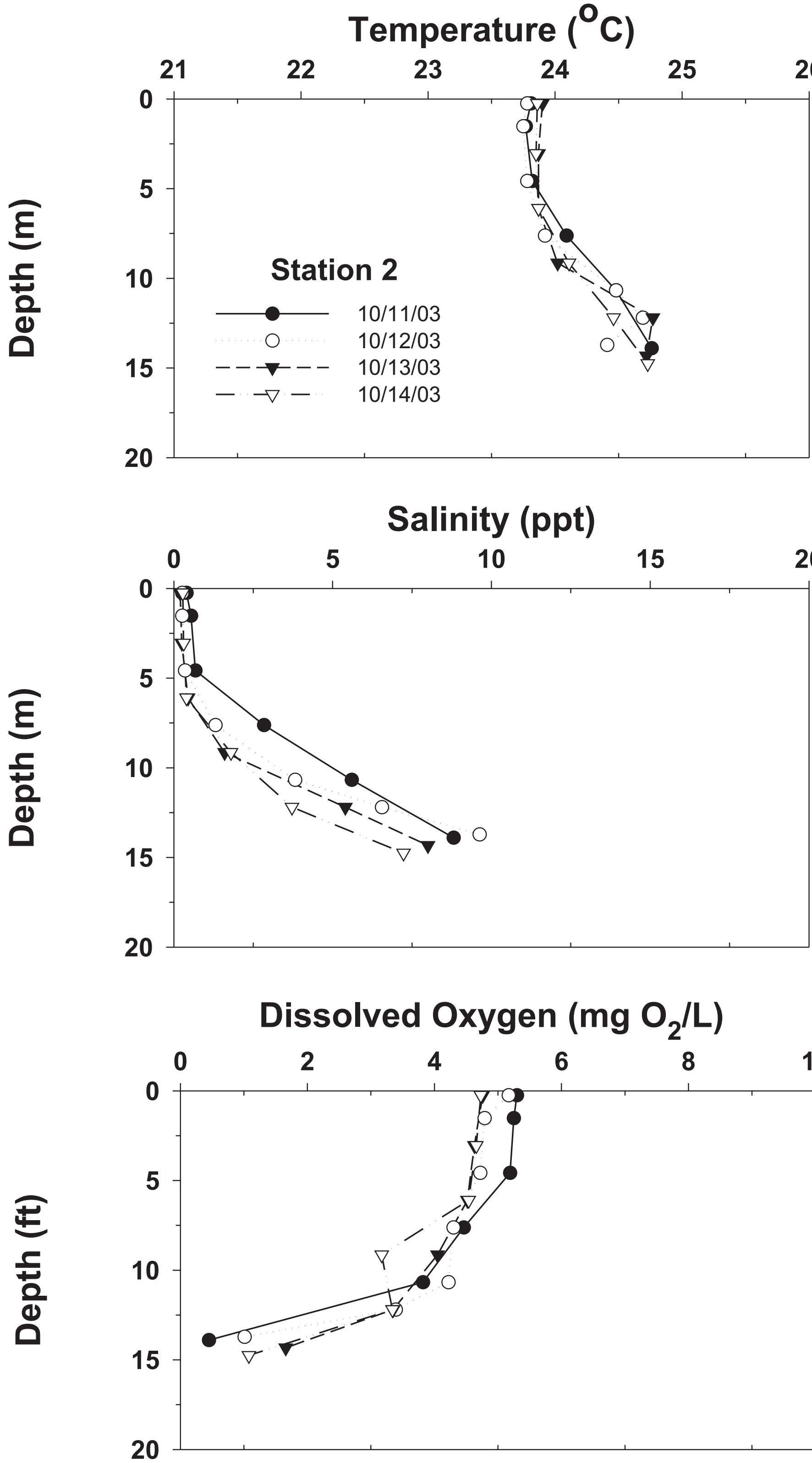


Figure 2.2. Depth profiles of temperature, salinity and dissolved oxygen for Station 2 for the four sampling dates.

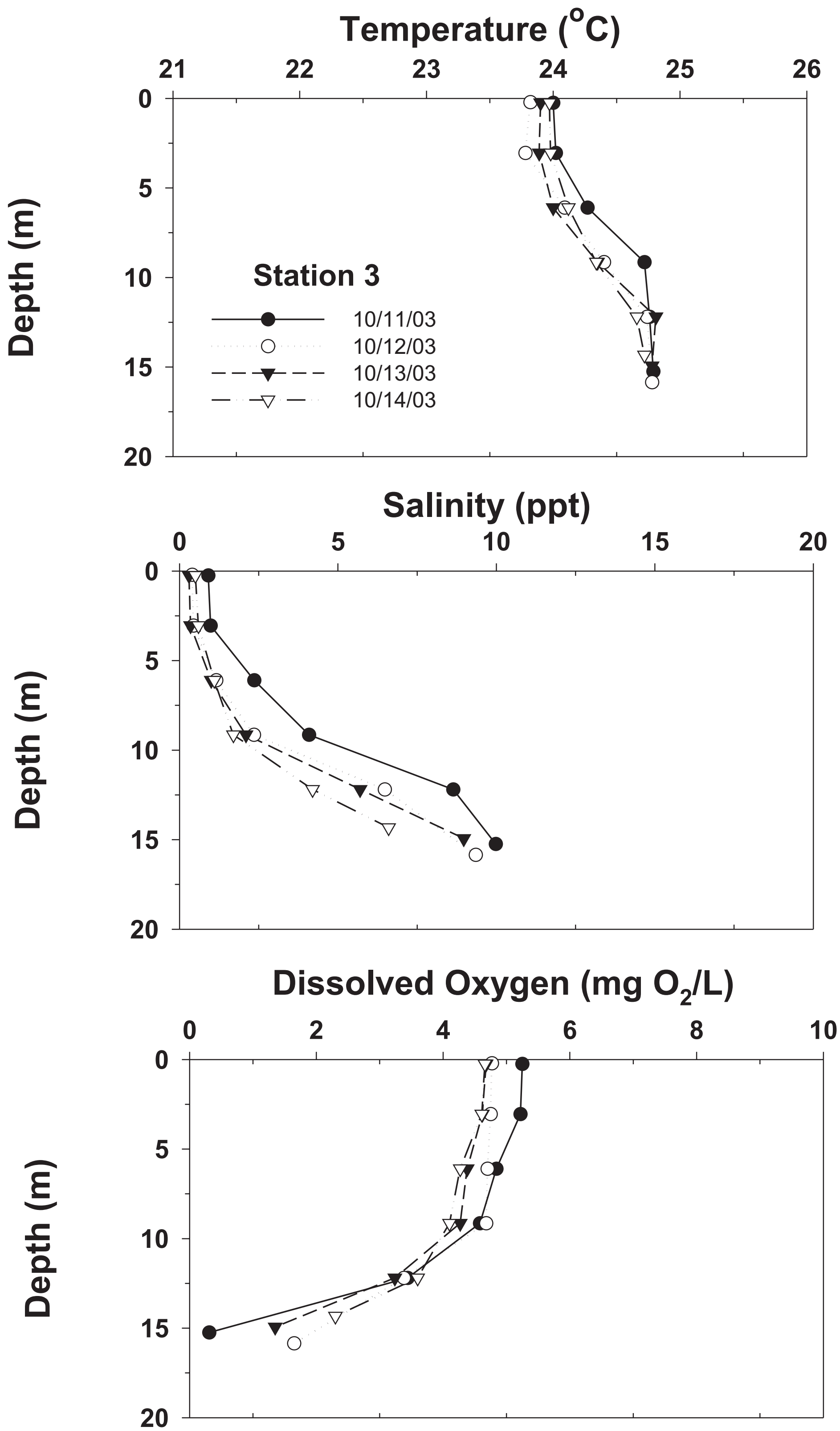


Figure 2.3. Depth profiles of temperature, salinity and dissolved oxygen for Station 3 for the four sampling dates.

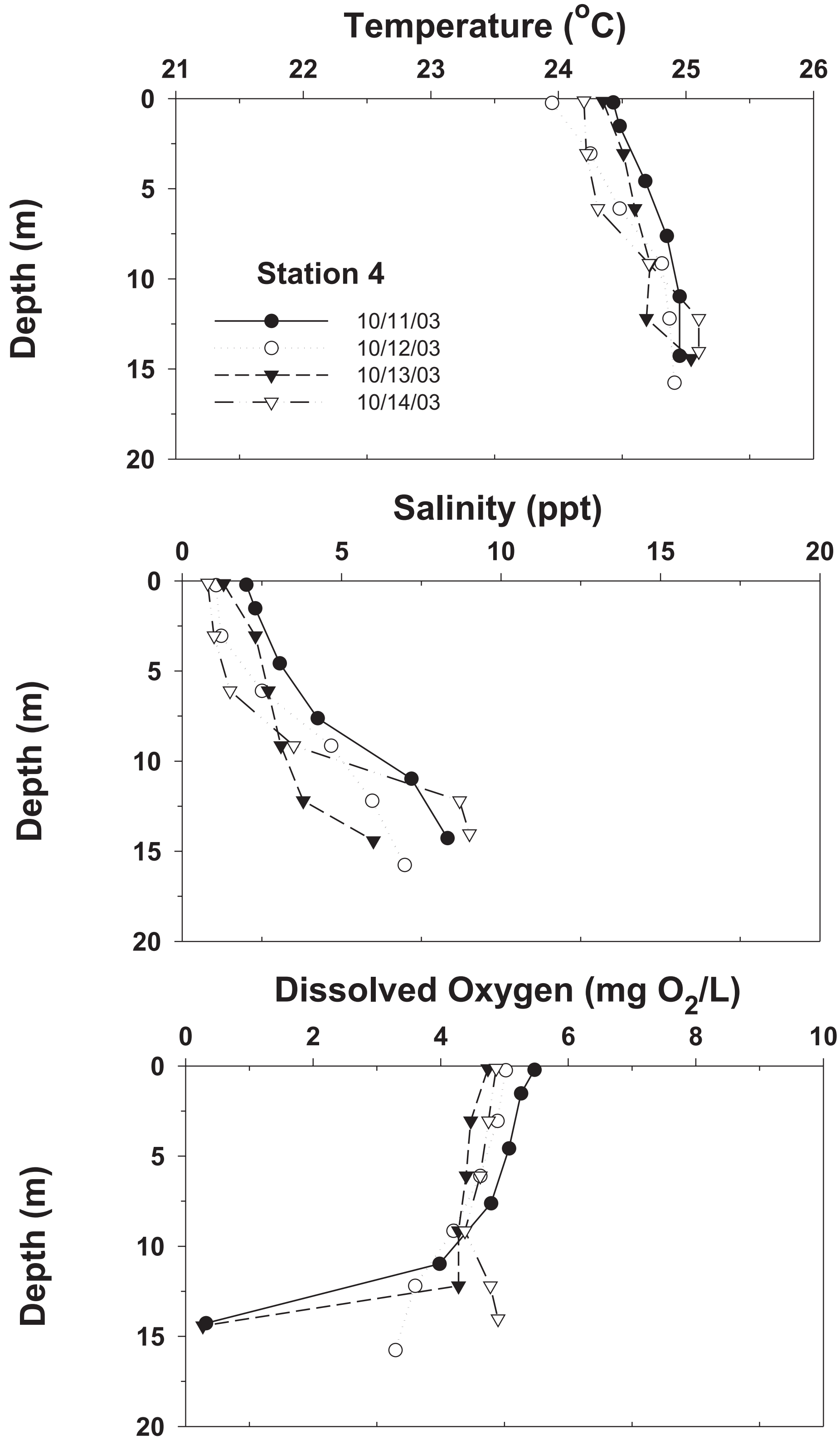


Figure 2.4. Depth profiles of temperature, salinity and dissolved oxygen for Station 4 for the four sampling dates.

The observed DO profiles are the result of a net balance between processes that produce and consume dissolved oxygen (i.e., photosynthesis and mixing with the atmosphere versus microbial oxidation of organic matter). Overlaid with these processes is the limited mixing of surface and bottom waters in this portion of the Neches River. This is related to the density structure during estuarine circulation as indicated by the salinity/temperature distribution and is most evident at Stations 2 and 3 in the upper portion of the study area. With the limited mixing, microbial processes can consume dissolved oxygen during aerobic organic matter degradation (i.e., biochemical oxygen demand) and without sufficient inputs from mixing or photosynthesis, the concentration of DO can decrease to undetectable levels (Figs. 2.2 and 2.3).

2.1.2.2 Water Column Solids, Fecal Coliform and Nutrients

Sub-surface water samples (ca. 0.5 m) for solids (turbidity, total suspended solids, volatile solids), fecal coliforms, and nutrients were collected on 11 to 14 October at all stations. Data are presented in Table 2.3.

Total suspended solids (TSS) ranged from approximately 8 to 31 mg/L for all time periods and stations (Table 2.3; Fig. 2.5). Higher concentrations were observed at Station 1 (mean = 22 mg/L) with a slight decrease by Station 4 (mean = 11 mg/L; Fig. 2.5). The decrease in TSS maybe a result of the dilution of watershed derived solids from the large runoff event and mixing with coastal waters. Turbidity ranged, on average, from 20 to 32 NTU, and was higher within the lower salinity area at Station 1 (Fig. 2.5; Table 2. 3). Over the four-day sampling period turbidity decreased overall. Volatile suspended solids (VSS) ranged from 2 to 6.3 mg/L and decreased slightly from Station 1 to Station 4. On average, there was a decrease in VSS from 11 to 14 October from 5.8 to 2.0 mg/L (Fig. 2.5).

Fecal coliform (FC) amounts were high and variable during the study period (Table 2.3; Fig. 2.5). Texas Surface Water Quality Standards for this segment (601) states that fecal coliform shall not equal or exceed 400 colonies per 100 ml in more than 10% of all samples, based on at least 5 samples,

Table 2.3. Solids, nutrients and bacteria levels in Segment 601 of the lower Neches River in October of 2003.

Station Number	TSS (mg/L)	VSS (mg/L)	Turbidity (FTU)	Fecal Coliform (cols./100 ml)	TOC (mg C/L)	NO_3-N (mg N/L)	TKN (mg N/L)	NH_4-N (mg N/L)	TP (mg P/L)	o-PO_4 (mg P/L)
Date: 10/11/2003										
Station 1	31	6.3	30	2560	10.1	0.04	4.81	0.08	0.09	0.04
Station 2	21	6.0	40	1716	8.34	0.05	0.534	0.08	0.1	0.04
Station 3	22	5.6	35	1683	7.29	0.07	0.491	0.11	0.09	0.04
Station 4	15	5.2	23	1040	6.53	0.09	0.789	0.09	0.08	0.04
Date: 10/12/2003										
Station 1	22	5.6	30	1000	12	0.04	1.44	0.09	0.09	0.04
Station 2	13	4.4	27	880	9.99	0.04	0.41	0.11	0.08	0.04
Station 3	16	4.8	25	700	9.23	0.05	0.57	0.11	0.09	0.04
Station 4	9	5.2	24	1867	7.64	0.06	0.505	0.11	0.08	0.04
Date: 10/13/2003										
Station 1	22	4.4	20	283	13.7	0.04	0.535	0.09	0.07	0.04
Station 2	10	4.0	18	83	11.9	0.05	0.399	0.09	0.07	0.04
Station 3	11	3.0	21	233	11.1	0.04	0.509	0.1	0.06	0.04
Station 4	15	4.0	18	540	8.57	0.07	0.484	0.08	0.07	0.04
Date: 10/14/2003										
Station 1	15	4.0	21	500	14.9	0.04	0.424	0.07	0.07	0.04
Station 2	12	2.4	21	200	13.2	0.04	0.623	0.09	0.07	0.04
Station 3	10	3.2	20	167	12.1	0.04	0.579	0.1	0.06	0.04
Station 4	8	2.0	18	133	10.1	0.06	0.548	0.17	0.06	0.04

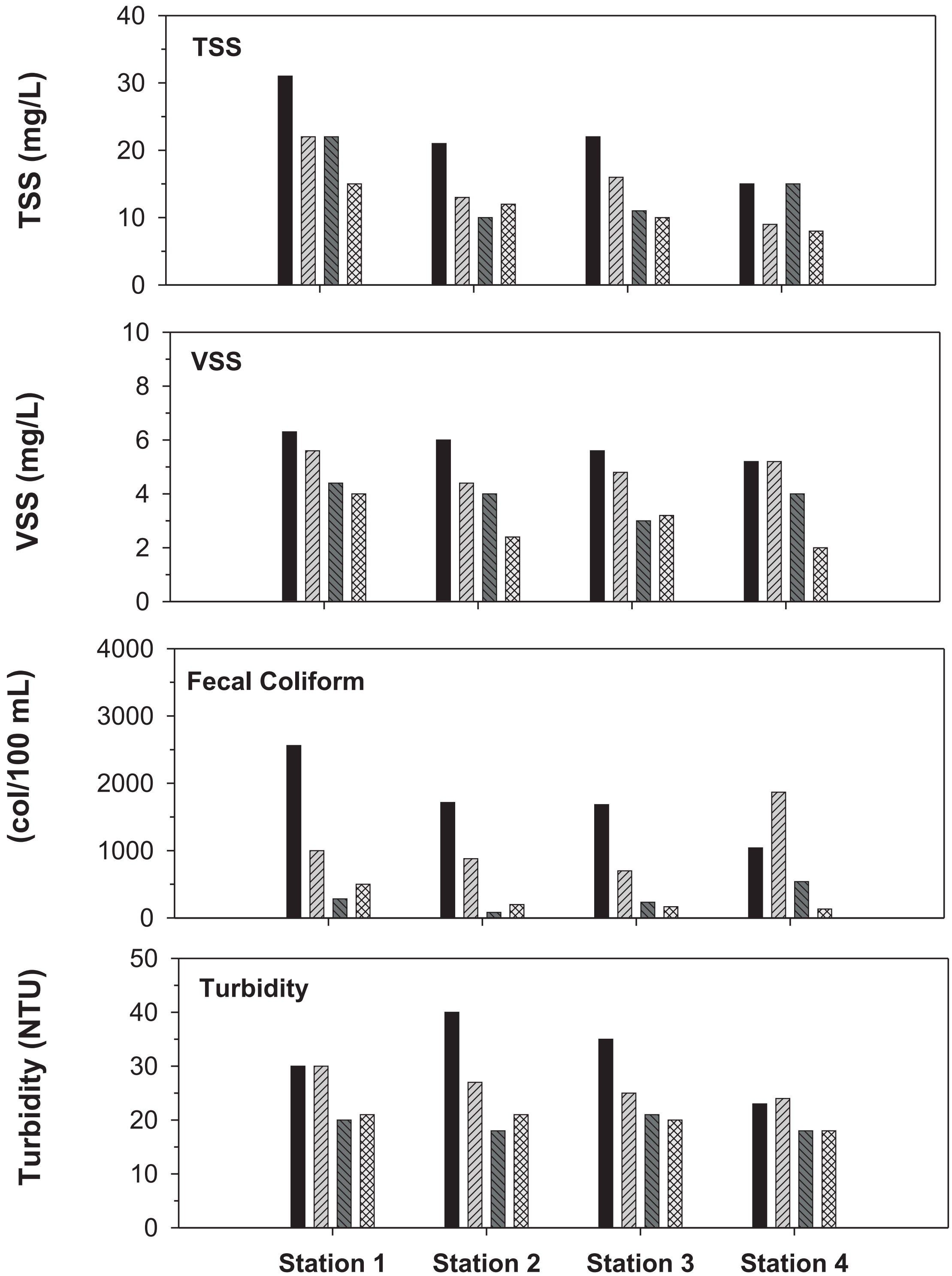


Figure 2.5. Concentrations of total suspended solids, volatile suspended solids, fecal coliform and turbidity in the lower Neches River (Segment 601) for the four sampling dates in 2003.

taken during any 30-day period. If 10 or fewer samples are analyzed, no more than 1 sample shall exceed 400 colonies per 100 ml (TCEQ 2000). In many samples this limit was exceeded. The highest FC concentrations were found at Stations 1, 2 and 3 on 11 October and ranged from 1683 to 2560 colonies/100 ml. This may be due to the high runoff during and preceding that sampling period. On average, highest concentrations were found at Station 1 and lowest at Station 4. From 11 to 14 October, the average FC concentration decreased from 1750 colonies/100 ml to 250 colonies/100 ml. Overall, 63% (10 out of 16) of the samples contained FC above the State's water quality criterion.

Total organic carbon, the sum of dissolved and particulate organic material, ranged from 6.5 to 14.9 mg C/L (mean = 10.4 mg C/L; Fig. 2.6). From 11 to 14 October the average concentration of TOC increased from 8.1 to 12.6 mg C/L. In addition, during each sampling date concentrations decreased from upstream to downstream (Fig. 2.6). For example, on 12 October, TOC concentrations decreased from 12 mg C/L at Station 1 to 7.6 mg C/L at Station 4. There are no water quality criteria to compare these concentrations with.

Three forms of nitrogen were measured for this study: dissolved nitrate+nitrite, total Kjeldahl nitrogen (TKN) and ammonium (+ ammonia) (Table 2.1). Dissolved nitrate (i.e., nitrate+nitrite) concentrations were always low and near the reporting limit at Stations 1 and 2, averaging 0.04 and 0.048 mg N/L, respectively (Table 2.3; Fig. 2.6). Concentrations at Station 3 were only slightly higher (ca. 0.04 to 0.07 mg N/L) while at Station 4, dissolved nitrate concentrations were highest and averaged 0.07 mg N/L (Fig. 2.6). Total Kjeldahl nitrogen concentrations ranged from 0.39 mg N/L at Station 2 on 13 October to 4.81 mg N/L at Station 1on 11 October (Fig. 2.6). Concentrations were highest at Station 1 on the first three sampling dates (0.54 to 4.8 mg N/L) with generally similar concentrations (mean = 0.54 ± 0.1 mg N/L; n = 12) downstream during all sampling periods. Lastly, dissolved ammonium (+ammonia) concentrations ranged from 0.07 to 0.17 mg N/L (mean = 0.098 ± 0.027 mg N/L). There were no substantial differences among sampling dates and the average value for each sampling date ranged from 0.09 to 0.11 mg N/L. The screening level criteria for dissolved nitrate (+ni-

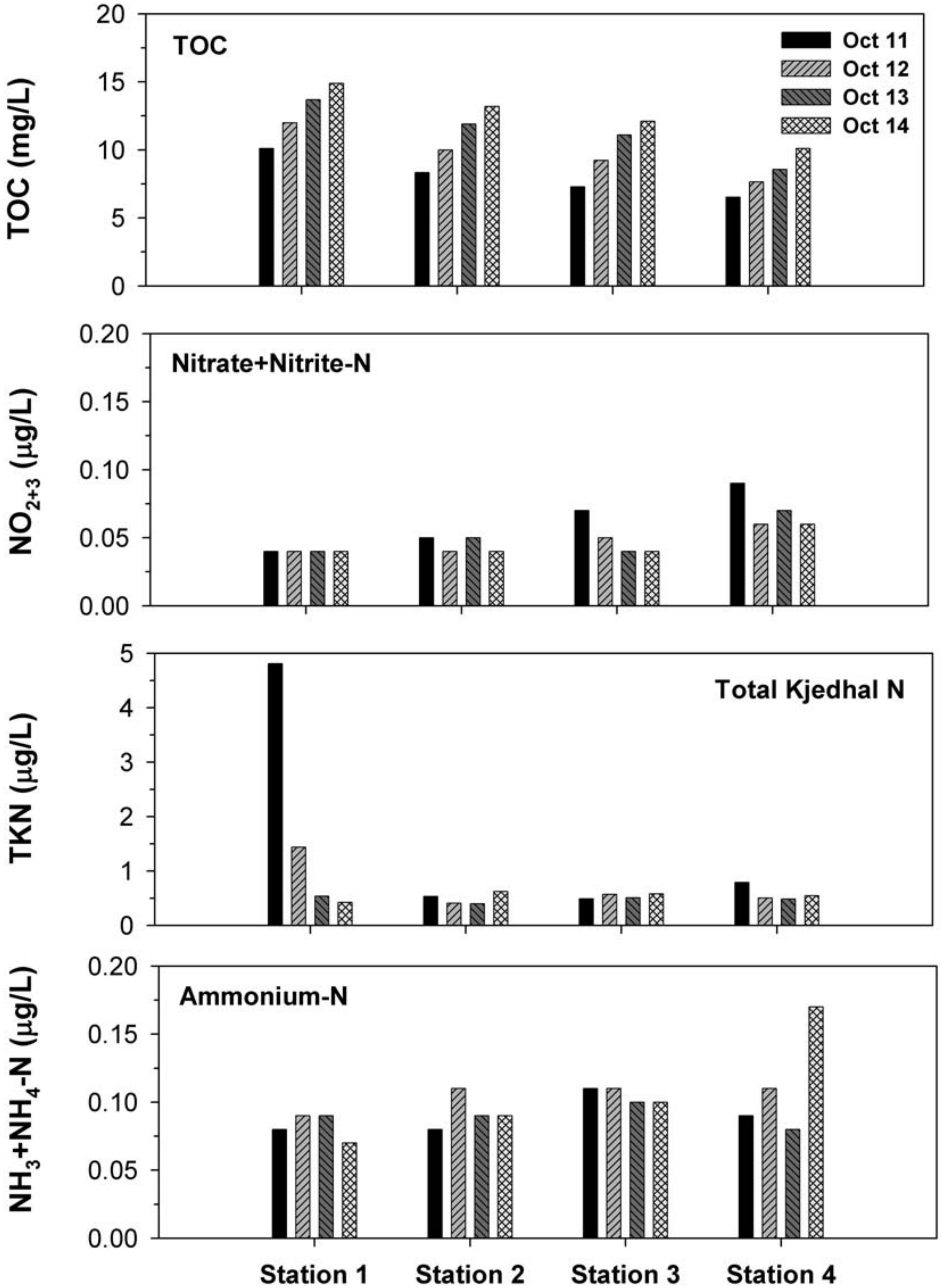


Figure 2.6. Concentrations of total organic carbon, dissolved nitrate+nitrite, total kjeldhal nitrogen, and dissolved ammonia+ammonium in the lower Neches River (Segment 601) for the four sampling dates in 2003.

trite) and ammonium set by the State of Texas (LNVA 2004) are 2.34 and 0.44 mg N/L, respectively. No sample exceeded its published criterion.

Dissolved inorganic phosphorus concentrations were below the method detection limit and are reported at 0.04 mg P/L, while total phosphorus concentrations ranged from 0.06 to 0.10 mg P/L (mean = 0.08 mg P/L) for all time periods and stations (Table 2.3). Concentrations were relatively low given the reported detection limit and there was no distinct trend related to location in the river. The screening level criterion for total phosphorus set by the State of Texas (TCEQ 2000) is 0.7 mg/L. The concentrations of all forms of phosphorus were below the published screening criterion.

2.1.2.3 Selected Organic Compounds

Sub-surface water grab samples were collected on 12 October 2003 for selected organic compounds: 1,3-butadiene, acetone, styrene, ethylene glycol, and methanol. Included in the list are a series of phenols including: phenol, 2-chlorophenol, 2-methylphenol, 4-methylphenol, 2-nitrophenol, 2,4-dimethylphenol, 2,4-dichlorophenol, 2,6-dichlorophenol, 4-chloro-3-methylphenol, 2,4,6-trichlorophenol, 2,4,5-trichlorophenol, 2,4-dinitrophenol, 4-nitrophenol, 2,3,4,6-tetrachlorophenol, 4,6-dinitro-2-methylphenol, and pentachlorophenol. These samples were analyzed by Earth Analytical Sciences (Beaumont, TX).

All samples yielded undetectable concentrations (below the practical quantitation limits [PQL]) for all organic parameters except ethylene glycol (Table 2.4). The PQL for the organic compounds was either 0.005 or 0.01 mg/L (see Table 2.4).

Ethylene glycol was detected at similar concentrations at all four stations (5.4, 5.6, 3.0, and 4.8 mg/L at Stations 1, 2, 3, and 4 respectively). However, several properties of the reported concentrations and flow characteristics of the river (tidal and non-tidal portions) lead us to question their accuracy, as we now briefly discuss.

To identify possible sources of ethylene glycol along the Neches River, we accessed US EPA’s Toxic Release Inventory (TRI) and identified all facilities along the river that re-

Table 2.4. Volatile organic compounds in Neches River Water (11 October 2003).*

Station	1,3-Butadiene	Acetone	Styrene	Ethylene Glycol	Methanol
1	0.005	0.01	0.005	5.4	ND
2	0.005	0.01	0.005	5.6	ND
3	0.005	0.01	0.005	3.0	ND
4	0.005	0.01	0.005	4.8	ND

Station	Phenol	2-Chlorophenol	2-Methylphenol	4-Methylphenol	2-Nitrophenol	2,4-Dimethylphenol	2,4-Dichlorophenol	2,6-Dichlorophenol
1	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005
2	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005
3	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005
4	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005

Station	4-Chloro-3-methylphenol	2,4,6-Trichlorophenol	2,4,5-Trichlorophenol	2,4-Dinitrophenol	4-Nitrophenol	2,3,4,6-Tetrachlorophenol	4,6-Dinitro-2-methylphenol	Pentachlorophenol
1	0.005	0.005	0.005	0.01	0.01	0.005	0.005	0.01
2	0.005	0.005	0.005	0.01	0.01	0.005	0.005	0.01
3	0.005	0.005	0.005	0.01	0.01	0.005	0.005	0.01
4	0.005	0.005	0.005	0.01	0.01	0.005	0.005	0.01

* Note: all concentrations are below the PQL except ethylene glycol.

ported ethylene glycol releases in 2002 or prior years (data are not yet available for 2003). Several such facilities were identified (e.g., there were six such facilities in 2002, listed in TRI as “BASF CORP BEAUMONT”, “EXXONMOBIL OIL CORP DBA MOBIL CHEMICAL CO”, “HUNTSMAN CORP PO/MTBE PLANT”, “HUNTSMAN CORP. C4/O&O FACILITIES”, “LNVA - NORTH REGIONAL TREATMENT PLANT”, and “PD GLYCOL”), and all are located in Beaumont or Port Neches, well downstream from Station 1.

We also obtained Neches River flow (discharge) data for USGS gauge 08041780, just upstream of Station 1, and determined that the daily maximum and minimum flows on the sampling day (11 October 2003) and on the previous day were elevated and positive (Fig. 2.7). Flow at this station can be influenced by tides especially when the flow is low, and a positive direction indicates normal discharge and no tidal influence. This indicates that river flow did not reverse direc-

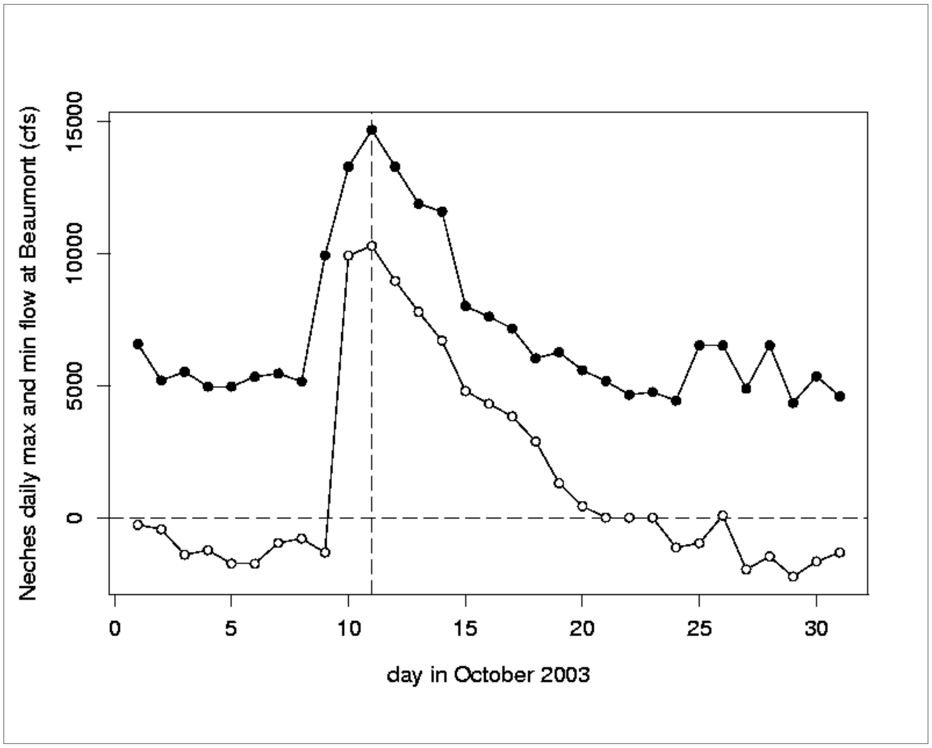


Figure 2.7. Maximum and minimum daily flows at USGS gauge 08041780 on the Neches River at the saltwater barrier, just upstream of Station 1, during October 2003. The horizontal dashed line indicates a flow of zero; positive flows are in the downstream direction, negative flows in the upstream direction (due to tidal influence). The vertical dashed line indicates the sampling day at Station 1 (11 October 2003).

tion with the tide on either day. In addition, ship traffic does not extend up to Station 1, so ships could not have mixed ethylene-glycol-contaminated water this far upstream. Therefore, the reported ethylene glycol concentration at Station 1 should reflect loadings upstream of this station. But, as indicated above, there are no upstream facilities that have reported releases of this compound. Where, then, could the ethylene glycol at Station 1 have come from?

One possibility is that the magnitude of the concentration is low enough so it could reflect small loadings associated with rainfall runoff during the precipitation event that increased river flow during the sampling period. To assess this possibility, we first used TRI data to determine the annual amounts (in pounds) of ethylene glycol released to surface water by every facility located along the Neches River for each of the previous 10 years (1993–2002). We calculated the combined total for all facilities in each year, and then calculated the average annual total, which was 5,566 pounds per year. This value provided a benchmark for use in the next step of our analysis, which was to estimate the ethylene glycol loading that would have to have occurred upstream of Station 1 in order to produce the reported concentration at that station.

Assuming that the ethylene glycol concentration was approximately uniform across the channel at Station 1 (which is plausible, given the fact that the reported mid-channel concentrations were approximately uniform all the way from Station 1 to Station 4), the loading required to account for the reported concentration is, by mass balance, simply the reported concentration times the river flow (expressed in compatible measurement units). USGS reports daily maximum and minimum flows for gauge 08041780 on the sampling day. Based on these values (14,700 and 10,300 cfs) and the reported ethylene glycol concentration at Station 1 (5.43 mg/L), the ethylene glycol loading required in order to achieve mass balance is between 17,939 and 12,570 pounds per hour. Thus, assuming that the concentration at Station 1 remained approximately constant for at least one hour, it follows that the hourly loading upstream of Station 1 was about 2 to 3 times the total average annual surface-water release of all facilities on the Neches River. It seems highly unlikely that a loading of this magnitude could be due to rainfall runoff.

Finally, we note that Stations 2–4 are located in areas where it is plausible that ethylene glycol releases from facilities along the Neches River could have been present at measurable concentrations during the sampling period. Since this is not the case for Station 1, the concentrations of ethylene glycol at Stations 2–4 should have been noticeably higher than the concentration at Station 1. Instead, all four concentrations were very similar.

Though limited by several assumptions that cannot be checked with available data, the analysis outlined above clearly indicates that the reported ethylene glycol concentrations are suspiciously high and suspiciously similar. We do not know of any irregularities in sample collection or analysis. However, the reported values were only 2-3 times the detection limit (~ 2 mg/L) and daily variations in the method may have yielded a slightly higher method detection limit for these samples. Therefore, given that the concentrations were just above the detection limit and our rough loadings calculation, we suggest that there was little or no chemical present in the river at this time. However, further monitoring (upstream and downstream of Stations 1-4) during low and high flow conditions should be undertaken to provide additional information as to whether there is some unknown source of ethylene glycol to the river.

2.1.2.4 Water Column Trace Metals and Metalloids

In 2003, nine trace metals and two metalloids (arsenic and selenium) were measured in the lower Neches River (Segment 601). Most elements were in the dissolved phase except mercury (Hg) and selenium (Se) which were listed as total recoverable. Dissolved silver (Ag) and cadmium (Cd) were below the detection limit of between 0.05 and 0.1 μg/L (Table 2.5). Dissolved chromium (Cr) was below or just at the detection limit of 1.0 μg/L. The other trace elements had concentrations that were low with little spatial variation. There was a slight decrease in concentration from Station 1 to Station 4 for total recoverable mercury (TR-Hg), dissolved copper (D Cu) and dissolved lead (D Pb) (Fig. 2.8).

Table 2.5. Neches River trace element total recoverable data collected on 13 October 2003.

	D Ag (µg/L)	D Al (µg/L)	D Cd (µg/L)	D Cr (µg/L)	D Cu (µg/L)	D Ni (µg/L)	D Pb (µg/L)	D Zn (µg/L)	D As (µg/L)	TR -Hg (µg/L)	TR-Se (µg/L)
Station 1	< 0.10	136	< 0.10	< 1.0	1.16	1.32	0.21	2.12	0.75	0.00812	0.127
Station 2	< 0.10	54.1	< 0.10	< 1.0	1.01	1.28	0.11	2.06	0.69	0.00655	0.145
Station 3	< 0.10	47.3	< 0.10	< 1.0	1.00	1.31	0.13	2.04	0.76	0.00584	0.150
Station 4	< 0.10	19.7	< 0.05	1.08	0.93	1.10	0.077	1.91	0.79	0.00478	0.149

D - Dissolved fraction

TR - Total Recoverable

For dissolved arsenic (D As), the laboratory which performed the analysis stated a method detection limit (MDL) of 0.50 µg/L and a reporting limit of 1.0 µg/L. All data (n=4) were between these values and ranged from 0.69 to 0.75 µg/L with an average of 0.75 ± 0.04 µg/L. There was no geographic trend with the limited data set.

2.1.2.5 Comparison to Previous Monitoring by ANSP

The first chemical monitoring effort by the Academy was in 1953 in which basic water quality and nutrients were measured at the four stations in the tidal Neches River. Chemical monitoring, as part of larger surveys, was undertaken in 1973, 1996 and the present one in 2003. A summary of the surface concentrations from these surveys is presented in Tables 2.6-2.9. Presented are the average, standard error, minimum and maximum values for each station over four consecutive days, except in 1953, when samples were only collected on one day.

In comparing the 2003 dataset to historical ANSP data collected in 1953, 1956 and 1973, it appears that some water quality parameters remain above screening level criteria (TCEQ 2000).

Surface water dissolved oxygen (DO) concentrations measured in the current study are generally similar to those measured in previous studies with some small differences (Fig. 2.9). In 1953 surface water concentrations were less than 3

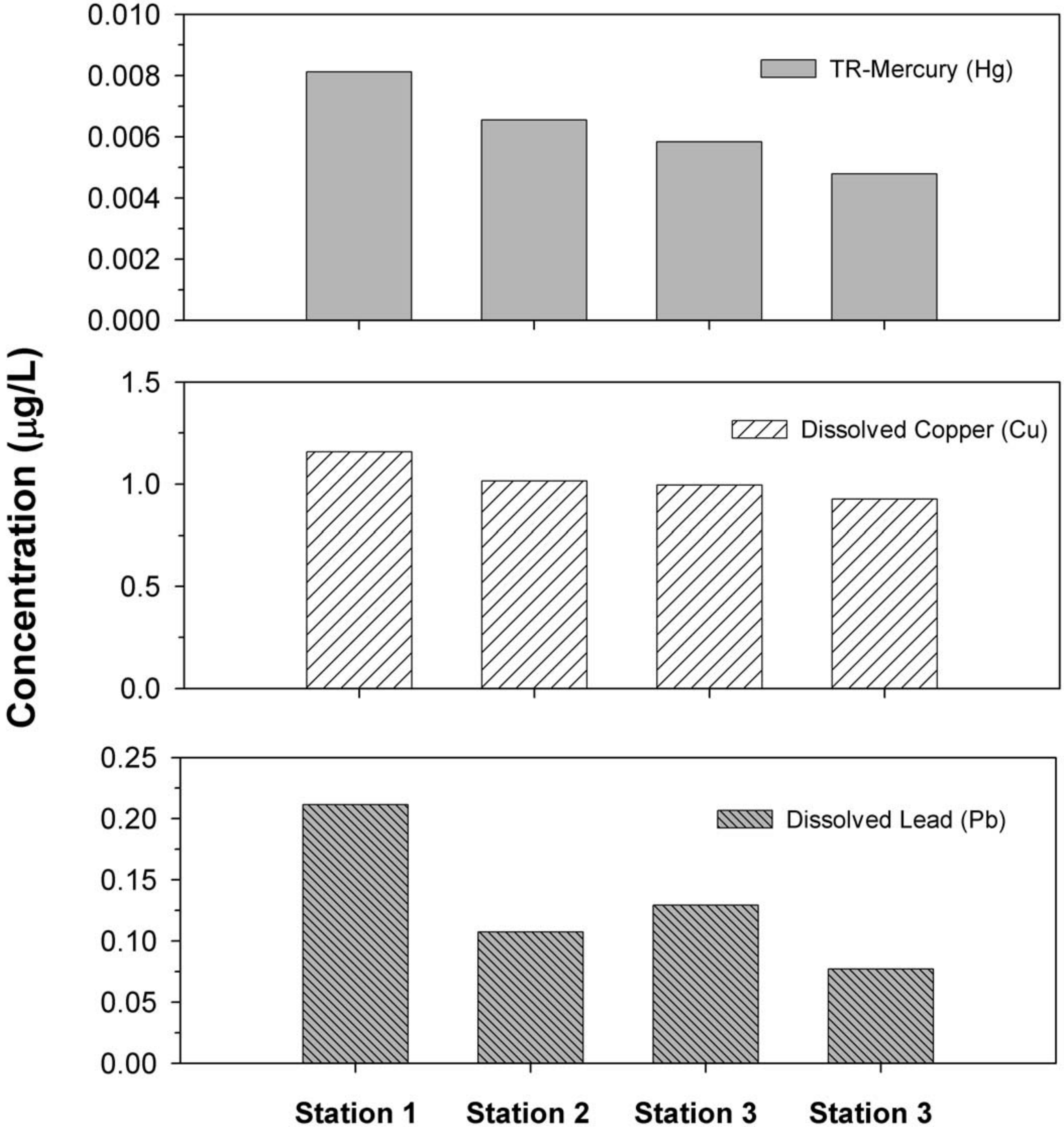


Figure 2.8. Concentrations of dissolved and total recoverable metals in the lower Neches River (Segment 601). Samples were collected during one sampling period.

Table 2.6. Academy data collected in 1953.

Parameter	**Salinity**	**Temp**	**pH**	**DO**	**DO**	**PO4-P**	**TKN**	**NH4-N**	**NO3-N**
Unit	**(ppt)**	**(°C)**	**unitless**	**(mg/L)**	**(% Sat)**	**(mg P/L)**	**(mg N/L)**	**(mg N/L)**	**(mg N/L)**
Station 1: Surface	NA	29.2	6.9	5.7	74	0.001	NA	0.14	0.04
Station 2 Surface	NA	31.5	7.1	1.1	15	0.001	NA	0.27	0.11
Station 3: Surface	NA	31.5	7.2	6.0	81	0.001	NA	0.28	0.09
Station 4: Surface	NA	31.6	7.3	2.4	33	0.001	NA	0.68	0.14

Parameter	**Fecal Coliform**	**Sp. Cond.**	**TP**	**TSS**	**TOC**
Unit	**(cols./100 ml)**	**(μS/cm)**	**(mg P/L)**	**(mg/L)**	**(mg C/L)**
Station 1: Surface	240	430	NA	NA	NA
Station 2: Surface	110000	10400	NA	NA	NA
Station 3: Surface	17000	10600	NA	NA	NA
Station 4: Surface	2400	12200	NA	NA	NA

Table 2.7. Academy data collected in 1973.

Parameter Unit	Salinity (ppt)	Temp (°C)	pH unitless	DO (mg/L)	DO (% Sat)	o-PO4 (mg P/L)	TKN (mg N/L)	NH4-N (mg N/L)	NO3-N (mg N/L)
Station 1: Surface									
Mean	NA	27.7	6.6	5.6	71	0.03	0.31	0.06	0.07
SE		0.4	0.0	0.1	1	0.002	0.07	0.01	0.02
Min		26.5	6.5	5.2	65	0.02	0.10	0.05	0.04
Max		28.5	6.7	5.8	75	0.03	0.50	0.08	0.12
Station 2 Surface									
Mean	NA	28.1	6.7	4.5	57	0.05	0.21	0.12	0.06
SE		0.3	0.0	0.2	1	0.01	0.07	0.01	0.01
Min		27.0	6.6	4.0	50	0.02	0.12	0.10	0.02
Max		29.0	6.8	5.0	65	0.08	0.46	0.14	0.10
Station 3: Surface									
Mean	NA	26.6	6.7	3.9	49	0.03	0.35	0.30	0.05
SE		1.7	0.0	0.2	1	0.00	0.10	0.06	0.01
Min		20.0	6.7	3.4	37	0.02	0.10	0.10	0.01
Max		29.0	6.8	4.6	60	0.04	0.55	0.43	0.08
Station 4: Surface									
Mean	NA	28.2	6.8	3.9	50	0.03	0.54	0.33	0.09
SE		0.4	0.0	0.2	2	0.01	0.11	0.04	0.03
Min		27.0	6.8	3.4	43	0.02	0.37	0.23	0.02
Max		29.0	6.8	4.6	60	0.49	0.74	0.41	0.19

%DO Sat calculated from raw data.
NA = No Analyzed or Sampled
Date is composite of low and high tide samples

Table 2.7 (continued). Academy data collected in 1973.

Parameter **Unit**	**Fecal Coliform** **(cols./100 ml)**	**Sp. Cond.** **(μS/cm)**	**TP** **(mg P/L)**	**TSS** **(mg/L)**	**TOC** **(mg C/L)**
Station 1: Surface					
Mean	47260	278	NA	NA	NA
SE	31021	42			
Min	4500	132			
Max	170000	360			
Station 2: Surface					
Mean	26400	2008	NA	NA	NA
SE	6038	231			
Min	15000	1380			
Max	48000	2800			
Station 3: Surface					
Mean	67200	3040	NA	NA	NA
SE	29060	246			
Min	22000	2300			
Max	170000	3800			
Station 4: Surface					
Mean	34300	3880	NA	NA	NA
SE	16563	339			
Min	8500	3200			
Max	99000	5100			

Table 2.8. Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, for samples collected in 1996.

Parameter **Unit**	**Salinity** **(ppt)**	**Temp** **(°C)**	**pH** **unitless**	**DO** **(mg/L)**	**DO** **(% Sat)**	**o-PO4** **(mg P/L)**	**TKN** **(mg N/L)**	**NH4-N** **(mg N/L)**	**NO3-N** **(mg N/L)**
Station 1: Surface									
Mean	3.7	21.6	6.7	3.0	36	0.17	0.62	0.10	0.60
SE	1.5	0.5	0.1	1.3	14	0.01	0.05	0.00	0.20
Min	0.3	20.2	6.0	0.1	3	0.14	0.54	0.10	0.30
Max	8.3	23.0	7.0	6.5	73	0.19	0.72	0.10	1.20
Station 2: Surface									
Mean	9.9	22.1	6.9	4.5	55	0.17	0.49	0.10	0.50
SE	1.2	0.32	0.06	0.35	4	0.01	0.02	0.00	0.18
Min	6.1	21.1	6.8	2.4	30	0.15	0.45	0.10	0.20
Max	15.1	23.4	7.2	6.1	72	0.18	0.54	0.10	1.00
Station 3: Surface									
Mean	10.3	21.9	7.0	5.3	65	0.16	0.57	0.10	0.48
SE	1.2	0.3	0.1	0.3	4	0.0	0.1	0.0	0.2
Min	7.6	21.2	6.9	3.8	46	0.14	0.45	0.10	0.20
Max	15.6	23.5	7.4	6.6	79	0.18	0.74	0.10	1.00
Station 4: Surface									
Mean	12.2	21.7	7.2	5.8	72	0.18	0.54	0.10	0.50
SE	1.5	0.4	0.1	0.2	2	0.01	0.06	0.00	0.18
Min	9.0	20.8	7.0	5.0	62	0.15	0.40	0.10	0.20
Max	17.2	23.3	7.5	6.5	78	0.20	0.68	0.10	1.00

Samples collected once per day from 26 to 28 October 1996

NR - Not Reported

NH4-N at the DL of 0.1 mg N/L

Table 2.8 (continued). Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, for samples collected in 1996.

Parameter Unit	Fecal Coliform (cols./100 ml)	Sp. Cond. (μS/cm)	TP (mg P/L)	TSS (mg/L)	TOC (mg C/L)
Station 1: Surface					
Mean	289	NR	0.22	5.8	8.1
SE	72		0.02	0.5	0.3
Min	122		0.15	5.0	7.3
Max	465		0.25	7.0	8.8
Station 2: Surface					
Mean	1327	NR	0.19	8.3	4.5
SE	805		0.01	1.0	0.3
Min	166		0.15	6.0	4.0
Max	3600		0.21	11.0	5.1
Station 3: Surface					
Mean	1036	NR	0.17	8.8	4.4
SE	735		0.01	0.6	0.1
Min	44		0.15	7.0	4.2
Max	3200		0.21	10.0	4.5
Station 4: Surface					
Mean	524	NR	0.20	13.3	3.6
SE	135		0.01	1.0	0.0
Min	185		0.18	11.0	3.5
Max	780		0.21	16.0	3.7

Table 2.9. Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, for samples collected in 2003.

Parameter Unit	Salinity (ppt)	Temp (°C)	pH unitless	DO (mg/L)	DO (% Sat)	o-PO4 (mg P/L)	TKN (mg N/L)	NH4-N (mg N/L)	NO3-N (mg N/L)
Station 1: Surface									
Mean	0.01	23.5	6.40	5.71	67	0.04	1.80	0.08	0.04
SE	0.01	0.1	0.04	0.06	1	0.000	1.03	0.00	0.00
Min	0.00	23.3	6.33	5.59	66	0.04	0.42	0.07	0.04
Max	0.03	23.6	6.50	5.86	69	0.04	4.81	0.09	0.04
Station 2: Surface									
Mean	0.29	23.8	6.69	4.99	59	0.04	0.49	0.09	0.05
SE	0.04	0.0	0.10	0.14	2	0.000	0.05	0.01	0.00
Min	0.20	23.8	6.50	4.73	56	0.04	0.40	0.08	0.04
Max	0.40	23.9	6.94	5.30	63	0.04	0.62	0.11	0.05
Station 3: Surface									
Mean	0.53	23.9	6.82	4.84	58	0.04	0.54	0.11	0.05
SE	0.13	0.0	0.11	0.14	2	0.000	0.02	0.00	0.01
Min	0.30	23.8	6.56	4.66	56	0.04	0.49	0.10	0.04
Max	0.91	24.0	7.08	5.25	63	0.04	0.58	0.11	0.07
Station 4: Surface									
Mean	1.29	24.2	6.89	5.03	60	0.04	0.58	0.11	0.07
SE	0.26	0.1	0.06	0.16	2	0.000	0.07	0.02	0.01
Min	0.80	24.0	6.73	4.74	57	0.04	0.48	0.08	0.06
Max	2.01	24.4	6.99	5.47	66	0.04	0.79	0.17	0.09

NH4-N at the DL of 0.04 mg N/L

Table 2.9 (continued). Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, for samples collected in 2003.

Parameter **Unit**	**Fecal Coliform (cols./100 ml)**	**Sp. Cond. (μS/cm)**	**TP (mg P/L)**	**TSS (mg/L)**	**TOC (mg C/L)**
Station 1: Surface					
Mean	1086	60	0.08	22.5	12.7
SE	514	2	0.01	3.3	1.0
Min	283	54	0.07	15.0	10.1
Max	2560	65	0.09	31.0	14.9
Station 2: Surface					
Mean	720	575	0.08	14.0	10.9
SE	376	95	0.01	2.4	1.1
Min	83	365	0.07	10.0	8.3
Max	1716	825	0.10	21.0	13.2
Station 3: Surface					
Mean	696	1053	0.08	14.8	9.9
SE	350	257	0.01	2.8	1.1
Min	167	618	0.06	10.0	7.3
Max	1683	1789	0.09	22.0	12.1
Station 4: Surface					
Mean	895	2533	0.07	11.8	8.2
SE	373	467	0.00	1.9	0.8
Min	133	1665	0.06	8.0	6.5
Max	1867	3819	0.08	15.0	10.1

mg O_2/L at Stations 2 and 4, while in 1996, concentrations of DO were, on average, higher except at Station 1 which was just at the current criterion (Table 2.7; Fig. 2.9). At depth (summary data not shown), DO concentrations were lower and many times below or near the detection limit (< 0.5 mg O_2/L). The percent DO saturation for surface samples is shown in Tables 2.6-2.9 and Figure 2.10. The lowest surface water value was observed in 1953 at Station 2 with the highest value at Station 3 in 1953. Percent DO saturation fell below the stated minimum of 49% to as low as 36% on average for Station 1 in the 1996 survey (Tables 2.6-2.9).

Fecal coliform (FC) concentrations exhibited large changes during the four surveys. Other than at Station 1 in 1953, FC average concentrations were significantly higher in 1953 and 1973 than in 1996 and 2003 (Fig. 2.11). Average concentrations in 1996 and 2003 were similar and still above published screening criteria of 400 colonies per 100 ml.

Three different nitrogen forms were measured during the four surveys that allow comparison (Fig. 2.12; Tables 2.6-2.9). For dissolved ammonia, all samples in 1996 were below the detection limit (DL) of 0.1 mg N/L. In 1953 and 1973, ammonia concentrations averaged between 0.06 to 0.68 mg N/L and generally increased from Station 1 to Station 4, while in 2003 average concentrations ranged from 0.08 to 0.11 mg N/L with a slight increase downstream (Tables 2.6-2.9). Dissolved nitrate concentrations in 2003 were at or near the stated DL of 0.04 mg N/L (Table 2.3; Tables 2.6-2.9). Concentrations in 1973 were generally lower than those detected in either 1953 or 1996. The 1996 survey had the highest concentrations which averaged from 0.48 to 0.60 mg N/L. All values were below published screening levels for dissolved nitrate and ammonium (TCEQ 2000). Total Kjeldahl nitrogen (TKN) was not measured in 1953 and on average ranged from 0.21 to 1.80 mg N/L for the other three sampling periods (Tables 2.6-2.9; Fig. 2.12). At Station 1, there was a substantial increase in TKN concentrations from 1973 to 2003 with concentrations increasing from 0.31 ± 0.07 to 1.80 ± 1.03 mg N/L ($n=4$). At Stations 2 to 4 average concentrations were generally similar and ranged from 0.21 to 0.58 mg N/L.

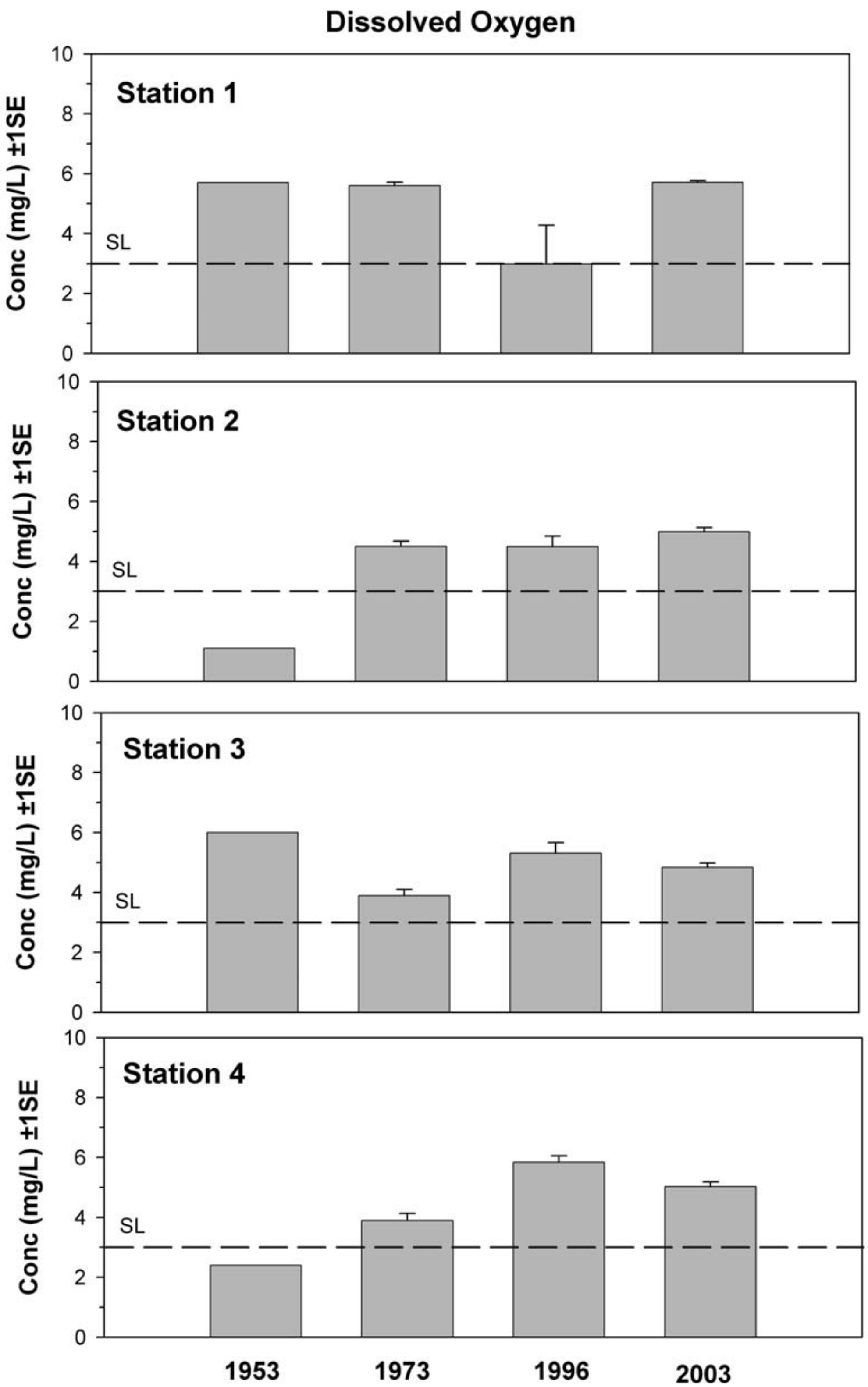


Figure 2.9. Concentrations (average mg/L ± 1SE) of dissolved oxygen from each of the four study periods from 1953 to the present study. SL = current screening level.

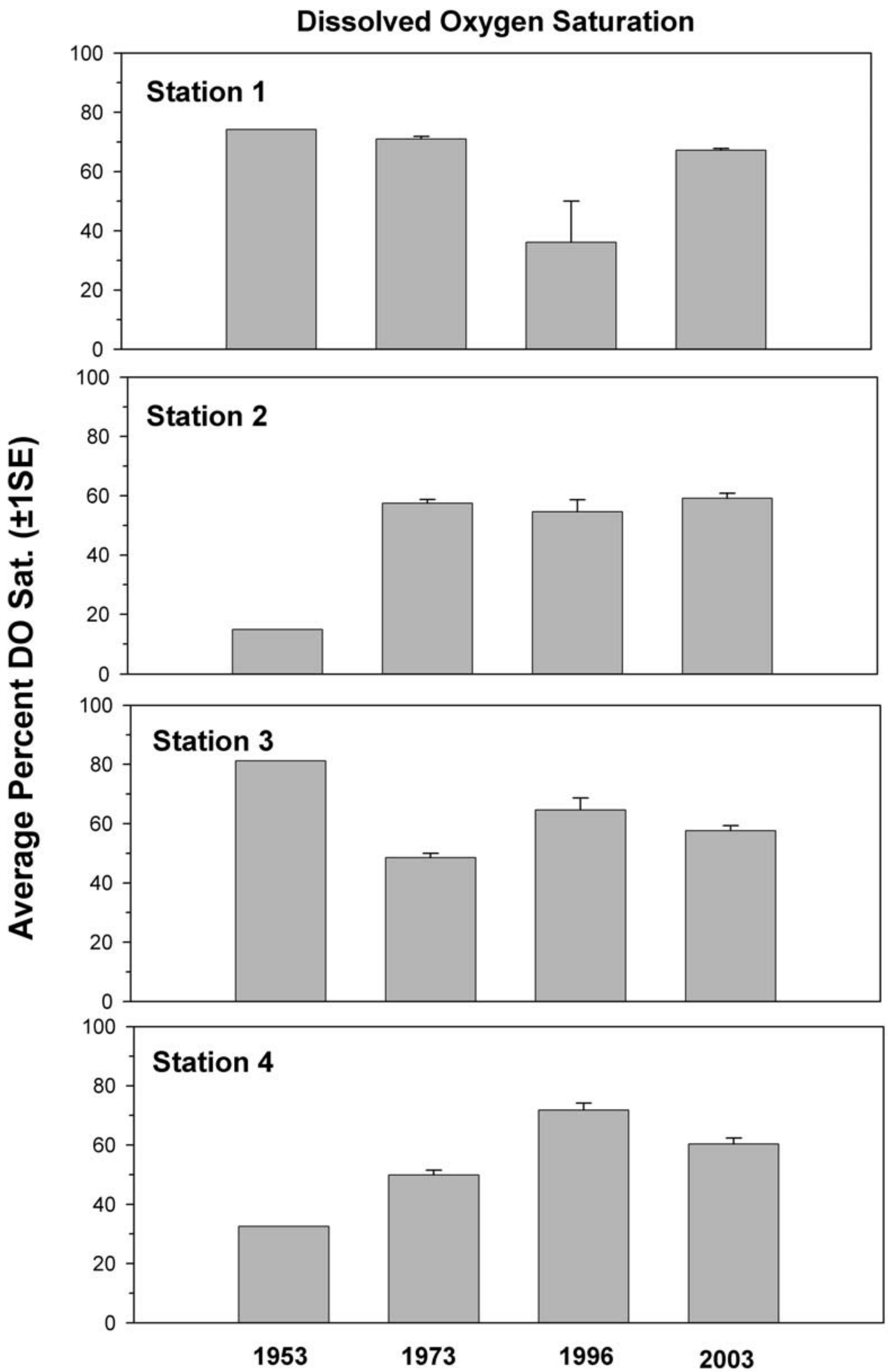


Figure 2.10. Percent dissolved oxygen saturation (average ± 1SE) from each of the four study periods from 1953 to the present study. Note: saturation data were not corrected for salinity which, in most cases, was low.

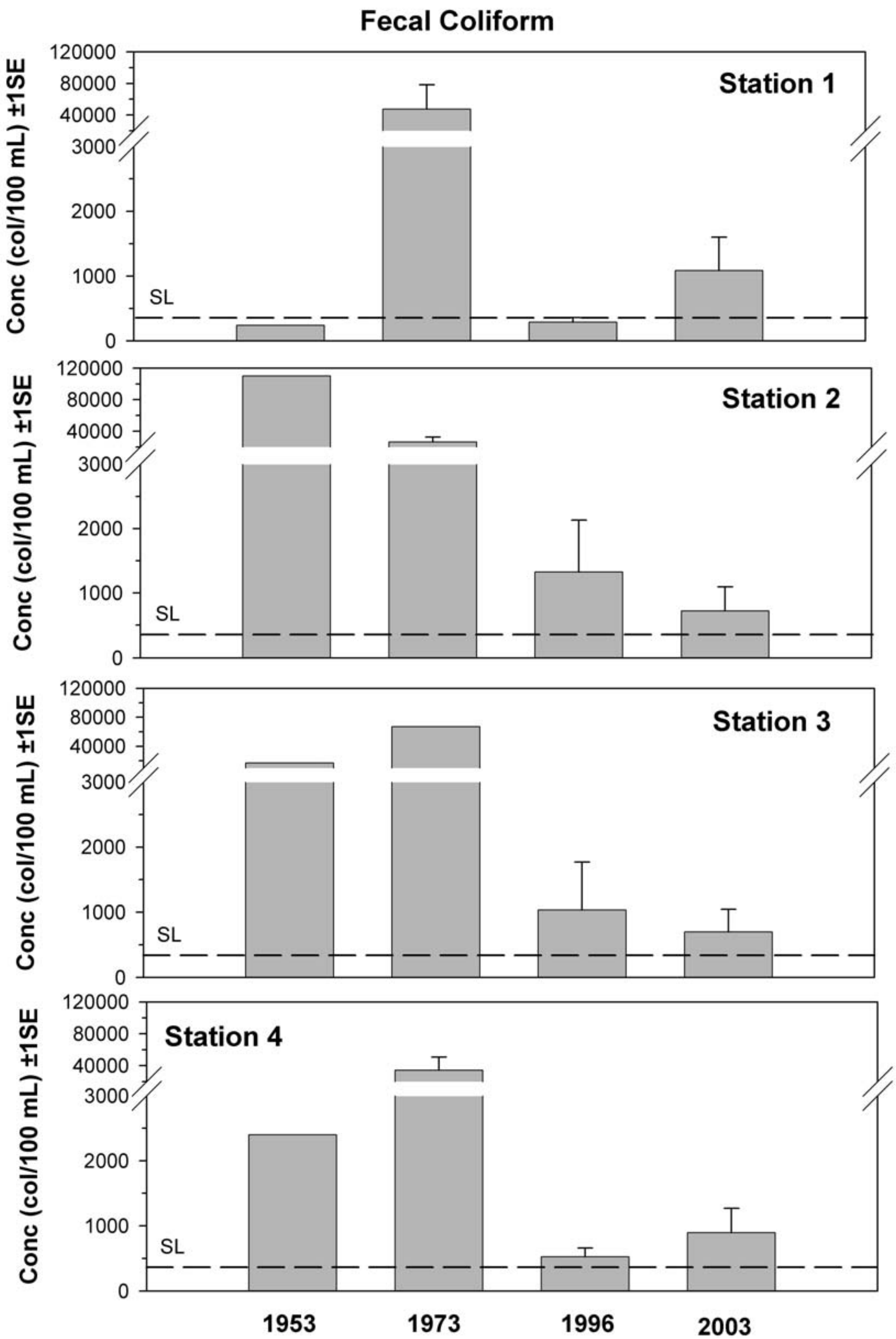


Figure 2.11. Concentrations (average cols./100 ml ± 1SE) of fecal coliform from each of the four study periods from 1953 to the present study. SL = current screening level.

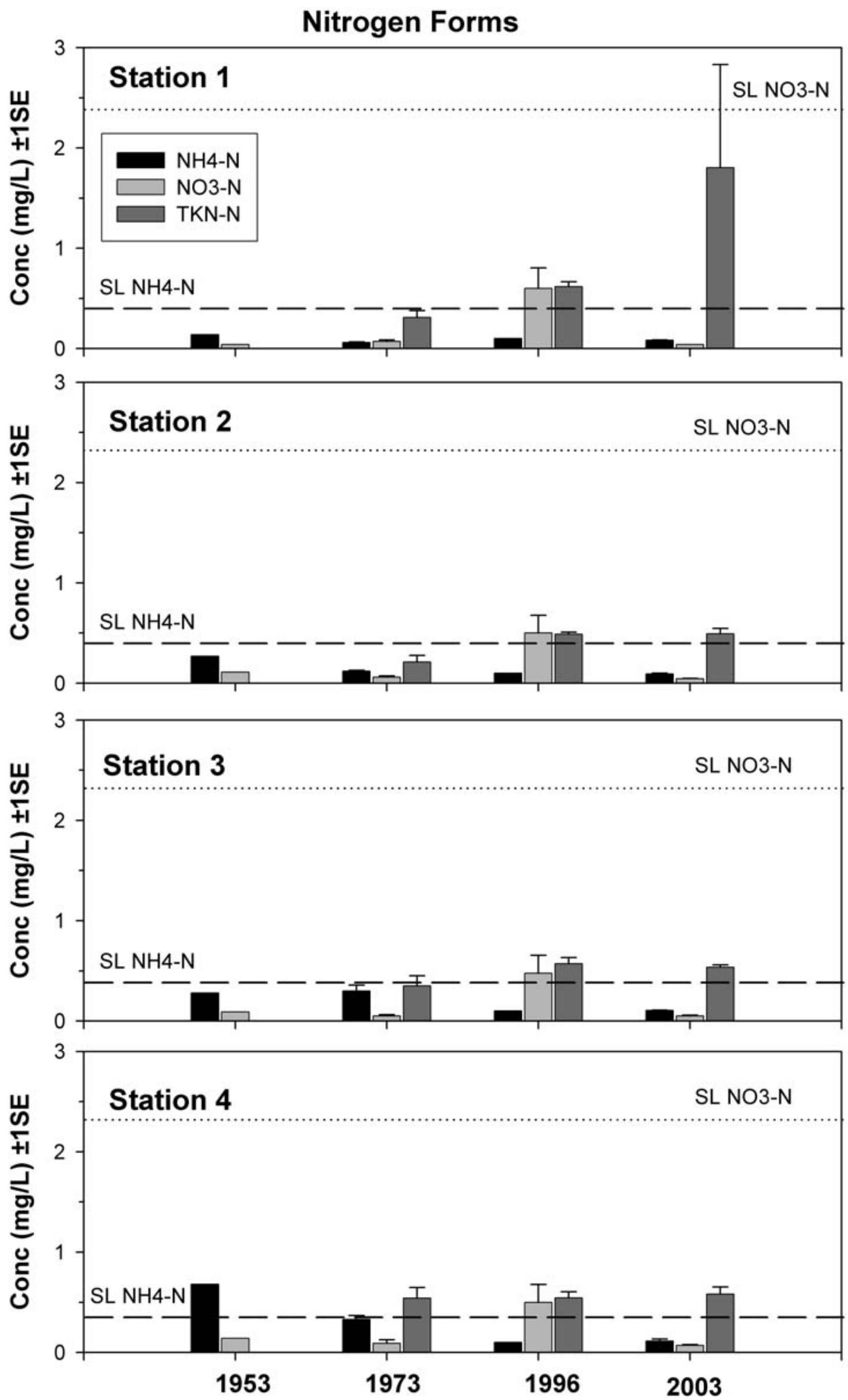


Figure 2.12. Concentrations (average mg/L ± 1SE) of the different nitrogen forms from each of the four study periods from 1953 to the present study. SL = current screening level for ammonia and nitrate.

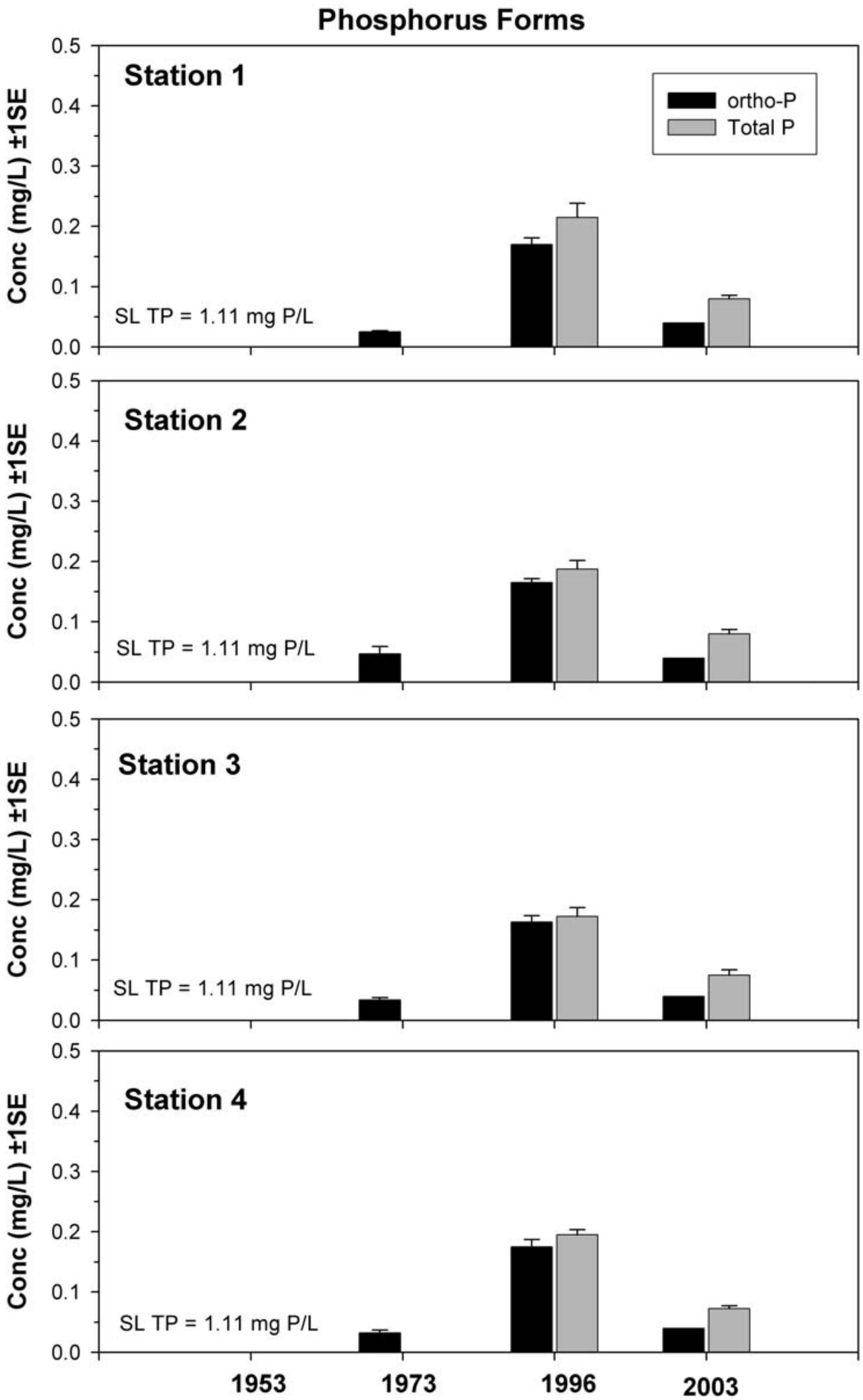


Figure 2.13. Concentrations (average mg/L ± 1SE) of the different phosphorus forms from each of the four study periods from 1953 to the present study. SL = current screening level for TP.

Phosphorus concentrations are presented for dissolved inorganic phosphorus (oPO_4) and total phosphorus (TP) (Fig. 2.13). Dissolved orthophosphate (oPO_4) samples were all below the stated detection limit (0.04 mg P/L) in 2003 as well as in 1953 (0.001 mg P/L). On average oPO_4 concentrations were higher in 1996 (approx. 0.17 mg P/L) than in 1973 and 2003. Total phosphorus levels, on average, were similar to oPO_4 concentrations suggesting that a majority of the TP was dissolved inorganic phosphorus. TP had a similar temporal distribution as oPO_4 with higher concentrations in 1996.

Organic contaminant data were measured in 1996 and 2003 (Table 2.1). In all cases, except for ethylene glycol, concentrations were below the reported method detection limit. In 2003, ethylene glycol was detectable at all stations (Table 2.4), however, the data are suspect (see section 2.1.2.3).

Trace element data were obtained and summarized for seven trace metals (Cd, Cr, Cu, Pb, Ni, Ag, and Zn) and two trace metalloids (As and Se) collected from the time period between approximately 1982 and 2003 (Table 2.10). The period of record was different for each station, with Stations 0100 (downstream) and 0500 (upstream) (within the same reach as Stations 1 to 4) containing the most data over an approximately 10-year period. However, there was not sufficient monitoring coverage to allow a statistically valid trend analysis. Also, in most cases, many concentrations were below the stated detection limit which varied over the time period. For example, at Station 0100 all cadmium data (total recoverable) were below the detection limit (DL). The DL ranged from <20 µg/L in the mid-1980s to < 1 µg/L by 1991. A similar trend is seen in other trace elements. This decrease is most likely related to the recent implementation of clean sampling and analysis techniques for trace metals by the TCEQ. The 1996 data were collected using newer methods and appear to better reflect the current ambient trace metal concentrations (Table 2.10). In 2003, only dissolved arsenic was measured, at concentrations similar to 1996 data. Current 1996 and 2003 trace element concentrations were substantially lower than the previous historical concentrations. This is most likely due to the change in sampling and analysis methods as opposed to a decrease in the ambient levels in the river.

Table 2.10. Summary of historical trace metal data for the Lower Neches River (Segment 601).

Station 100	**Period of Record: June 1982 to July 1991**								
Chemical:	**TAs**	**TCd**	**TCr**	**TCu**	**TPb**	**TNi**	**TAg**	**TZn**	**TSe**
Number of Samples	13	13	13	13	13	10	13	13	10
Number above DL	2	0	2	5	2	6	2	10	1
Range*	< 2 to < 20	< 1 to < 20	< 8 to < 40	< 4 to 255	< 3 to 160	5 to 57	8 to < 50	< 6 to 100	< 2 to < 50
Station 300	**Period of Record: October 1989 to May 1990**								
Chemical:	**TAs**	**TCd**	**TCr**	**TCu**	**TPb**	**TNi**	**TAg**	**TZn**	**TSe**
Number of Samples	3	3	3	3	3	3	3	3	3
Number above DL	0	0	3	0	0	2	1	3	0
Range*	< 5	< 1	15 to 35	< 10	< 3	< 11 to 15	< 16 to 16	70 to 75	< 5
Station 500	**Period of Record: June 1982 to May 1990**								
Chemical:	**TAs**	**TCd**	**TCr**	**TCu**	**TPb**	**TNi**	**TAg**	**TZn**	**TSe**
Number of Samples	11	11	11	11	11	11	11	11	11
Number above DL	0	3	3	2	3	9	4	10	0
Range*	< 2 to < 20	< 1 to < 20	< 8 to 55	< 1 to < 40	< 3 to < 50	< 11 to 30	2 to <20	15 to 79	< 2 to < 20
Station 700	**Period of Record: December 1987**								
Chemical:	**TAs**	**TCd**	**TCr**	**TCu**	**TPb**	**TNi**	**TAg**	**TZn**	**TSe**
Number of Samples	1	1	1	1	1	1	1	1	1
Number above DL	0	0	0	0	0	1	0	1	0
Range*	< 2	< 10	< 40	< 5	< 50	15	< 20	25	< 2
Station 800	**Period of Record: November 1989 to May 1990**								
Chemical:	**TAs**	**TCd**	**TCr**	**TCu**	**TPb**	**TNi**	**TAg**	**TZn**	**TSe**
Number of Samples	3	3	3	3	3	3	3	3	3
Number above DL	0	0	1	0	1	1	0	3	0
Range*	< 5	< 1	< 9 to 30	< 10	< 3 to 7	< 11 to 15	< 16	15 to 75	< 5
1996 Study Range*	0.5 to 1.3	< 0.1	< 0.5	1 to 2	0.3 to 0.8	2 to 4.8	< 0.5	1.6 to 3.7	< 0.05 to 0.1
Number of Samples	4	4	4	4	4	4	4	4	4
2003 Study Range**	0.69 to 0.79	NS	NS	NS	NS	NS	NS	NS	NS
Number of Samples	4	NS	NS	NS	NS	NS	NS	NS	NS

* Total recoverable concentrations are in µg/L. Range includes variations in reported detection limits (DL). 1996 Cr data are Cr(VI).

**Dissolved fraction only in µg/L

Data courtesy of LNVA (A. Bruno, personal communication).

NS - Not Sampled or Analyzed

2.1.2.6 Summary

The concentration of certain parameters was elevated in the lower tidal Neches River and in some cases above (or below in the case of dissolved oxygen) published water quality guidelines from the State of Texas (TCEQ 2000). This is evident with the concentrations of fecal coliform and dissolved oxygen. The distribution of most analytes, while limited with only four stations in a tidal system, indicate no particular source area to the river, suggesting that both inputs from upstream or non-point sources (e.g., urban runoff) are the predominant sources. In this regard, there were substantially higher flows recorded at the Barrier during this sampling period, as there was a significant rainfall prior to the sampling event. Discharges ranged from 11600 to 14700 cfs, almost 3 times higher than approximate average discharge prior to and after the sampling. The higher flows most likely resulted in more non-point source runoff with higher amounts of particulate matter and fecal coliform.

As a result of estuarine circulation (i.e., low density freshwater overriding higher density salt water) and the input of organic material to the river, dissolved oxygen concentrations decreased to near undetectable levels in parts of the tidal river. This is most evident in the mid-tidal portion at Stations 2 and 3 where dissolved oxygen concentrations decreased through the halocline to undetectable levels near the bottom (ca. 10-15 m). Two main sources of labile organic matter that are utilized by bacteria (i.e., biochemical oxygen demand) are inputs from upstream and facilities (i.e., petrochemical, processing and shipping) around the river and in situ production in the river itself (i.e., allochthonous versus autochthonous sources). The high amount of organic matter in the river is evident by the high levels of total organic carbon (TOC) and total Kjeldahl nitrogen (TKN). TOC averaged 10 mg C/L (range of 6.5 to 15 mg C/L), while TKN averaged 0.85 mg N/L (range of 0.4 to 4.8 mg N/L). These high levels of organic matter within the tidal river provide energy for bacterial growth and result in oxygen depletion in the bottom waters.

Currently, the lower Neches River (Segment 601) has been noted as having acceptable levels of fecal coliform for intermediate contact recreational use and sufficient levels of dissolved oxygen to be designated for intermediate aquatic life use (LNVA, 2004). However, the sampling performed in mid-October of 2003 yielded values that are outside the bounds for these parameters. Texas Surface Water Quality Standards states that fecal coliform shall not equal or exceed 400 colonies per 100 ml in more than 10% of all samples, based on at least 5 samples, taken during any 30-day period. If 10 or fewer samples are analyzed, no more than 1 sample shall exceed 400 colonies per 100 ml. For fecal coliform abundances in October 2003, approximately 60% of the samples were above the State of Texas criterion (400 col per 100 ml). The level or rainfall and increased flows (see above) may have resulted in these exceedances of the criteria at this time. Given the recent historical level of excceedence for coliform (Figure 2.11), this segment should be evaluated for source reduction and monitoring should be continued.

Overall, this section of the lower tidal Neches River is moderately impacted, especially with fecal coliform and organic matter, the latter which can affect the oxygen balance. Bacterial indicators such as fecal coliform are also elevated in this section of the river and are at times above published screening levels. Dissolved oxygen in the near bottom waters is low and can impact the biological community in or near the bottom. Contaminants such as volatile organic compounds and trace metals do not appear to be elevated in the water and are close to the detection limits of the methods.

2.2 Long-Term Water Quality Analysis

For the long-term analysis of water quality, electronic data were obtained from the LNVA (from the Texas Commission on Environmental Quality data base; A. Bruno, personal communication). Data were obtained from Segment 601 of the tidal Neches River for Stations 0100, 0300, 0500 and 0800. Stations 0100 and 0300 are located roughly 6 river miles and 1 river mile (respectively) downstream from Academy Station 4, station 0500 is less than 1 river mile downstream from Academy Station 2, and station 0800 is roughly midway between Academy Stations 1 and 2. There were no additional data since the last report for Station 0700 so no analysis was performed on this data set. Unfortunately, not all stations and depths had sufficient data for all parameters for long-term trend analysis. Only parameters that contained sufficient data for time series analysis were collected and processed and include dissolved oxygen, fecal coliform, total phosphorus, ortho-phosphorus, nitrate+ nitrite, and the dissolved forms of ammonia (i.e., ammonia+ ammonium). In addition, the temperature and dissolved oxygen data were used to calculate percent oxygen saturation for each station's time series. Unfortunately, there was not always corresponding salinity data with each record. Therefore data were not corrected for salinity. Given the potential range of salinity encountered in more recent data (see above), it is expected that the bias could be no more than 5 to 10% of the final value. Given the changes in the record, this potential effect would be minimal for trend analysis. For all parameters only samples collected just below the surface (0.3 m) at each station were used for this analysis when sufficient.

2.2.1 Water Quality Trends

2.2.1.1 Historical Chemical Data Analyses

In the previous report (ANSP 1998) data from the Neches River were analyzed for temporal variability and change from 1981 through 1996. In that study, time series analyses were used for specific parameters (i.e., dissolved oxygen, total phosphorus, and the dissolved forms of ammonia (i.e., ammonia+ammonium), nitrate+ nitrite, inorganic phosphorus (ortho-phosphorus) at four stations (Segment 601.01, 03, 05, 08) to demonstrate temporal trends and changes in variance structure (i.e., heteroscedasticity). In this report, the period is extended to 2002, depending on the parameter, and the complete data set analyzed for temporal changes over this period (i.e., 1981 through 2002).

Since the earlier data (ANSP 1998) still comprise the bulk of the updated data set, conclusions of the earlier study are expected to be relevant to the updated data set. In these new analyses, we focus on temporal trends over the longer time period. We also investigate potential seasonal patterns of variation, which could explain some of the variability in the concentration data.

2.2.1.2 Methods

Data were analyzed by a variety of linear and nonlinear models of trend and seasonal variation. Each sampling time was converted to a decimal date (i.e., year+ (day of year)/365; DecDate), which was used as the primary independent variable. Linear and polynomial (second and third order) models of trend were fit using linear regression and nonlinear regression (in Statistica software). Additional nonlinear models were fit in some cases, as noted in the results. A seasonal parameter (termed DayRad) was calculated as the number of radians of the day of sampling (i.e., pi*(day of year)/365). Sinusoidal seasonal terms were added to linear and nonlinear trend models (Equation 1)

(Eq. 1) Chemical Parameter (DecDate, DayRad) = p_1 + p_2*DecDate + p_3*DecDate^2 +

p_4*sin(DayRad- p_5) + p_6*cos(DayRad-p_5) +

p_7*sin(DayRad/2-p_8) +p_9*cos(DayRad/2-p_8),

where Chemical Parameter (DecDate, DayRad) is a given chemical parameter modeled as a function of DecDate and DayRad; p_1, p_2 and p_3 fit linear and second-order terms of the long term trend in DecDate, p_4 and p_6 fit the seasonal pattern, p_7 and p_8 fit higher order harmonics of the seasonal pattern, and p_5 and p_8 are lag terms.

For most data sets, there were clear outliers (e.g., a concentration was significantly above all other concentrations), which were deleted in performing the analyses. Outlier removal was conservative, with questionable points left in the data set, since they could represent unusual chemical conditions of interest. For a few parameters, the pattern of data indicated a change in detection limit over time. The effect of this change on interpretation of change is indicated in interpretation of results. In some cases (especially for dissolved ammonia), the change in detection limit prevents full assessment of temporal trends.

Dissolved oxygen (DO) varies with water temperature and salinity. Water temperature data were available, and DO concentrations were converted to % DO saturation (% Sat), which will reduce some variation due to diel and seasonal temperature variation. There may still be seasonal variation in % Sat, due to seasonal differences in biological activity, nutrient inputs, etc. There were insufficient salinity/conductivity data for most stations and we could not adjust the saturation value. For the two upstream stations (601.08 and 601.05), the conductivity was low enough most of the year that any correction would be very small (approximately <2% change in % Sat value). For stations 601.03 and 601.01, the solubility correction would be larger and on the order of 10% of the % Sat value. Therefore, the % Sat data potentially include some variation due to within- or among-year variation in salinity.

2.2.1.3 Results

A summary of the data is presented in Table 2.11. This table contains a summary of all the data evaluated for the temporal trend analysis. Long-term trends were apparent for several parameters at various stations. In most cases, nonlinear trend models were not substantially better than linear models. Nonlinear trends in a few cases will be noted below.

<u>% DO Saturation:</u> % Sat showed temporal trends over time at all stations. Short-term variation in % Sat varied over the time series as well, with low variation in the middle of the time series (Figs. 2.14-2.17). As a result, the p-values for regression models are approximate, since the p-values are based on assumptions of homogeneity of variance. In many cases, % Sat may be high under "typical" conditions, but show decreases during conditions of high temperature and possibly high nutrient input and resultant biological activity (i.e., production or decomposition).

Occasional periods of very high % Sat (including supersaturation with values > 100%) may be present during periods of high algal or macrophyte productivity. As a result, low values of % Sat may be more responsive to improvements in water quality than mean or high values. This pattern was evident in the Neches time series, where high values around

Table 2.11. Data summary (1981 to 2002) for water quality parameters of the lower Neches River (Segment 601).

	Screening Level	Number of Samples	Number of Detects	Minimum	Maximum	Average	Median	Percent outside of Screening Level
Station 601.0100								
Dissolved Oxygen (mg O_2/L)	< 3.0	215	215	3.50	9.80	6.66	6.60	0
Total Ammonia (mg N/L)	>0.44	145	61	0.01	0.30	0.06	0.05	0
Nitrate+Nitrite (mg N/L)	>2.34	71	68	0.01	0.36	0.16	0.16	0
Total Phosphorus (mg P/L)	>1.11	145	145	0.02	0.13	0.07	0.06	0
Dissolved Orthophosphate (mg P/L)	NV	123	85	0.01	0.10	0.03	0.02	0
Fecal Coliform (colnies/100ml)	>400	142	142	2.00	1640	98	37	6
Station 601.0300								
Dissolved Oxygen (mg O_2/L)	< 3.0	149	149	3.90	10.50	6.45	6.30	0
Total Ammonia (mg N/L)	>0.44	79	31	0.01	0.45	0.06	0.05	1
Nitrate+Nitrite (mg N/L)	>2.34	4	3	0.01	0.17	0.11	0.14	0
Total Phosphorus (mg P/L)	>1.11	79	78	0.01	0.46	0.07	0.06	0
Dissolved Orthophosphate (mg P/L)	NV	58	51	0.01	0.09	0.04	0.04	0
Fecal Coliform (colnies/100ml)	>400	76	76	3.00	800	111	57	3
Station 601.0500								
Dissolved Oxygen (mg O_2/L)	< 3.0	147	147	3.10	11.50	6.25	6.10	0
Total Ammonia (mg N/L)	>0.44	80	41	0.01	0.79	0.09	0.06	4
Nitrate+Nitrite (mg N/L)	>2.34	4	3	0.01	0.13	0.07	0.07	0
Total Phosphorus (mg P/L)	>1.11	80	80	0.02	0.70	0.08	0.07	0
Dissolved Orthophosphate (mg P/L)	NV	57	51	0.01	0.10	0.05	0.05	0
Fecal Coliform (colnies/100ml)	>400	81	81	11.00	1400	189	103	12
Station 601.0800								
Dissolved Oxygen (mg O_2/L)	< 3.0	145	145	3.40	12.60	6.63	6.40	0
Total Ammonia (mg N/L)	>0.44	80	35	0.01	0.75	0.06	0.05	1
Nitrate+Nitrite (mg N/L)	>2.34	4	3	0.01	0.07	0.04	0.05	0
Total Phosphorus (mg P/L)	>1.11	79	78	0.01	0.70	0.09	0.08	0
Dissolved Orthophosphate (mg P/L)	NV	54	44	0.01	0.09	0.05	0.05	0
Fecal Coliform (colnies/100ml)	>400	78	78	3.00	1440	146	57	12

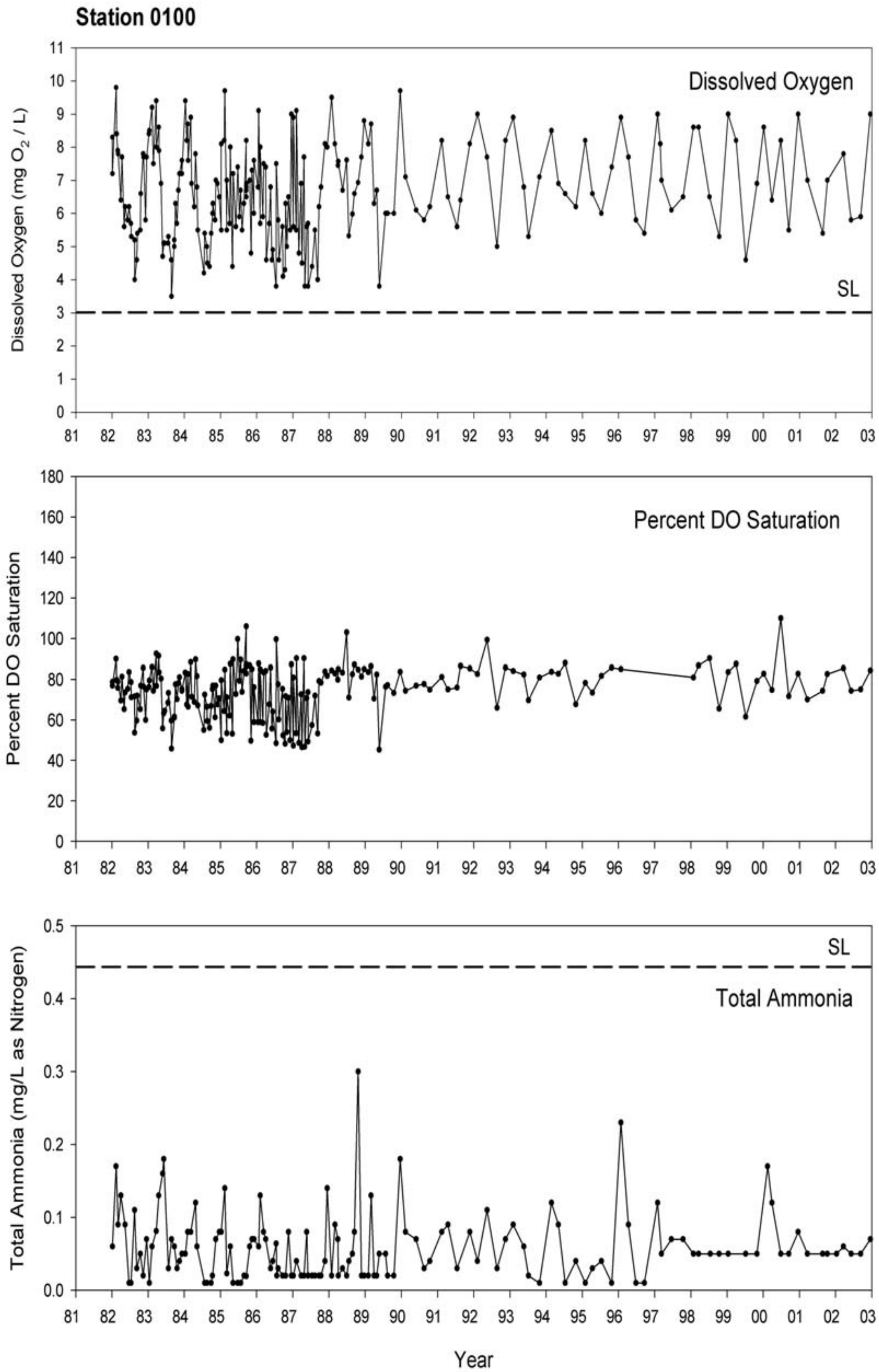


Figure 2.14. Temporal distribution of water quality parameters at Station 0100 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on Envionmental Quality.

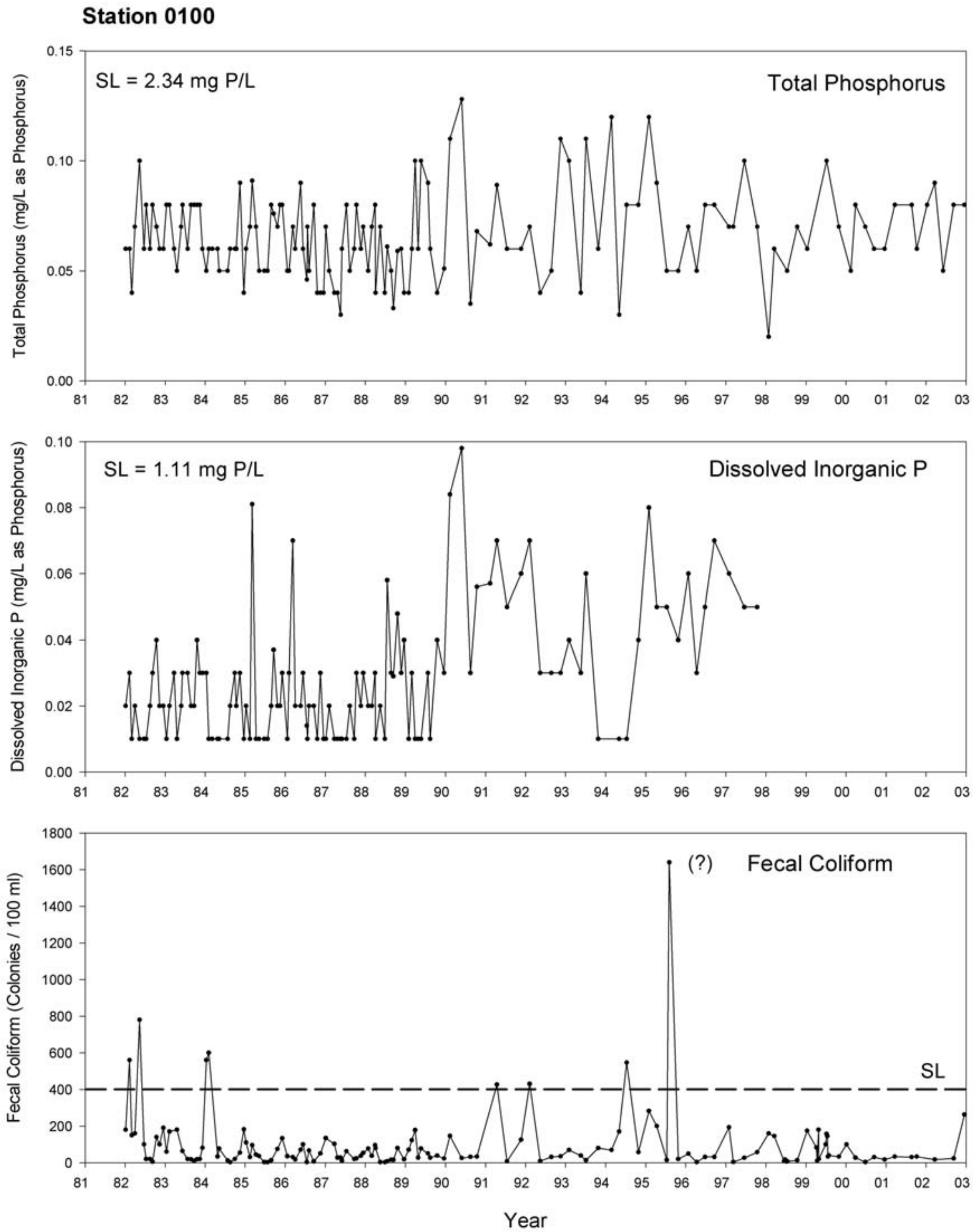


Figure 2.14 (continued). Temporal distribution of water quality parameters at Station 0100 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on EnvironmentalQuality.

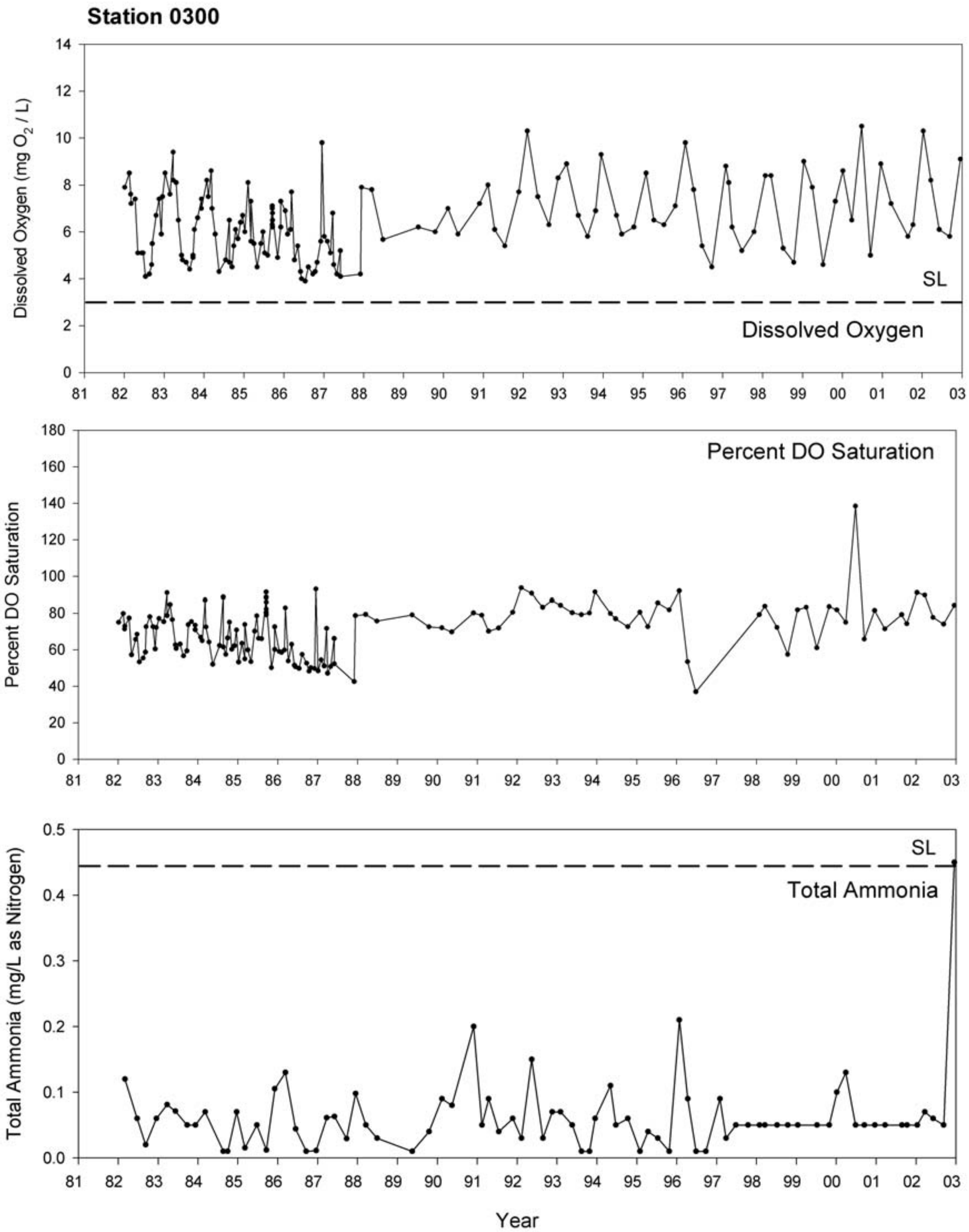


Figure 2.15. Temporal distribution of water quality parameters at Station 0300 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on EnvironmentalQuality.

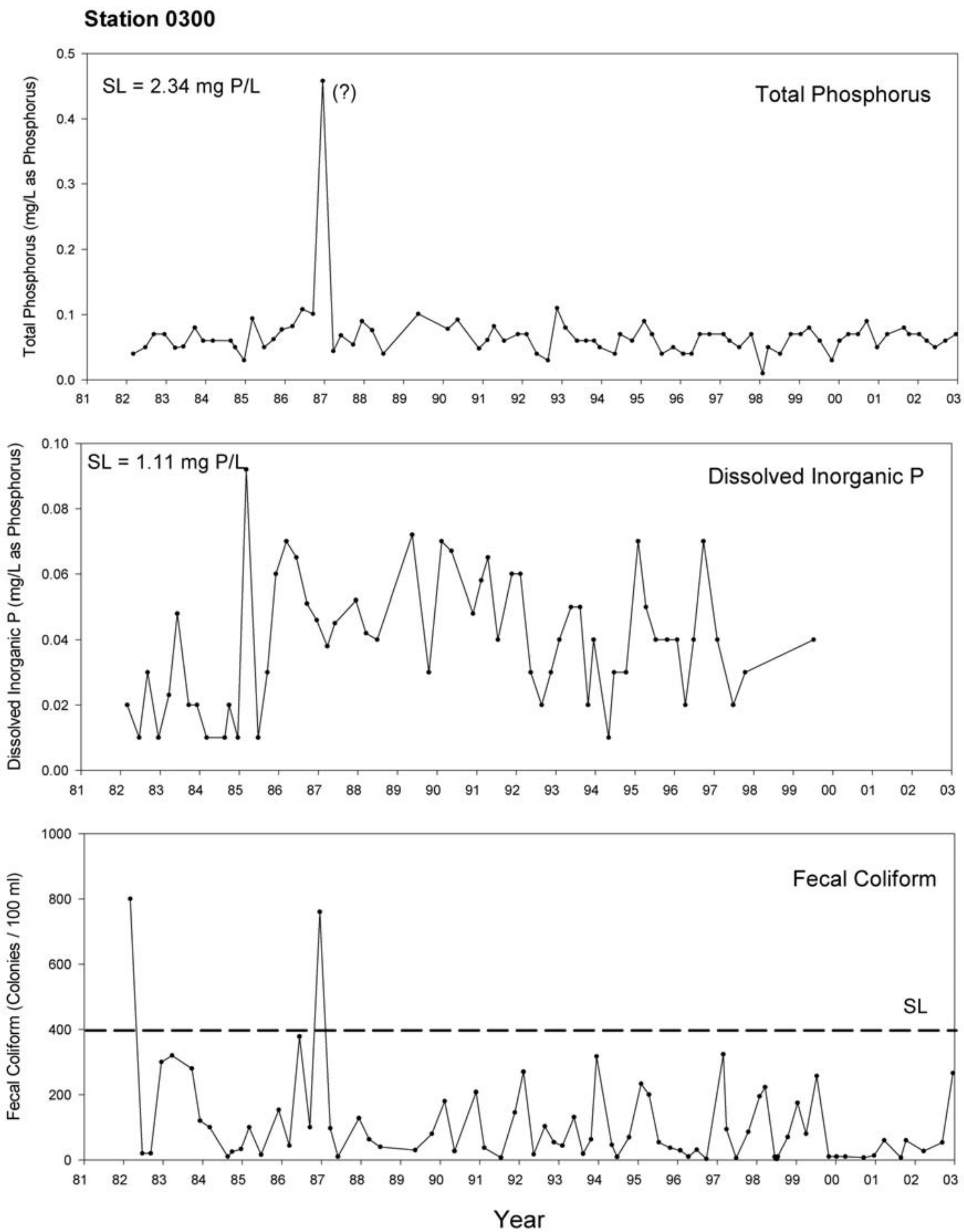


Figure 2.15 (continued). Temporal distribution of water quality parameters at Station 0300 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on EnvironmentalQuality.

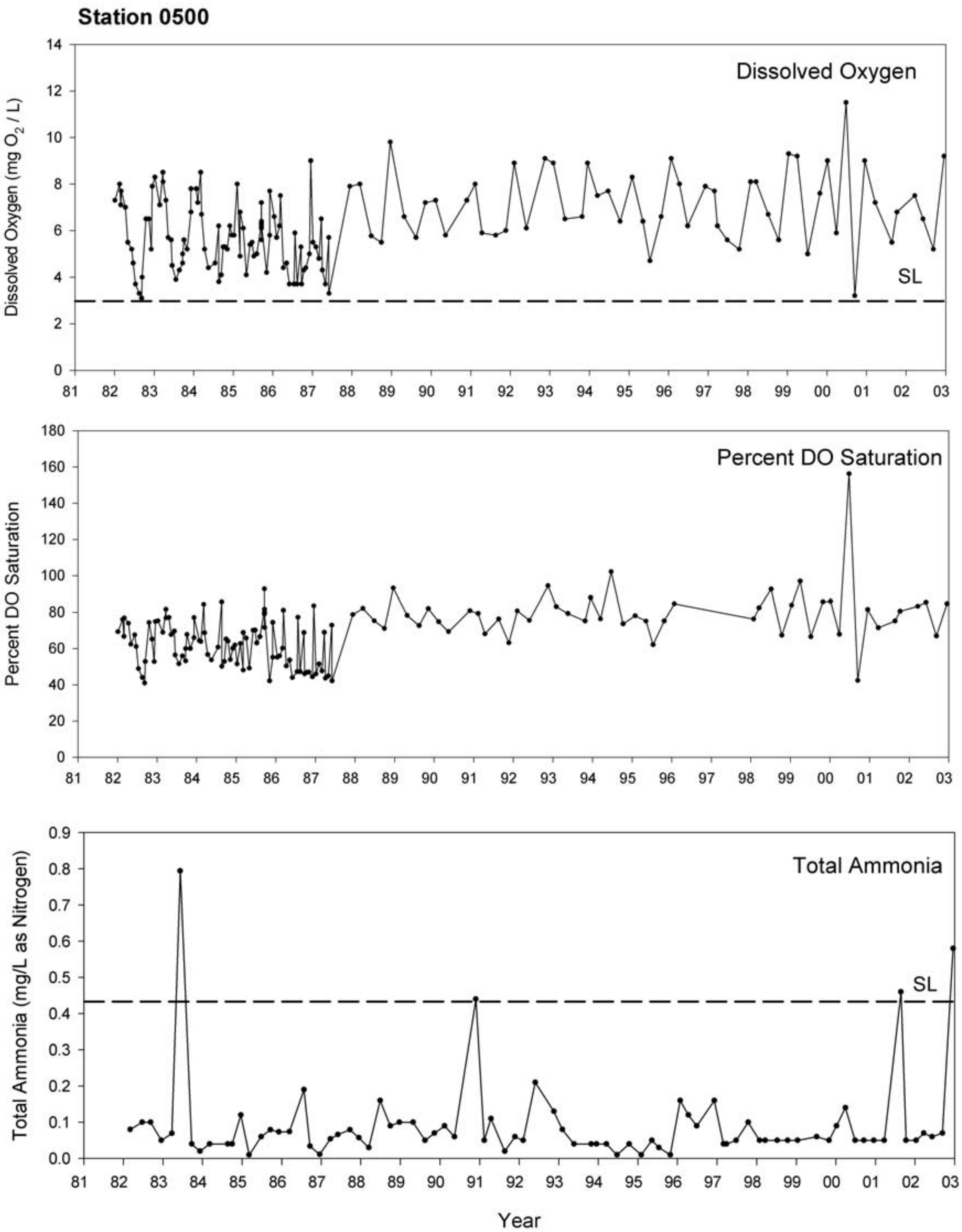


Figure 2.16. Temporal distribution of water quality parameters at Station 0500 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on Environmental Quality.

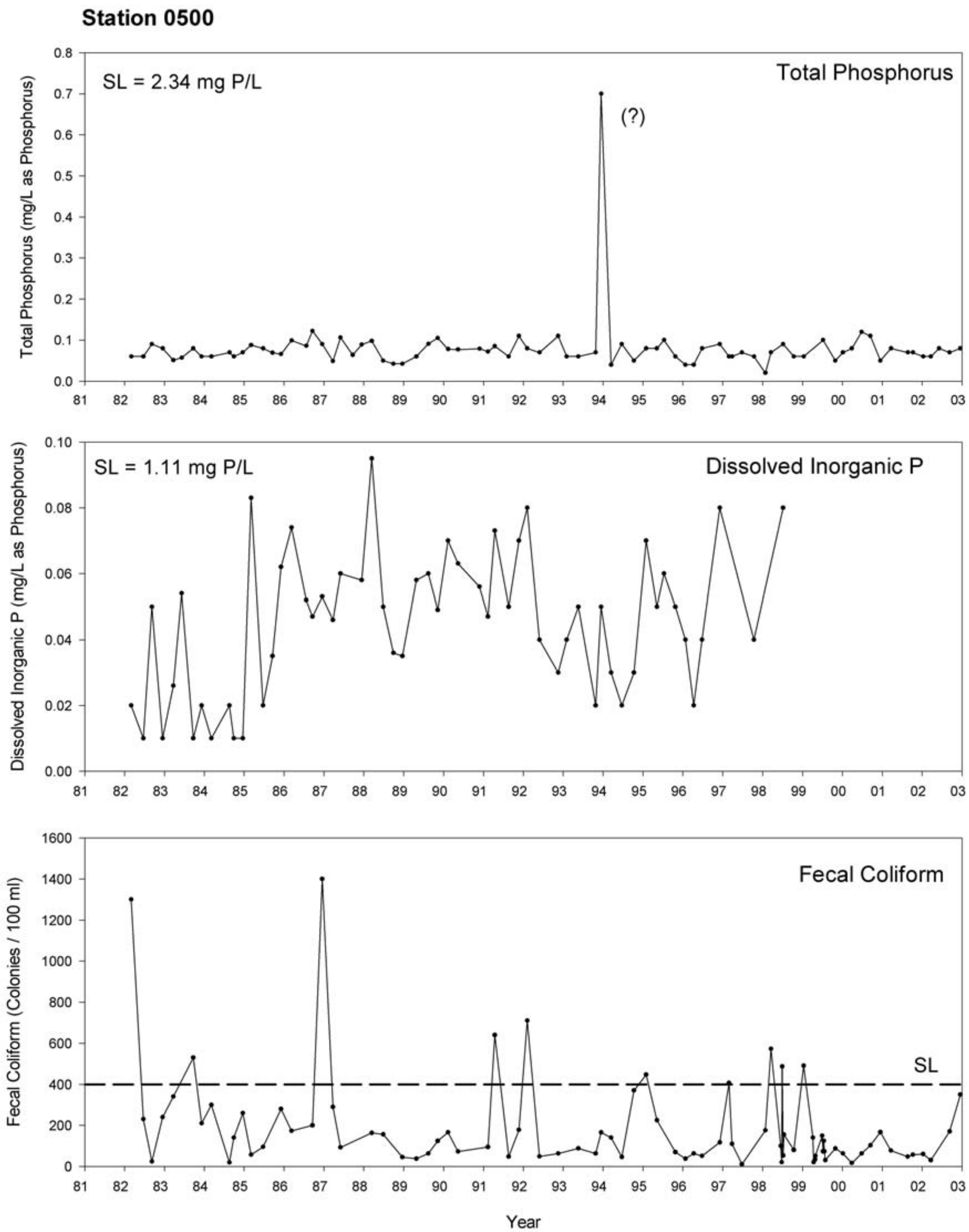


Figure 2.16 (continued). Temporal distribution of water quality parameters at Station 0500 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on Environmental Quality.

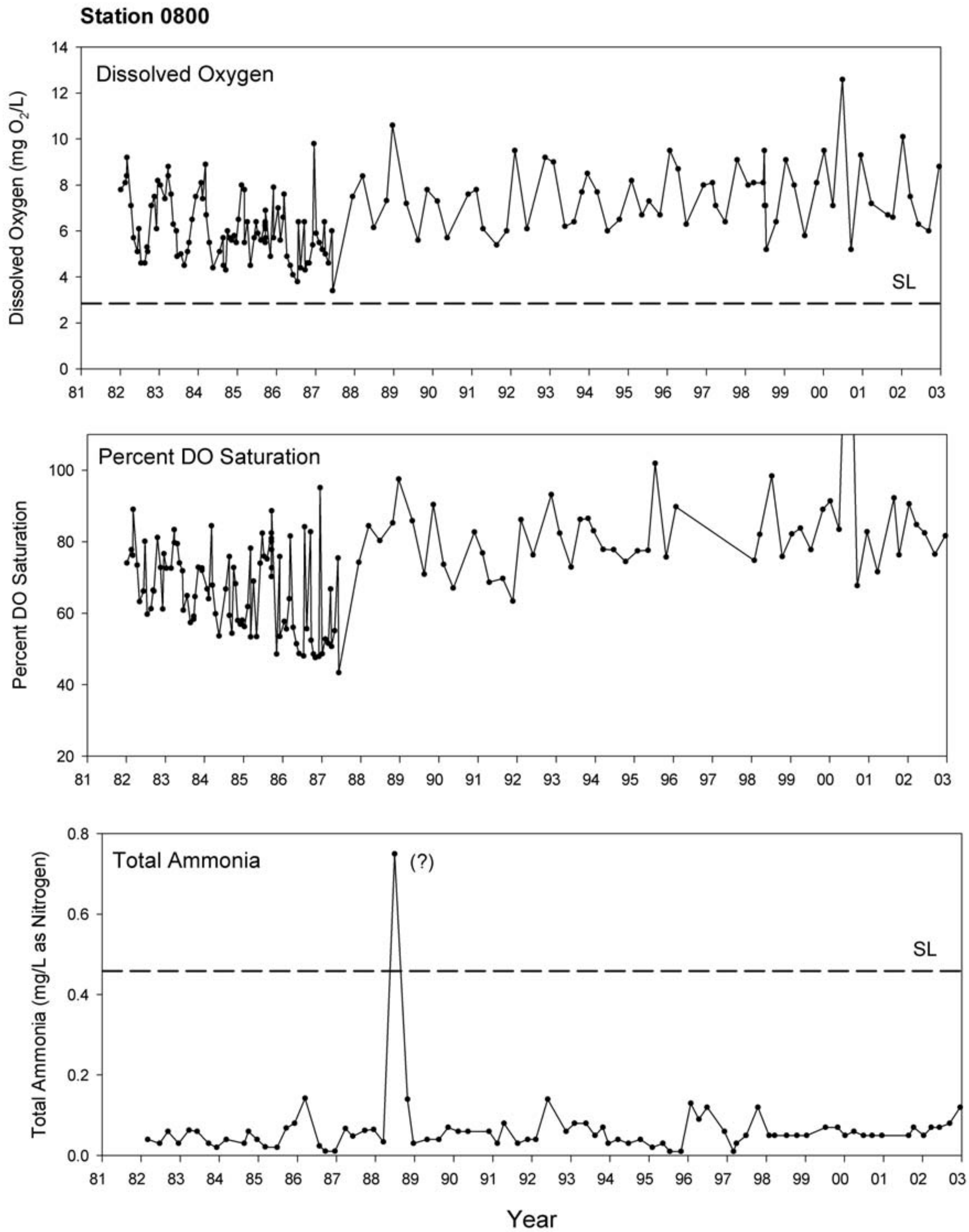


Figure 2.17. Temporal distribution of water quality parameters at Station 0800 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on Environmental Quality.

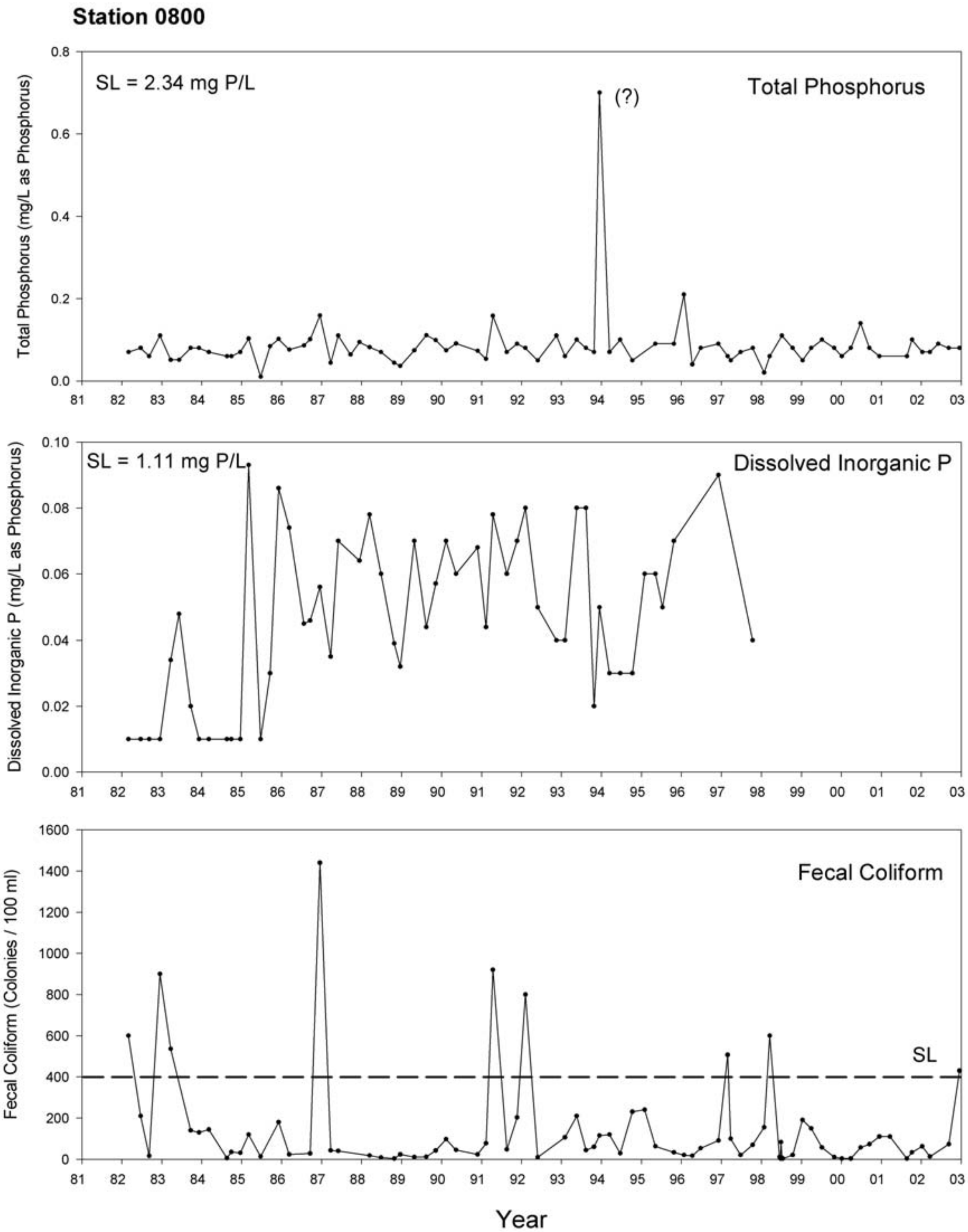


Figure 2.17 (continued). Temporal distribution of water quality parameters at Station 0800 in the lower tidal Neches River. The dashed line is the screen level (SL) concentration presented by the Texas Commission on Environmental Quality.

90% were frequently achieved throughout the period of record, a few samples of 90-110% were seen throughout the record, and changes in the frequency of low values were seen. This pattern can be detected by statistical regression. Because of the upper limit for % Sat, asymptotic patterns rather than linear patterns may be evident. Several asymptotic models were fit to the data, but these did not improve model fit. Other forms of regression (e.g., percentile regression) might be more sensitive to changes in frequency of low % Sat values and may be valuable in future analyses. In general, higher variance was seen in the earlier years of study (prior to 1988) than in later years (either all later years, or 1989-1992). This difference could reflect water quality conditions, but might also be methodological. For example, changes in instrumentation or protocols for selecting time-of-day of sampling could affect variance. Also, there was more frequent sampling during the early years, which might result in higher detection of short-term periods of low saturation.

Station 0100: A linear model (Table 2.11, Fig. 2.14) provided the best fit. The fit indicates an average increase of about 0.5% per year. The model was highly significant, but explained relatively little total variation. However, it must be noted that this data set was not corrected for salinity which may impact the results.

Station 0300: The data set contained one clear outlier with a very high value (around 160%), which is out of range and chemically or environmentally unreasonable. A second, low outlier was also present; this value is within range for the data set (and chemically reasonable), but well outside the range for the time period. These two points were removed prior to analysis. A linear model (Table 2.11, Fig. 2.15) provided the best fit, with an estimated average increase of about 0.7% per year. The data showed lower variance in the period 1989-1992. The model was highly significant, but explained relatively little total variation. However, it must be noted that this data set was not corrected for salinity which may impact the results.

Station 0500: As at Station 0300, the data set contained one very high, chemically unreasonable outlier and a second, low but in range outlier which were removed prior to analyses. A linear model provided the best fit (Table 2.11, Fig. 2.16), with an estimated average increase of about 1.1% per year. The data showed higher variation prior to 1988 than in later years.

Station 0800: The data set contained one high, chemically unreasonable outlier, which was removed prior to further analysis. A linear model provided the best fit (Table 2.11, Fig. 2.17), with an estimated average increase of about 0.9% per year. The data showed higher variation prior to 1988 than in later years.

Dissolved Ammonia (NH_4+NH_3): Based on minimal values for different periods, it appears that the detection limit increased after 1998. This can lead to the appearance of temporal increases in ammonia concentrations, which needs to be considered in interpreting trends.

Station 0100: There were two points with relatively high values (approx. 0.2 and 0.33 mg N/L), but is unclear whether these are outliers or taken during a runoff event or riverine biogeochemical processes. For all of the data, there is no trend over the period of record. However, there is an apparent increase in the detection limit (to 0.05 mg N/L) after 1997. The detection limit is near the long-term mean for the data, complicating trend analysis.

Station 0300: There was one clear outlier (0.45 mg N/L in 2002). Even after removing this value, there is no evidence of a temporal trend. There is an apparent increase in detection limit after 1997 as noted above.

Station 0500: There were four apparent outlier concentrations ranging from approximately 0.4 to 0.8 mg N/L. There is no evidence of a temporal trend, whether these points are included or not.

Station 0800: There was one clear outlier in the dataset (> 0.7 mg N/L). After removing this concentration, there is a small increasing trend, but this trend is created by an increased detection limit after 1997 (up to 0.05 mg/L).

Total Phosphorus (TP): There were limited data for TP for all stations over the years (Table 2.11; Figs. 2.14-2.17). There were only a few outliers in each of the stations which are listed below.

Station 0100: There is no evidence of any temporal trend in TP.

Station 0300: There was one clear high outlier concentration (approx. 0.45 mg P/L), and a possible low outlier concentration (0.01 mg P/L). There is no evidence of a temporal trend, with or without either of these points.

Station 0500: There is no evidence of any temporal trend in TP.

Station 0800: There was one clear outlier (0.07 mg P/L) and a possible second outlier value (0.21 mg P/L). Most of the concentrations were around 0.05 to 0.10 mg/L throughout the period of record (Table 2.11), and there was no indication of any temporal trend with all data points or with one or both outliers removed.

Fecal Coliform (FC): Fecal coliform data were transformed using the natural logarithm function. The transformed data were more normally distributed and there were weakly significant linear trends at Stations 0300 and 0500 (Table 2.11). Station 0300 did not have any obvious outliers while at Station 0500 a number of points were well above the other points. However, a number of data points followed the same pattern as the other points (i.e., weak decline). Both stations showed approximately the same rate of decline of approximately 4-5% each year.

Station 0100: No significant trend in FC.

Station 0300: There were no clear outliers in the data set. There was a weak significant trend in that the concentrations of FC decreased by approximately 4 to 5% per year.

Station 0500: A number of points were well above the other points, however most of these data followed the same pattern as the other points (i.e., weak decline). There was a weak significant trend in that the concentrations of FC decreased by approximately 4 to 5% per year.

Station 0800: No significant trend in FC.

Dissolved Inorganic Phosphorus (DIP): The DIP data tend to show lowest values at the start of the record, highest values toward the middle of the record and lower or variable values at the end of the record. The timing and strength of these apparent changes varies among the four stations, resulting in differences in model shape among stations.

Station 0100: There were several data points with relatively high values from the period 1985 to 1995. However, these data are not clear outlier concentrations and were not removed from the analysis. There is an apparent increase in DIP over time, with an estimated average increase of 0.0022 mg P/L per year. Nonlinear models did not provide appreciably better fits to the data. The trend reflects uniformly low values through 1990, with mostly higher values after 1990. However, there is no evidence of any change in detection limit. The highest data are near the middle of the record (around 1990), so that removing outliers would probably have relatively little effect on the estimated trend.

Station 0300: There was one apparent outlier, which was removed for further analysis. DIP showed low values through 1986, higher values from 1986 through 1992, and variable values after 1992. These data are best fit by nonlinear models, e.g., a parabolic model with a maximum around 1991 and lower values before and after, or a cubic model with low values rising to a maximum around 1988 and decreasing slightly through 2000.

Station 0500: The lowest values (all 0.01 mg P/L) were recorded in 1982-1985. These presumably reflect measurements at or below the detection limit. The absence of any later data with equally low concentrations could either reflect an increase in detection limit or an increase in concentrations. Including all the points, there is an apparent increasing trend of about 0.0014 mg/L per year. Deleting these points, the rate of increase is much smaller (0.0003 mg P/L per year), and the trend is only weakly significant ($p<0.03$).

Station 0800: There is a significant increase in DIP, with an estimated average increase of about 0.0026 mg P/L per year. However, the time series shows a pattern similar to that at the other stations, with lowest values in the early period, higher values near the middle of the record, and variable data in the later years. There are no data after 1998, obscuring long-term trends.

2.3 Summary

2.3.1 Basic Water Quality Parameters

The concentration of certain parameters was elevated in the lower tidal Neches River and in some cases above (or below in the case of dissolved oxygen) published water quality guidelines from the State of Texas (TCEQ 2000). This is evident with the concentrations of fecal coliform and dissolved oxygen. The distribution of most analytes, while limited with only four stations in a tidal system, indicate no particular source area to the river, suggesting that both inputs from upstream or non-point sources (e.g., urban runoff) are the predominant sources. In this regard, there were substantially higher flows recorded at the Barrier during this sampling period, as there was a significant rainfall prior to the sampling event. Discharges ranged from 11600 to 14700 cfs, almost 3 times higher than approximate average discharge prior to and after the sampling. The higher flows most likely resulted in more non-point source runoff with higher amounts of particulate matter and fecal coliform.

As a result of estuarine circulation (i.e., low density freshwater overriding higher density salt water) and the input of organic material to the river, dissolved oxygen concentrations decreased to near undetectable levels in parts of the tidal river. This is most evident in the mid-tidal portion at Stations 2 and 3 where dissolved oxygen concentrations decreased through the halocline to undetectable levels near the bottom (ca. 10-15 m). Two main sources of labile organic matter that are utilized by bacteria (i.e., biochemical oxygen demand) are inputs from upstream and facilities (i.e., petrochemical, processing and shipping) around the river and in situ production in the river itself (i.e., allochthonous versus autochthonous sources). The high amount of organic matter in the river is evident by the high levels of total organic carbon (TOC) and total Kjeldahl nitrogen (TKN). TOC averaged 10 mg C/L (range of 6.5 to 15 mg C/L), while TKN averaged 0.85 mg N/L (range of 0.4 to 4.8 mg N/L). These high levels of organic matter within the tidal river provide energy for bacterial growth and result in oxygen depletion in the bottom waters.

Currently, the lower Neches River (Segment 601) has been noted as having acceptable levels of fecal coliform for intermediate contact recreational use and sufficient levels of dissolved oxygen to be designated for intermediate aquatic life use (TCEQ, 2000). However, the sampling performed in mid-October of 2003 yielded values that are outside the bounds for these parameters. Texas Surface Water Quality Standards states that fecal coliform shall not equal or exceed 400 colonies per 100 ml in more than 10% of all samples, based on at least 5 samples, taken during any 30-day period. If 10 or fewer samples are analyzed, no more than 1 sample shall exceed 400 colonies per 100 ml. For fecal coliform abundances in October 2003, approximately 60% of the samples were above the State of Texas criterion (400 col per 100 ml). The level or rainfall and increased flows (see above) may have resulted in these exceedances of the criteria at this time. Given the recent historical level of excceedence for coliform (Figure 2.11), this segment should be evaluated for source reduction and monitoring should be continued.

Overall, this section of the lower tidal Neches River is moderately impacted, especially with fecal coliform and organic matter, the latter which can affect the oxygen balance. Bacterial indicators such as fecal coliform are also elevated in this section of the river and are at times above published screening levels. Dissolved oxygen in the near bottom waters is low and can impact the biological community in or near the bottom. Contaminants such as volatile organic compounds and trace metals do not appear to be elevated in the water and are close to the detection limits of the methods.

2.3.2 Long-Term Water Quality Analysis

There is no overall definition of trend for which monitoring programs can be designed. In the broadest sense, a trend may be considered as any change in the behavior of a variable over time. Trends may occur with respect to any of the attributes of temporal variation in an index: change in mean value, change in variance, change in auto-correlation of oscillatory behavior. This study deals largely with trends in mean concentrations and variance over a 20+ yr time period as these are of general interest to monitoring programs for the Neches River. The analysis of the temporal pattern of the concentration data from the tidal Neches River database focused on the identification of several types of trends: linear; quadratic or polynomial, and changes in variability (i.e., heteroscedasticity) of each parameter over time.

Due to the lack of sufficient monitoring data for trace elements, a statistically-based trend analysis cannot be completed. This is due to the low sampling frequency over a long enough time period, as well as low data quality in the earlier database.

Analysis of the near surface water dissolved oxygen saturation data indicate temporal trends over time at all stations with an increasing positive trend at most stations. For this section of the river there was an approximately 0.5 to 1% per year increase in oxygen saturation levels.

There was not sufficient dissolved nitrate+nitrite concentration data for additional trend analysis (see ANSP 1998). Dissolved ammonia concentrations were too variable to derive a statistically-based trend. In addition, the detection limit changes over the decades hinders the analysis. Total P concentrations were too variable to make a definite analysis of trend, while dissolved inorganic phosphorus showed a slight increasing trend in two stations in the upper tidal river. For fecal coliform, linear trends were significant at only two stations (Stations 0300 and 0500) and indicate a decrease in concentration over the time record. Lastly, although there are not many firm conclusions to be made based on the trend analysis, most of the data for each of the parameters (except fecal coliform) fall below the screening levels (SL) for the period of record (1981-2003).

Overall, to enable a better long-term analysis of data collected on the river, current monitoring programs should be evaluated and possibly redesigned with regard to determining long-term trends. In other words, do more samples need to be collected during the year and at what frequency, both temporal and spatial? This will help assure managers that specific control strategies are sufficient to improve water quality.

3. ALGAL STUDIES

3.1 Introduction

In estuarine and riverine ecosystems such as the Neches River near Beaumont, TX, algae are important as primary producers for essential materials and as substrate. Positioned at the base of the food chain, algae, through the process of photosynthesis, transform solar energy into a form utilized by other aquatic organisms. Oxygen, a by-product of this process, is also an essential element for other aquatic organisms. In addition, larger macroalgae serve as habitat and shelter for smaller invertebrates and fish.

Many algal forms, especially the diatoms, are useful as biological indicators of ecological conditions. The sessile, periphytic forms must be able to withstand changes in their environment. Because of the short generation times, algae respond relatively quickly to changes in water quality; established communities are presumed to be adapted to prevailing water quality conditions. Diatoms, in particular, exhibit a wide range of responses and are especially sensitive to dissolved nutrients, metals and organic compounds.

The purpose of the 2003 study was to characterize the periphytic or attached algae in the Neches River in the vicinity of Beaumont, TX. Comparisons were made with previous studies conducted in 1953, 1973 and 1996.

3.2 Methods

Methods used to collect attached algae or periphyton during the 2003 study were similar to previous studies, especially the 1996 study. As in previous studies, algal collections were made from all distinctive habitats at the four established stations on the Neches River near Beaumont, TX. To reduce the amount of natural variation among the four stations (due to habitat rather than water quality conditions), care was taken to collect several similar microhabitats under similar conditions (e.g., similar depth and flow) at each station. Field observations regarding notable habitats, general amounts of algal cover and relative proportions of major algal groups were recorded at the time of sampling for each station.

Because of the variety of microhabitats supporting algal growth, a number of collecting methods and techniques were used. Uniform, flat algal colonies on solid substrates (e.g., rocks and logs) were scraped and lifted with a pocket knife and scalpel. Forceps were used to collect filamentous and “streamer” algae on various substrates. Communities on unstable substrates (e.g., sand and mud) were collected with pipets and small turkey basters. Filamentous algal forms and tree roots and rootlets were placed in vials and shaken to separate epiphytic forms.

Collections were taken to a field laboratory for preliminary observations, preservation and sorting. Observations of untreated samples were made to establish the species, especially of the diatoms, that were living at the time of collection. In addition, some important diagnostic characteristics of filamentous and fragile forms are lost through preservation. Blue-green and other filamentous and macroalgal forms were dried onto herbarium cards and wrapped in packets. Diatoms subsamples were made by separating them from the collections with abundant diatoms; these samples were preserved with a couple drops of formaldehyde. The remainder of the samples were preserved with formaldehyde (3-5% final concentration).

In The Academy laboratories, diatom collections were prepared by cleaning the siliceous diatom frustules of organic material and mounting on glass slides. The digestions, utilizing nitric acid were made in a microwave apparatus (CEM model MDS-2100; ANS SOP P-13-42 "Diatom Cleaning by Nitric Acid Digestion With a Microwave Apparatus"). After the samples were washed of digestion salts (by rinsing and decanting with distilled water), the frustules were mounted on glass slides (Naphrax mounting medium; ANS SOP P-13-49 "Preparation of Diatom Slides Using Naphrax Mounting Medium"). These procedures clearly expose the diagnostic characteristics of the diatom cell wall and produce a permanent slide that can be reviewed far into the future. In addition, a composite slide for each station was made with the combined cleaned frustules from each sample.

Analysis of algal collections involved identification to the lowest possible taxonomic unit and determination of the relative abundance of the various algal populations. Samples other than diatoms were re-examined on wet mounts at 400x and 1000x. Further identifications were made by comparing with previous voucher collections (from 1953, 1956, 1960, 1973 and 1996) and specimens in The Academy herbarium. A general relative abundance ranking (rare, frequent, common, abundant or very abundant) was given to each non-diatom algal form.

Diatom communities were determined by identifying and enumerating frustules at 1000x magnification. Two hundred frustules were identified and enumerated on each slide from a specific habitat. The composited slide from each station was analyzed using a detailed reading method. The detailed reading method involves identifying and counting between approximately 3000 and 7500 frustules until a mathematical model of a truncated lognormal distribution could be fitted to the data (Patrick et al. 1954). The analytical techniques are the same as were used in the previous Neches studies and allow for comparison of 2003 data with previous surveys (1953, 1973 and 1996). To a certain extent, the data from this study are also comparable to data from diatometer studies (diatom communities growing on artificial substrates) conducted by The Academy in this area from 1954 through 1976.

3.3 Results

Results of the algal survey are mostly qualitative, comparing the relative abundances of the major forms observed. The substrate or microhabitat from which an algal community is collected is important when comparing the different sampling areas. Data from the composited diatom samples consist of the parameters of the lognormal curve (Table 3.1) and major diatom species (Table 3.2). A listing of the algal species observed during 2003 studies is included in Appendix 3.1. During the period between these studies and the previous studies, there were major changes in algal taxonomy, mostly for diatom species. A listing of diatom taxa name changes is presented in Appendix 3.2.

Table 3.1. Listing of lognormal curve parameters from composited periphyton samples collected in October 2003 from the Neches River near Beaumont, TX.

Station	Σ^2	Dispersion Factor	Position of Mode	Species In Mode	Observed Species	Species In Theoretical Universe
1	6.6	0.282	2.2	25.0	130	161.2
2	8.8	7.837	1.1	14.7	115	109.5
3	12.5	2.974	1.2	18.6	104	164.9
4	15.6	0.758	1.1	15.3	92	152.0

3.3.1 Detailed Reading Analysis

The diatom species abundance curves plotted for the composite sample from each station (i.e., lognormal curves; Figs. 3.1-3.4) indicate that diatom communities at the upstream station were richer in species and had more even species distributions than at the lower three

Table 3.2. Relative abundances of the most abundant diatoms (greater than 2% relative abundance) from composited periphyton samples collected in October 2003 from the Neches River near Beaumont, TX.

Diatom Taxa	Station 1	Station 2	Station 3	Station 4
Bacillaria paradoxa Gmelin	1.1	3.0	1.9	0.4
Berkeleya sp. 1 Idaho DW				2.5
Gyrosigma nodiferum (Grun.) Reim.	1.0	0.1	0.3	+
Luticola goeppertiana (Bleisch) Mann	0.1	0.4	4.7	0.8
Navicula arvensis Hustedt	6.1	+	+	0.4
Navicula erifuga Lange-Bert.	0.2	0.1	+	2.4
Navicula longicephala Hustedt	2.3	+	+	
Navicula recens Lange-Bert.	0.3	1.2	1.7	11.6
Navicula schroeteri var. *escambia* Patr.	10.3	0.2	+	0.1
Nitzschia amplectens Hustedt	+	4.5	38.8	23.9
Nitzschia archibaldii Lange-Bertalot	3.5	0.1	0.1	0.3
Nitzschia brevissima Grun. in V. H.	1.6	13.2	2.0	0.1
Nitzschia clausii Hantz.	6.4	0.7	1.9	15.0
Nitzschia filiformis (W. Sm.) V. H.	3.7	8.1	6.1	0.1
Nitzschia filiformis var. *conferta* (Reich.) Lange-	0.5	20.6	3.4	12.5
Nitzschia liebethruthii Rabenhorst	1.5	5.4	4.8	0.2
Nitzschia lorenziana Grunow	6.7	+	+	+
Nitzschia palea (Kützing) Smith	5.8	0.2	0.6	0.2
Nitzschia perminuta (Grun.) Peragallo	0.7	1.3	2.5	1.5
Opephora martyi Hérib.	+	1.4	1.1	2.6
Planothidium delicatulum (Kützing) Round et	0.1	0.8	0.4	4.2
Staurosira construens var. *venter* (Ehr.)	0.9	3.0	1.4	1.1
Synedra rumpens var. *fragilarioides* Grunow	2.7	+		
Tabularia fasciculata (Ag.) Williams and Round	10.0	27.9	16.9	9.5

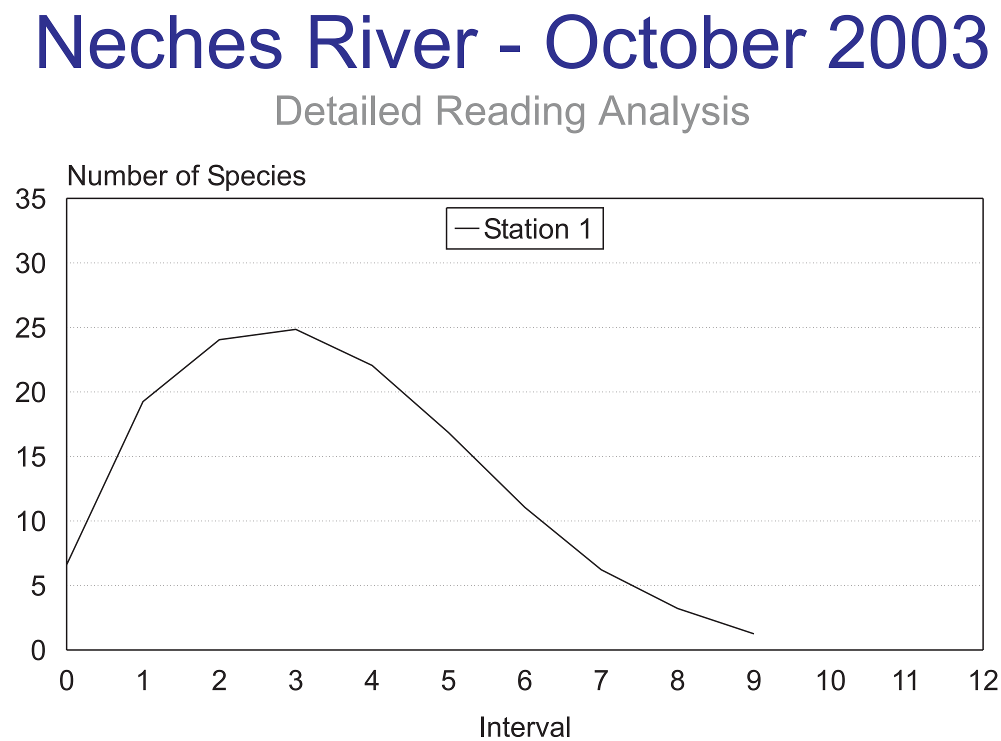


Figure 3.1. Frequency distribution from the detailed reading of diatom species at Station 1 on the Neches River, 2003.

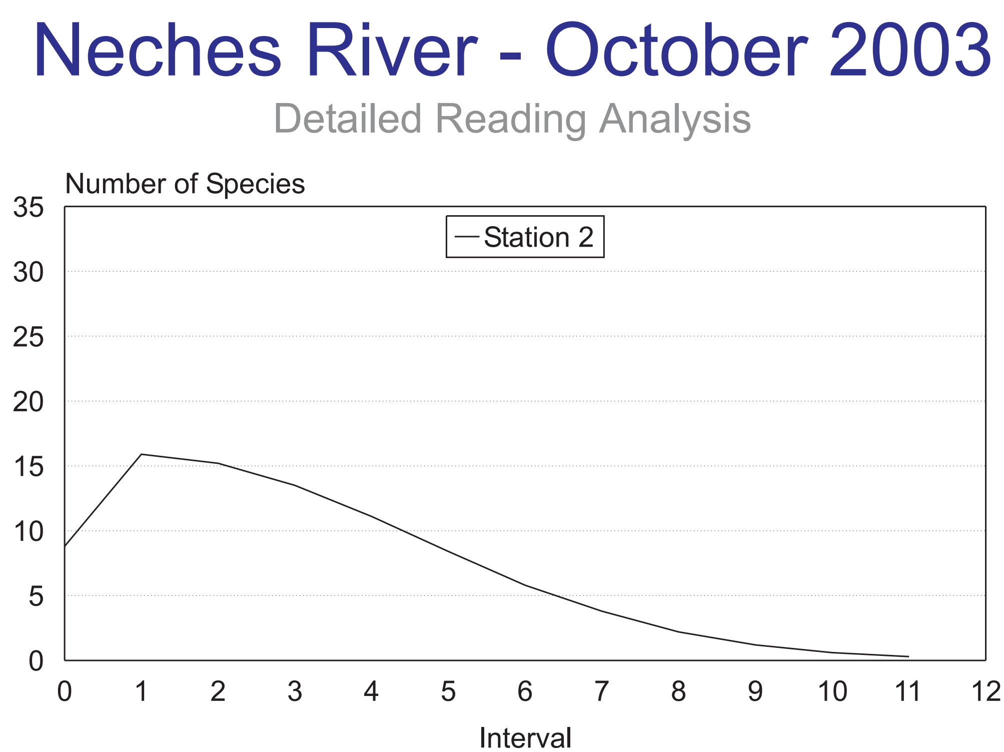


Figure 3.2. Frequency distribution from the detailed reading of diatom species at Station 2 on the Neches River, 2003.

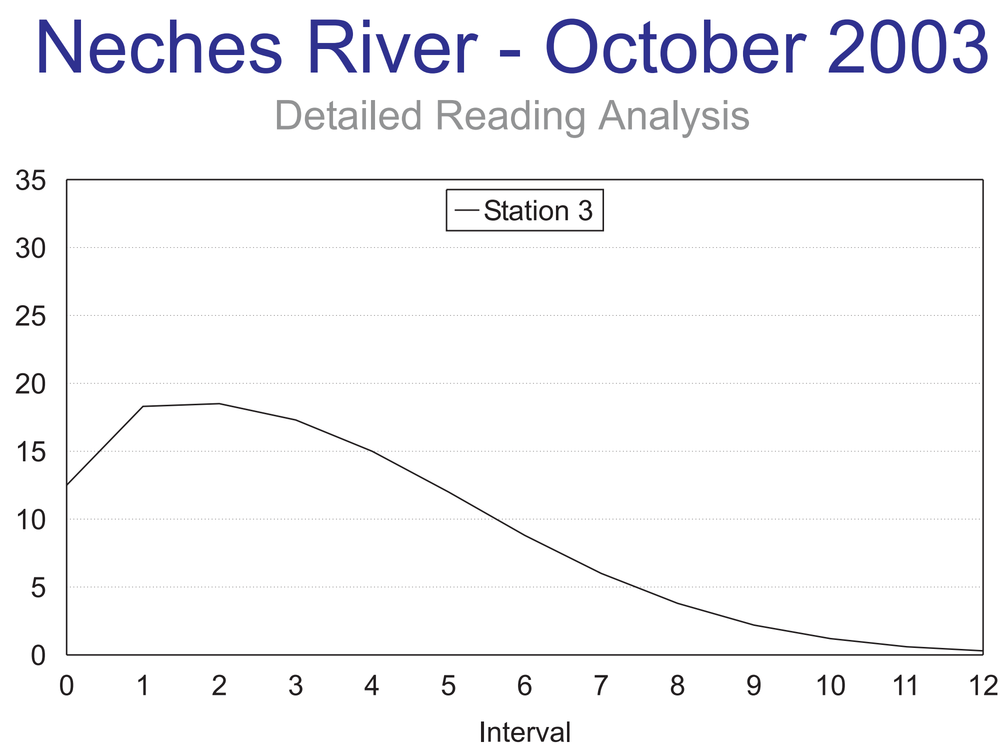


Figure 3.3. Frequency distribution from the detailed reading of diatom species at Station 3 on the Neches River, 2003.

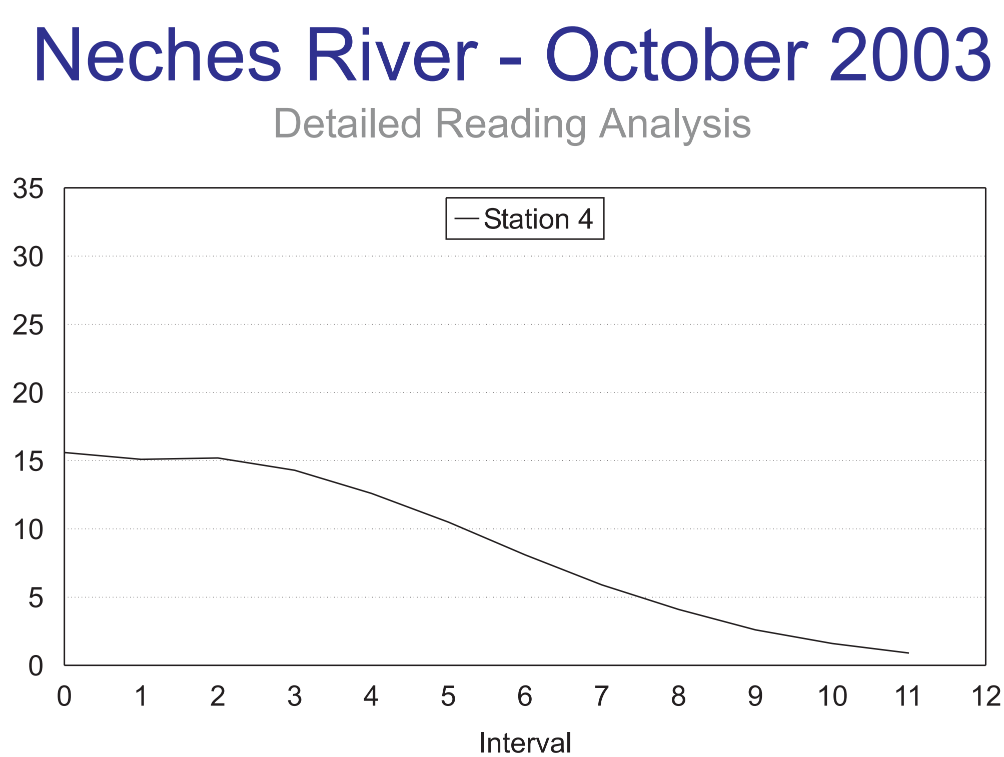


Figure 3.4. Frequency distribution from the detailed reading of diatom species at Station 4 on the Neches River, 2003.

stations. The higher species richness was indicated by more species in the mode (25, 16, 19 and 15 species at Stations 1, 2, 3 and 4, respectively) and more species in the completed lognormal curves (number of observed species was 130, 115, 104 and 92 species, at Stations 1, 2, 3 and 4, respectively). The length of the completed lognormal curves (lognormal curves covered 9, 11, 12 and 11 intervals at Stations 1, 2, 3 and 4, respectively) and relative abundances of the dominant species (highest species relative abundance of 10, 28, 39 and 24% at Stations 1, 2, 3 and 4, respectively) demonstrate the difference in the evenness of diatom species distributions.

As was noted in the previous report and earlier studies (including diatometer monitoring of the Neches River), the number of periphyton species in brackish waters is naturally lower than in fresh waters. Dominance, as observed in the previous Neches study (ANSP 1998) and noted by the number of species in the tail of the lognormal curve (i.e., species beyond the 10th interval), was much lower in the 1996 and 2003 studies, especially compared with earlier surveys where one or two populations composed 60 to 80% of the diatom communities.

3.3.2 Station 1

A light to moderate mixture of blue-greens and diatoms were the predominant algal forms observed at Station 1. The small filamentous forms, *Pseudanabaena* sp. and *Phormidium autumnale* (synonymous with the taxon *Schizothrix calcicola* observed in previous surveys) along with the larger *Lyngbya martensiana*, formed light sheens on the clayey bank and with sediments on various substrates (plant stems, tree bases, logs, etc.). Diatom populations were associated with the blue-green sheens and were abundant in the submerged area 2 or 3 ft below the shoreline. Additionally, at Station 1, the yellow-green alga *Vaucheria* sp. formed several velvety patches on sandy substrates.

Although there were several very specific diatom populations, in general the diatom communities fell into two categories, probably related to amounts of sediment. There were several large populations of *Synedra*-like species, *Synedra rumpens* var. *fragilarioides* and *Tabularia fasciculata* (listed as

Synedra fasciculata in previous studies), around the stems of aquatic plants and associated with areas of the least sedimentation. In the more heavily sedimented areas there were several populations of *Nitzschia* (*N. clausii* and *N. lorenziana*) and *Navicula*-like (*Navicula schroeteri* var. *escambia* and *Diadesmis contenta* [previously *Navicula contenta* var. *biceps*) species.

The composited diatom sample consisted of 66 species (a species is listed if it occurred 6 or more times in the completed detailed reading), the majority being *Nitzschia* and *Navicula*-like species (68%) with notable *Synedra*-like populations (13%). Only two species, *Navicula schroeteri* (10%) and *Tabularia fasciculata* (10%), composed 10% or more of the composited sample. An analysis of diatom communities at Station 1 for pollution tolerance (Patrick and Palavage 1994) shows that 28 species are tolerant of pollution and 27 are characteristically found in natural waters (11 species found at Station 1 were not rated).

3.3.3 Station 2

Blue-green algae were abundant and dominant in most collections from Station 2. The filamentous blue-greens *Geitlerinema splendidum* and *Microcoleus chthonoplastes* formed several moss-like communities in lightly sedimented areas near aquatic plants and trees. Other filamentous blue-greens, including *Lyngbya martensiana* and *Phormidium* sp., formed sheens mixed with moderate to heavy sediments. The red alga *Calogassa* sp. was found attached to the ends of twigs and roots near the base of trees.

Diatoms were common and abundant usually associated with the heavy sediment. There were several large populations of *Nitzschia*, *N. filiformis*, *N. brevissima*, *N. filiformis* var. *conferta* and *N. perminuta*, especially in the heavily sedimented areas near the bases of the trees. Similar to Station 1, populations of *Tabularia fasciculata* were found near the stems and roots of aquatic plants.

The composited diatom sample consisted of 37 species composed mostly of *Nitzschia* and *Synedra*-like species (84%).

Populations larger than 20% included *Tabularia fasciculata* (28%) and *Nitzschia filiformis* var. *contenta* (21%); *Nitzschia brevissima* composed 13% of the composited sample. At Station 2, there were 17 diatom species tolerant of pollution and 12 diatom species characteristic of natural waters (8 species were not rated).

3.3.4 Station 3

Throughout Station 3 blue-green algal communities were moderate to abundant; smaller communities of diatoms and red algae were encountered frequently, however usually in more shaded areas. The filamentous blue-green *Lyngbya martensiana,* and to a lesser extent, *Phormidium* sp., formed populations in nearly every habitat (areas of lightest sedimentation were an exception). Populations of the blue-greens *Microcoleus chthonoplastes* and *Geitlerinema splendidum* were found, usually in the few areas of lesser sedimentation. The red alga *Calogassa* sp. was found in moderate flow near the base of trees. Small, but notable populations of the heterocystic blue-greens *Microchaete tenera* and *Nostoc* formed a sheen on a log without much sediment.

Diatom communities were not as readily apparent at Station 3 as at the other stations. Diatoms were most often associated with tree roots and rootlets and with plants. *Tabularia fasiciculata* was abundant in nearly every diatom sample, especially in the limited amount of algae at the base of reeds and on lightly sedimented objects near the waterline. Similarily, *Nitzschia amplectens* formed several notable populations on objects without much sediment, in moderate flow. *Cocconeis fluviatilis* was found in the roots and rootlets of trees and aquatic plants.

The composited diatom sample consisted of 37 species composed almost completely (91%) of *Nitzschia*, *Navicula*-like and *Synedra*-like species. The largest populations consisted of *Nitzschia amplectens* (39%) and *Tabularia fasciculata* (17%). There were 16 diatom species tolerant of pollution and 10 diatom species characteristic of natural waters (11 species were not rated) at Station 3.

3.3.5 Station 4

Algal communities at Station 4 were mostly diatoms, with several distinct red algal growths and light blue-green growths. The red alga *Polysiphonia* sp. was found several times as net-like material near the base of trees within the "splash-zone" area. Also within this splash zone area, including the bases of reeds, the blue-green filamentous forms *Lyngbya martensiana* and *Lyngbya diguetii* formed notable populations. The smaller blue-green filaments *Microcoleus chthonoplastes* and *Geitlerinema splendidum* formed an abundant population on a lightly sedimented log. The green alga *Enteromorpha* sp. was a bright green amongst aquatic plants.

Many of the diatom communities were unique, found in a specific habitat. *Navicula recens* and *Nitzschia clausii* were found on clayey sediments in the "splash-zone" area; similarly *Planothidium delicatula* (previously named *Achnanthes hauckiana*) was found near a sandbar affected by wave action. *Nitzschia amplectens* populated a lightly sedimented log. *Tabularia fasciculata* was more widespread, found similar to its distribution at the other stations, around and on the stems of aquatic plants, sometimes with sediment.

Forty-seven (47) species were found in the composited sample from Station 4; the sample was composed mostly of *Nitzschia* (57%). *Navicula* (19) and *Synedra*-like (10%) species. Several species formed populations of (10%) or more including *Nitzschia amplectens* (24%), *Nitzschia clausii* (15%), *Nitzschia filiformis* var. *conferta* (13%), *Navicula recens* (12%) and *Tabularia fasciculata* (10%). For the composited sample from Station 4, 20 species are tolerant of pollution and 12 species are characteristic of natural waters (14 were not rated).

3.4 Discussion

Comparison of algal communities in the Neches River near Beaumont, TX involves using several factors, including the amount of algae, its major groups, the number of taxa (species richness) and the amount of dominance by one or a few taxa. Large algal growths, especially of blue-green algae, are usually indicative of enrichment. Algal communities are considered more balanced, and thus "healthier" when there is an increased number of taxa and less dominance by one or a few taxa.

During the 2003 survey, similar to the previous survey (1996), blue-green algal growths were indicative of enrichment effects. It would appear that this enrichment was less at Station 1 due to less dominance of blue-greens in 2003 as compared with 1996. However, high water submerged many of the habitats sampled in 1996 (and previous surveys) and there were very abundant algal growths at 2-3 ft depth. Stations 2 and 3 were probably a little more enriched in comparison with 1996, but probably not as much as in previous studies (1953 and 1973). Blue-greens were more dominant in 2003 at Stations 2 and 3, however, there was no notable increase in overall amounts of algae. Algal communities at Station 4 in 2003 were similar to the previous study in 1996 with small amounts of blue-green algae, an improvement over earlier studies in 1953 and 1973. The ratio of pollution-tolerant diatom species to diatom species characteristic of natural waters decreased at all stations, especially at Stations 2 and 3 (ratios in 2003 were 28:27, 17:12, 16:10 and 20:12 at Stations 1, 2, 3 and 4, respectively).

During the 2003 survey, the number of algal taxa (Table 3.3) was similar to the 1996 study at Stations 1 and 4, probably indicating that there were few changes in water quality between the years. However, there was a lower number of algal taxa at Stations 2 and 3, probably reflecting lessened water quality conditions. The percentage of the raphid diatom forms *Nitzschia* and *Navicula* used as an indicator of sediment load (i.e., higher numbers of raphid forms indicates higher sedimentation) continued to be high, ranging from 56 to 74% (range of 69-81% in 1996, however only 10-60% in 1973). The amounts of sediment on substrates influenced the algal species distributions, with some forms found more often where sediment build-up was lower than other substrates.

There was less dominance by a few species in the 2003 study in comparison with the early studies (1953 and 1973). However, at Stations 2 and 3 dominance by a few species was

Table 3.3. Comparison of the number of algal species collected from the Neches River near Beaumont, TX in 1953, 1973, 1996 and 2003.

	Station 1				Station 2				Station 3				Station 4			
	1953	1973	1996	2003	1953	1973	1996	2003	1953	1973	1996	2003	1953	1973	1996	2003
Chlorophyceae (green algae)	4	4	4	6	4	3	5	2	1	4	4	5	0	3	4	1
Chrysophyceae (yellow-green algae)	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Bacillariophyceae (diatoms)	65	39	68	66	10	59	54	37	23	56	47	37	31	25	50	46
Myxophyceae (blue-green algae)	8	3	5	8	5	5	4	6	5	5	4	8	5	7	3	9
Rhodophyceae (red algae)	0	2	1	1	0	0	1	1	0	0	1	1	0	0	1	1
Dinophyceae (dinoflagellates)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Euglenophyceae (euglenoids)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

greater in 2003 than in 1996. In 2003, all except one population was less than 15% at Stations 1 and 4, which is very similar to the 1996 study. However, there were several populations of 20% or greater at Stations 2 and 3 (maximum of 39%) in 2003, which is still less than populations which commonly exceeded 50% in studies prior to 1996.

In summary, studies of the algal communities on the Neches River near Beaumont, TX in 2003 revealed a few changes compared with the results of the previous survey in 1996. However, improved conditions, indicated by more balanced algal communities in 1996 compared with earlier studies in 1953 and 1973, were still observed in 2003. Algal communities at Stations 1 and 4 had similar numbers of species and species dominance compared with 1996; algal communities in 1996 at these stations represented improved water quality conditions from similar surveys conducted in 1953 and 1973. At Stations 2 and 3, diatom species richness was decreased and species dominance increased in comparison with 1996. Both of these results indicate less balanced algal communities in 2003 at Stations 2 and 3 than in 1996. Although the number of diatom species is lower in 2003 than 1973 at Stations 2 and 3, overall improvements in species dominance, relative importance of diatoms as opposed to blue-greens and lessened overall amounts of algae, represent improved conditions in 2003 when compared with the early surveys in 1973 and 1953.

Appendix 3.1 Listing of algal species in the composited samples from the October 2003 surveys on the Neches River near Beaumont, TX.

	Station			
	1	2	3	4
Taxon Name				
Bacillariophyta (Diatoms)				
Achnanthes conspicua Mayer		+		
Achnanthidium minutissimum (Kützing) Czarnecki	+			
Amphipleura pellucida (Kützing) Kützing	+			
Amphora acutiuscula Kützing		+	+	+
Amphora copulata (Kützing) Schoeman et Archibald		+	+	
Aulacoseira ambigua (Grunow) Simonsen	+			
Aulacoseira granulata (Ehrenberg) Simonsen	+			
Bacillaria paradoxa Gmelin	+	+	+	+
Berkeleya sp. 1 Idaho DW				+
Caloneis bacillum (Grunow) Cleve	+			
Capartogramma crucicula (Grunow ex Cleve) Ross	+			
Cocconeis fluviatilis Wallace		+		
Cyclotella meneghiniana Kützing	+	+	+	+
Cylindrotheca gracilis (Brébisson) Grunow				+
Cymatosira belgica Grunow				+
Cymbella sp. 6 ANS WRC		+	+	+
Denticula subtilis Grunow	+			
Diadesmis confervacea Kützing	+	+		
Diadesmis contenta (Grunow ex Van Heurck) Mann	+			+
Diploneis ovalis (Hilse ex Rabenhorst) Cleve			+	
Diploneis parma Cleve	+	+	+	+
Diploneis subovalis Cleve		+		
Encyonema silesiacum (Bleisch) Mann	+			
Entomoneis alata (Ehrenberg) Ehrenberg			+	
Fallacia omissa (Hustedt) Mann				+
Fallacia tenera (Hustedt) Mann	+	+	+	+
Fragilaria capucina Desmazières	+			
Fragilaria cassubica Witkowski et Lange-Bertalot			+	
Fragilaria crotonensis Kitton	+			
Fragilaria vaucheriae (Kützing) Petersen	+			
Frustulia crassinervia (Brébisson) Lange-Bertalot et Krammer	+			
Gomphonema parvulum (Küting) Kützing	+			
Gyrosigma nodiferum (Grunow) Reimer	+		+	
Hippodonta lueneburgensis (Grunow) Lange-Bertalot, Metzeltin et Witkowski	+	+	+	+
Luticola goeppertiana (Bleisch) Mann		+	+	+
Luticola nivalis (Ehrenberg) Mann			+	
Mayamaea atomus (Kützing) Lange-Bertalot	+			
Navicula arvensis Hustedt	+			+
Navicula biconica Patrick	+			
Navicula cryptocephala Kützing	+			
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot.	+	+		+
Navicula diluviana Krasske				+

	Station			
	1	2	3	4
Navicula erifuga Lange-Bertalot	+			+
Navicula germainii Wallace	+			
Navicula gregaria Donkin	+	+	+	+
Navicula longicephala Hustedt	+			
Navicula luciae Witkowski et Lange-Bertalot				+
Navicula recens Lange-Bertalot	+	+	+	+
Navicula rostellata Kützing	+			
Navicula schroeteri var. *escambia* Patrick	+	+		+
Navicula symmetrica Patrick	+			
Navicula tenelloides Hustedt				+
Navicula veneta Kützing	+			
Nitzschia acicularis (Kützing) Smith	+			
Nitzschia amphibia Grunow	+			
Nitzschia amplectens Hustedt		+	+	+
Nitzschia archibaldii Lange-Bertalot	+	+		+
Nitzschia bita Hohn et Hellerman	+			
Nitzschia brevissima Grunow ex Van Heurck	+	+	+	+
Nitzschia cf. *sigmaformis* Hustedt				+
Nitzschia clausii Hantzsch	+	+	+	+
Nitzschia fasciculata (Grunow) Grunow ex Van Heurck	+	+		+
Nitzschia filiformis (Wm. Smith) Van Heurck	+	+	+	+
Nitzschia filiformis var. *conferta* (Reichardt) Lange-Betralot	+	+	+	+
Nitzschia fonticola Grunow	+			
Nitzschia frustulum (Kützing) Grunow	+			
Nitzschia inconspicua Grunow				+
Nitzschia liebethruthii Rabenhorst	+	+	+	+
Nitzschia lorenziana Grunow	+			
Nitzschia nana Grunow ex Van Heurck				+
Nitzschia obtusa Wm. Smith	+	+	+	+
Nitzschia palea (Kützing) Smith	+	+	+	+
Nitzschia paleacea Grunow ex Van Heurck			+	
Nitzschia perminuta (Grunow) Peragallo	+	+	+	+
Nitzschia prolongata var. *hoehnkii* (Hustedt) Lange-Bertalot			+	+
Nitzschia recta Hantzsch ex Rabenhorst	+			
Nitzschia scalpelliformis Grunow				+
Nitzschia sociabilis Hustedt		+	+	+
Nitzschia subacicularis Hustedt	+			
Nitzschia subcohaerens var. *scotica* Grunow	+	+	+	+
Opephora martyi Héribaud		+	+	+
Placoneis gastrum (Ehrenberg) Mereschkowsky	+			
Planothidium delicatulum (Kützing) Round et Bukhtiyarova		+	+	+
Pleurosira laevis (Ehrenberg) Compere		+	+	
Sieminskia zeta (Brockmann) Metzeltin et Lange-Bertalot		+	+	
Simonsenia delognei (Grunow) Lange-Bertalot	+			
Staurosira construens var. *venter* (Ehrenberg) Hamilton	+	+	+	+
Staurosirella pinnata (Ehrenberg) Williams et Round	+			

	Station			
	1	2	3	4
Navicula erifuga Lange-Bertalot	+			+
Navicula germainii Wallace	+			
Navicula gregaria Donkin	+	+	+	+
Navicula longicephala Hustedt	+			
Navicula luciae Witkowski et Lange-Bertalot				+
Navicula recens Lange-Bertalot	+	+	+	+
Navicula rostellata Kützing	+			
Navicula schroeteri var. *escambia* Patrick	+	+		+
Navicula symmetrica Patrick	+			
Navicula tenelloides Hustedt				+
Navicula veneta Kützing	+			
Nitzschia acicularis (Kützing) Smith	+			
Nitzschia amphibia Grunow	+			
Nitzschia amplectens Hustedt		+	+	+
Nitzschia archibaldii Lange-Bertalot	+	+		+
Nitzschia bita Hohn et Hellerman	+			
Nitzschia brevissima Grunow ex Van Heurck	+	+	+	+
Nitzschia cf. *sigmaformis* Hustedt				+
Nitzschia clausii Hantzsch	+	+	+	+
Nitzschia fasciculata (Grunow) Grunow ex Van Heurck	+	+		+
Nitzschia filiformis (Wm. Smith) Van Heurck	+	+	+	+
Nitzschia filiformis var. *conferta* (Reichardt) Lange-Betralot	+	+	+	+
Nitzschia fonticola Grunow	+			
Nitzschia frustulum (Kützing) Grunow	+			
Nitzschia inconspicua Grunow				+
Nitzschia liebethruthii Rabenhorst	+	+	+	+
Nitzschia lorenziana Grunow	+			
Nitzschia nana Grunow ex Van Heurck				+
Nitzschia obtusa Wm. Smith	+	+	+	+
Nitzschia palea (Kützing) Smith	+	+	+	+
Nitzschia paleacea Grunow ex Van Heurck			+	
Nitzschia perminuta (Grunow) Peragallo	+	+	+	+
Nitzschia prolongata var. *hoehnkii* (Hustedt) Lange-Bertalot			+	+
Nitzschia recta Hantzsch ex Rabenhorst	+			
Nitzschia scalpelliformis Grunow				+
Nitzschia sociabilis Hustedt		+	+	+
Nitzschia subacicularis Hustedt	+			
Nitzschia subcohaerens var. *scotica* Grunow	+	+	+	+
Opephora martyi Héribaud		+	+	+
Placoneis gastrum (Ehrenberg) Mereschkowsky	+			
Planothidium delicatulum (Kützing) Round et Bukhtiyarova		+	+	+
Pleurosira laevis (Ehrenberg) Compere		+	+	
Sieminskia zeta (Brockmann) Metzeltin et Lange-Bertalot		+	+	
Simonsenia delognei (Grunow) Lange-Bertalot	+			
Staurosira construens var. *venter* (Ehrenberg) Hamilton	+	+	+	+
Staurosirella pinnata (Ehrenberg) Williams et Round	+			

	Station			
	1	2	3	4
Navicula erifuga Lange-Bertalot	+			+
Navicula germainii Wallace	+			
Navicula gregaria Donkin	+	+	+	+
Navicula longicephala Hustedt	+			
Navicula luciae Witkowski et Lange-Bertalot				+
Navicula recens Lange-Bertalot	+	+	+	+
Navicula rostellata Kützing	+			
Navicula schroeteri var. *escambia* Patrick	+	+		+
Navicula symmetrica Patrick	+			
Navicula tenelloides Hustedt				+
Navicula veneta Kützing	+			
Nitzschia acicularis (Kützing) Smith	+			
Nitzschia amphibia Grunow	+			
Nitzschia amplectens Hustedt		+	+	+
Nitzschia archibaldii Lange-Bertalot	+	+		+
Nitzschia bita Hohn et Hellerman	+			
Nitzschia brevissima Grunow ex Van Heurck	+	+	+	+
Nitzschia cf. *sigmaformis* Hustedt				+
Nitzschia clausii Hantzsch	+	+	+	+
Nitzschia fasciculata (Grunow) Grunow ex Van Heurck	+	+		+
Nitzschia filiformis (Wm. Smith) Van Heurck	+	+	+	+
Nitzschia filiformis var. *conferta* (Reichardt) Lange-Betralot	+	+	+	+
Nitzschia fonticola Grunow	+			
Nitzschia frustulum (Kützing) Grunow	+			
Nitzschia inconspicua Grunow				+
Nitzschia liebethruthii Rabenhorst	+	+	+	+
Nitzschia lorenziana Grunow	+			
Nitzschia nana Grunow ex Van Heurck				+
Nitzschia obtusa Wm. Smith	+	+	+	+
Nitzschia palea (Kützing) Smith	+	+	+	+
Nitzschia paleacea Grunow ex Van Heurck			+	
Nitzschia perminuta (Grunow) Peragallo	+	+	+	+
Nitzschia prolongata var. *hoehnkii* (Hustedt) Lange-Bertalot			+	+
Nitzschia recta Hantzsch ex Rabenhorst	+			
Nitzschia scalpelliformis Grunow				+
Nitzschia sociabilis Hustedt		+	+	+
Nitzschia subacicularis Hustedt	+			
Nitzschia subcohaerens var. *scotica* Grunow	+	+	+	+
Opephora martyi Héribaud		+	+	+
Placoneis gastrum (Ehrenberg) Mereschkowsky	+			
Planothidium delicatulum (Kützing) Round et Bukhtiyarova		+	+	+
Pleurosira laevis (Ehrenberg) Compere		+	+	
Sieminskia zeta (Brockmann) Metzeltin et Lange-Bertalot		+	+	
Simonsenia delognei (Grunow) Lange-Bertalot	+			
Staurosira construens var. *venter* (Ehrenberg) Hamilton	+	+	+	+
Staurosirella pinnata (Ehrenberg) Williams et Round	+			
Stephanodiscus minutulus (Kützing) Cleve et Moller	+			
Surirella splendida (Ehrenberg) Kützing			+	
Surirella stalagma Hohn et Hellerman	+			
Synedra acus Kützing	+			
Synedra rumpens var. *fragilarioides* Grunow	+			
Synedra ulna (Nitzsch) Ehrenberg	+			
Tabularia fasciculata (Agardh) Williams et Round	+	+	+	+
Thalassiosira eccentrica (Ehrenberg) Cleve				+
Thalassiosira oestrupii (Ostenfeld) Hasle				+
Thalassiothrix sp. 1 Idaho DW		+	+	
Tryblionella apiculata Gregory	+			
Tryblionella levidensis Wm. Smith	+			
number of diatom taxa:	66	37	37	46

	Station			
	1	2	3	4
Cyanophyta (Blue-Green Algae)				
Aphanothece stagnina (Sprengel) A. Braun	+			
Calothrix parietina (Nägeli) Thuret			+	
Geitlerinema splendidum (Greville) Anagnostidis	+	+	+	+
Heteroleibleinia sp.	+			
Hydrococcus rivularis Kützing		+		+
Leptolyngbya sp.	+	+	+	+
Lyngbya diguetii Gomont				+
Lyngbya maior (Meneghini) Gomont				+
Lyngbya martensiana (Meneghini) Gomont	+	+	+	+
Microchaete tenera (Thuret) Bornet et Flahault			+	
Microcoleus chthonoplastes (Thuret) Gomont	+	+	+	+
Nostoc sp.			+	
Pleurocapsa sp.				+
Phormidium autumnale (C. Agardh) Gomont	+			
Phormidium sp.		+	+	+
Pseudanabaena sp.	+			
number of blue-green algae taxa:	8	6	8	9
Chrysophyta (Yellow-Green Algae)				
Vaucheria sp.	+			
Chlorophyta (Green Algae)				
Cladophora glomerata (Linnaeus) Kützing	+		+	
Cosmarium granatum Brébisson ex Ralfs	+			
Enteromorpha sp.			+	+
Mougeotia sp.	+	+	+	
Oedogonium sp.	+			
Spirogyra sp.	+	+	+	
Stigeoclonium lubricum (Dillwyn) Kützing	+			
Ulothrix zonata (Weber et Mohr) Kützing			+	
number of green algae taxa:	6	2	5	1
Rhodophyta (Red Algae)				
Calogassa sp.		+	+	
Polysiphonia sp.				+
Florideophycidae (chantransia)	+			
number of red algae taxa:	1	1	1	1

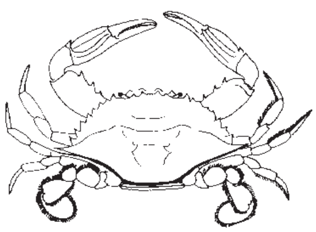
Appendix 3.2. Listing of diatom taxonomic changes between algal surveys conducted in 1996 and 2003. Most changes represent new taxon designations (i.e., an updating of taxonomy). However, there were several taxa that were combined together and several taxa that were split. In addition, corrections were made to insure that consistent taxonomy was used in both years.

Name Used in 2003	Name Used in 1996
Achnanthes cf. lemmermannii Idaho DW Hustedt	Achnanthes hauckiana Grunow
Achnanthidium exiguum (Grunow) Czarnecki	Achnanthes exigua Grunow
Achnanthidium exiguum (Grunow) Czarnecki	Achnanthes exigua var. heterovalva Krasske
Achnanthidium minutissimum (Kützing) Czarnecki	Achnanthes minutissima Kützing
Amphora copulata (Kützing) Schoeman et Archibald	Amphora ovalis (Kützing) Kützing
Aulacoseira ambigua (Grunow) Simonsen	Melosira ambigua (Grun.) O. Müll.
Aulacoseira distans (Ehrenberg) Simonsen	Melosira distans var. alpigena Grunow
Aulacoseira granulata (Ehrenberg) Simonsen	Melosira granulata (Ehr.) Ralfs
Berkeleya sp. 1 Idaho DW	Amphipleura rutilans var. dillwynii (Agardh) Cleve-Euler
Cocconeis neodiminuta Krammer	Cocconeis thumensis Mayer
Cocconeis placentula var. lineata (Ehrenberg) Van Heurck	Cocconeis placentula var. euglypta (Ehrenberg) Cleve
Diadesmis confervacea Kützing	Navicula confervacea (Kütz.) Grun.
Diadesmis contenta (Grunow ex Van Heurck) Mann	Navicula contenta var. biceps (Arnott) V. H.
Diploneis parma Cleve	Diploneis puella (Schumann) Cleve
Encyonema silesiacum (Bleisch) Mann	Cymbella minuta Hilse ex Rabenhorst
Encyonema silesiacum (Bleisch) Mann	Cymbella minuta var. silesiaca (Bleisch ex Rabenhorst) Reimer
Encyonopsis microcephala (Grunow) Krammer	Cymbella microcephala Grunow
Fallacia pygmaea (Kützing) Stickle et Mann	Navicula pygmaea Kützing
Fallacia tenera (Hustedt) Mann	Navicula tenera Hustedt
Frustulia crassinervia (Brebisson) Lange-Bertalot et Krammer	Frustulia rhomboides var. crassinervia (Bréb. ex W. Sm.) Ross
Geissleria decussis (Hustedt) Lange-Bertalot et Metzeltin	Navicula decussis Østr.
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	Navicula capitata Ehrenberg
Hippodonta lueneburgensis (Grunow) Lange-Bertalot, Metzeltin et Witkowski	Navicula capitata var. lueneburgensis (Grun.) Patr.
Hippodonta lueneburgensis (Grunow) Lange-Bertalot, Metzeltin et Witkowski	Navicula capitata var. hungarica (Grun.) Ross
Luticola mutica (Kutz.) Mann	Navicula mutica Kützing
Luticola mutica (Kutz.) Mann	Navicula cohnii (Hilse) Lange-Bert.
Melosira moniliformis (O.F. Müller) Agardh	Melosira borreri Grev.
Navicula cryptocephala Kützing	Navicula cryptocephala var. exilis Grunow
Navicula cryptotenella L.B. in Kramm. & L.-B.	Navicula radiosa var. tenella (Bréb. ex Kütz.) Grun.
Navicula diluviana Krasske	Navicula ilopangoensis Hustedt
Navicula erifuga Lange-Bert.	Navicula tripunctata var. schizonemoides (V. H.) Patr.
Navicula germainii Wallace	Navicula rhynchocephala var. germainii (Wallace) Patr.

Name Used in 2003	Name Used in 1996
Navicula kotschyi Grunow	Navicula texana Patr.
Navicula perminuta Grunow	Navicula diserta Hustedt
Navicula recens Lange-Bert.	Navicula tripunctata var. schizonemoides (V. H.) Patr.
Navicula schroeteri var. escambia Patr.	Navicula symmetrica Patr.
Navicula tenelloides Hustedt	Navicula salinicola Hustedt
Navicula veneta Kützing	Navicula cincta var. rostrata Reim.
Nitzschia amplectens Hustedt	Nitzschia diserta Hustedt
Nitzschia bita Hohn et Hellerman	Nitzschia tryblionella var. debilis (Arnott) Hust.
Nitzschia filiformis var. conferta (Reich.) Lange-Betralot	Nitzschia filiformis (W. Sm.) V. H.
Nitzschia lorenziana Grunow	Nitzschia lorenziana var. subtilis Grun. in Cl. et Grun.
Nitzschia obtusa W. Sm.	Nitzschia obtusa var. scalpelliformis Grun. in Cl. et Möller
Nitzschia obtusa W. Sm.	Nitzschia obtusa W. Sm.
Nitzschia panduriformis var. continua Grun. in Cl. et Grun.	Nitzschia panduriformis var. minor Grun. in Cl. et Grun.
Nitzschia perminuta (Grun.) Peragallo	Nitzschia frustulum var. perminuta Grunow
Nitzschia recta Hantz. ex Rabh.	Nitzschia dissipata var. media (Hantz.) Grun.
Pinnularia microstauron (Ehr.) Cl.	Pinnularia subcapitata Greg.
Plagiotropis lepidoptera var. proboscidea (Cl.) Reim.	Plagiotropis lepidoptera (Greg.) Kuntze
Planothidium apiculatum (Patrick) Lange-Bertalot	Achnanthes lanceolata var. apiculata Patrick
Planothidium delicatulum (Kützing) Round et Bukhtiyarova	Achnanthes hauckiana Grunow
Planothidium delicatulum (Kützing) Round et Bukhtiyarova	Achnanthes hauckiana var. rostrata Schulz
Pleurosigma salinarum Grunow	Pleurosigma elongatum W. Sm.
Pleurosigma salinarum Grunow	Pleurosigma delicatulum W. Sm.
Pleurosira laevis (Ehrenberg) Compere	Biddulphia laevis Ehrenberg
Pseudostaurosira brevistriata (Grun. in V.H.) Williams & Round	Fragilaria brevistriata Grunow
Sellaphora laevissima (Kutz.) Mann	Navicula laevissima Kützing
Sellaphora pupula (Kütz.) Meresckowsky	Navicula pupula Kützing
Sellaphora seminulum (Grun.) Mann	Navicula seminulum Grunow
Staurosira construens var. venter (Ehr.) Hamilton	Fragilaria construens var. pumila Grunow
Staurosirella pinnata (Ehrenberg) Williams et Round	Fragilaria pinnata Ehrenberg
Stephanodiscus minutulus (Kütz.) Cleve & Moller	Stephanodiscus astraea var. minutula (Kütz.) Grun. in V. H.
Synedra ulna (Nitz.) Ehr.	Synedra ulna var. contracta Østr.
Tabularia fasciculata (Ag.) Williams and Round	Synedra fasciculata var. truncata (Grev.) Patr.
Tabularia fasciculata (Ag.) Williams and Round	Synedra fasciculata (Ag.) Kütz.
Tryblionella levidensis Wm. Sm.	Nitzschia tryblionella var. levidensis (W. Sm.) Grun. in Cl. et Grun.

4. MACROINVERTEBRATES

4.1 Introduction



Callinectes sapidus
Blue Crab

A survey for macroinvertebrates in the Neches River system in the area of the city of Beaumont, TX, downriver to the Port Neches region was conducted on 11 to 14 October 2003. The Neches River is dredged, including the removal of several meanders to create new channels, upriver to the Port of Beaumont. Stations 2 through 4 are distributed along this main channel region of the estuary, and benthic macroinvertebrate habitats at these study stations are distributed primarily along a narrow shelf at the margins of the river. Substrates in these margins consisted of sandy beaches, sand and clay banks and small muddy/detrital backwaters often margined with the common reed (*Phragmites australis*). Upriver of the Port, at Station 1, more natural river habitats are found consisting of both broad, shallow sandy depositional banks and cut banks as well as muddy substrates in a large right bank (oriented downriver) backwater. Station 1 lies immediately upriver of the estuary in a more densely wooded area dominated by cypress, gum and elm. The tidal waters among the stations ranged from fresh at Station 1 to high mesohaline at Stations 3 and 4 during the sampling period (salinity measures taken during the biological sampling events are presented in the section 5. Fish). The survey was undertaken to (1) provide an inventory of the organisms in this portion of the Neches River system, (2) compare the faunas among the four stations and (3) relate the results with previous surveys by the Academy of Natural Sciences of Philadelphia (ANSP) at or near the same survey stations in 1953 (ANSP 1954), 1973 (ANSP 1974) and 1996 (ANSP 1998). The Academy studies sampled macroinvertebrates from all habitats and complement quantitative faunal investigations of soft bottom regions of the Neches River by Harrel et al. (1976), Harrel and Hall (1991) and Harrel and Smith (2002).

Biological inventories are widely recognized as establishing necessary baseline data against which important comparisons with later investigations can be made to discern environmental changes. Alterations in community composition and population sizes can disturb the food web and alter an aquatic ecosystem's ability to regulate water quality by eliminating microorganisms, nutrients, suspended materials, etc. Traditionally, benthic non-insect macroinvertebrates have been chosen as reliable indicators, because many species exhibit sedentary habits, some taxa are long-lived and have low reproductive rates, while others exhibit complex, easily interrupted reproductive life histories and different tolerances to stress. Together the group possesses phylogenetic, physiological, behavioral and ecological diversity with a sensitivity to a wide range of ecological perturbations that can persist for years. Consequently, studies of benthic macroinvertebrates are an important component of synoptic surveys designed for environmental impact assessment (e.g., Stein and Denison 1967, Wass 1967, Wilhm and Dorris 1968, Hynes 1972, 1974, O'Conner 1972, Boesch 1973, Holland et al. 1973, Reisch 1973, Boesch et al. 1976, Harrel et al. 1976, Pearson and Rosenberg 1978, Hart and Fuller 1979, Krueger et al. 1988, Wilson and Elkaim 1991, Harrel and Hall 1991, Dauer 1993, Engle et al. 1994, Wilson 1994, Wilson and Jeffrey 1994, Deegan et al. 1997, Weisberg et al. 1997, Engle and Summers 1999, Van Dolah et al. 1999, Dauer et al. 2000, Hyland et al. 2000, Eaton 2001, Paul et al. 2001, Alden et al. 2002, Harrel and Smith 2002, Llanso et al. 2002a, 2002b, Ranasinghe et al. 2002, Morrisey et al. 2003, Hale et al. 2004).

4.2 Materials and Methods

In October 2003, macroinvertebrates were sampled at four stations in the Neches River. These stations were established in 1953 (ANSP 1954) to measure river health as reflected by species diversity and pollution tolerances in a series of stations upriver and downriver from certain industries in the Neches River. Complete information on station locations and general characteristics of the river at each station are presented in the section 1. Introduction. Sites within stations where macroinvertebrates were collected are outlined herein. The shallow water sampling sites at Station 1 were along a depositional right (downstream orientation) bank of the river in a region with a narrow flooded spit of land (dry in 1996) that separated the main channel from a large backwater. Sampling occurred on both sides of this peninsula and upriver on the channel side. Besides bed sediments (sand to muddy sand along the channel margin and muddy on the backwater side), woody debris, leaf litter (in the backwater) and flooded emergent aquatic vegetation were present. Station 2 was collected from an area downriver from Light 54 to a region upriver of Light 56. The left bank consisted primarily of low sand and clay banks with alternating sand beaches (largest just upriver from Light 54) and scattered woody debris. The 1996 sampling area along the right bank, opposite the large left bank beach, could not be sampled in 2003 due to lack of access as a result of a pipeline being laid along the right bank. A right bank shoreline north of Clark Island was sampled instead, and substrates here consisted of muddy sand with a stand of California bulrush (*Scirpus californicus*). Station 3 was sampled along the right bank approximately from the middle of McFadden Bend Cutoff to just upriver from Light 40. The left bank was inaccessable in 1996, but in 2003 the east side of the Reserve Fleet Area was sampled back from its junction with the main channel. Along the upper portion of the right bank study area, a series of indented sand beaches (one with rip rap) in shallow coves and a high clay bank were present. Station 4 samples were taken primarily from left bank habitats between the level of the right bank mouth of Block Bayou upriver to an unnamed canal. Primarily sand with scattered clay banks and sandy beaches with woody debris were present. A large indented portion along the right bank just downriver from Light 29 also served as a sampling area. This latter region lacked a sand beach, and substrates consisted of clay, firm mud and detrital mixtures. Water hyacinth (*Eichhornia crassipes*), probably washed from tributaries by a recent rain event (q.v., Fig. 1.2), was common in and along the main channel at Stations 2 through 4. Nektonic and benthic macroinvertebrate taxa were taken via trawl in deeper waters of Station 1 through 4.

Since macroinvertebrates are a phylogenetically diverse group that exhibits numerous morphologies and behaviors and occupy a range of habitats, they were sampled in a number of ways. Intertidal areas were collected by hand, with smaller species handled with small forceps or pried off hard substrates with a knife. Vegetation searched included stems and exposed root mats of common reed, beds of the California bulrush, root mats of the water hyacinth, and dense stands of lake acanthus (*Hygrophila lacustris*). Wooden debris, rip rap and construction materials, consisting primarily of concrete fragments, were examined. Crabs (spined fiddler, *Uca spinicarpa*, and squareback and heavy marsh crabs, *Armases cinereum* and *Sesarma reticulatum*, respectively) were collected from open habitats on the river banks and tree roots exposed by wave action. Beach hoppers (amphipods) were abundant under stranded debris above the tide line. The three aforementioned species of crabs were also dug from simple burrows in sand banks. Sea pill bugs (*Sphaeroma terebrans*) were removed from their wood galleries by splitting wooden debris. Bark was peeled from submerged and beached limbs to remove organisms hiding beneath the bark. Burrowing intertidal and subtidal forms, such as bivalve molluscs, were collected from sandy, muddy sand and muddy substrates by hand. More mobile and nektonic animals were taken by dipnets, otter trawl and seine. The dip nets consisted of a Wildco bottom aquatic dip net (#425-A50) and a Wildco dip net (#484-D82) with a 3-mm (1/8-in) ace mesh. The otter trawl, 3.7-m (12-ft) wide with a 3-mm (1/8-in) mesh inner lining in the cod end, was towed for five min. Shallow water areas were collected with a 6.1-m x 1.2-m (20-ft x 4-ft) bag seine with 3-mm (1/8-in) mesh. Approximately 7.5 to 8 hr were spent at each station, including time to survey the area by foot or boat to identify accessible habitats that differed in substrate type, current velocity and water depth. Shoreline sampling was conducted in shallow water areas up to about 1.2-m (4-ft) deep.

The contents of the dip nets, otter trawl and seine were rinsed in the river to remove sediment, and dip net samples were placed into a shallow white tray for sorting. Against such a uniform, neutral background, small animals were observed and removed. From these samples and the hand collections, some reference material as well as taxa that could not be identified with certainty in the field were preserved in 75% ethyl alcohol and taken to the Philadelphia laboratory for identification. Before storage in alcohol, hand collected highly contractile organisms (polychaete and oligochaete worms) were relaxed. They were passed through an intermediate step in 10% formalin solution and washed before storage in alcohol. No effort was employed to collect commensal (e.g., branchiobdellids and mites) or parasitic (e.g., leeches and isopods) species from other invertebrates or fishes, although the parasitic isopod *Probopyrus*, conspicuous in the gill chambers of palaemonid shrimps, was noted. Because of instar stage or condition, some insect specimens could not be identified to species. These insects are noted in Appendix 4.1 with an asterisk. If a genus contains both an identified species (e.g., *Erythemis simplicicollis*) and an undetermined species (e.g., *Erythemis* sp.*) from the same station, the undetermined species is not counted in the station totals or total for the survey, since the undetermined species may be the same as the identified species. If a genus contains both an identified species (e.g., *Caenis* sp. nr. *diminuta* from Stations 1 and 2) and an undetermined species (e.g., *Caenis* sp.* from Station 4) from a different station both taxa are counted in the station totals for Stations 1, 2 and 4 but the *Caenis* sp. nr. *diminuta* is not counted in the survey total, since the undetermined species may be the same as the identified species. The habitat and relative abundance of all the taxa were noted and the macroinvertebrates later identified to the lowest practical taxon. Relative abundances were defined on the basis of the number of animals collected as rare (1 individual), uncommon (2 to 3), moderately common (4 to 15), common (16 to 30) and abundant (31 or more). The taxonomy used herein was retrieved [June 2004], from the Integrated Taxonomic Information System on-line database, and from Williams et al. (1989) and Martin and Davis (2001) for crustaceans, Turgeon et al. (1998) for molluscs and Epler (2001) for chironomids (= midges).

In order to provide as comprehensive and comparative an examination as possible of the 2003 results of the macroinvertebrate fauna of the Neches River at the four stations with that from earlier surveys, a compilation of data from the previous comprehensive (1953, 1973 and 1996) and cursory studies (1956 and 1960) are included. This comparison of the fauna encompasses its distribution under various conditions, and provides taxonomic consistency among the years. Habitat data, however, is spotty in the pre-1996 investigations.

4.3 Results

4.3.1 Macroinvertebrate Taxa

4.3.1.1 Sponges (Porifera)

In 2003, an undetermined species of sponge was collected from the leaves of the southern swamp lily (*Crinum americanum*) and branches at Station 1. From this station in 1996, a single colony of an unidentified species was collected from a branch along the steep left bank. An undetermined species of sponge, assumed to be the same species, *Trochospongilla horrida*, identified from the first (1953) survey of the Neches River, was collected in 1973. In both these years sponges were found on submerged wood.

4.3.1.2 Comb Jellies (Ctenophora)

In 2003, damaged specimens of an undetermined species of comb jelly were found in trawl samples from Station 4, while in 1996 an undetermined species belonging to the group of Beroe's Comb Jellies, *Beroe* species, was common in otter trawl hauls at Stations 2 through 4. Comb jellies were noted from earlier Academy surveys (ANSP 1954, 1974), and this probably reflects the use of the otter trawl in the Academy studies of the lower Neches River in 1996 and 2003.

4.3.1.3 Jellyfishes and Hydrozoans (Cnidaria)

Unlike 1996, no jellyfishes were found in the 2003 samples. In 1996, as with the comb jelly, two unidentified species of jellyfishes were collected from the water column at Stations 2 through 4. One small species occurred at all stations, while a larger taxon was found at the downriver Stations 2 through 4.

4.3.1.4 Flatworms (Platyhelminthes)

As in the 1996 Academy survey, no flatworms were collected in the October 2003 study. In the 1973 study, *Dugesia tigrina* was observed on submerged solid objects at Station 1 and an undetermined species of flatworm was recorded from protozoan collections at Station 4 in 1953.

4.3.1.5 Moss Animals (Ectoprocta)

No bryozoans were collected in the 2003 study. The bryozoan *Membranipora tenuis* was found in the high mesohaline portion of the estuary at Station 4 in 1996. Two small colonies of this encrusting organism were cut from the roots of a tree stump that was lodged in bed substrates. This species was not collected in the 1953 and 1973 Academy comprehensive investigations and this may in part be due its uncommon presence in the study area. In 1996, a single colony of the freshwater bryozoan *Plumatella repens* was observed on a submerged branch along the steep left cut bank at Station 1. This species was also collected from Station 1 in both of the Academy's earlier comprehensive studies on woody substrates. In addition, two other species of bryozoans were noted from woody substrates in the 1953 survey and consisted of an undetermined species of the family Crissidae and possibly a member of the genus *Paludicella*.

4.3.1.6 Segmented Worms (Annelida)

Three main morphological groups of annelids, oligochaetes, leeches and polychaetes, were found in the 2003 collections. Among the oligochaetes, two species of tubificids, *Branchiura sowerbyi* and an undetermined taxon, were obtained from Station 1. A single specimen of *B. sowerbyi* was taken from muddy leaf litter, while the undetermined tubificid was moderately common in substrates consisting of silt and algae over fine sand. Because of their small size, transparent nature, naidid and tubificid oligochaetes are under-represented in hand collections and their actual diversity and abundance is better measured by grab samples that are sorted from their accompanying substrate material under a microscope. A single freshwater earthworm, *Lumbriculus variegatus*, was present in samples from among flooded grasses at Station 1. In 1996, an undetermined tubificid was obtained from under bark at Station 1 and a second undetermined species was collected from muddy substrata at Stations 1 and 3. *Lumbriculus variegatus* was collected from muddy deposits at Station 1 and among grassy chunks of soil from a spring feeder at the margin of the river bank at Station 4. An undetermined species of oligochaeta, probably a tubificid, was noted from Station 2 in 1973. *Pristina longiseta* and an undetermined species of *Stylaria* (naidid oligochaetes) were found at Station 1 in 1953 with a single specimen of the latter having been taken in algal samples. The tubificid *B. sowerbyi* and the earthworm *L. variegatus* were collected from stations upriver from ANSP Station 1 by Harrel et al. (1976) in 1971/1972.

Two species of leeches were obtained in the 2003 study. Although leeches are better represented in freshwaters, species are known to occur in brackish and marine waters. In 2003, one species, *Helobdella triserialis,* was moderately common in muddy leaf litter at the freshwater Station 1, while a second species, *Myzobdella lugubris*, a fish parasite, was collected from the more saline waters at Stations 2 through 4. *Myzobdella lugubris* lives in freshwaters and a range of salinities from brackish to marine waters. This species was present in seine samples collected by the fisheries crew at Stations 2 (uncommon) and 3 (rare) and moderately common in dip net collections from flooded grasses and from under an undercut bank at Station 4.

One or more of the three *M. lugubris* collected by the fisheries crew could have been dislodged from fish during the process of seine landing. In 1996, a single *Myzobdella lugubris* was found at Station 3. Leeches were not represented in any of the previous Academy surveys, although they would be expected to be part of the Station 1 fauna. An undetermined species of leech was collected by Harrel et al. (1976) from stations upriver from ANSP Station 1 in 1971 /1972.

Two species of polychaetes from the families Nereidae and Serpulidae were part of the 2003 survey. *Neanthes succinea* was sampled at the three downriver Stations 2 through 4. The species was rare on wood at Station 2, moderately common at Station 3 on and under overturned rip rap and wood and within crevices of finished wood and uncommon at Station 4 in a range of habitats consisting of sand and flooded grasses, muddy sand and detritus and from under wood. During 1996, when average annual freshwater discharges were lower and more saline waters penetrated further upriver, three species of polychaetes were noted. *Neanthes succinea* was observed at the low to high mesohaline Stations 2 through 4. The species was uncommon in wood and mud substrates at Stations 2 and 4, respectively. At Station 3 it was common in muddy sand, fine grained mud and among barnacles encrusting a section of PVC pipe. In the 1973 study, two nereid species, *Laeonereis culveri* (Station 1 in mud and Station 2) and *Websterinereis tridentata* (as *Ceratonereis tridentata* at Stations 2 and 3), were recorded from the lower Neches River. A *Nereis* species was taken at Station 4 in 1956 and an undetermined nereid species were noted from Stations 3 and 4 in 1960. Nereid worms were absent from the 1953 investigation. From Neches River studies directed by Harrel (Harrel et al., 1976; Harrel and Hall 1991, Harrel and Smith 2002), *Neanthes succinea* and *L. culveri* were collected from a range of stations during each study from the area of the Star Lake and Gulf States canals upriver to stations in the areas of Lake Bayou (*succinea*) and Pine Island Bayou (*culveri*).

The tubicolous polychaete, *Ficopomatus miamiensis*, with its white to salmon colored calcareous tubes, was conspicuous on hard substrates in 2003. It was pried from hard substrates, where it was common on rip rap at Station 3 and moderately common on rusted metal and wood at Station 4. *Ficopomatus miamiensis* was new to the macroinvertebrate faunal list of the Academy surveys in the Neches River studies in 1996. In that year it was collected by hand from the low to high mesohaline Stations 2 through 4. It was found on hard substrates such as metal debris (cable at Station 2), woody materials (Stations 2 to 4), barnacles (Stations 2 and 3) and the Atlantic rangia (*Rangia cuneata*) (Station 2). Because of the conspicuous nature of their tube dwellings, their absence from earlier Academy surveys in 1953 (ANSP 1954), 1956 (ANSP 1958), 1960 (ANSP 1961) and 1973 (ANSP 1974) probably signifies that the species was absent from the study areas during these periods.

Parandalia americana was not collected in 2003 but was uncommon in muddy sand substrates at Station 3 in 1996. This species was also absent from previous Academy studies in 1953, 1956, 1960 and 1973 and was also absent from grab samples taken at various stations upriver from Sabine Lake in 1971/1972 by Harrel et al. (1976). This pilargiid polychaete was later noted from grab samples taken upriver and downriver from the Star Lake and Gulf States canals region in 1984/1985 by Harrel and Hall (1991) and from this same area upriver to a station 1 km upriver from the entrance of the ExxonMobil Canal by Harrel and Smith (2002).

4.3.1.7 Molluscs (Mollusca)

The 2003 molluscan fauna at the four Neches River stations included six species of snails and seven species of bivalves. The snails found in the study areas included *Physella gyrina* (tadpole physa), *Planorbella trivolvis* (marsh ramshorn), *Hebetoncylus excentricus* (excentric ancylid), *Amnicola limosus* (mud amnicola), *Pyrgophorus spinosus* (spiny crownsnail) and an undetermined species of hydrobiid snail. The bivalves included four species of clams, two taxa of freshwater mussels and one species of estuarine mussel. The clams consisted of *Rangia cuneata* (Atlantic rangia), *Polymesoda caroliniana* (Carolina marshclam), *Musculium securis* (pond fingernailclam) and *Eupera cubensis* (mottled fingernailclam). The two freshwater mussels were *Fusconaia askewi* (Texas pigtoe) and *Quadrula apiculata* (southern mapleleaf), while the estuarine dreissenid bivalve was *Mytilopsis leucophaeta* (dark falsemussel).

In 2003, the tadpole physa was abundant on muddy leaf litter and aquatic vascular plants (backwater) and moderately common on flooded grasses (channel) at Station 1 and uncommon in flooded grasses at Station 4. In the backwater area of Station 1, the marsh ramshorn was rare in flooded vegetation and the excentric ancylid was moderately common on submerged leaves. Three species of hydrobiid snails were taken in the study at Station 1: the mud amnicola, spiny crownsnail and an undetermined species. The mud amnicola was very abundant in a variety of habitats consisting of silt and algae over fine sand (channel), muddy leaf litter (backwater) and flooded vegetation (backwater). The spiny crownsnail was rare and the undetermined species of hydrobiid snail uncommon in the silt, fine sand and algae habitat along the main channel. In 1996, a single tadpole physa, was taken from leaf litter at Station 1. In 1973, two species of snails, *Pseudosuccinea columella* (mimic lymnaea), on emergent vegetation at Station 1, and an undetermined species of hydrobiid snail at Station 2, were collected. A snail of the genus *Amnicola* was collected from stations upriver from ANSP Station 1 in 1971/1972 (Harrel et al. 1976) and was found to be wide ranging from this same area downriver to the region of the Star Lake and Gulf States canals in 1999 (Harrel and Smith 2002).

The Atlantic rangia, in 2003, was abundant at Stations 1 through 3 and common at Station 4. It occurred primarily in sands [muddy sands (channel) at Stations 1 and 2, mud (backwater) at Station 1, detritus over sand at Stations 3 and 4 and fine sand, silt and algae (channel) at Station 1]. In 1996, the Atlantic rangia was also collected by hand at all stations. This species was common in sand at Station 1, moderately common to common in sand to clay substrates at Station 2 and uncommon in muddy substrates at Stations 3 and 4. At the left bank beach at Station 2, the Atlantic rangia had been uprooted by strong wave action of ship traffic and numerous individuals were found lying in shallow water or deposited on the beach at the tide line. This species was also collected at Station 1 in the 1953 (clay substrate) and 1973 Academy surveys. In 1971/1972, this species was found only in grab samples from stations upriver of the Interstate Highway 10 bridge by Harrel et al. (1976), while in 1984/1985 Harrel and Hall (1991) and in 1999 Harrel and Smith (2002) the Atlantic rangia was present in all seven of their study stations ranging from the area of the Star Lake and Gulf States canals upriver to the area of Lake Bayou upriver from the Interstate Highway 10 bridge. The value of the estuarine Atlantic rangia as a biomonitor of heavy metals, dioxins, and furans was demonstrated by Richard Harrel and Marc McConnell (Harrel and McConnell 1995, McConnell and Harrel 1995).

The second estuarine clam represented in the 2003 Neches River samples was the Carolina marshclam. It was collected from muddy sand substrates at Stations 2 and 3. It was moderately common at Station 2 and common at Station 3. In 1996, the Carolina marshclam was common in a broken gallon plastic jug filled mostly with a fine grained mud. No Carolina marshclams had been collected in past Academy investigations of the Neches River. Although the primarily intertidal Carolina marshclam lives in shallower areas than the subtidal Atlantic rangia, the fewer numbers of Carolina marshclams in main channel habitats may be due to its preference for fine grained sediments [mud, mud-fine sand or fine sand-silt (Heard 1982)]. This intertidal species can reach large numbers and in portions of the Neches estuarine system, where appropriate habitat occurs, may be abundant. The study stations of the main channel of the Neches River are dominated by coarser sediments and it appears the Carolina marshclam is not a common component of main channel habitats at these stations as the Atlantic rangia.

The pond fingernailclam was moderately common at Station 1, where it was found in substrates containing flooded vegetation and open areas with silt, fine sand and algae. The mottled fingernailclam was moderately common on logs and among leaf litter. Fingernailclams were not collected during any of the earlier studies.

Of the two freshwater mussel species collected in 2003, both were found only in the backwater at Station 1. The Texas pigtoe was common and the southern mapleleaf uncommon in muddy substrates. In this backwater, there were more than two to three times as many Atlantic rangia as there were freshwater mussels. The only other survey in which live mussels were collected in the Academy's Neches River studies was in 1953 when a single specimen of a very young mussel, probably of the genus *Anodonta*, was found within a bed of Atlantic rangia. A single valve of the giant floater, *Anodonta grandis*, was collected from the backwater at Station 1 in 2003.

The estuarine dark falsemussel was moderately common on woody materials at Stations 2 and 4, while at Station 3 it was common on rip rap and abundant on and within galleries of wood.

In 1996, this species was abundant on branches and common in crevices or on exposed wood surfaces at Station 1 and under bark and among barnacles at Stations 2 through 4. This species had only been collected at Station 1 during the previous Academy studies of 1953 and 1973. This species was taken in grab samples by Harrel et al. (1976) in 1971/1972 from stations near the Interstate Highway 10 bridge upriver to the area of Lake Bayou with no dark falsemussels recorded in any of their downriver stations. These stations occur upriver from the Academy's Stations 2 through 4. The later 1984/1985 Harrel and Hall (1991) and 1999 Harrel and Smith (2002) studies found this species at all their study stations from the area of the Star Lake and Gulf States canals upriver to the area of Lake Bayou upriver from the Interstate Highway 10 bridge.

One additional bivalve species from the Neches River surveys was collected in 1996. A single young eastern oyster, *Crassostrea virginica*, was pried from a wood substrate to which it was cemented at Station 4. The Atlantic oyster appears to be a rare component of the lower Neches River fauna.

4.3.1.8 Insects (Insecta)

Whereas insect diversity is a significant part of the freshwater fauna, in estuarine and marine habitats its niches are filled by crustaceans and insects are less common to rare depending on the salinities and season. During the October 2003 survey, 67 taxa of aquatic insects, the most diverse group in the study area, were obtained. Insect species richness decreased drastically from the freshwater portion of the system at Station 1 (38 species) to the oligohaline shallow waters further downriver in the main stem of the Neches River (23, 17 and 15 species at Stations 2 through 4, respectively).

The insect diversity in the autumn 2003 study was represented by Odonata (dragonflies and damselflies) of the families Aeshnidae (darners), Gomphidae (clubtails), Macromiidae (belted and river skimmers), Corduliidae (greeneyed skimmers), Libellulidae (common skimmers) and Coenagrionidae (narrow-winged damselflies); mayflies of the families Baetidae (small minnow mayflies), Ephemeridae (common burrowers), Caenidae (small squaregills) and Tricorythidae (little stout crawlers); Hemiptera consisting of the Corixidae (water boatmen), Gerridae (water striders), Veliidae (broad-shouldered water striders), Belostomatidae (giant water bugs), Nepidae (waterscorpions), Notonectidae (backswimmers) and Naucoridae (creeping water bugs); Megaloptera (alderflies, Sialidae); Lepidoptera (butterflies and moths) of the family Pyralidae (pyralid moths) and Trichoptera (caddisflies) of the family Leptoceridae (long-horned caddisflies); Coleoptera (beetles) of the families Noteridae (burrowing water beetles), Haliplidae (crawling water beetles), Dytiscidae (predacious diving beetles) and Hydrophilidae (water scavenger beetles); and three families of Diptera (true flies) that included Chironomidae (blood worms as larvae or midges as adults), Culicidae (mosquitoes) and Ceratopogonidae (biting midges). This diversity is much higher than in previous investigations (Table 4.1). Differences in the insect fauna among the three most recent studies (few species were collected in 1953) reflects precipitation patterns and discharge rates of the Neches River. The drought conditions of 1996 permitted more frequent salt water intrusion into Station 1 and the altered salinity patterns were not conducive to the survival of a diverse insect fauna in the main channel.

Ten species of dragonflies were collected in 2003 with most of the species (8) from Station 1 (Appendix 4.1). Two other libellulid dragonfly species (*Erythemis simplicicollis*, eastern

Table 4.1. Numbers of macroinvertebrate taxa collected from the lower Neches River at Stations 1 through 4 in 1953, 1973, 1996 and 2003 during Academy surveys. Numbers indicate **non-insect macroinvertebrates/insects:totals**.

	Station				
Survey	1	2	3	4	Total
1953	13/7:20	0/0:0	3/0:3	4/0:4	16/7:23
1973	14/23:37	10/10:20	5/6:11	6/3:9	21/32:53
1996	20/12:32	22/0:22	26/1:27	28/2:30	44/14:58
2003	28/38:66	23/23:46	23/17:40	26/15:41	52/67:119

pondhawk, and *Miathyria marcella*, hyacinth glider) were recorded from the downriver Station 4. Dragonflies from Station 1 were common in flooded vegetation and muddy leaf litter, while the few species at Stations 2 through 4 were moderately common in water hyacinth roots at Station 2, common at Station 3 with two animals present in water hyacinth roots and moderately common (water hyacinth roots) to uncommon (flooded grasses) at Station 4. The orange bluet damselfly, *Enallagma signatum,* was moderately common in flooded vegetation at Station 1, while members of the genus *Ischnura* were noted from Stations 2 through 4. Rambur's forktail, *Ischnura ramburii*, was moderately common in water hyacinth roots at Station 2, an undetermined species of *Ischnura* was moderately common in flooded grasses at Station 3 and the fragile forktail, *I. posita,* was uncommon in water hyacinth root mats.

In 1996, a pondhawk (Libellulidae, *Erythemis*) was collected with a dip net from under a bank overhang at Station 3. Two species of dragonflies, a meadlowhawk (Libellulidae, *Sympetrum* from Station 3) and a darner [Aeshnidae, *Nasiaeschna* (probably *N. pentacantha*, the cyrano darner) from Stations 1 and 3] were captured in 1973. No dragonfly naiads were taken in the 1953 survey. A member of the genus *Ischnura* was obtained by Harrel et al. (1976) from a station upriver from Pine Island Bayou and ANSP Station 1 in 1971/1972.

Five species of mayflies of the genera *Hexagenia*, *Caenis*, *Callibaetis*, *Procloeon* and *Tricorythodes* were collected in the 2003 samples, all occurring at least at Station 1, with a *Callibaetis* species ranging downriver through Stations 2 through 4, and a *Caenis* species collected at Stations 2 and 4. The broad mix of mayflies from Station 1 were all taken from substrates consisting of silt, fine sand and algae (channel). At Station 1, the ephemerid *Hexagenia* was abundant, *Caenis* common, *Callibaetis* and *Procloeon* moderately common and *Tricorythodes* uncommon. At the downriver stations the *Callibaetis* was abundant at Station 2 (water hyacinth roots), rare at Station 3 (flooded grasses) and uncommon at Station 4 (water hyacinth roots). The *Caenis* species was common at Station 2 (algae, silt and fine sand) and uncommon at Station 3 (water hyacinth roots). Only a single species of mayfly was found in 1996. This baetid mayfly, *Procloeon*, was represented by two individuals that were removed from the surface of a branch at Station 1. Three taxa of mayflies, one each in the families Caenidae, Tricorythidae and Baetidae, were taken in the 1973 study. They were all collected from Station 1 and the caenid ranged downriver to Station 2. In 1953, a burrowing mayfly (Ephemeridae) was obtained (Station 1), while in 1960 an undetermined mayfly was collected from Station 3. The mayflies *Hexagenia limbata* (upriver from the ExxonMobil Canal to the area of the LNVA Canal) and a *Caenis* species (Pine Island Bayou to the area of the LNVA Canal) were noted in Harrel et al. (1976), Harrel and Hall (1991) and Harrel and Smith (2002).

Of the seven families of Hemiptera or true bugs noted in the 2003 investigation, the water boatmen, *Palmacorixa buenoi,* was common in algae over silt and fine sand channel substrates at Stations 1 and a *Trichocorixa* species was moderately common at Stations 3 and 4 in flooded grasses. The water strider, *Rheumatobates,* was present in open water areas at Station 1 and an undetermined water strider was taken from the same habitat at Station 2. Broad-shouldered water striders were rare in open water habitats at Stations 1 and 2 and the giant water bug, *Belostoma,* was rare at Stations 1, 2 and 4 and uncommon at Station 3 in flooded grasses. Waterscorpions were uncommon in flooded vegetation at Station 1 and backswimmers were moderately common at Station 3 and uncommon at Station 4 in flooded grasses. Creeping water bugs were found in water hyacinth roots at the three downriver stations where they were rare at Stations 2 and 4 and moderately common at Station 3. Three families of Hemiptera were noted in the 1996 investigation. These included the water boatmen, *Trichocorixa,* at Stations 1 and 4, and a water strider, *Rheumatobates,* and giant water bug, *Belostoma*, at Station 1. The water boatman was obtained from among emergent aquatic vegetation at Station 1 and in flooded grasses at Station 4. The water strider and giant water bug were captured in the same flooded vegetation as the water boatman at Station 1. Both a water strider (Station 1) and giant water bug (Stations 1 and 3) were recorded in 1973. Additional hemipterans found in 1973 and not 1996 included a creeping water bug and waterscorpion. The only hemipteran present in the 1953 study was the waterscorpion *Ranatra buenoi*.

Orders represented by single families include the alderflies (Sialidae), pyralid moths (Pyralidae) and long-horned caddisflies (Leptoceridae). Alderflies and pyralid moths were taken from unrecorded habitats from Station 1 and Stations 2 and 3, respectively. Long-horned caddisflies of the genera *Oecetis* and *Nectopsyche* were moderately common in flooded vegetation at Station 1.

Of the four families of aquatic beetles found in the Neches River in 2003, only the haliplid, *Peltodytes sexmaculatus*, was taken at Station 1, where it was rare. The remaining taxa were captured from the three downriver stations. A second species of crawling water beetle (Haliplidae), *Peltodytes dunavani*, was uncommon at Station 3. Two species of burrowing water beetle, *Hydrocanthus atripennis* and *Suphisellus puncticollis,* were collected in 2003. *Hydrocanthus atripennis* was moderately common at Station 3 and an undetermined *Hydrocanthus*, possibly *atripennis*, was rare at Stations 2 and 4. The second species, *Suphisellus puncticollis,* was rare at Station 4. One species of predaceous diving beetles, *Desmopachria*, was rare at Station 3 and two species of water scavenger beetles, *Tropisternus* (uncommon at Station 4) and *Berosus* (rare at Station 2), were obtained from the downriver group of stations. As in 2003, four families of beetles were found in the Neches River in 1996 and included a whirligig beetle (Gyrinidae), burrowing water beetles, crawling water beetle and predacious diving beetles. All four groups were observed at Station 1, with one species of crawling water beetle recorded from Station 4. Large whirligig beetles (*Dineutus*) were dip netted from surface waters along the shoreline. One species of burrowing water beetle (*Hydrocanthus*), along with a crawling water beetle (*Peltodytes*), were found in leaf litter. A second species of burrowing water beetle (*Suphisellus*) was collected at Station 4, where a small spring feeder (less than a third of a meter wide) was sampled at its junction with the Neches River channel at the upper end of the intertidal zone. Two species of predaceous diving beetles were taken at Station 1. Both were members of the genus *Uvarus* and were captured from inundated emergent aquatic vascular plants along the shoreline. Aquatic beetles taken in the 1973 survey included the families noted in 1996 as well as water scavenger beetle, riffle beetle (Elmidae), marsh beetle (Scirtidae as Helodidae) and a snout beetle or weevil (Curculionidae). All were found at Station 1, with the dytiscid also collected from Stations 2 and 4 and the burrowing water beetle from Stations 3 and 4. No beetles were noted in the 1953 survey, and an undetermined beetle larva was obtained in samples from Station 4 in 1960.

Dipterans collected in 2003 consisted of mosquitoes of the three most economically important genera, *Anopheles*, *Aedes*, and *Culex*. Mosquitoes were only collected from Station 2 where, as a group, they were moderately common in the root mats of water hyacinth. Three species of biting midges (Appendix4. 1), one from each of Stations 1 through 3, were uncommon in substrates of fine sand, silt and algae at Station 1 and in water hyacinth roots at Stations 2 and 3. By far the most diverse group of insects in the study were the midges with 23 taxa. Their relative abundance and habitat at the 4 stations were as follows: Station 1, 13 species, abundant in muddy leaf letter, flooded vegetation and substrates consisting of silt, fine sand, and algae; Station 2, 8 species, moderately common in water hyacinth roots and 1 specimen from riparian root mats; Station 3, 5 species, common in flooded grasses; and Station 4, 3 species, uncommon in flooded grasses and moderately common in detritus (Appendix 4.1). In 1996, chironomids were the only dipterans obtained and were represented by three taxa from Station 1 that included members of the genera *Endochironomus, Polypedilum* and an undetermined genus. Faunal components of the first two genera were collected from under bark, while the latter was found in muddy leaf litter. During the 1973 study, 1, 2, 4 and 1 species of chironomids were collected from Stations 1 through 4, respectively. Two taxa of chironomids were taken in the 1953 study (one each from stations 1 and 3) and an undetermined midge larva was taken from Station 3 in 1960. From the Neches River studies of Harrel et al. (1976), Harrel and Hall (1991) and Harrel and Smith (2002) a phantom midge, biting midges and a diverse midge assemblage were found in a wide range of study stations during one or more of their studies..

4.3.1.9 Crustaceans (Crustacea)

Like 1996, 28 species of crustaceans were collected in 2003 and exhibited a great deal of diversity that included barnacles, tanaids, isopods, amphipods, mysids (=opossum shrimp), crayfish, crabs and decapod shrimps. Six of the crustacean species dominated the freshwater Station 1 (mysid, *Taphromysis louisianae*; isopod *Lirceus louisianae*; Mississippi grass shrimp *Palaemonetes kadiakensis*; parasitic isopods, *Probopyrus floridensis* and *P. bithynis,* present in the gill chambers of the Mississippi grass and Ohio shrimps, respectively; and the red swamp crawfish, *Procambarus clarkii*). Eighteen species were found only in the downriver oligohaline (shallower water) to low mesohaline (deeper water) Stations 2 through 4 (barnacle, *Balanus subalbidus*; mysid, *Mysidopsis almyra*; tanaid, *Leptochelia rapax*; isopods, sea pill bug, *Sphaeroma terebrans, Ligia exotica* and *Edotia triloba*; amphipods, *Gammarus mucronatus*, *G*. sp. nr. *mucronatus*, *Corophium lacustre*, *Grandidierella bonnieroides*, *Melita nitida* and *Orchestia platensis*; decapod shrimps, white shrimp, *Litopenaeus setiferus* and daggerblade grass shrimp, *Palaemonetes pugio*; crabs, Harris mud crab, *Rhithropanopeus harrisii,* squareback marsh crab, *Armases cinereum,* heavy marsh crab*, Sesarma reticulatum*, and spined fiddler, *Uca spinicarpa*). Three species were common throughout the study area (the amphipods *Gammarus* sp. nr. *mucronatus* and *Hyalella azteca* and the blue crab, *Callinectes sapidus*). The Ohio shrimp was only collected from Stations 1 and 2 and its parasitic isopod, *Probopyrus bithynis*, at Station 1 (Appendix 4.1).

The barnacle *Balanus subalbidus* was taken from the oligohaline-mesohaline portions of the estuary at Stations 2 through 4 in 2003. It was abundant at Stations 2 and 4 on wood and rusted metal, respectively, while at Station 3 it was common on rip rap and moderately common on wood. In 1996, this same species (as *B. eberneus*) was present under low to high mesohaline conditions at the same three downrivermost stations. This barnacle was abundant at Stations 2 and 3 on hard substrates such as metal debris (e.g., cable), wood and PVC pipe and common at Station 4 on wood. No barnacles were present in the 1973 investigation, while in 1953, *B. subalbidus* (as *B. improvisus*) was noted from Station 1. An undetermined species of barnacle was observed on pilings at Station 4 in 1956 and Stations 3 and 4 in 1960 (as *Balanus* species in 1960).

The mysid or opossum shrimp *Mysidopsis almyra* was collected in dip net samples at the downriver Stations 2 through 4, where it was found in detritus over sandy substrates at Stations 2 and 3. At Station 1, only the mysid shrimp *Taphromysis louisianae* was collected and was abundant in algae over a silt and sand substrate. In 1996, the opossum shrimp (*M. almyra* as *Americamysis almyra*) was present at all four survey stations, although less common at Station 1. At Station 1, in waters ranging from freshwater to low mesohaline, depending upon depth, the more abundant mysid was *T. louisianae*. Mysid shrimps were entrained in the otter trawl along with the fish catch. The mysid *T. louisianae* was identified from most stations between the Star Lake and Gulf States canals upriver beyond ANSP Station 1 in 1971/1972 (Harrel et al. 1976).

The tanaid *Leptochelia rapax* was uncommon in detritus at Station 4. In 1996, the same species (as *Hargeria rapax*) from the same station was collected from a muddy-detrital substrate. This species was taken in grab samples by Harrel, et al. (1976, as *Leptochelia dubia*), Harrel and Hall (1991) and Harrel and Smith (2002) from one or more sites in the area of the Star Lake and Gulf States canals [in Harrel and Smith (2002) the 1984-85 Station 1 datum is transposed to Station 7 in the 1971-72 column and Station 2 datum to Station 1 in the 1984-85 column, *cf*., Harrel and Hall (1991)].

In 2003, six secies of isopods were found in the study area (Appendix 4.1). The only common and widespread taxon was the sea pill bug, *Sphaeroma terebrans*. This species was taken from galleries in wood at Stations 2 through 4. Their presence in woody substrates is marked by conspicuous openings to their gallery system. Although no effort was made to collect parasitic species in this study, the parasitic isopods *Probopyrus bithynis* and *P. floridensis* were conspicuous in the gill chambers of some individuals of the Ohio shrimp and Mississippi grass shrimp, and for this reason they are included in the species list (Appendix 4.1). These parasitic isopods were noted in their hosts only from Station 1, where large numbers of the host shrimps were collected. Both the sea roach, *Ligia exotica* (uncommon on finished wood), and the isopod *Edotia triloba* were found only at Station 4. The remaining isopod, the freshwater slater *Lirceus louisianae*, was moderately common in flooded vegetation and muddy leaf litter at Station 1. Three species of isopods were noted in the Neches River in 1996. The sea pill bug was taken from galleries in driftwood at Stations 2 through 4. A single larval cymothoid isopod, a fish parasite, was taken in a seine haul at Station 3. It is uncertain if this specimen was collected free swimming in the water column or detached from one of the fishes caught in the seine. The freshwater slater *Caecidotea* was collected from Station 1 in leaf litter that had accumulated along the margins of the main channel of the river. A freshwater isopod of the genus *Lirceus* was reported by Harrel et al. (1976) from a grab sample upriver from the ANSP Station 1 and the sea pill bug from stations both up- and downriver from this same ANSP station.

The eight species of amphipods collected in 2003 represented the most diverse group of crustaceans. All but one of the species (*Corophium lacustre*) was collected at all the downriver oligohaline (shallow water) Stations 2 through 4, which included two predominantly freshwater species (*Gammarus* sp. nr. *tigrinus* and *Hyalella azteca*). The three gammarid amphipods included the euryhaline *G. mucronatus* , freshwater-oligohaline *G*. sp. nr. *tigrinus* and oligohaline *G*. sp. nr. *mucronatuus*. *Gammarus mucronatus* was moderately common at Station 2 and increased in abundance downriver (common at Station 3 and very abundant at Station 4). The *G*. sp. nr. *tirginus* was abundant at Station 1 and rare (Station 2) to moderately common (Stations 3 and 4) downriver. The *G*. sp. nr. *mucronatus* was abundant at Station 2 and moderately common at the downriver Stations 3 and 4. The gammarids were found in flooded grasses at Stations 1 (*G.* Sp. nr. *tigrinus*), 3 and 4; water hyacinth roots at Station 2 through 4 and from under an undercut bank at Station 4. In 2003, *Corophium lacustre* was moderately common in wood and rare in roots of the water hyacinth at Station 2, while a second corophiid, *Grandidierella bonnieroides*, was moderately common at Stations 2 and 3 and uncommon at Station 4. The euryhaline *G. bonnieroides* and *C. lacustre* are both tube dwellers. They construct mucous tubes to which adhere silt and detritus and in the case of the *C. lacustre* may include sand grains. The euryhaline amphipod *Melita nitida* was found only at the three downriver stations, where it was moderately common at Station 2, common at Station 3 and uncommon at Station 4. The freshwater amphipod *Hyalella azteca* was abundant at Stations 1 (moderately common in habitats consisting of muddy leaf liter, flooded vegetation and algae over silt and fine sand) and 3 and common at Stations 2 and 4. Although the habitat of the hyalellid at Stations 2 through 4 was not discerned, it was probably associated with root mats of water hyacinth that accumulated along the shoreline. The beach hopper was abundant in high intertidal to supratidal regions, especially near the high tide line. In high intertidal areas it was found in flooded branches, while in the supratidal portions of the river it lived under debris on the shore. The beach hopper, *Orchestia platensis*, was moderately common (Station 2) to abundant (Stations 3 and 4) under debris stranded at the tideline of the river margins and under the bark of both dead tress (rare at Station 2) and live *Sapium sebiferum*, Chinese tallow, (common at Station 4) near the water line.

In 1996, amphipods represented the second most diverse group of crustaceans. At this time six species were collected at the survey stations. A third of the species, *Gammarus mucronatus* and *Orchestia platensis* (beach hopper), were obtained at most of the stations, while the remaining species were represented at only one or two stations. The distribution of the two most widespread species ranged from Stations 2 through 4 in the then low to high mesohaline portions of the estuary. The gammarid amphipod was rare to common in a wide range of habitats that included flooded vegetation, wood, undercut banks, concentrations of detritus and in both the frayed and bound portions of braided rope. The beach hopper was abundant in high intertidal to supratidal regions, especially near the high tide line. Like in 2003, it was found in high intertidal areas that included flooded branches, while in the supratidal portions of the river it lived under debris on the shore. The four less common species in the 1996 collections included two freshwater to oligohaline species (a *Gammarus* sp. nr. *tigrinus* and *Hyalella azteca*) and two euryhaline species (*Grandidierella bonnieroides* and *Corophium louisianum*). As expected, the freshwater to oligohaline gammarid and hyalellid amphipods were part of the Station 1 fauna. There was a gap in the range of the hyalelled amphipod between Stations 1 and 4, where at the latter station it was collected at the interface of a freshwater feeder stream and the river associated with clods of grass that had slumped from the bank. The two species of amphipods at Station 1 were taken from leaf litter and associated with branches where it occurred among surface furrows as well as under bark., The tube dwellers *Grandidierella bonnieroides* (Station 2) and *Corophium louisianum* (Station 4) were collected in flooded grasses at the river's margin. Gammarid amphipods were collected at Station 1 in 1953 (as *G. fasciatus*) and Stations 1, 2 and 3 in 1973 (as *Gammarus* species). In addition, the tubicolous amphipod *Corophium lacustre* and hyalellid amphipod *H. azteca* were found at Station 1 in 1973. Two or more of eight species of amphipods have been collected from various stations along the study reach of the Neches River by Harrel et al. (1976), Harrel and Hall (1991) and Harrel and Smith (2002).

Shrimps, crayfishes and crabs constitute the decapod crustacean fauna and include some of the most familiar species. The typically swimming forms, the shrimps, were represented in October 2003 by four species that include one species of penaeid shrimp (white shrimp) and three species of palaemonid shrimps (the larger Ohio shrimp and two smaller species, the daggerblade grass shrimp and Mississippi grass shrimp).

The white shrimp was abundant in the upper Neches River estuary at Stations 2 through 4. Most specimens were collected by shoreline seining or otter trawl in deeper water. The species was also common at Station 4 in dip net samples over sand and in flooded grasses and uncommon over mud. The presence of so many juvenile and subadult white shrimp indicates the Neches River estuary to be an important nursery ground for this species. White shrimp were uniformly sized among the four stations ranging from 2.0 to 19.6 mm postorbital carapace length (4.5-17.4 mm at Station 2, 4.8-19.3 mm at Station 3 and 2.0-19.6 mm at Station 4). In 1996, the white shrimp was moderately common to abundant in the Neches River estuary at all stations. All specimens appeared in the seine in near shore habitats or the otter trawl in 6 to 15 m of water. The white shrimp was captured in the 1973 study at the three downrivermost stations. It was also collected along with the brown shrimp, *Penaeus aztecus*, at Stations 3 and 4 in 1956 and 1960.

In 1996, a second species of penaeid shrimp, the seabob, *Xiphopenaeus kroyeri*, was collected along with the white shrimp in the the low to high mesohaline stations (2 through 4). It was much less common than the white shrimp. The seabob was not taken during any of the earlier surveys.

Of the palaemonid shrimps captured in 2003, the Ohio shrimp was very abundant at Station 1 and moderately common at Station 2. This, the largest of the palaemonid shrimps recorded in the October survey, is a freshwater species whose larvae require estuarine conditions to complete their life cycle (*q.v*., Horne and Beisser 1977). The more saline waters are necessary for the survival of the larval stages. Both adult and juvenile Ohio shrimp were abundant at Station 1 and moderately common at Station 2. At Station 1 it was common in seine and otter trawl samples and moderately common in dip net samples from flooded vegetation, while at Station 2 it was moderately common in trawl samples. Of the two small grass shrimps, the daggerblade grass shrimp is the more euryhaline, while the Mississippi grass shrimp is less tolerant of higher salinities. In October 2003, the daggerblade shrimp was captured at Stations 2 through 4 with a dip net. It was common in water hyacinth root mats at Station 2 and abundant at Stations 3 (flooded grasses and water hyacinth roots) and 4 (flooded grasses). The Mississippi grass shrimp was abundant over substrates of algae and fine silt and sand and moderately common in seine hauls. The Ohio shrimp, in 1996, was abundant at Station 1 and uncommon at Stations 2 through 4. Both adult and juvenile shrimp were present in otter trawl samples, while dip net samples from flooded vegetation and leaf litter produced only juveniles. In 1996, the daggerblade shrimp was captured at Stations 2 through 4 with a dip net. It was abundant in undercut banks, exposed roots of riparian vegetation, flooded grasses and muddy detrital areas at Stations 2 and 4. At Station 3 it was common in sheltered areas such as undercut banks. The daggerblade grass shrimp was taken from Stations 1, 3 and 4 in 1953 and Stations 2 and 4 in 1973, while the Ohio shrimp and brackish grass shrimp, *P. intermedius,* were identified from Stations 1 and 4, respectively, in the 1973 investigation.

Unlike 1996, no sergestid or callianassid shrimps were collected in the 2003 study. In 1996, the sergestid *Acetes americanus* was moderately common to common in otter trawl samples from the low to high mesohaline Stations 2 through 4, while from the high mesohaline portion of the system at Station 4 the estuarine ghost shrimp, *Lepidophthalmus jamaicensis,* was collected. This species burrows in muddy to sandy mud substrates and was collected when it and a portion of the substrate it was inhabiting were cut from the river bottom by the lead line of the otter trawl. These species were not present in either of the earlier comprehensive surveys of 1953 and 1973.

From the 2003 samples, the red swamp crawfish, *Procambarus clarkii*, was common in dip net samples from flooded grasses and muddy leaf litter at Station 1 as well as uncommon in seine samples. In 1996, the red swamp crawfish and the crayfish *P. angelinae* were rare in leaf litter from main channel habitats. Crayfishes were not recorded from any of the earlier surveys.

In the October 2003 survey, the crab fauna consisted of five species that included the blue crab, Harris mud crab, squareback marsh crab, heavy marsh crab and spined fiddler. The blue crab was moderately common to abundant at the four stations. At Station 1 it was moderately common in dip net samples from substrates of algae over silt and sand, uncommon in shallow water seine samples and rare in deeper water trawl samples. At the three downriver stations, it was moderately common at Station 2 in flooded grasses and water hyacinth root mats, common at Station 3 in flooded grasses and abundant at Station 4, where it was moderately common in California bulrush and flooded grasses. The presence of so many juvenile and subadult blue crabs indicates the Neches River estuary to be an important nursery ground for this species. Juvenile blue crabs ranged in size from 2.4 to 22.6 mm carapace width (3.6-22.0 mm at Station 2, 10.0-18.0 mm at Station 3 and 2.4-22.6 mm at Station 4). Larger crabs ranged in size up to 126 mm (Station 2). In 1996, the blue crab was common to abundant at Stations 1 through 4 in a variety of habitats, especially in areas with mud and detrital substrates. Specimens were taken in the otter trawl, seine and by dip net. Blue crabs were recorded in 1953 at Stations 3 and 4 and in 1973 at all stations. In the more cursory investigations of 1956 and 1960, the blue crab was represented in collections from Stations 3 and 4. The blue crab was noted by Harrel et al (1976) from a station downriver from ANSP Station 4.

The Harris mud crab, in 2003, was moderately common at the three downriver Stations 2 through 4. Habitats included water hyacinth root mats at Station 2, hyacinth roots, flooded grasses and under wood debris and uncommon under rip rap at Station 3 and among the emergent California bulrush and abundant under overhanging banks at Station 4. In October 1996, the Harris mud crab was moderately common to common at Stations 2 through 4. The species appeared in hand collections from crevices in wood and under tree bark and in dip net samples, especially from muddy substrata. The Harris mud crab was represented in the 1953 study from Station 1, and its distribution in the 1973 survey was the same as in 1996 and 2003.

In 2003, the heavy marsh crab was uncommon under rocky rip rap at Station 3. This species had not been observed in any of the earlier surveys. Like the Harris mud crab in 2003, the squareback marsh crab was present at all collecting sites, except Station 1. This marsh crab was moderately common at Station 2 with two animals taken from the aerial roots of the bald cypress, *Taxodium distichum*, moderately common at Station 3 under grasses and rip rap, with 2 animals taken from a submerged branch, and moderately common at Station 4 under vegetation on the river banks. In 1996, the squareback marsh crab was present at the same three stations as in 2003 and was rare to uncommon in open areas. All crabs were collected by hand from a variety of supratidal habitats that included the roots of a cypress tree that were exposed by erosion, under a log and dug from shallow burrows in clay banks. Squareback marsh crabs were not represented in any of the earlier Academy investigations of the lower Neches River.

Only one species of fiddler crab, the spined fiddler, was obtained in the study area in 2003. A female spined fiddler was dug from a simple burrow at Station 2, while this species was common under rip rap and grasses at Station 3 and moderately common in simple burrows in the banks and under riparian vegetation at Station 4. In 1996, all spined fiddlers were collected above the water line by either digging them from shallow burrows in clay banks or they were captured as they scurried over the banks. They were recorded as moderately common in open areas and rare in regions in which they had to be dug from burrows. This species (as *Uca minax*) was taken from Stations 3 and 4 in 1953 and Station 4 in 1973. Unidentified fiddler crabs were recorded from Station 3 in 1956 and fiddler crab burrows were noted in the 1960 report.

4.3.4.10 Mites (Arachnida)

In 2003, in algae over a silt and sand substrate along the shore of the main channel, undetermined species of aquatic mites of the genera *Arrenurus* and *Unionicola* were found to be moderately common. No mites were collected in any of the previous Academy surveys.

4.4 Conclusions

Estuarine habitats are dynamic ecosystems based primarily on detrital energy pathways that are subject to populational, seasonal and annual fluctuations tied to variations in salinity, water temperature, dissolved oxygen and turbidity; hydrodynamic factors (currents, tides, etc.); timing and amounts of freshwater discharges; faunal predation, competition and recruitment; composition and extent of vegetation patterns; types, stability and heterogeneity of substrates; reproductive traits of individual species; and human activities. Because of these many variables, thorough sampling regimes conducted monthly or at least seasonally for more than one year with multiple techniques are important to assess faunal diversity. Previous Academy comprehensive collections of macroinvertebrates in the Neches River have been made during several seasons and a wide range of years (summer of 1953 and 1973 and autumn of 1996 and 2003). Cursory investigations were also conducted in the autumn of 1956 and winter of 1960 to monitor changes in the health of the river that was classified by the 1953 Academy study as polluted to very polluted at the downriver Stations 2 through 4.

4.4.1 Comparisons Among Stations (2003)

Based on the distribution of macroinvertebrates collected in 2003, a faunal division in distribution is present between Station 1 and the downriver Stations 2 through 4. The two regions contrast markedly in their habitat, with Station 1 reflecting a greater freshwater influence that varies with annual precipitation patterns (*cf*., 1973 and 2003 vs 1996). During the Academy surveys, Station 1 at times has ranged from freshwater (e.g., 1996 and 2003) to oligohaline and low mesohaline (1996), depending upon depth. It drains a mixed deciduous woodland with detrital inputs primarily from leaf abscission. The downriver Stations 2 through 4 are located in the channelized portion of the river and bear stronger tidal influences and higher salinities (oligohaline to low mesohaline in 2003 and low to high mesohaline in 1996). The river here is margined by common reed, pastureland, wooded areas and scattered trees with additional detrital input from emergent riparian vegetation (e.g., common reed).

At Station 1 in 2003, 55 species of macroinvertebrates were found that did not range downriver to Stations 2 through 4 (Table 4.2 and Appendix 4.1). The 55 species were represented by 22 taxa of non-insects and 33 species of insects. The dominant freshwater groups collected at Station 1 (i.e., having greater than 50% of the species collected in the survey) included an undetermined species of sponge, segmented worms (earthworm, two species of tubificid worms and the leech *H. triserialis*), snails (marsh ramshorn, excentric ancylid, mud amnicola, spiny crownsnail and an undetermined hydrobiid snail), bivalve molluscs (pond fingernailclam, mottled fingernailclam, Texas pigtoe and southern mapleleaf) and water mites (*Arrenurus* species and *Unionicola* species). Dominant insect groups at Station 1 incuded the dragonflies and damselflies (9 species at Station 1), alderflies (1 species found only at Station 1), caddisflies (2 species from Station 1) and mayflies. Of the five species of mayflies, three were collected only at Station 1, while the other two species ranged downriver through Stations 2 through 4. Other groups of freshwater macroinvertebrates common (having less than 50% of the species) at Station 1 included crustaceans (29%) and insects such as the true bugs (33%) and true flies (48%). The freshwater species found only at Station 1 are listed in Table 4.2.

Fifty-three species of macroinvertebrates were found at the downriver 3 oligohaline to high mesohaline Stations 2 through 4, almost as many were found at the upriver freshwa-

Table 4.2. List of taxa of macroinvertebrates collected **only** at **Station 1** on the lower Neches River, Texas, October 2003 (X, present; -, absent).

Phylum Porifera
  Undetermined sp.

Phylum Annelida
Class Clitellata
Subclass Oligochaeta
Family Tubificidae
  Brachiura sowerbyi
  Undetermined sp.
Family Lumbriculidae
  Lumbriculus variegatus
Subclass Hirudinea
Family Glossiphoniidae
  Helobdella triserialis

Phylum Mollusca
Class Gastropoda
Family Hydrobiidae
  Amnicola limosus
  Pyrgophorus spinosus
  Undetermined sp.
Family Planorbidae
  Planorbella trivolvis
Family Ancylidae
  Hebetoncylus excentricus

Class Bivalvia
Family Unionidae
  Fusconaia askewi
  Quadrula apiculata
Family Sphaeriidae
  Eupera cubensis
  Sphaerium securis

Phylum Arthropoda
Class Insecta
Order Odonata
Suborder Anisoptera
Family Aeshnidae
  Nasiaeschna pentacantha
Family Gomphidae
  Aphylla williamsoni
  Arigomphus maxwelli
Family Macromiidae
  Macromia taeniolata
Family Corduliidae
  Epitheca princeps
  Epitheca nr. *cynosura*
Family Libellulidae
  Libellula auripennis
  Pachydiplax longipennis
Suborder Zygoptera
Family Coenagrionidae
  Enallagma signatum

Order Ephemeroptera
Family Baetidae
  Procloeon sp.
Family Ephemeridae
  Hexagenia sp.
Family Tricorythidae
  Tricorythodes sp.

Order Hemiptera
Family Veliidae
  Platyvelia sp.
Family Nepidae
  Ranatra buenoi
Family Corixidae
  Palmacorixa buenoi

Order Megaloptera
Family Sialidae
  Sialis sp.

Order Trichoptera
Family Leptoceridae
  Oecetis sp.
  Nectopsyche sp.

Table 4.2 (continued). List of taxa of macroinvertebrates collected **only** at Station 1 on the lower Neches River, Texas, October 2003 (X, present; -, absent).

Order Coleoptera
Family Haliplidae
Peltodytes sexmaculatus

Order Diptera
Family Ceratopogonidae
Probezzia sp.
Family Chironomidae
Subfamily Tanypodinae
Clinotanypus sp.
Ablabesmyia sp.
Ablabesmyia grp.
Procladius (*Holotanypus*) sp.
Subfamily Orthocladiinae
Epoicocladius flavens
Subfamily Chironominae
Tribe Chironomini
Dicrotendipes modestus
Fissimentum sp.
Polypedilum illinoense grp.
Stictochironomus caffrarius grp.
Cladopelma sp.
Cryptochironomus sp.
Tribelos fuscicorne
Tribe Tanytarsini
Tanytarsus sp. K

Subphylum Crustacea
Class Malacostraca
Order Mysida
Family Mysidae
Taphromysis louisianae

Order Isopoda
Family Asellidae
Lirceus louisianae
Family Bopyridae
Probopyrus bithynis
Probopyrus floridensis

Order Decapoda
Suborder Pleocyemata
Infraorder Caridea
Family Palaemonidae
Palaemonetes kadiakensis
Infraorder Astacidea
Family Cambaridae
Procambarus clarkii

Class Arachnida
Order Trombidiformes
Family Arrenuridae
Arrenurus sp.
Family Unionicolidae
Unionicola sp.

ter Station 1 (55) (*cf*. Tables 4.2 and 4.3 and Appendix 4.1). In 2003, 23 species were indicative of this brackish portion of the estuary. These species included a comb jelly, polychaete worms (*N. succinea* and *F. miamiensis*), bivalves (Carolina marsh clam and dark falsemussel), barnacle *B. subalbidus*, opposum shrimp *M. almyra*, tanaid *H. rapax*, isopods (sea pill bug, sea roach and *E. triloba*), amphipods (*G. mucronatus, G.* sp. nr. *mucronatus, G. bonnieroides, C. lacustre, M. nitida* and beach hopper), shrimps (white shrimp and daggerblade grass shrimp) and crabs (Harris mud crab, heavy marsh crab, squareback marsh crab and spined fiddler). The polychaete worms represented the one group of annelids that were dominant at the three downriver brackish water stations. Along with the two species of polychaete worms, an additional annelid, the leech *M. lugubris*, was found only at Stations 2 through 4. Although the leech *M. lugubris* has only been collected at the lower stations in the two most recent Neches River surveys (1996, Station 3 and 2003, Stations 2 through 4), this species also occurs in freshwaters and would be expected to be part of the Station 1 fauna. With increasing salinities, crustaceans typically replace insects, and in the lower Neches River in 2003 twice as many crustacean species were found only at 1 or more of the brackish water Stations 2 through 4 (16) as were found only at Station 1 (8) (Appendix 4.1). While primarily a freshwater group, almost half of the insect species (29) collected in 2003 at Stations 2 through 4 were found in shallow oligohaline waters at 1 or more of the three downriver stations compared to the 33 species collected only at Station 1 (Table 4.1). These dominant groups (i.e., having greater than 50% of the species collected in the survey) include moths (100%) beetles (6 of 7 species, 86%) and true flies (15 of 29 species, 52%), while a common species group (having less than 50% of the species) was the true bugs (3 of 9 species, 33%). Many of the insects collected from the lower stations were taken in root mats of the water hyacinth that had floated downriver from upriver tributaries. The brackish water species found only at Stations 2 through 4 are listed in Table 4.3.

Only 7 of the 119 taxa collected in the Neches River ranged from Stations 1 through 4: the Atlantic rangia, mayflies (*Callibaetis* and *Caenis*), giant water bug (*Belostoma*), two

Table 4.3. List of taxa of macroinvertebrates collected only at the downriver Stations 2 through 4 on the lower Neches River, Texas, October 2003 (X, present; -, absent) (taxa labeled with an asterisk not used in the species total counts).

Taxa	Station 2	Station 3	Station 4
Phylum Ctenophora			
Undetermined sp.	-	-	X
Phylum Annelida			
Class Clitellata			
Subclass Hirudinea			
Family Piscicolidae			
Myzobdella lugubris	X	X	X
Class Polychaeta			
Family Nereididae			
Neanthes succinea	X	X	X
Family Serpulidae			
Ficopomatus miamiensis	-	X	X
Phylum Mollusca			
Class Bivalvia			
Family Corbiculidae			
Polymesoda caroliniana	X	X	-
Family Mytilidae			
Mytilopsis leucophaeta	X	X	X
Phylum Arthropoda			
Class Insecta			
Order Odonata			
Suborder Anisoptera			
Family Libellulidae			
Erythemis simplicicollis	X	X	X
Miathyria marcella	-	-	X
Suborder Zygoptera			
Family Coenagrionidae			
Ischnura ramburii	X	-	-
Ischnura posita	-	-	X
Ischnura sp.*	-	X	-
Order Hemiptera			
Family Corixidae			
Trichocorixa sp.	-	X	X

Table 4.3 (continued). List of taxa of macroinvertebrates collected **only** at the downriver **Stations 2 through 4** on the lower Neches River, Texas, October 2003 (X, present; -, absent) (taxa labeled with an asterisk not used in the species total counts).

	Station		
Taxa	**2**	**3**	**4**
Family Notonectidae			
Buenoa sp.	-	X	X
Family Naucoridae			
Pelocoris sp.	X	X	X
Order Lepidoptera			
Family Pyralidae			
Crambus sp.	X	X	X
Order Coleoptera			
Family Haliplidae			
Peltodytes dunavani	-	-	-
Family Dytiscidae			
Desmopachia sp.	-	-	-
Family Noteridae			
Hydrocanthus atripennis	-	-	-
Hydrocanthus sp.*	X	X	X
Suphisellus puncticollis	-	-	-
Family Hydrophilidae			
Tropisternus sp.	-	-	-
Berosus sp.	X	X	X
Order Diptera			
Family Culicidae			
Anopheles sp.	X	X	X
Aedes sp.	X	X	X
Culex sp.	X	X	X
Family Ceratopogonidae			
Dasyhelea sp.	-	-	-
Bezzia or *Palpomyia* sp.	X	X	X
Family Chironomidae			
Subfamily Tanypodinae			
Coelotanypus sp.	X	X	X
Labrundinia neopilosella	X	X	X
Subfamily Chironominae			
Tribe Chironomini			
Dicrotendipes neomodestus	X	X	X
Polypedilum halterale grp	X	X	X
Polypedilum scalaenum grp	-	-	-
Chironomus decorus grp	X	X	X
Endochironomus sp.	X	X	X

Table 4.3 (continued). List of taxa of macroinvertebrates collected **only** at the downriver **Stations 2 through 4** on the lower Neches River, Texas, October 2003 (X, present; -, absent) (taxa labeled with an asterisk not used in the species total counts).

Taxa	Station 2	Station 3	Station 4
Tribe Tanytarsini			
Tanytarsus sp. H**	X	X	X
Tanytarsus sp. E**	-	-	-
Tanytarsus sp. F**	X	X	X
Subphylum Crustacea			
Class Maxillopoda			
Order Sessilia			
Family Balanidae			
Balanus subalbidus	X	X	X
Class Malacostraca			
Order Mysida			
Family Mysidae			
Mysidopsis almyra	X	X	X
Order Tanaidacea			
Family Leptocheliidae			
Leptochelia rapax	-	-	-
Order Isopoda			
Family Sphaeromatidae			
Sphaeroma terebrans	X	X	X
Family Ligiidae			
Ligia exotica	-	-	-
Family Idoteidae			
Edotia triloba	-	-	-
Order Amphipoda			
Family Gammaridae			
Gammarus mucronatus	X	X	X
Gammarus nr. *mucronatus*	X	X	X
Family Corophiidae			
Corophium lacustre	X	X	X
Grandidierella bonnieroides	X	X	X
Family Melitidae			
Melita nitida	X	X	X
Family Talitridae			
Orchestia platensis	X	X	X

Table 4.3 (continued). List of taxa of macroinvertebrates collected **only** at the downriver **Stations 2 through 4** on the lower Neches River, Texas, October 2003 (X, present; -, absent) (taxa labeled with an asterisk not used in the species total counts).

Taxa	Station 2	Station 3	Station 4
Litopenaeus setiferus	X	X	X
Suborder Pleocyemata			
Infraorder Caridea			
Family Palaemonidae			
Palaemonetes pugio	X	X	X
Infraorder Brachyura			
Family Panopeidae			
Rhithropanopeus harrisii	X	X	X
Family Sesarmidae			
Armases cinereum	X	X	X
Sesarma reticulatum	-	-	-
Family Ocypodidae			
Uca spinicarpa	X	X	X

species of amphipods (*G.* sp. nr. *tigrinus* and *H. azteca*) and the blue crab. Only the Atlantic rangia (estuarine) and blue crab (euryhaline) are typically found throughout the lower Neches River, while the insects and amphipods are common freshwater species. The two mayfly taxa were found primarily in water hyacinth root mats that were present in the downriver stations after probably having been washed into the main channel from freshwater tributary streams following a heavy rain event on 9 October 2003. Only at Station 3 was *Callibaetis* found in a different habitat (flooded grasses). Giant water bugs are typical inhabitants of lentic waters and frequently leave their aquatic habitats by flying. They are usually associated with aquatic vegetation and in 2003 were found in flooded grasses at all stations. The habitat of the freshwater amphipod *H. azteca* was not discerned in the field, but this amphipod was probably associated with root mats of water hyacinth that had accumulated along the shoreline at Stations 2 through 4. The freshwater to oligohaline *G.* sp. nr. *tirginus* was abundant at Station 1 and rare (Station 2) to moderately common (Stations 3 and 4) downriver. The habitat for the three species of *Gammarus* collected from the three downriver stations was not discernable in the field, but all three were collected from water hyacinth roots at Stations 2 through 4 and from under an undercut bank at Station 4. It seems likely that the extended range of the *G*. sp. nr. *tigrinus* to the three downriver stations, like the mayflies and hyalellid amphipod, was primarily due to rafting in the root mats of the water hyacinth. The freshwater to euryhaline species found at all the study stations are listed in Table 4.4.

Four taxa were collected only at Stations 1 and 2 (three species) and Stations 1 and 4 (one species). These four taxa included two species of insects, surface dwelling water striders of the families Gerridae (*Rheumatobates*) and Veliidae (*Microvelia*) at Stations 1 and 2, the Ohio shrimp, abundant at Station 1 and moderately common at Station 2, and the tadpole physa, abundant at Station 1 and uncommon at Station 4. At Station 4 the tadpole physa was collected from along the left bank in a limited area influenced by a small freshwater spring feeder. All four of the species are inhabitants of freshwater with only the Ohio shrimp typically ranging into more saline waters. These freshwater species collected at Station 1 and at an additional downriver station are listed in Table 4.5.

4.4.2 Comparisons Among Years (1953, 1973, 1996 and 2003)

Comparisons among the four Academy surveys (2003, 1996, 1973 and 1953) reveal several patterns reflecting differences among the stations related to salinity, annual discharges and improvements in water quality in the Neches River. Differences in the presence and/or prevalence of insects at a station can differ seasonally and yearly with lower numbers during periods of decreased annual precipitation and concomitant decreased river discharge rates. Precipitation patterns in 2003 were more similar to 1973 and 1953 when freshwater influences extended further downriver than in 1996, a drier year in which the saltwater wedge extended upriver to Station 1 (*cf*. Table 4.1 and Fig. 1.3). The 119 taxa of macroinvertebrates collected in the October 2003 survey is a significant increase from the numbers of taxa collected in

Table 4.4. List of taxa of freshwater to euryhaline macroinvertebrates collected at Stations 1 through 4 on the lower Neches River, Texas, October 2003 (X, present; -, absent) (taxa labeled with an asterisk not used in the species total counts).

	Station			
Taxa	**1**	**2**	**3**	**4**
Class Bivalvia				
Family Mactridae				
Rangia cuneata	X	X	X	X
Phylum Arthropoda				
Class Insecta				
Order Ephemeroptera				
Family Baetidae				
Callibaetis sp.	X	X	X	X
Family Caenidae				
Caenis nr. *diminuta*	X	X	-	-
Caenis sp.*	-	-	-	X
Family Belostomatidae				
Belostoma sp.	X	X	X	X
Subphylum Crustacea				
Class Malacostraca				
Order Amphipoda				
Family Gammaridae				
Gammarus nr. *tigrinus*	X	X	X	X
Family Hyalellidae				
Hyalella azteca	X	X	X	X
Order Decapoda				
Suborder Pleocyemata				
Infraorder Brachyura				
Family Portunidae				
Callinectes sapidus	X	X	X	X

Table 4.5. List of taxa of macroinvertebrates collected at Stations 1 and 2 or Stations 1 and 4 on the lower Neches River, Texas, October 2003 (X, present; -, absent).

Taxa	Station 1	Station 2	Station 3	Station 4
Phylum Arthropoda				
Class Insecta				
Order Hemiptera				
Family Gerridae				
Rheumatobates sp.	X	X	-	-
Family Veliidae				
Microvelia sp.	X	X	-	-
Phylum Mollusca				
Class Gastropoda				
Family Physidae				
Physella gyrina	X	-	-	X
Phylum Arthropoda				
Subphylum Crustacea				
Class Maxillopoda				
Family Palaemonidae				
Macrobrachium ohione	X	X	-	-

previous years (58 in October 1996, 53 in August 1973 and 23 in August 1953, Table 4.1). Differences in species totals between 2003 and 1996 reflect variations in salinity patterns in the river (see below). The differences between 2003 and the earlier surveys of 1953 and 1973 indicate improvements in water quality in the lower Neches River.

A comparison of the species composition among the years shows a greater number of insects (67) in 2003 than in 1996 (14), 1973 (32) or 1953 (7). The low number of insect species in 1996 compared to 1973 and 2003, reflects a drought year in which decreased discharge rates were present in the Neches River (*q.v.*, Fig. 1.2, Introduction). Influxes of freshwaters escalate insect drift rates and lower salinity regimes better exploited by insects. Insects are a vagile group with many members exhibiting short life cycles that take advantage of short-term changes in environmental conditions. Differences in the number of insect species among 2003, 1973 and 1953 are a result of improvements in water quality. The numbers of non-insect macroinvertebrates in 2003 (52) is slightly more than the 44 species collected in 1996, more than twice that of 1973 (21) and more than 3 times greater than 1953 (16). The strong difference between 2003 and 1973 and 1953 reflects improvements in water quality.

In 2003, the numbers of species occurring at each of the stations ranged from a high of 66 at Station 1 to 46, 40 and 41 species, respectively, at Stations 2 through 4 (Table 4.1). The highest number of species at Station 1 reflects a fauna dominated by insects (38 of 66 species) with decreasing numbers of insects downriver at the oligohaline (shallow water) Stations 2 through 4 (23 insects of 46 total species, 17 of 40 and 15 of 41 species, respectively). Many of the insects collected at the downriver stations were taken from root mats of the water hyacinth that were probably washed from freshwater tributaries following a storm event on 9 October 2003. In the drought year of 1996, because of tidal influences with more saline waters extending further upriver, insects were a less dominant component than the non-insect species, but the pattern of more insect species at Station 1 with decreasing numbers downriver remained constant (Table 4.1). Both 1973 and 2003 were years with higher annual discharge patterns, and the higher numbers of species and numbers of insect taxa among the four stations in 2003 reflects improvements in water quality between the two surveys. The insect fauna reveals a sharp drop in the numbers of species between Station 1 and the downriver Stations 2 through 4 among all years (Table 4.1). In two of the three (1973, 1996 and 2003) years in which insects were collected from the downriver stations there is a decreasing number of insects collected from Stations 2 through 4 (10, 6 and 3 species in 1973 and 23, 17 and 15 species in 2003). The pattern is obscured by the presence of more saline waters in 1996 with few species of insects collected at the three downriver stations. No insects were taken at the three downriver stations in 1953. This pattern of more insects at Station 1 strongly influences the higher numbers of macroinvertebrate species at Station 1 that is found among all surveys (66 at Station 1 vs 46 at Station 2, 40 at Station 3 and

41 at Station 4 in 2003; 32 vs 22, 27 and 30 in 1996; 37 vs 20, 11 and 9 in 1973; and 20 vs 0, 3 and 4 in 1953, Table 4.1). Station 1 represents a less disturbed environment with more freshwater influences than Stations 2 through 4 where more saline waters, in a channelized portion of the river, are subject to the disturbances of shipping, more boating traffic and run-off and effluents from the Beaumont area.

Unlike the insect fauna, no strong difference in the number of non-insect macroinvertebrate species was recorded in 2003 among the stations (28, 23, 23 and 26 species at Stations 1 through 4, respectively). Similar numbers of species were also evident among stations in 1996, with a slight increase in species numbers downriver (20, 22, 26 and 28 species from Stations 1 through 4), following the classic increase in species diversity with increasing salinity (Gunter 1961, Remane and Schlieper 1971). Salinities in the shallow waters, where most macroinvertebrates were collected, at the three downriver stations in 1996 ranged from low to high mesohaline, while in 2003, shallow water salinities at these same stations were oligohaline. The high mesohaline waters in 1996 resulted in the presence of species at one or more of the downriver stations not found in 2003. These taxa included two undetermined species of jellyfishes, ectoproct *M. tenuis*, sergestid shrimp *A. americanus*, seabob (a penaeid shrimp) *X. kroyeri* and estuarine ghost shrimp *L. jamaicensis*. Because of the impact of water pollution in 1953 and 1973, patterns among the non-insects are less clear because of the low numbers of macroinvertebrates collected, especially at Stations 2 through 4 in 1953 and Stations 3 and 4 in 1973. One discernable pattern is the larger number of species at Station 1 (13 and 14 species in 1953 and 1973, respectively) than at the 3 downriver stations (0 species at Station 2, 3 at Station 3 and 4 at Station 4 in 1953 and 10, 5 and 6 species in 1973). This pattern differs from that of 1996/2003 where similar numbers of non-insects are present at all stations. This station order is a result of the impact of pollution at all stations in 1953, especially at Stations 2 through 4, while in 1973 improvements in water quality can be seen at Stations 1 and 2 and less so at Stations 3 and 4.

At Station 1, the 66 species of macroinvertebrates (28 non-insects/38 insects) obtained in 2003 is roughly double the

32 (20 non-insects/12 insects) species collected in 1996. Because 1996 was a drought year, the number of non-insect species, 28 in 2003 and 20 in 1996, is a better comparative measure of differences in the macroinvertebrate fauna between these years. The number of non-insects in 1973 (14) at Station 1 is similar to the 13 taken in 1953 and does not indicate significant improvement in water quality as measured by this group of generally more pollution-tolerant species. The non-insect fauna among the four years at Station 1 (1953–13, 1973–14, 1996–20 and 2003–28) shows a marked improvement between the 1953/1973 (13 and14 species, respectively) surveys and the 1996/2003 (20 and 28) studies. Total macroinvertebrate differences are primarily due to the greater numbers of insect species found in the river in 2003. Freshwater discharges are responsible for slightly more than 3 times as many species of insects recorded in 2003 (38) versus 1996 (12). The 23 species of insects in 1973 is more than 3 times the number that appeared in the 1953 survey (7 species) and indicates an improvement in water quality at least up to the level measured by this pollution-sensitive group.

The Station 2 macroinvertebrate fauna was more than twice as diverse in 2003 (46 species consisting of 23 non-insects and 23 insects) as in 1996 (22 non-insects and no insects). The non-insect macroinvertebrate fauna was similar between the two years with a very significant increase in the numbers of insects. The total numbers of macroinvertebrates (46), insects (23) and non-insects (23) in 2003 was roughly double that of 1973 (20, 10 and 10) and reflects improvements in water quality. Differences in the fauna between 2003 and 1953 are very dramatic. The river at this station in 1953 was classified as very polluted (ANSP 1954) and no macroinvertebrates were collected. The non-insect fauna among the 4 years show a steady improvement from 1953 through 1996/2003 (1953–0, 1973–10, 1996–22 and 2003–23). The insect biota among the 4 years showed marked changes between 2003 and 1996 (23 species in 2003 and no insects in 1996) and 1973 and 1953 (10 species in 1973 and no insects in 1953). These dramatic changes reflect differences in salinity patterns between 2003 and the drought year of 1996 and improvements in water quality from 1953 to 1973 and 2003.

In 2003, 40 species of macroinvertebrates were collected at Station 3, including 23 taxa of non-insects and 17 insect species. The total number in 2003 represents a steady increase in species from 3 in 1953, 11 in 1973 and 27 species in 1996. The 23 non-insect species in 2003 is close to the 26 species collected in 1996 and almost 5 to 7 times the numbers of non-insects captured in 1973 (5 species) and 1953 (3 species). Differences in the non-insect fauna show an improvement in water quality between 1996 and 1973/1953. As at Stations 1 and 2, the 2003 results reflect dramatic changes in the insect fauna between 2003 (17 insect species) and 1996 (1 species) and between 1973 (6 species) and 1953 (no insects). These differences are a result of salinity patterns between 2003 and 1996 and improvements in water quality from 1953 to 1973 and 2003.

At Station 4, as at Station 3, similar patterns in numbers of macroinvertebrates can be seen in 1) total numbers of species; 2) for the non-insects, similar numbers between 1953 and 1973, a dramatic change between 1973 and 1996 and similar numbers between 1996 and 2003; and 3) for the insects, a slight increase in the number of species between 1953 and 1973 a small decline between 1973 and 1996 and a large increase from 1996 to 2003. The total number of species in 2003 (41 species) represents a steady increase from the 4 species in 1953, 9 in 1973 and 30 species in 1996. The 26 non-insect species in 2003 is close to the 28 species collected in 1996 and more than 4 to 6 times the numbers of non-insects captured in 1973 (6 species) and 1953 (4 species). Differences in the non-insect fauna show an improvement in water quality between 1973 and 1996. As at the three upriver stations, the 2003 results also reflect changes in the insect fauna between 2003/1996 (15 and 2 insect species, respectively) and 1973/1953 (3 and 0 species). Contrasts among these years are a result of salinity pattern differences between 2003 and 1996 and slight to significant improvement in water quality between 1953 and 1973 and 1973 and 2003, respectively.

Improvement in water quality of the lower Neches River can be seen between 1953 and 1973 and more significantly between 1973 and 1996/2003. Recoveries in water quality between the early 1970s and more recent surveys were also observed in the macrobenthic fauna among the 1971/1972, 1984/1985 and 1999 surveys by Harrel et al. (1976), Harrel and Hall (1991) and Harrel and Smith (2002).

4.4.3 Summary

The results of the October 2003 survey showed the following trends:

4.4.3.1 Faunal Distribution Patterns Within 2003

- In 2003, there was a decrease in the total numbers of macroinvertebrate species between Station 1 (66) and the downriver Stations 2 through 4 (46, 40 and 41 species, respectively), primarily reflecting a larger freshwater insect component at Station 1.
- In 2003, there was a decrease in the numbers of insect species in a downriver direction (38, 23, 17 and 15 from Stations 1 through 4, respectively) that is associated with higher salinities downriver.
- In 2003, there were similar numbers of non-insect macroinvertebrate species among all the stations (28, 23, 23 and 26 from Stations 1 through 4, respectively).

4.4.3.2 Faunal Distribution Patterns Between 2003 and the Most Recent Study in 1996

- In 2003, the total number of macroinvertebrate species (119) was greater than in 1996 (58) and primarily reflects the greater total number of insect species (67 in 2003 and 14 in 1996) as a result of salinity patterns with higher salinity waters in 1996, a drought year.
- In 2003, there was a decrease in the numbers of insect species in a downriver direction (38, 23, 17 and 15 from Stations 1 through 4 in 2003) with few species of insects taken in 1996 (12, 0, 1 and 2, with one of the species at Station 4 collected from the Neches River channel at the interface of a freshwater tributary).
- In 2003, the total number of non-insect macroinvertebrate species (52) and numbers at each station (28, 23, 23 and 26 at Stations 1 through 4, respectively) are roughly similar to those found in 1996 (44 total with 20, 22, 26 and 28 species at each station).

- The lower Neches River estuary provides nursery grounds for the juvenile stages of at least two species of commercially important decapod crustaceans, the white shrimp and the blue crab.

4.4.3.3 Faunal Distribution Patterns Among all Surveys (1953, 1973, 1996, 2003)

- Station 1 supports more species than the downriver Stations 2 through 4. Station 1 represents a less disturbed environment with more freshwater influences than Stations 2 through 4, where more saline waters, in a channelized portion of the river, are subject to the disturbances of shipping, more boating traffic and runoff and effluents from the Beaumont area.
- Based upon the macroinvertebrate assemblages, the survey stations were polluted at Station 1 to very polluted at Stations 2 through 4 in 1953, with some improvement in water quality at Stations 1 and 2 and less so at Stations 3 and 4 in 1973, while the greatest improvement in water quality was evident between 1973 and the 1996/2003 surveys.
- Improvements in water quality can be seen in the total numbers of macroinvertebrate species and total numbers of insect species between 1953 and 1973 and more significantly between 1973 and 2003.
- Improvements in water quality can be seen in the numbers of non-insect macroinvertebrate species (at Station 2 only) between 1953 and 1973 and at all stations between 1973 and 1996/2003.
- Faunal differences due to salinity patterns were most evident between 1996, a drought year, and 2003. In 1996, there were significantly lower numbers of total macroinvertebrate species (58), total insect species (14) and insect and macroinvertebrate species at each station (12 insect species of 32 macroinvertebrates at Station 1, 0 of 22 at Station 2, 1 of 27 at Station 3 and 2 of 30 at Station 4) than were found in 2003 (119 and 67 totals with 38 of 66, 23 of 46, 17 of 40 and 15 of 41 at Stations 1 through 4, respectively). Some species that prefer higher salinity waters were present in 1996 and not 2003.

- Faunal differences due to salinity patterns were present between 1996 and 1973. In 1996, a lower total number of insect species (14) and fewer insect species at each station (12 at Station 1, 0 at Station 2, 1 at Station 3 and 2 at Station 4) were found compared to 1973 (32 total with 23, 10, 6 and 3 at Stations 1 through 4, respectively).

Appendix 4.1. List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Phylum Porifera				
Undetermined sp.	X	-	-	-
Phylum Ctenophora				
Undetermined sp.	-	-	-	X
Phylum Annelida				
Class Clitellata				
Subclass Oligochaeta				
Family Tubificidae				
Brachiura sowerbyi	X	-	-	-
Undetermined sp.	X	-	-	-
Family Lumbriculidae				
Lumbriculus variegatus	X	-	-	-
Subclass Hirudinea				
Family Glossiphoniidae				
Helobdella triserialis	X	-	-	-
Family Piscicolidae				
Myzobdella lugubris	-	X	X	X
Class Polychaeta				
Family Nereididae				
Neanthes succinea	-	X	X	X
Family Serpulidae				
Ficopomatus miamiensis	-	-	X	X
Phylum Mollusca				
Class Gastropoda				
Family Hydrobiidae				
Amnicola limosus	X	-	-	-
Pyrgophorus spinosus	X	-	-	-
Undetermined sp.	X	-	-	-
Family Planorbidae				
Planorbella trivolvis	X	-	-	-
Family Physidae				
Physella gyrina	X	-	-	X
Family Ancylidae				
Hebetoncylus excentricus	X	-	-	-
Class Bivalvia				
Family Unionidae				
Fusconaia askewi	X	-	-	-

Appendix 4.1 (continued). List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Quadrula apiculata	X	-	-	-
Family Sphaeriidae				
Eupera cubensis	X	-	-	-
Sphaerium securis	X	-	-	-
Family Corbiculidae				
Polymesoda caroliniana	-	X	X	-
Family Mactridae				
Rangia cuneata	X	X	X	X
Family Mytilidae				
Mytilopsis leucophaeta	-	X	X	X
Phylum Arthropoda				
Class Insecta				
Order Odonata				
Suborder Anisoptera				
Family Aeshnidae				
Nasiaeschna pentacantha	X	-	-	-
Family Gomphidae				
Aphylla williamsoni	X	-	-	-
Arigomphus maxwelli	X	-	-	-
Family Macromiidae				
Macromia taeniolata	X	-	-	-
Macromia sp.*	X	-	-	-
Family Corduliidae				
Epitheca princeps	X	-	-	-
Epitheca nr.*cynosura*	X	-	-	-
Family Libellulidae				
Libellula auripennis	X	-	-	-
Pachydiplax longipennis	X	-	-	-
Erythemis simplicicollis	-	X	X	X
Erythemis sp.*	-	X	-	-
Miathyria marcella	-	-	-	X
Suborder Zygoptera				
Family Coenagrionidae				
Enallagma signatum	X	-	-	-
Ischnura ramburii	-	X	-	-
Ischnura posita	-	-	-	X
Ischnura sp.*	-	-	X	-

Appendix 4.1 (continued). List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Order Ephemeroptera				
Family Baetidae				
Callibaetis sp.	X	X	X	X
Procloeon sp.	X	-	-	-
Family Ephemeridae				
Hexagenia sp.	X	-	-	-
Family Caenidae				
Caenis nr. *diminuta*	X	X	-	-
Caenis sp.*	-	-	-	X
Family Tricorythidae				
Tricorythodes sp.	X	-	-	-
Order Hemiptera				
Family Gerridae				
Rheumatobates sp.	X	-	-	-
Undetermined sp.*	-	X	-	-
Family Veliidae				
Microvelia sp.	X	X	-	-
Platyvelia sp.	X	-	-	-
Family Nepidae				
Ranatra buenoi	X	-	-	-
Ranatra sp.*	X	-	-	-
Family Belostomatidae				
Belostoma sp.	X	X	X	X
Family Corixidae				
Trichocorixa sp.	-	-	X	X
Palmacorixa buenoi	X	-	-	-
Family Notonectidae				
Buenoa sp.	-	-	X	X
Family Naucoridae				
Pelocoris sp.	-	X	X	X
Order Megaloptera				
Family Sialidae				
Sialis sp.	X	-	-	-
Order Lepidoptera				
Family Pyralidae				
Crambus sp.	-	X	X	-

Appendix 4.1 (continued). List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Order Trichoptera				
Family Leptoceridae				
Oecetis sp.	X	-	-	-
Nectopsyche sp.	X	-	-	-
Order Coleoptera				
Suborder Adephaga				
Family Haliplidae				
Peltodytes sexmaculatus	X	-	-	-
Peltodytes dunavani	-	-	X	-
Family Dytiscidae				
Desmopachia sp.	-	-	X	-
Family Noteridae				
Hydrocanthus atripennis	-	-	X	-
Hydrocanthus sp.*	-	X	-	X
Suphisellus puncticollis	-	-	-	X
Suborder Polyphaga				
Family Hydrophilidae				
Tropisternus sp.	-	-	-	X
Berosus sp.	-	X	-	-
Order Diptera				
Family Culicidae				
Anopheles sp.	-	X	-	-
Aedes sp.	-	X	-	-
Culex sp.	-	X	-	-
Family Ceratopogonidae				
Dasyhelea sp.	-	-	X	-
Bezzia or Palpomyia sp.	-	X	-	-
Probezzia sp.	X	-	-	-
Family Chironomidae				
Subfamily Tanypodinae				
Clinotanypus sp.	X	-	-	-
Coelotanypus sp.	-	X	X	-
Labrundinia neopilosella	-	X	-	-
Ablabesmyia mallochi	X	-	-	-
Ablabesmyia rhamphe grp.	X	-	-	-
Ablabesmyia sp.*	X	-	-	-
Procladius(*Holotanypus*) sp.	X	-	-	-
Procladius sp.*	X	-	-	-
Subfamily Orthocladiinae				
Epoicocladius flavens	X	-	-	-

Appendix 4.1 (continued). List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Subfamily Chironominae				
Tribe Chironomini				
Dicrotendipes modestus	X	-	-	-
Dicrotendipes neomodestus	-	X	X	X
Fissimentum sp.	X	-	-	-
Polypedilum illinoense grp	X	-	-	-
Polypedilum halterale grp	-	X	-	-
Polypedilum scalaenum grp	-	-	X	X
Chironomus decorus grp	-	X	-	-
Chironomus sp.*	-	X	-	-
Endochironomus sp.	-	X	-	-
Stictochironomus caffrarius grp	X	-	-	-
Cladopelma sp.	X	-	-	-
Cryptochironomus sp.	X	-	-	-
Tribelos fuscicorne	X	-	-	-
Tribe Tanytarsini				
Tanytarsus sp. K**	X	-	-	-
Tanytarsus sp. H**	-	X	X	X
Tanytarsus sp. E**	-	-	X	-
Tanytarsus sp. F**	-	X	-	-
Subphylum Crustacea				
Class Maxillopoda				
Order Sessilia				
Family Balanidae				
Balanus subalbidus	-	X	X	X
Class Malacostraca				
Order Mysida				
Family Mysidae				
Taphromysis louisianae	X	-	-	-
Mysidopsis almyra	-	X	X	X
Order Tanaidacea				
Family Leptocheliidae				
Leptochelia rapax	-	-	-	X
Order Isopoda				
Family Asellidae				
Lirceus louisianae	X	-	-	-
Family Sphaeromatidae				
Sphaeroma terebrans	-	X	X	X

Appendix 4.1 (continued). List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Family Ligiidae				
Ligia exotica	-	-	-	X
Family Idoteidae				
Edotia triloba	-	-	-	X
Family Bopyridae				
Probopyrus bithynis	X	-	-	-
Probopyrus floridensis	X	-	-	-
Order Amphipoda				
Family Gammaridae				
Gammarus nr. *tigrinus*	X	X	X	X
Gammarus mucronatus	-	X	X	X
Gammarus nr. *mucronatus*	-	X	X	X
Family Corophiidae				
Corophium lacustre	-	X	-	-
Grandidierella bonnieroides	-	X	X	X
Family Melitidae				
Melita nitida	-	X	X	X
Family Hyalellidae				
Hyalella azteca	X	X	X	X
Family Talitridae				
Orchestia platensis	-	X	X	X
Order Decapoda				
Suborder Dendrobranchiata				
Family Penaeidae				
Litopenaeus setiferus	-	X	X	X
Suborder Pleocyemata				
Infraorder Caridea				
Family Palaemonidae				
Macrobrachium ohione	X	X	-	-
Palaemonetes kadiakensis	X	-	-	-
Palaemonetes pugio	-	X	X	X
Infraorder Astacidea				
Family Cambaridae				
Procambarus clarkii	X	-	-	-
Infraorder Brachyura				
Family Portunidae				
Callinectes sapidus	X	X	X	X

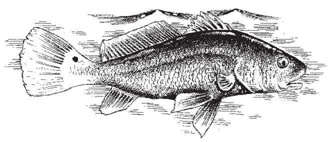
Appendix 4.1 (continued). List of taxa of macroinvertebrates collected 11-14 October 2003 at Stations 1-4 on the lower Neches River from the areas of Beaumont to Port Neches, Texas (X, present; -,absent)(taxa labeled with an asterisk not used in the station total count if the same genus is present from the station or in the species total count).

	Stations			
Taxa	**1**	**2**	**3**	**4**
Family Panopeidae				
Rhithropanopeus harrisii	-	X	X	X
Family Sesarmidae				
Armases cinereum	-	X	X	X
Sesarma reticulatum	-	-	X	-
Family Ocypodidae				
Uca spinicarpa	-	X	X	X
Class Arachnida				
Order Trombidiformes				
Family Arrenuridae				
Arrenurus sp.	X	-	-	-
Family Unionicolidae				
Unionicola sp.	X	-	-	-

** *Tanytarsus* sp. E, F, H and K *sensu* Epler,2001.

5. FISH

5.1 Introduction



Sciaenops ocellatus
Red Drum

The 2003 fish survey of selected portions of the Lower Neches River was the sixth in a series of Academy studies since 1953. Comprehensive surveys, during which collections were made at Stations 1-4, were conducted during 1953, 1973 and 1996. Cursory surveys of only Stations 3 and 4 were performed in 1956 and 1960. The Academy fish surveys have provided information on the occurrence, abundance and diversity of the fish fauna recorded within the Lower Neches River system. The main goals of the 2003 study were:

- assessing the spatial differences in the fish communities throughout four locations within the Lower Neches River in the vicinity of Beaumont and Port Arthur, Texas;
- determining the utilization of primary habitats (river bottom, nearshore) within each station; and
- comparing the fish communities recorded during the 2003 study with previous Academy lower Neches River fisheries surveys.

The October 2003 fish survey used a variety of collecting techniques including seining, trawling and dipnetting. Field personnel complied with ANSP Standard Operating Procedures P-14-13 (Collection of fish and macroinvertebrates by benthic otter trawling) and P-14-10 (Collection of fishes by seining). These techniques primarily target fishes in nearshore and benthic habitats. Larger fish and those species frequently associated with habitats containing more structure i.e., submerged brush and fallen trees, or those species that utilize the lower Neches River during winter through summer periods may be under-represented.

5.2 Methods

5.2.1 Techniques

The Lower Neches River fish communities were sampled at Stations 1, 2, 3 and 4 on 11-14 October 2003. Moderate to deep-water habitats were sampled using a 3.7-m (12-ft) benthic otter trawl with a 0.32-cm (0.125-in) mesh inner liner. Five to seven trawl samples, approximately equally spaced from bank to bank, were taken within the main channel at each station. Trawl samples were typically 5 min in duration with the exception of some samples at Station 1 that were shortened due to snagging of the trawl. Trawls were taken in an upstream direction, at a speed of about 2.5-3 knots. Some additional effort was taken at Station 3 when a couple of the trawl samples brought up bags of mud and peat when towed through uneven bottom contours. The temperature (°C), salinity (ppt), dissolved oxygen (mg/L), and pH were taken at the depth of the individual trawls at each station. All water quality parameters were also recorded at the surface (0.5 m depth) once within each station.

Near-shore shallow water habitats were sampled with a 6.1-m x 1.2-m (20-ft x 4-ft) bag seine with 0.32-cm (0.125-in) mesh at four sites within each station. Two additional samples were collected at Station 2, one in a cove area off the main river in the vicinity of Clark's Island. The seine was equipped with a weighted chain along the lead line to keep the net on the bottom. Each seine sample consisted of one haul which was typically pulled downstream with the flow. The length swept on each seine haul was measured to the nearest 0.1 m with a Leitz metric tape measure. Fish catches with seines are reported both as total catch and catch per unit effort, with number of fish per 100 m^2 as the standardized unit of measure. The temperature (°C) , salinity (ppt), dissolved oxygen (mg/L), specific conductance (μmhos) and pH were recorded at the first and last sampling locations within each station.

Water quality parameters were measured with a YSI Model 556 MPS Multi Probe System.

Slightly deeper habitats near shore were sampled using a 15.25-m x 1.8-m (50-ft x 6-ft) bag seine with 1.27-cm (0.5-in) mesh. Two seine samples were taken within each station, either by dragging the seine along shore or, in deeper water, anchoring it on shore and dragging it through a quarter-arc pulled into shore. No extra weight was attached to this seine. The length swept on each seine haul was measured to the nearest 0.1-m with a Leitz metric tape measure. Catches with seines are reported both as total catch and catch per unit effort, with number of fish per 100 m^2 as the standardized unit of measure.

Fish were also collected with a fine mesh dip net in conjunction with the macroinvertebrate sampling throughout each station. Up to three separate dip net samples (each comprising a number of net hauls) were taken at each station. Dip net samples were taken from areas of submerged vegetation, snag/brush piles, cut banks and coves found in shallow near shore habitats. Only unusual species were recorded and kept in these samples. These samples were received by the fisheries crew in the field and recorded as separate samples in the field notes.

5.2.2 Specimen Handling

Specimens from all samples were recorded separately. All fish were identified, enumerated, and either released in the field, or preserved with 10% buffered formalin for subsequent laboratory identification at the Academy. Released fish were measured (total length in cm, using standard metric ruler). In the laboratory, preserved fish were transferred to 70% ethanol (after a two-day rinse in water and a one-day rinse in 50% ethanol), identified and enumerated. Total lengths (to the nearest 0.5 mm) of selected specimens were measured with a standard metric ruler. Size ranges (minimum and maximum in mm) were measured for some of the more common species including the juvenile sciaenids (drums), ictalurids (catfish) and anchovies.

Fish were identified using standard references, including Douglas (1974), Hoese and Moore (1977), Miller and Robinson (1973), Robins and Ray (1986), Smith-Vaniz (1968), and

Walls (1975). Identifications of some young-of year and juvenile sciaenids (drums) and cyprinodontidae (killifish) required the use of taxonomic papers from the primary literature, including Brown (1956), Ditty (1989), Ditty and Shaw (1994), United States Fish and Wildlife Service (1978), and Wiley (1977). The common and scientific names of fishes used in this report (Table 5.1) are consistent with Robins et al. (1991), except that the western form of the spotted sunfish (formerly Lepomis punctatus miniatus) is considered a separate species, the redspotted sunfish Lepomis miniatus (Mayden et al. 1992). Selected fish specimens will be curated in the permanent fish collection of The Academy of Natural Sciences of Philadelphia (ANSP). Macroinvertebrates collected during seining and trawling were given to Dr. Raymond W. Bouchard for identification and enumeration.

White mullet (Mugil curema) were identified in preserved samples from Station 4. Other mullet were either captured and released in the field or observed during sampling. These mullet may have been either white mullet, striped mullet (M. cephalus) or a mixture. Most mullet captured, including the white mullet from Station 4, were 8 to 13 cm in total length. One mullet from Station 2 was 24.3 cm in length. This may have been striped mullet, since large striped mullet occur more commonly in fresh and brackish water than large white mullet. For the report, mullet from Stations 1 to 3 are listed as Mugil species. In comparisons of occurrence among stations, all mullets are treated together.

Species identifications were taken from reports of the previous surveys (ANSP 1954, 1958, 1961, 1974 and 1998). Some names are changed on the basis of taxonomic revisions of the groups. Some specimens have been re-identified after the reports were prepared and the revised identifications are given. However, no attempt was made to examine fishes from earlier surveys to confirm identifications.

Table 5.1. Common and scientific names of fishes caught in 1996 and 2003 ANSP Neches River surveys.

Family	Scientific	Common Name
Lepisosteidae	*Lepisosteus oculatus*	spotted gar
Ophichthidae	*Myrophis punctatus*	speckled worm eel
Clupeidae	*Brevoortia patronus*	gulf menhaden
	Dorosoma petenense	threadfin shad
Engraulidae	*Anchoa mitchilli*	bay anchovy
Cyprinidae	*Cyprinella lutrensis*	red shiner
	Cyprinella venusta	blacktail shiner
	Lythrurus fumeus	ribbon shiner
	Notropis texanus	weed shiner
	Opsopoeodus emiliae	pugnose shiner
Ictaluridae	*Ameiurus melas*	black bullhead
	Ictalurus furcatus	blue catfish
	Ictalurus punctatus	channel catfish
Ariidae	*Arius felis*	hardhead catfish
Aphredoderidae	*Aphredoderus sayanus*	pirate perch
Cyprinodontidae	*Adinia xenica*	diamond killifish
	Cyprinodon variegatus	sheepshead minnow
	Fundulus blairae	Blair's starhead topminnow
	Fundulus chrysotus	golden topminnow
	Fundulus grandis	gulf killifish
	Fundulus jenkinsi	saltmarsh topminnow
	Fundulus notatus	blackstripe topminnow
	Fundulus pulvereus	bayou killifish
	Lucania parva	rainwater killifish
Poeciliidae	*Gambusia affinis*	western mosquitofish
	Heterandria formosa	least killifish
	Poecilia latipinna	sailfin molly
Atherinidae	*Labidesthes sicculus*	brook silverside
	Membras martinica	rough silverside
	Menidia beryllina	tidewater silverside
Sygnathidae	*Syngnathus scovelli*	gulf pipefish
Triglidae	*Prionotus species*	searobin species
Centrarchidae	*Lepomis macrochirus*	bluegill
	Lepomis megalotis	longear sunfish
	Lepomis microlophus	redear sunfish
	Lepomis miniatus	redspotted sunfish
	Lepomis species	sunfish species
	Micropterus punctulatus	spotted bass
	Pomoxis annularis	white crappie
	Pomoxis nigromaculatus	black crappie

Table 5.1. Common and scientific names of fishes caught in 1996 and 2003 ANSP Neches River surveys.

Family	Scientific	Common Name
Elassomatidae	*Elassoma zonatum*	banded pygmy sunfish
Percidae	*Etheostoma asprigene*	mud darter
	Etheostoma proeliare	cypress darter
Carangidae	*Selene vomer*	lookdown
Gerreidae	*Eucinostomus argenteus*	spotfin mojarra
	Eucinostomus gula	silver jenny
Sparidae	*Archosargus probatocephalus*	sheepshead
Sparidae	*Lagodon rhomboides*	pinfish
Sciaenidae	*Aplodinotus grunniens*	freshwater drum
	Cynoscion arenarius	sand seatrout
	Cynoscion nebulosus	spotted seatrout
	Leiostomus xanthurus	spot
	Micropogonias undulatus	Atlantic croaker
	Sciaenidae species	drum species
	Sciaenops ocellatus	red drum
	Stellifer lanceolatus	star drum
	Cynoscion nothus	silver seatrout
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish
Mugilidae	*Mugil cephalus*	striped mullet
	Mugil curema	white mullet
Gobiidae	*Dormitator maculatus*	fat sleeper
	Gobionellus boleosoma	darter goby
	Gobionellus shufeldti	freshwater goby
	Gobiosoma bosc	naked goby
Bothidae	*Citharichthys spilopterus*	bay whiff
Cynoglossidae	*Symphurus species*	tonguefish species
Soleidae	*Achirus lineatus*	lined sole
	Symphurus plagiusa	blackcheek tonguefish
	Trinectes maculatus	hogchoker

5.2.3 Sampling Sites and Conditions

5.2.3.1 Station 1

Station 1 was located approximately 0.8 km (0.5 mi) downstream from the Salt Water Barrier and 2.4 km (1.5 miles) upstream from the Beaumont Country Club. The left bank (all bank references are facing downstream) was steep-sided with many tree snags with no available seining habitat. The right bank contained several shallow sloping sand and mud/sand beaches with pockets of flooded brush, cypress knees and Juncus that were suitable for seining. A large backwater at the downstream end of the statio off of the main river was also sampled. This cove contained a large stand of the emergent plant Lake Acanthus (Hygrophila lacustris). Several submerged log snags were noted along the river bottom nearer the left bank while trawling. Juvenile catfish were collected from these samples.

Trawling depths ranged from 2.4-8.5 m (about 8-28 ft). Salinity (Table 5.3) ranged from 0.03 ppt at the surface to 0.05 ppt near the bottom (8.5 m). Dissolved oxygen values ranged from 5.39 mg/L(surface) to 4.71 mg/L (8.5 m) (Table 5.2). One dip net sample was collected along the right bank in the vicinity of the large backwater.

5.2.3.2 Station 2

Station 2 extended upstream from green channel marker #51 to about 100 m downstream from red channel marker #56. The left bank, with a large, open, firm sand beach with pockets of flooded shoreline grasses, provided ample seining habitat. Because of flooded conditions and lack of available shallow water habitat only one sample was taken along the right bank at the upstream end of Clark's Island. A small right bank backwater area off the main river just upstream of Clark's Island was sampled by seine. The sample was collected by pulling the net through the flooded Phragmites along the soft mud shoreline. Trawling depths ranged from 3.7-13.7 m (about 12-45 ft). One dip net sample was collected along the in the cove area upstream of Clark's Island on the right bank. This sample was combined with the fish from our seine sample and preserved. Salinity ranged from 0.18 (surface) to 5.57 ppt (about 14 m). Dissolved oxygen values ranged from 3.97 mg/L (surface) to 0.53 mg/L (around 14 m).

Table 5.2. Summary of physico-chemical measurements associated with fish trawl sampling in the 2003 ANSP Neches River survey.

			Depth (m)	DO mg/L	Start DO (%) %sat	Salinity (ppt)	Conductivity (μmho)	pH	Water Temp. °C	No. of Measurements
Station 1										
	Shallow									
		mean	0.20	5.03	59.83	0.03	68.40	6.38	24.05	10
		min	0.20	4.10	50.60	0.03	66.00	5.79	23.48	10
		max	0.20	5.60	67.00	0.03	70.00	6.60	26.24	10
	Mid depth									
		mean	2.75	5.18	61.00	0.03	69.00	6.37	23.55	2
		min	2.50	5.18	61.00	0.03	68.00	6.34	23.53	2
		max	3.00	5.18	61.00	0.03	70.00	6.40	23.56	2
	Deep									
		mean	6.33	4.95	58.13	0.04	65.33	6.30	23.47	3
		min	5.00	4.71	55.30	0.03	65.00	6.27	23.45	3
		max	8.00	5.11	60.10	0.05	66.00	6.32	23.49	3
Station 2										
	Shallow									
		mean	0.23	3.77	44.29	0.27	553.90	6.56	24.17	10
		min	0.20	3.30	39.00	0.18	373.00	6.40	23.72	10
		max	0.30	4.25	50.90	0.49	987.00	6.71	25.54	10
	Deep									
		mean	8.00	1.99	24.10	2.05	3779.00	6.64	24.02	5
		min	5.00	0.53	7.00	0.27	572.00	6.49	23.81	5
		max	12.00	3.52	42.00	5.57	9900.00	6.90	24.48	5
Station 3										
	Shallow									
		mean	0.34	5.15	62.44	0.57	1148.75	6.79	25.08	8
		min	0.20	4.59	54.00	0.43	872.00	6.66	23.69	8
		max	0.50	6.26	78.90	0.84	1679.00	7.12	26.63	8
	Deep									
		mean	9.75	3.80	46.55	5.25	9117.50	6.94	24.50	4
		min	5.00	2.61	33.00	2.05	3340.00	6.76	24.15	4
		max	13.00	5.12	61.80	8.89	15290.00	7.12	24.71	4
Station 4										
	Shallow									
		mean	0.33	5.02	61.44	2.18	4108.25	6.86	24.78	8
		min	0.20	4.71	56.70	1.51	2917.00	6.27	24.34	8
		max	0.50	5.28	63.90	2.80	5200.00	7.18	25.27	8
	Deep									
		mean	9.00	4.27	53.13	6.03	10721.75	7.17	24.73	4
		min	6.00	3.64	46.00	3.34	6137.00	7.01	24.56	4
		max	6.00	4.86	59.50	8.43	14850.00	7.27	24.82	4

5.2.3.3 Station 3

Station 3 extended upstream from channel marker # 40 in McFadden Bend Cutoff approximately 0.4 km (0.25 mi). The left channel margin was bordered by the Fleet Reserve Area, an embayment used to anchor large ships. The series of islands that formed the left-bank boundary within the station, cited in ANSP (1974), were no longer visible, and remnants of the islands were marked with wooden posts. We were able to trawl within the inner margins of the Fleet Reserve restricted area and seine at the downstream end of the embayment, on a firm sandy beach with emergent grasses. The substrates along the right bank consisted of firm mud/sand, softer mud and slick, hard-packed clay with flooded Spartina, Phragmites and submerged tree roots.

Trawling depths of the samples taken between the main channel borders ranged from 1.8-14.6 m (about 8-48 ft). One dip net sample was collected along the right bank. Salinity ranged from 0.43 (surface) to 8.89 ppt (around 14 m). Dissolved oxygen values ranged from 2.61 mg/L recorded at around 14 m, and 4.80 mg/L at the surface.

5.2.3.4 Station 4

Station 4 extended from about 150 m downstream of the marsh canal located below red channel marker #28 upriver to 25 m downstream of green channel marker #29. Several pockets of hard-sand beach, some with flooded grasses, were seined along the left bank near the mouth of a large marsh channel. Areas of soft mud and organic detritus, with flooded Phragmites, were seined along the right bank.

Trawling depths ranged from 2.4-14.6 m (about 8-48 ft). One dip net sample was collected along the left bank. Salinity ranged from 2.15 (surface) to 8.43 ppt (around 14 m). Dissolved oxygen values varied between 3.64 (12 m) and 5.28 mg/L between 6 and 10 m.

5.3 Results

5.3.1 General Overview

The chemical measurements taken along with the samples (Table 5.2) show the clear estuarine gradient from Stations 1 to 4. Station 1 was freshwater, with no evident vertical stratification. Salinity increased from Stations 2 through 4. Vertical stratification was evident at the three lower stations (especially at Stations 3 and 4), with markedly higher salinity and slightly warmer water in deeper water. Dissolved oxygen was relatively high at Station 1, ranging from 4.1 to 5.6 mg/L. Dissolved oxygen was also relatively high in surface water at Stations 3 and 4, ranging from 4.6 to 6.3 mg/L. Dissolved oxygen concentration was lower in surface water from Station 2, lower in deeper water at Stations 2 through 4, and was lowest in deep water from Station 2.

In all, 28,567 fish of 51 species were caught in the 2003 ANSP Neches River survey (Tables 5.1, 5.3 and 5.4). The majority of these (95% of all fish caught) were bay anchovy. Bay anchovy made up over 90% of the catch at the four stations. Only three other species (tidewater silversides, western mosquitofish, and rainwater killifish) were caught at all four stations. Mullet (*Mugil* species) were also caught at all four stations. Twenty-nine species were caught at only one station (20 of these were caught at Station 1, 2 at Station 2, 3 at Station 3, and 4 at Station 4), and 12 others were caught at only 2 stations (4 from Stations 1 and 2, 2 from Stations 2 and 3, 2 from Stations 2 and 4, and 4 from Stations 3 and 4). This pattern reflects the salinity gradient, with several freshwater species (e.g., some minnows and channel catfish) relatively common at Station 1, and several estuarine species (e.g., gulf menhaden, sailfin molly and bay whiff) found only a Station 4. Several other estuarine species, such as sand seatrout and spot, were found only at Stations 2-4.

5.3.2 Seining

More species (41) were caught in the 20-ft seines than by any of the other techniques (9-17 species), and 19 species were collected only by the 20-ft seines (Tables 5.4 and 5.5). The seine samples represent standardized sampling in shallow shore habitats, and comparisons of abundance (as ln(catch per unit effort+1)) were made for selected taxa (Table 5.5). For most species, abundance varied among stations consistent with differences in salinity. However, while the overall pattern of species occurrence is clear, the variation in abundance within samples from stations where species occurred and the small sample size make it difficult to demonstrate statistical significance of individual species patterns. The abundance of blacktail shiner was significantly greater at Station 1 (where it was found in all 20-ft seine samples) than at the other stations (where none was caught). Bay anchovy was the only species common at all

Table 5.3. Total numbers and proportions of species collected by all techniques in the 2003 ANSP Neches River survey.

Common Name	Number of Individuals by Station 1	2	3	4	TOTAL	Proportion of All Specimens	Proportion of Station Total 1	2	3	4
spotted gar	6	0	0	0	6	0.00021004	0.0008768	0	0	0
threadfin shad	0	0	3	4	7	0.000245047	0	0	0.001122	0.000283
gulf menhaden	0	0	0	5	5	0.000175033	0	0	0	0.0003537
bay anchovy	6164	4733	2506	13701	27104	0.948820276	0.9007745	0.96297	0.93717	0.9692961
blacktail shiner	184	0	0	0	184	0.006441224	0.0268888	0	0	0
weed shiner	117	0	0	0	117	0.004095778	0.0170978	0	0	0
pugnose shiner	13	0	0	0	13	0.000455086	0.0018998	0	0	0
ribbon shiner	10	0	0	0	10	0.000350067	0.0014613	0	0	0
red shiner	7	1	0	0	8	0.000280053	0.0010229	0.000203	0	0
channel catfish	98	0	0	0	98	0.003430652	0.0143212	0	0	0
blue catfish	32	6	4	0	42	0.001470279	0.0046763	0.001221	0.001496	0
black bullhead	0	0	1	0	1	3.50067E-05	0	0	0.000374	0
hardhead catfish	0	1	0	5	6	0.00021004	0	0.000203	0	0.0003537
pirate perch	1	0	0	0	1	3.50067E-05	0.0001461	0	0	0
sheepshead minnow	0	2	0	59	61	0.002135406	0	0.000407	0	0.004174
rainwater killifish	23	1	1	1	26	0.000910173	0.0033611	0.000203	0.000374	7.075E-05
blackstripe topminnow	10	0	0	0	10	0.000350067	0.0014613	0	0	0
bayou killifish	1	6	0	0	7	0.000245047	0.0001461	0.001221	0	0
golden topminnow	3	0	0	0	3	0.00010502	0.0004384	0	0	0
saltmarsh topminnow	0	2	0	0	2	7.00133E-05	0	0.000407	0	0
western mosquitofish	35	5	1	94	135	0.004725898	0.0051147	0.001017	0.000374	0.0066502
sailfin molly	0	0	0	126	126	0.004410838	0	0	0	0.008914
least killifish	0	0	1	0	1	3.50067E-05	0	0	0.000374	0
tidewater silverside	7	18	96	14	135	0.004725898	0.0010229	0.003662	0.0359	0.0009904
brook silverside	3	0	0	0	3	0.00010502	0.0004384	0	0	0
gulf pipefish	0	4	0	0	4	0.000140027	0	0.000814	0	0
redspotted sunfish	28	9	0	0	36	0.001260239	0.0040918	0.001628	0	0
bluegill	19	1	0	0	20	0.000700133	0.0027766	0.000203	0	0
black crappie	16	0	0	0	16	0.000560106	0.0023382	0	0	0
redear sunfish	11	0	0	0	11	0.000385073	0.0016075	0	0	0
longear sunfish	4	0	0	0	4	0.000140027	0.0005845	0	0	0
white crappie	2	0	0	0	2	7.00133E-05	0.0002923	0	0	0
spotted bass	1	0	0	0	1	3.50067E-05	0.0001461	0	0	0
cypress darter	6	0	0	0	6	0.00021004	0.0008768	0	0	0
banded pygmy sunfish	4	0	0	0	4	0.000140027	0.0005845	0	0	0
mud darter	1	0	0	0	1	3.50067E-05	0.0001461	0	0	0
silver jenny	0	0	1	1	2	7.00133E-05	0	0	0.000374	7.075E-05
sheepshead	0	0	1	1	2	7.00133E-05	0	0	0.000374	7.075E-05
sand seatrout	0	81	41	62	184	0.006441224	0	0.01648	0.01533	0.0043863
spot	0	20	9	8	37	0.001295246	0	0.004069	0.003367	0.000566
star drum	0	0	1	23	23	0.000805153	0	0	0.00037	0.0016272
Atlantic croaker	0	3	2	0	5	0.000175033	0	0.00061	0.000748	0
silver seatrout	0	1	2	0	3	0.00010502	0	0.000203	0.000748	0
freshwater drum	1	0	0	0	1	3.50067E-05	0.0001461	0	0	0
spotted seatrout	0	0	1	0	1	3.50067E-05	0	0	0.000374	0
Mullet species	1	15	1	0	17	0.000595113	0.0001461	0.003052	0.000374	0
white mullet	0	0	0	4	4	0.000140027	0	0	0	0.000283
darter goby	1	6	0	24	31	0.001085206	0.0001461	0.001221	0	0.0016979
freshwater goby	11	1	1	0	13	0.000455086	0.0016075	0.000203	0.000374	0
fat sleeper	0	0	1	1	2	7.00133E-05	0	0	0.000374	7.075E-05
bay whiff	0	0	0	2	2	7.00133E-05	0	0	0	0.0001415
hogchoker	23	0	0	0	23	0.000805153	0.0033611	0	0	0
total	6843	4915	2674	14135	28567	1	1	1	1	1

Table 5.4. Capture of species by various techniques in the 2003 ANS Neches River survey. Techniques are 20-ft seine (S), 50-ft seine (F), otter trawl (T) and dipnetting (H). *

Scientific Name	Station 1	Station 2	Station 3	Station 4	All Stations
Lepisosteus oculatus	S F				S F
Brevoortia patronus				F	F
Dorosoma petenense			F	S F	S F
Anchoa mitchilli	STFH	STF	STF	STF	STFH
Cyprinella lutrensis	S	S			S
Cyprinella venusta	S				S
Lythrurus fumeus	S				S
Notropis texanus	S				S
Opsopoeodus emiliae	S				S
Ameiurus melas			S		S
Ictalurus furcatus	T	T	T		T
Ictalurus punctatus	ST				ST
Arius felis		S		TF	STF
Aphredoderus sayanus	H				H
Cyprinodon variegatus		S		S	S
Fundulus chrysotus	SH				SH
Fundulus jenkinsi		S*			S
Fundulus notatus	S				S
Fundulus pulvereus	H	S*			SH
Lucania parva	SH	S	S	S	SH
Gambusia affinis	SH	S	S	S	SH
Heterandria formosa			S		S
Poecilia latipinna				S F	S F
Labidesthes sicculus	S				S
Menidia beryllina	S	S F	S F	S H	S FH
Syngnathus scovelli		S*			S
Lepomis macrochirus	S FH	S			S FH
Lepomis megalotis	S H				SH
Lepomis microlophus	S F				S F
Lepomis miniatus	S H	S			SH
Micropterus punctulatus	S				S
Pomoxis annularis	S				S
Pomoxis nigromaculatus	S F				S F
Etheostoma asprigene	H				H
Etheostoma proeliare	S H				SH
Elassoma zonatum	H				H
Eucinostomus gula			S	S	S
Archosargus probatocephalus			S	F	S F
Aplodinotus grunniens	F				F
Cynoscion arenarius		SFT	SFT	SFT	SFT
Cynoscion nebulosus			S		S
Cynoscion nothus		S	S		S
Leiostomus xanthurus		S F	S F	S F	S F
Micropogonias undulatus		FT	FT		FT
Stellifer lanceolatus			T	T	T
Mugil species	F		H		FH
Mugil curema		F		F	F
Dormitator maculatus			S	S	S
Gobionellus boleosoma	S	S		ST H	STH
Gobionellus shufeldti	S	S	S		S
Citharichthys spilopterus				F	F
Trinectes maculatus	STF				STF

*Species caught in non-standard seine samples.

Table 5.5. Mean and standard deviation of catch rate (ln(catch per 100 m^2 +1) in 20-ft seine samples from the 2003 ANSP Neches River survey. Means are based on four samples from each station.

	Station 1		Station 2		Station 3		Station 4	
Scientific Name	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lepisosteus oculatus	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Dorosoma petenense	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52
Anchoa mitchilli	6.11	1.58	6.55	0.21	4.24	1.94	7.26	0.84
Cyprinella lutrensis	0.39	0.67	0.13	0.22	0.00	0.00	0.00	0.00
Cyprinella venusta	2.97	0.81	0.00	0.00	0.00	0.00	0.00	0.00
Lythrurus fumeus	0.64	0.88	0.00	0.00	0.00	0.00	0.00	0.00
Notropis texanus	2.16	1.51	0.00	0.00	0.00	0.00	0.00	0.00
Opsopoeodus emiliae	0.73	0.98	0.00	0.00	0.00	0.00	0.00	0.00
Ameiurus melas	0.00	0.00	0.00	0.00	0.08	0.14	0.00	0.00
Ictalurus punctatus	0.11	0.18	0.00	0.00	0.00	0.00	0.00	0.00
Arius felis	0.00	0.00	0.13	0.22	0.00	0.00	0.00	0.00
Cyprinodon variegatus	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.53
Fundulus chrysotus	0.13	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Fundulus notatus	0.77	0.57	0.00	0.00	0.00	0.00	0.00	0.00
Lucania parva	0.73	1.26	0.13	0.22	0.08	0.15	0.12	0.21
Gambusia affinis	0.39	0.67	0.11	0.18	0.08	0.14	1.74	1.74
Heterandria formosa	0.00	0.00	0.00	0.00	0.08	0.14	0.00	0.00
Poecilia latipinna	0.00	0.00	0.00	0.00	0.00	0.00	1.96	1.77
Labidesthes sicculus	0.29	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Menidia beryllina	0.52	0.68	0.41	0.72	1.72	1.62	0.64	0.87
Lepomis macrochirus	1.26	0.47	0.11	0.18	0.00	0.00	0.00	0.00
Lepomis megalotis	0.35	0.21	0.00	0.00	0.00	0.00	0.00	0.00
Lepomis microlophus	0.55	0.96	0.00	0.00	0.00	0.00	0.00	0.00
Lepomis miniatus	0.62	0.41	0.31	0.32	0.00	0.00	0.00	0.00
Micropterus punctulatus	0.11	0.18	0.00	0.00	0.00	0.00	0.00	0.00
Pomoxis annularis	0.24	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Pomoxis nigromaculatus	0.47	0.59	0.00	0.00	0.00	0.00	0.00	0.00
Etheostoma proeliare	0.36	0.63	0.00	0.00	0.00	0.00	0.00	0.00
Eucinostomus gula	0.00	0.00	0.00	0.00	0.13	0.22	0.11	0.19
Archosargus probatocephalus	0.00	0.00	0.00	0.00	0.13	0.22	0.00	0.00
Cynoscion arenarius	0.00	0.00	1.28	0.23	1.32	0.42	0.69	0.74
Cynoscion nebulosus	0.00	0.00	0.00	0.00	0.13	0.22	0.00	0.00
Cynoscion nothus	0.00	0.00	0.11	0.18	0.14	0.24	0.00	0.00
Leiostomus xanthurus	0.00	0.00	0.11	0.18	0.53	0.55	0.34	0.39
Dormitator maculatus	0.00	0.00	0.00	0.00	0.13	0.22	0.11	0.19
Gobionellus boleosoma	0.15	0.26	0.00	0.00	0.00	0.00	0.39	0.41
Gobionellus shufeldti	0.68	0.82	0.13	0.22	0.08	0.15	0.00	0.00
Trinectes maculatus	0.24	0.41	0.00	0.00	0.00	0.00	0.00	0.00

four stations. There were no significant differences in the mean abundance of bay anchovy among stations, and the abundance in samples could not be related to differences in dissolved oxygen. Differences in mean abundance among stations reflect low catch rates in a few samples (one sample at Station 1 and two samples at Station 3). There are no clear differences in habitat or water chemistry at these specific samples which can explain these differences. The abundance of the other widespread species (tidewater silversides, western mosquitofish and rainwater killifish) did not differ significantly among stations, reflecting patchy occurrence of these species in samples within individual stations.

The 50-ft seine samples were useful in collecting some larger fishes, and four species were documented only using this technique (Tables 5.4 and 5.6).

5.3.3 Trawling

Nine species were caught by trawling (Table 5.7), but sand seatrout and bay anchovy dominated. As in the seine samples, there was an estuarine gradient, with two species (channel catfish and hogchoker) found only at Station 1 and two species (hardhead catfish and darter goby) caught only at Station 4.

Comparisons of abundance (ln(catch rate per 5 minutes+1)) show significant differences among stations, habitat (depth of samples), and physico-chemical conditions (DO, salinity) for several taxa. There was no deep habitat at Station 1; therefore, tests of depth-station interactions could only be done for Stations 2-4.

5.3.3.1 Sand Seatrout

There was a highly significant difference in sand seatrout abundance ($p<0.001$), with abundances at Stations 2 and 4 significantly higher than those at Stations 1 and 3. There was no relationship between sand seatrout abundance and depth (as maximum depth of the trawl sample, or as discrete categories of shallow versus deep samples), salinity or DO.

5.3.3.2 Bay Anchovy

There was a weakly significant difference in bay anchovy abundance ($p<0.022$). Abundance increased from Stations 1 to 4; pairwise contrasts indicate that abundance at Station 1 was significantly lower than at Stations 3 and 4. Among Stations 2-4, there was a marginally non-significant ($p<0.06$) station-depth class interaction, resulting from differences in abundance in shallow trawls from Stations 2 and 4. Despite the gradient in abundance from Station 1 to 4, there was no relationship between observed abundance and measured salinity or DO.

Table 5.6. Occurrence of fishes in 50-ft seine (above) and dipnet (below) samples in the 2003 ANSP Neches River survey.

50-ft Seine		Station			
		1	**2**	**3**	**4**
	Number of Samples	**3**	**3**	**2**	**2**
Anchoa mitchilli	bay anchovy	2	7	1	4
Aplodinotus grunniens	freshwater drum	1			
Archosargus probatocephalus	sheepshead				1
Arius felis	hardhead catfish				4
Brevoortia patronus	gulf menhaden				5
Citharichthys spilopterus	bay whiff				2
Cynoscion arenarius	sand seatrout		6	7	4
Dorosoma petenense	threadfin shad			3	1
Leiostomus xanthurus	spot		19	2	5
Lepisosteus oculatus	spotted gar	3			
Lepomis macrochirus	bluegill	1			
Lepomis microlophus	redear sunfish	1			
Menidia beryllina	tidewater silverside		1	1	
Micropogonias undulatus	Atlantic croaker		1	1	
Mugil sp.	mullet species	1	15		
Mugil curema	white mullet				4
Poecilia latipinna	sailfin molly				1
Pomoxis nigromaculatus	black crappie	11			
Trinectes maculatus	hogchoker	1			
TOTAL		21	49	15	31
Dipnet samples					
Anchoa mitchilli	bay anchovy	5			
Aphredoderus sayanus	pirate perch	1			
Etheostoma asprigene	mud darter	1			
Etheostoma proeliare	cypress darter	2			
Elassoma zonatum	banded pygymy sunfish	4			
Fundulus chrysotus	golden topminnow	2			
Fundulus pulvereus	bayou killifish	1			
Gambusia affinis	western mosquitofish	28			
Gobionellus boleosoma	darter goby				19
Lepomis macrochirus	bluegill	1			
Lepomis megalotis	longear sunfish	1			
Lepomis miniatus	redspotted sunfish	22			
Lucania parva	rainwater killifish	2			
Menidia beryllina	tidewater silverside				1
Mugil sp.	mullet species			1	

Table 5.7. Geometric mean of trawl catch (number of fish per 5 min of trawling). S is sites less than 10 m in depth, and D is sites greater than 10 m in depth.

	Station:	**1**	**2**	**2**	**3**	**3**	**4**	**4**
	Depth Group:	**S**	**D**	**S**	**D**	**S**	**S**	**D**
Scientific Name	**Number:**	**6**	**3**	**2**	**4**	**3**	**3**	**2**
Anchoa mitchilli	Bay anchovy	0.1	1.0	0.2	1.8	0.8	21.9	0.7
Ictalurus furcatus	Blue catfish	3.2	0.0	1.0	0.2	0.8	0.0	0.0
Ictalurus punctatus	Channel catfish	3.6	0.0	0.0	0.0	0.0	0.0	0.0
Arius felis	Hardhead catfish	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Cynoscion arenarius	Sand seatrout	0.0	6.0	9.5	0.6	1.2	8.2	6.9
Micropogonias undulatus	Atlantic croaker	0.0	0.0	0.3	0.0	0.3	0.0	0.0
Stellifer lanceolatus	Star drum	0.0	0.0	0.0	0.02	0.0	2.0	5.9
Gobionellus boleosoma	Darter goby	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Trinectes maculatus	Hogchoker	3.8	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		9.7	7.0	10.7	3.6	3.3	48.9	13.8

5.3.3.3 Star Drum

Star drum was found only at Station 4 (23 of 24 individuals) and Station 3 (1 individual). The station difference was highly significant ($p<0.002$). There was no relationship between trawl depth and star drum abundance. There was a weakly significant relationship between star drum abundance and bottom salinity ($p<0.042$) when DO was also included in the regression, although DO was not significant and there was no significant salinity relationship when DO was not included. However, salinity and DO data were not available for one of the samples in which star drum was caught.

5.3.3.4 Channel Catfish

Channel catfish was found only at Station 1. The station difference is weakly significant ($p<0.054$). There was no relationship between channel catfish abundance and depth, salinity or DO.

5.3.3.5 Blue Catfish

There was no significant station difference in blue catfish abundance. However, there was a significant regression between blue catfish abundance and depth ($p<0.0015$). All but one blue catfish was caught in trawls less than 8 m in depth.

5.3.4 Dipnetting

Dipnet samples (Table 5.7) were used to document occurrence of some species, especially small species which hide in cover. The collections showed a variety of freshwater species using cover in the backwater at Station 1. Darter goby was caught commonly in dipnet samples at Station 4.

5.3.5 Texas Parks and Wildlife Data

The Texas Parks and Wildlife Department (TPWD) has sampled several stations in the lower Neches River and adjacent estuary. Sampling is done with bag seines and gill nets. TPWD made data from these samples available, and results are summarized in Tables 5.8-5.19 at the end of this section. Samples were taken using 18.3-m bag seines with 13-mm mesh. Samples were taken from the mouth of the river in Sabine Lake upstream to above the Bessie Heights canal. Relevant stations, in downstream order, are 298, 305, 306, 16, 17, 29, 30 and 31. Catches were lower than those in this survey, presumably because of the larger meshes size of the seines, which do not effectively capture small fish. While the common species were similar in the two groups of surveys, a number of less common species was caught in only one of the groups of surveys. The TPWD surveys report fewer freshwater species and more mesohaline or near shore species (e.g., Atlantic threadfin *Polydactylus octonemus*, least puffer *Sphoeroides parvus*, gulf kingfish *Menticirrhus littoralis*), attributable to the more downtream sampling sites. Other species collected by TPWD which have not been recorded by the ANSP surveys are the ladyfish *Elops saurus*, inshore lizardfish *Synodus foetens,* Atlantic needlefish *Strongylura marina,* striped bass *Morone saxatilis,* crevalle jack *Caranx hippos,* leatherjacket *Oligoplites saurus,* Florida pompano *Trachinotus carolinus*, silver jenny *Eucinostomis gula*, southern stargazer *Astroscopus y-graecum*, and southern flounder *Paralichthys lethostigma.* There were also some differences in relative abundance. For example, three species of sea trout were caught by both surveys. The sand sea trout was the most common of the three species in the ANSP survey, and few

Table 5.8. Total numbers of fishes collected by bag seine and gill net by Texas Department of Parks and Wildlife at Stations 298, 305, 306, 16,17, 18, 29, 30, and 31 from 1984-2002.

Scientific Name	Common Name	Bag Seine	Gill Net	Total
Achirus lineatus	Lined sole	1		1
Alosa chrysochloris	Skipjack herring		3	3
Archosargus probatocephalus	Sheepshead		12	12
Anchoa hepsetus	Striped anchovy	4		4
Anchoa mitchilli	Bay anchovy	520		520
Archosargus probatocephalus	Sheepshead	1		1
Arius felis	Hardhead catfish	165	71	236
Astroscopus y-graecum	Southern stargazer	2		2
Bagre marinus	Gafftopsail catfish	1	2	3
Brevoortia patronus	Gulf menhaden	8064	8	8072
Carcharhinus leucas	Bull shark		1	1
Caranx hippos	Crevalle jack	13		13
Chloroscombrus chrysurus	Atlantic bumper	5		5
Citharichthys spilopterus	Bay whiff	53		53
Cynoscion arenarius	Sand seatrout	63	2	65
Cynoscion nebulosus	Spotted seatrout	48	44	92
Cynoscion nothus	Silver seatrout	2		2
Cyprinodon variegatus	Sheepshead minnow	53		53
Dorosoma cepedianum	Gizzard shad	1	341	342
Dorosoma petenense	Threadfin shad	226		226
Elops saurus	Ladyfish	3	2	5
Etropus crossotus	Fringed flounder	5		5
Eucinostomus argenteus	Spotfin mojarra	4		4
Eucinostomus gula	Silver jenny	10		10
Family Clupeidae	herring species	8		8
Fundulus grandis	Gulf killifish	16		16
Gobionellus boleosoma	Darter goby	8		8
Gobionellus shufeldti	Freshwater goby	6		6
Gobiosoma bosc	Naked goby	6		6
Harengula jaguana	Scaled sardine	8		8
Ictalurus furcatus	Blue catfish	3	12	15
Lagodon rhomboides	Pinfish	13		13
Leiostomus xanthurus	Spot	110	12	122
Lepisosteus oculatus	Spotted gar	1	100	101
Lepisosteus osseus	Longnose gar		4	4
Lepisosteus spatula	Alligator gar		61	61
Lepomis macrochirus	Bluegill	1		1
Lepomis microlophus	Redear sunfish		1	1
Lucania parva	Rainwater killifish	1		1
Membras martinica	Rough silverside	2		2
Menidia beryllina	Inland silverside	140		140
Menticirrhus americanus	Southern kingfish	5		5
Menticirrhus littoralis	Gulf kingfish	1		1
Micropogonias undulatus	Atlantic croaker	713	25	738
Micropterus salmoides	Largemouth bass	1		1
Morone mississippiensis	Yellow bass		3	3
Morone saxatilis	Striped bass	2	1	3
Mugil cephalus	Striped mullet	453	39	492
Mugil curema	White mullet	152		152
Oligoplites saurus	Leatherjacket	15		15
Paralichthys lethostigma	Southern flounder	40	8	48
Poecilia latipinna	Sailfin molly	2		2
Polydactylus octonemus	Atlantic threadfin	6		6
Prionotus tribulus	Bighead searobin	9		9
Pogonias cromis	Black drum		153	153
Sciaenops ocellatus	Red drum	47	237	284
Scomberomorus maculatus	Spanish mackerel		1	1
Sphoeroides parvus	Least puffer	5		5
Strongylura marina	Atlantic needlefish	16		16
Symphurus plagiusa	Blackcheek tonguefish	5		5
Syngnathus scovelli	Gulf pipefish	1		1
Synodus foetens	Inshore lizardfish	7		7
Trachinotus carolinus	Florida pompano	5		5
Trinectes maculatus	Hogchoker	1		1

Table 5.9. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Station 31 in the Neches River from 1986-2002.

Station			31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Year	**Total**	**Rank**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Anchoa mitchilli	13	6							2		2	9							
Arius felis	25	4		2	11			1							6		5		
Astroscopus y_graecum	2	17									2								
Brevoortia patronus	85	3	61		1	5						14				4			
Cynoscion arenarius	6	8								1				2	1	1	1		
Cyprinodon variegatus	12	7				1							11						
Dorosoma petenense	4	10																4	
Elops saurus	2	17							2										
Eucinostomus gula	3	13.5							3										
Fundulus grandis	2	17				2													
Gobionellus boleosoma	1	21										1							
Leiostomus xanthurus	4	10		4															
Menidia beryllina	4	10							3				1						
Menticirrhus americanus	1	21															1		
Micropogonias undulatus	24	5		5					3			9		3	3				1
Micropterus salmoides	1	21										1							
Mugil cephalus	88	2	4	12	4	10		29	10		1	5			6		5		2
Mugil curema	126	1							4							2	6		114
Oligoplites saurus	1	21							1										
Paralichthys lethostigma	3	13.5		1					2										
Strongylura marina	1	21	1																
Synodus foetens	3	13.5							3										
Trachinotus carolinus	3	13.5											3						

Table 5.10. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Station 305 in the Neches River from 1990-1998.

Station			**305**	**305**	**305**	**305**	**305**	**305**	**305**	**305**	**305**
Year	**Total**	**Rank**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Anchoa hepsetus	1	34.5									
Anchoa mitchilli	229	3	4	1				16		21	66
Archosargus probatocephalus	1	34.5									
Arius felis	17	12						10			
Brevoortia patronus	6198	1	1			1		2	1	13	6010
Caranx hippos	7	16						2		2	
Citharichthys spilopterus	27	9								2	1
Cynoscion arenarius	29	8		3			1			5	
Cynoscion nebulosus	24	10							1	5	
Cynoscion nothus	2	28.5									
Cyprinodon variegatus	2	28.5						1			
Dorosoma petenense	111	5	14			2		1			
Etropus crossotus	5	20								4	
Eucinostomus argenteus	3	24.5									
Eucinostomus gula	2	28.5									
Family Clupeidae	1	34.5									
Fundulus grandis	1	34.5									
Gobionellus boleosoma	6	17.5						1		1	
Gobionellus shufeldti	1	34.5				1					
Gobiosoma bosc	5	20						1	1	3	
Harengula jaguana	3	24.5									
Lagodon rhomboides	5	20								1	
Leiostomus xanthurus	39	7	3							1	1
Lepomis macrochirus	1	34.5					1				
Menidia beryllina	41	6				3	1	1	4	1	2
Micropogonias undulatus	299	2	21			3		16	35	7	49
Mugil cephalus	131	4	1		2		3	47	1	8	4
Mugil curema	16	13									
Oligoplites saurus	9	14								1	
Paralichthys lethostigma	18	11	3			1		2		2	1
Prionotus tribulus	3	24.5								3	
Sciaenops ocellatus	6	17.5							2	1	
Sphoeroides parvus	1	34.5									
Strongylura marina	8	15								1	
Symphurus plagiusa	4	22									
Syngnathus scovelli	1	34.5						1			
Synodus foetens	3	24.5								3	
Trachinotus carolinus	2	28.5								1	

Table 5.11. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Station 306 in the Neches River from 1993-2002.

Station			**306**	**306**	**306**	**306**	**306**	**306**	**306**	**306**	**306**	**306**
Year	**Total**	**Rank**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Anchoa hepsetus	1	34.5							1			
Anchoa mitchilli	229	3			8	1	6	13	25	14	49	
Archosargus probatocephalus	1	34.5							1			
Arius felis	17	12	2							5		
Brevoortia patronus	6198	1			2		10	3	102	47	1	
Caranx hippos	7	16		3								
Citharichthys spilopterus	27	9			1		2	1	2	14	3	
Cynoscion arenarius	29	8			2				12	6		
Cynoscion nebulosus	24	10			6			1	10	1		
Cynoscion nothus	2	28.5										
Cyprinodon variegatus	2	28.5									1	
Dorosoma petenense	111	5		1				1	92			
Etropus crossotus	5	20							1			
Eucinostomus argenteus	3	24.5								3		
Eucinostomus gula	2	28.5			1							
Family Clupeidae	1	34.5								1		
Fundulus grandis	1	34.5										
Gobionellus boleosoma	6	17.5							1	3		
Gobionellus shufeldti	1	34.5										
Gobiosoma bosc	5	20										
Harengula jaguana	3	24.5								3		
Lagodon rhomboides	5	20				4						
Leiostomus xanthurus	39	7				12		2	3	5	8	
Lepomis macrochirus	1	34.5										
Menidia beryllina	41	6	1			1	2	4	3	12	3	
Micropogonias undulatus	299	2		4	12		16	21	5	58	4	24
Mugil cephalus	131	4	8	2	7	1	4	1	11	11	8	
Mugil curema	16	13				2				8	6	
Oligoplites saurus	9	14				1		2	3	2		
Paralichthys lethostigma	18	11	1				1	2		2	1	
Prionotus tribulus	3	24.5										
Sciaenops ocellatus	6	17.5							1	2		
Sphoeroides parvus	1	34.5				1						
Strongylura marina	8	15						4			1	
Symphurus plagiusa	4	22							2	2		
Syngnathus scovelli	1	34.5										
Synodus foetens	3	24.5										
Trachinotus carolinus	2	28.5		1								

Table 5.12. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Stations 16 and 17 in the Neches River from 1986-2002.

Station			**16**	**16**	**16**	**17**	**17**	**17**	**17**	**17**
Year	**Total**	**Rank**	**1987**	**1988**	**1989**	**1986**	**1987**	**1988**	**1989**	**1990**
Anchoa mitchilli	1	13.5	1							
Arius felis	8	5				1	7			
Brevoortia patronus	4	7.5					4			
Caranx hippos	2	10.5					2			
Citharichthys spilopterus	1	13.5								1
Eucinostomus gula	1	13.5					1			
Fundulus grandis	4	7.5								4
Gobionellus shufeldti	3	9		2			1			
Lagodon rhomboides	1	13.5				1				
Leiostomus xanthurus	5	6		1		1	3			
Menidia beryllina	23	3		7	1		2	5		8
Micropogonias undulatus	33	1	1	9	1		6	1		15
Mugil cephalus	30	2	1			11	18			
Paralichthys lethostigma	2	10.5		1	1					
Sciaenops ocellatus	16	4		2			12			2

Table 5.13. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Station 18 in the Neches River from 1986-2002.

Station			**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**
Year	**Total**	**Rank**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Achirus lineatus	1	21														1		
Anchoa mitchilli	11	6			1					2	7				1			
Arius felis	5	10.5				1				4								
Bagre marinus	1	21														1		
Brevoortia patronus	1456	1		1453								2						1
Caranx hippos	2	15									2							
Citharichthys spilopterus	1	21			1													
Cynoscion arenarius	5	10.5						1		1	1					1	1	
Cyprinodon variegatus	29	4			1		17					8			2	1		
Eucinostomus gula	3	12.5							3									
Fundulus grandis	6	8.5		1			2	1	1			1						
Gobiosoma bosc	1	21			1													
Menidia beryllina	28	5		3		1			1	1	19	1	2					
Menticirrhus americanus	1	21														1		
Menticirrhus littoralis	1	21									1							
Micropogonias undulatus	72	2		7		1	1	2	2	6	13	8	9	4		12	3	4
Mugil cephalus	32	3		5		3		7	7		5		4	1				
Mugil curema	2	15				1										1		
Paralichthys lethostigma	3	12.5		1	1		1											
Poecilia latipinna	2	15			1						1							
Polydactylus octonemus	6	8.5		3										3				
Prionotus tribulus	1	21													1			
Sciaenops ocellatus	9	7		2	2		3					1	1					

Table 5.14. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Station 298 in the Neches River from 1988-2002.

Station		**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**
Year	**Total**	**1988**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Anchoa hepsetus	6											6			
Anchoa mitchilli	437					152	3	76	3		68	68	47		20
Arius felis	188							161					27		
Brevoortia patronus	741			10	24	8		4	144	136	236	12	161	6	
Caranx hippos	7							4					3		
Chloroscombrus chrysurus	20										16		4		
Citharichthys spilopterus	46							8	12	4	4		11		7
Cynoscion arenarius	43					12		8		2	10	8	2		1
Cynoscion nebulosus	29					19		8				2			
Cyprinodon variegatus	7			2				2				3			
Dorosoma cepedianum	3								3						
Dorosoma petenense	392		4	10		296		16			4	6	3	53	
Elops saurus	4			2							2				
Eucinostomus argenteus	4												4		
Eucinostomus gula	4									4					
Family Clupeidae	21						3					18			
Fundulus grandis	5					1		2			2				
Gobionellus boleosoma	3												3		
Gobionellus shufeldti	3						3								
Harengula jaguana	20												20		
Ictalurus furcatus	2			2											
Lagodon rhomboides	14								7	3			4		
Leiostomus xanthurus	123						1		100	9	4		7		2
Lepisosteus oculatus	2									2					
Lucania parva	3												3		
Membras martinica	6												6		
Menidia beryllina	74				3	8		43			8		10		2
Menticirrhus americanus	9											2	7		
Micropogonias undulatus	569		3		12	1	108	83	77	87	16	45	124		13
Mugil cephalus	159		2	2			4	48	2	4	4	60	5	24	4
Mugil curema	24									3			19		2
Oligoplites saurus	13		3	2									8		
Paralichthys lethostigma	19							15			2	2			
Prionotus tribulus	13							2	9			2			
Sciaenops ocellatus	26			8						6		2	10		
Sphoeroides parvus	7							4	3						
Strongylura marina	8		8												
Symphurus plagiusa	2							2							
Synodus foetens	3				3										
Trinectes maculatus	1									1					

Table 5.15. Numbers of fishes collected by bag seine by Texas Department of Parks and Wildlife at Stations 29 and 30 in the Neches River from 1986-1990.

Station			**29**	**29**	**29**	**29**	**29**	**30**	**30**	**30**	**30**
Year	**Total**	**Rank**	**1986**	**1987**	**1988**	**1989**	**1992**	**1987**	**1988**	**1989**	**1990**
Anchoa mitchilli	5	8.5		1						4	
Arius felis	61	2								61	
Brevoortia patronus	41	3		5		1			23	12	
Cynoscion arenarius	5	8.5				5					
Dorosoma petenense	2	10.5		2							
Gobionellus shufeldti	1	12							1		
Ictalurus furcatus	2	10.5								2	
Leiostomus xanthurus	16	5		1		2		1	11		1
Menidia beryllina	9	6	2	3				3	1		
Micropogonias undulatus	31	4		8		4	2	8	2	1	6
Mugil cephalus	83	1	77	3						1	2
Paralichthys lethostigma	7	7				6			1		

Table 5.16. Numbers of fishes collected by gill net by Texas Department of Parks and Wildlife at Station 298 in the Neches River from 1990-1998.

Station		**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**	**298**
Year		**TOTAL**	**1990**	**1991**	**1991**	**1992**	**1993**	**1993**	**1994**	**1994**	**1996**	**1996**	**1998**	**1998**
Date			**4/17**	**4/24**	**9/11**	**10/6**	**6/8**	**9/22**	**4/27**	**9/14**	**5/2**	**9/10**	**4/14**	**10/14**
Alosa chrysochloris	Skipjack herring	2											2	
Archosargus probatocephalus	Sheepshead	6									5			1
Arius felis	Hardhead catfish	19		3	2	6			1	4		2		1
Brevoortia patronus	Gulf menhaden	0												
Cynoscion nebulosus	Spotted seatrout	8			1				1		4		1	1
Dorosoma cepedianum	Gizzard shad	17	1	1					1	1		5	4	4
Ictalurus furcatus	Blue catfish	8		1						1	3	1	2	
Leiostomus xanthurus	Spot	3			1	1						1		
Lepisosteus oculatus	Spotted gar	54	8	3	1	1	2	6	11	1	10	1	9	1
Lepisosteus osseus	Longnose gar	4							1				3	
Lepisosteus spatula	Alligator gar	24	2	6		5	4	1	2	1			2	1
Micropogonias undulatus	Atlantic croaker	2			1									1
Morone mississippiensis	Yellow bass	2						1	1					
Morone saxatilis	Striped bass	1							1					
Mugil cephalus	Striped mullet	9						1	4		3			1
Paralichthys lethostigma	Southern flounder	0												
Pogonias cromis	Black drum	43			3	4	1		4	6	8	9		8
Sciaenops ocellatus	Red drum	45	5	4	4	1	2	8		4	7	7	2	1

Table 5.17. Numbers of fishes collected by gill net by Texas Department of Parks and Wildlife at Station 306 in the Neches River from 1993-1994.

Station		**306**	**306**	**306**	**306**
Year		**1993**	**1993**	**1994**	**1994**
Date		**6/9**	**9/21**	**6/1**	**9/21**
Alosa chrysochloris	Skipjack herring				
Archosargus probatocephalus	Sheepshead			1	
Arius felis	Hardhead catfish		4	3	6
Brevoortia patronus	Gulf menhaden				3
Cynoscion nebulosus	Spotted seatrout				
Dorosoma cepedianum	Gizzard shad				2
Ictalurus furcatus	Blue catfish	2			1
Leiostomus xanthurus	Spot	1	1		3
Lepisosteus oculatus	Spotted gar	1		1	
Lepisosteus osseus	Longnose gar				
Lepisosteus spatula	Alligator gar	2		6	
Micropogonias undulatus	Atlantic croaker	4			
Morone mississippiensis	Yellow bass				1
Morone saxatilis	Striped bass				
Mugil cephalus	Striped mullet			1	
Paralichthys lethostigma	Southern flounder		1		1
Pogonias cromis	Black drum	2	3	11	9
Sciaenops ocellatus	Red drum	7		6	4

spotted and silver sea trout were collected. The TPWD survey found greater abundance of spotted sea trout. The gill nets are expected to be more effective at catching many larger fishes, and gars were frequent in the gill net samples (Table 5.18). Gars were caught in earlier ANSP surveys using gill nets, but have not been caught in the recent surveys. Large individuals of several other species, such as bull shark, gafftopsail catfish, black drum, red drum and spotted seatrout were also caught. Red drum and black drum were caught mainly in the TPWD gill net samples. Red drum was rarely caught in ANSP surveys.

Table 5.18. Numbers of fishes collected by gill net by Texas Department of Parks and Wildlife at Station 31 in the Neches River from 1986-2002.

Station			**31**	**31**	**31**	**31**	**31**	**31**	**31**	**31**	**31**
Year			**1986**	**1989**	**1992**	**1992**	**1992**	**1993**	**1993**	**1995**	**1995**
Date		**Total**	**10/6**	**9/11**	**9/26**	**4/28**	**10/28**	**5/11**	**11/11**	**4/25**	**11/3**
Alosa chrysochloris	Skipjack herring	1				1					
Archosargus probatocephalus	Sheepshead	5			3						
Arius felis	Hardhead catfish	39	4	3	8	7	4	1		3	
Bagre marinus	Gafftopsail catfish	2				1					
Brevoortia patronus	Gulf menhaden	5		3							
Carcharhinus leucas	Bull shark	1									
Cynoscion arenarius	Sand seatrout	2									
Cynoscion nebulosus	Spotted seatrout	36	3		1						
Dorosoma cepedianum	Gizzard shad	322	4	1	1		69		9	5	12
Elops saurus	Ladyfish	2			2						
Ictalurus furcatus	Blue catfish	1								1	
Leiostomus xanthurus	Spot	4	1								1
Lepisosteus oculatus	Spotted gar	44						2	2	18	6
Lepisosteus spatula	Alligator gar	29		2	4	5	1	3	2	3	
Lepomis microlophus	Redear sunfish	1									1
Micropogonias undulatus	Atlantic croaker	19		2		4		5		1	
Morone mississippiensis	White bass	0									
Morone saxatilis	Striped bass	0									
Mugil cephalus	Striped mullet	29							10		5
Paralichthys lethostigma	Southern flounder	6		1		1		1			
Pogonias cromis	Black drum	85	2	7	1		9		5	1	9
Sciaenops ocellatus	Red drum	175	2	4	9	19	8	11	25	27	3
Scomberomorus maculatus	King mackerel	1									

Table 5.18 (continued). Numbers of fishes collected by gill net by Texas Department of Parks and Wildlife at Station 31 in the Neches River from 1986-2002.

Station		**31**	**31**	**31**	**31**	**31**	**31**	**31**	**31**
Year		**1998**	**1998**	**1999**	**2000**	**2000**	**2001**	**2002**	**2002**
Date		**6/9**	**11/11**	**9/28**	**4/12**	**11/1**	**5/30**	**5/15**	**9/17**
Alosa chrysochloris	Skipjack herring								
Archosargus probatocephalus	Sheepshead		1		1				
Arius felis	Hardhead catfish	2					3		3
Bagre marinus	Gafftopsail catfish							1	
Brevoortia patronus	Gulf menhaden			1		1			
Carcharhinus leucas	Bull shark						1		
Cynoscion arenarius	Sand seatrout								
Cynoscion nebulosus	Spotted seatrout	2	5	3	1	5	3	7	2
Dorosoma cepedianum	Gizzard shad	21	11	17	13	68	12	4	1
Elops saurus	Ladyfish								
Ictalurus furcatus	Blue catfish								
Leiostomus xanthurus	Spot			2					
Lepisosteus oculatus	Spotted gar		2		9		2	1	
Lepisosteus spatula	Alligator gar	1	2	1		1	2		
Lepomis microlophus	Redear sunfish								
Micropogonias undulatus	Atlantic croaker			3		1		1	
Morone mississippiensis	White bass								
Morone saxatilis	Striped bass								
Mugil cephalus	Striped mullet	1	3	2	1	4			
Paralichthys lethostigma	Southern flounder		1					1	
Pogonias cromis	Black drum	4	11	6	8	5	3		6
Sciaenops ocellatus	Red drum	3	9	5	6	6	4	11	9
Scomberomorus maculatus	King mackerel			1					

Table 5.19. Summary of total lengths (mm) of fishes collected by gill net by Texas Department of Parks and Wildlife at Stations 31, 298, and 306 in the Neches River from 1990-1998.

		Station 31				Station 298				Station 306			
Scientific Name	**Common Name**	**#**	**Mean**	**Min**	**Max**	**#**	**Mean**	**Min**	**Max**	**#**	**Mean**	**Min**	**Max**
Alosa chrysochloris	Skipjack herring	1	280.0			2	276.5	267	286				
Archosargus probatocephalus	Sheepshead	5	380.0	296	433	6	349.0	316	420				
Arius felis	Hardhead catfish	35	334.6	210	398	15	341.5	200	458	13	341.4	304	392
Bagre marinus	Gafftopsail catfish	2	567.0	562	572								
Brevoortia patronus	Gulf menhaden	5	233.0	170	292					3	118.0	116	120
Carcharhinus leucas	Bull shark	1	898.0										
Cynoscion arenarius	Sand seatrout	2	262.5	210	315								
Cynoscion nebulosus	Spotted seatrout	35	439.2	302	607	6	409.7	380	476				
Dorosoma cepedianum	Gizzard shad	167	336.1	233	409	14	330.8	267	386	2	323.0	284	362
Elops saurus	Ladyfish	2	295.0	294	296								
Ictalurus furcatus	Blue catfish	1	434.0			7	427.9	362	499	3	458.0	432	481
Leiostomus xanthurus	Spot	4	231.3	200	248	3	234.7	232	237	5	225.4	215	236
Lepisosteus oculatus	Spotted gar	42	565.3	479	671	51	560.0	413	741	2	691.5	637	746
Lepisosteus osseus	Longnose gar					4	994.5	1031	892				
Lepisosteus spatula	Alligator gar	29	846.8	1020	993	23	880.4	1001	976	8	898.3	1054	985
Lepomis microlophus	Redear sunfish	1	195.0										
Micropogonias undulatus	Atlantic croaker	13	308.4	187	456	1	271.0			1	296.0		
Morone mississippiensis	Yellow bass					2	218.5	180	257				
Morone saxatilis	Striped bass					1	523.0						
Mugil cephalus	Striped mullet	29	342.9	275	476	9	333.6	312	352	1	323.0		
Paralichthys lethostigma	Southern flounder	6	367.2	296	410					2	407.0	363	451
Pogonias cromis	Black drum	82	360.5	208	502	42	377.7	300	491	21	350.8	282	460
Sciaenops ocellatus	Red drum	168	519.0	297	758	41	518.4	317	726	16	518.4	328	699
Scomberomorus maculatus	Spanish mackerel	1	380.0										

5.4 Discussion

As in past surveys, species recorded during the 2003 lower Neches fish survey comprise a wide variety of freshwater, estuarine and oceanic species common throughout inland and coastal waters of the Gulf of Mexico bordering Texas and Louisiana. The fish fauna included the juvenile forms of many commercially and recreationally important species including spotted and sand seatrout, spot, Atlantic croaker, channel catfish, blue catfish and spotted bass. The lower Neches River system has an abundance of backwaters and readily available marshes that serve as primary nursery areas to numerous estuarine/oceanic species.

A notable record is the collection of a single least killifish (Heterandria formosa) at Station 3. This species was collected at the upstream edge of the cove across the river from the basin for the reserve fleet. It was caught in an area of firm sand substrate with some organic material and some surficial silt, with cover provided by undercut banks, and roots of bushes and small cypress trees The least killifish is common in the Gulf Coastal Plain from southern North Carolina to Louisiana. Regional faunas (e.g., Lee et al. 1980, Hubbs et al. 1991, Page and Burr 1991, Ross 2001) do not show it occurring in Texas. However, there are recent records from the west bank of the Sabine River (http://www.tpwd.state.tx.us/fish/infish/research/chcklist.htm; http://www.nativefish.org/Articles/least_killi.htm). The Neches specimen may represent the westernmost record for the species.

The 2003 survey represents the fourth comprehensive Academy fish survey since 1953. Cursory surveys were conducted in 1956 and 1960.

Some differences in species assemblages among the surveys is a result of shifts in the estuarine gradient in response to variable freshwater inflows. For example, the 1996 survey is notable for the absence of a number of freshwater species which had been caught in earlier surveys and were caught in the 2003 survey, as well. Several estuarine species were common in the 1996 survey, but have otherwise been uncommon in the surveys. Many of the records of freshwater species are from the backwater at Station 1, which was sampled by rotenone in the first three surveys. Several species (pirateperch, banded pygmy sunfish, mud darter and cypress darter) which had not been collected previously were collected in this backwater in 2003.

Some of the among-year differences reflect sampling effort and techniques. In particular, the 1956 and 1960 surveys did not include sampling at Stations 2 and 3. Thirty-three species were identified during the 1973 survey of the lower Neches River: Station 1, 22 species; Station 2, 12 species; Station 3, 12 species and Station 4, 16 species. Trawling, 50-ft seining and gill nets were the primary collecting techniques during the 1973 study. Thirty-eight species were taken during the 1953 fish collections using stationary fyke (hoop) nets, seining, wire basket traps and Rotenone. The number of species collected was: Station 1, 34 species; Station 2, 0 species; Station 3, 8 species and Station 4, 10 species. The greater number of species at Station 1 was attributable to the use of rotenone in selected backwater habitats.

The 2003 and 1996 surveys found high numbers and a greater variety of estuarine species at the lower three stations. In particular, bay anchovy, which was uncommon in the early surveys, was abundant in the two recent surveys. Bay anchovy is likely to be caught by seines, which was used in the early surveys, so the change is probably not related to technique differences. The change in abundance reflects an increase in water quality, at least in part. For example, no fish were caught at Station 2 in 1953, when water temperatures were 38°C and dead fish were seined from the bottom.

In 1996, 11% of the tidewater silversides collected in the 6.1-m seines from Station 1 contained a purple to pinkish stain which discolored the outer integument (including the scales and pelvic fins) of the fishes' mid-sections and extended internally to the periteneal cavity and internal organs causing a discoloration of all organs. The cause of the coloration was not established. While reddening of tissues due to hemorrhaging can occur as a result of systemic bacterial or viral infections (Noga 1996), the purplish color and its retention in preserved specimens seems inconsistent with this explanation. Exposure to and absorption of colored chemicals could explain the observations, though it is uncertain whether any candidate chemicals were present at the site. No such specimens were noted in the 2003 study.

Summary

Measurements of salinity, temperature and dissolved oxygen taken at the time of sampling showed differences among stations. Station 1 was freshwater, with no evident vertical stratification. Salinity increased from Stations 2 through 4. Vertical stratification was evident at the three lower stations (especially at Stations 3 and 4), with markedly higher salinity and slightly warmer water in deeper water. Dissolved oxygen was relatively high at Station 1. Dissolved oxygen was also relatively high in surface water at Stations 3 and 4. Dissolved oxygen was lower in surface water from Station 2. Dissolved oxygen was lower in deeper water at Stations 2 through 4, and was lowest in deep water from Station 2.

A total of 28,566 fish of 51 species were caught in the 2003 ANS Neches River survey (Tables 2-5). Bay anchovy composed 95% of all fish caught. Only three other species (tidewater silverside, western mosquitofish, and rainwater killifish) were caught at all four stations. Mullet (*Mugil* species) were also caught at all four stations. The pattern of occurrence of other species reflected the estuarine gradient from Stations 1 to 4. Several freshwater species (e.g., some minnows and channel catfish) were relatively common at Station 1, and several estuarine species (e.g., gulf menhaden, sailfin molly, star drum and bay whiff) were found only a Station 4. Several other estuarine species, such as sand seatrout and spot, were found only at Stations 2-4. One species, the rainwater killifish (*Lucania parva*) was collected by dip net at Station 1. This species has only rarely been collected in Texas.

Statistical comparisons of catch rates by specific techniques showed some differences, largely related to the estuarine gradient. There were significant differences in abundance of several species among stations, but these differences were not

related to plant location. Abundance of star drum was higher at Station 4 (the most estuarine station), and abundance of channel catfish was significantly higher at Station 1. Abundance of bay anchovy increased from Stations 1 to 4, although abundance was not significantly related to salinity or DO measured at the time of sampling. Sand seatrout was more common at Stations 2 and 4 than at Stations 1 and 3. Blue catfish was more abundant in shallow samples. In seines, there were no significant differences in the mean abundance of the four widespread species, bay anchovy, tidewater silverside, western mosquitofish and rainwater killifish, among stations, and the abundances in samples could not be related to differences in dissolved oxygen.

Data from the Neches River taken by the Texas Parks and Wildlife Department were compiled. These show some differences with the ANS results, largely reflecting the more seaward location of sampling sites and the use of gill nets by TPWD.

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