NECHES RIVER 2021
ENVIRONMENTAL MONITORING STUDIES

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Figure 0.1: Members of the survey crew (L to R): Brielle Patronella, Dennis Becker, Bethany Stanton, Chris Barrow, Trenton Harper, Jonathan Beavers, Jeannie Bowlen, Haden Burks, Jason Watson, Terry Corbett, Heath Thompson, David Keller, Cody Malin, Roger Thomas, Tanya Dapkey, Colin Rohrback, Danielle Odom, Daniel Morrill, Mariena Hurley.

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EXECUTIVE SUMMARY

Overview and Rationale

The Academy of Natural Sciences (the Academy) has conducted water quality surveys of the Neches River since 1953. Previous surveys varied in size and scope and were conducted in 1953, 1956, 1960, 1973, 1996 and 2003. The current survey was conducted from October 5 to 9, 2021, and included five portions (Stations 0, 1, 2, 3 and 4) of the lower Neches River from Port Neches to Beaumont, Texas. The same stations used during the 1953, 1973, 1996 and 2003 "comprehensive" surveys were investigated. Additionally, a station upstream of the saltwater barrier was included in the current survey to document the freshwater fauna in the vicinity of this facility. The 2021 survey examined current conditions in relation to results from the comprehensive surveys of 1953, 1973, 1996 and 2003, and to a lesser extent the surveys of 1956 and 1960 that included fewer stations and less sampling effort.

Components of the current and historical 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 ecosystem are studied because no single group is reliably the best indicator of ecosystem health, and because there is a broad consensus that maintaining the integrity of the entire ecosystem is important.

Study Design

The study design employed in the Neches River included five stations all of which were influenced by municipal and agricultural influences (i.e., livestock production, crops, and manufacturing facilities) above the study area (see Figure 1.1). Three of these stations were also exposed to industrial and municipal development originating in the vicinity of Beaumont and Port Neches (Stations 2, 3 and 4). There were two upstream reference stations (Stations 0 and 1) that were not exposed to these latter influences (although they were exposed to the disturbances upstream of the study area). Additionally, between Stations 0 and 1 is a saltwater barrier that may influence the ecosystem depending upon flows and management. The five stations lie along a salinity gradient. Along this gradient and during the current survey, Stations 0 and 1 consisted of freshwater and Stations 2, 3 and 4 consisted of brackish water.

Environmental Geochemistry

Water samples were collected by Lower Neches Valley Authority (LNVA) staff from each of the five stations on four consecutive days and were analyzed by a contract lab 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 conductance 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 were also compared with the Academy's data from historical studies of the Neches River. In addition, an assessment of long-term trends in several water quality parameters (dissolved oxygen, bacteria, and nutrients) was conducted, using data from 1981-2021 that were provided by LNVA (from the Texas Commission on Environmental Quality's [TCEQ] Surface Water Quality Monitoring Information System (SWQMIS).

Comparisons Among Stations in 2021

Stations below the saltwater barrier exhibited salinity stratification with depth. Additionally, dissolved oxygen concentrations were lowest near the bottom of Stations 2 and 3. Nutrient parameters were variable across station and dates, with nitrate+nitrite concentrations increasing substantially from the upstream stations to Stations 2 through 4. Contaminants such as volatile organic compounds and trace metals did not appear to be elevated and were close to the detection limits of the methods. Dissolved oxygen concentrations in the near-bottom waters at Stations 2 and 3 were low and at levels that could negatively impact biological communities in these areas. Also, nitrate+nitrite concentrations increased downstream of Station 1. This distribution was related to limited mixing due to density differences between surface and bottom waters. The less dense freshwater on top and the denser saltwater below causes a density difference that restricts mixing between surface and bottom layers.

Historical Comparisons

Dissolved oxygen levels in the surface waters were like those in previous surveys and above screening levels (except for the 1953 survey), and nutrient parameters were similar or slightly lower compared to historical surveys. Additionally, fecal coliform levels were much lower than in historical surveys. Note: Due to changes in state regulations, fecal coliform should be replaced with either *Enterococci* criteria for saltwater recreation or *E. coli* criteria for freshwater recreation in the future. Overall, this section of the lower Neches River appeared to have slightly better water quality than found in 2003 and other historical surveys.

Long-term Temporal Trends

The long-term trends analysis of data obtained from TCEQ revealed substantial variability from upstream to downstream stations. Dissolved oxygen saturation values showed a positive trend over the ~40-yr period, while fecal coliform showed a decrease in concentration. Seasonal flows may impact the trend analysis and should be included in future studies.

Attached Algae

Attached algae were sampled at all five stations 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.

Comparisons Among Stations in 2021

The current survey showed a clear shift in algal communities when comparing the upper stations (Station 0 and 1) to the downstream stations (Stations 2, 3 and 4) with some improvement from Station 3 to 4. Diatom species richness and evenness did not vary dramatically, and overall showed low species evenness across all stations. The taxonomic shift seen for the current survey corresponded to the salinity gradient and the higher levels of disturbance at Station 3. The overall higher abundances of *Nitzschia* and *Navicula* species since the 1973 survey continues to suggest high sedimentation along the lower Neches River.

Historical Comparisons

The current survey results are like the results from 2003 and continue to show a long-term trend of improved water quality when compared to the 1953 and 1973 surveys. Changes in algal taxa appear to follow changes in the salinity gradient across each station. However, Station 3, as in past surveys, showed the highest level of disturbance suggesting a response to industrial activity at this station. There did not appear to be any effect of the saltwater barrier on the algal community at the time of the survey.

Macroinvertebrates

Macroinvertebrates were sampled at all five stations by hand or with a dip net from several habitats. 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.

Comparisons Among Stations in 2021

Over all samples, 122 macroinvertebrate species were collected from the lower Neches River. Of these, 63 were non-insect and 59 were insect species. Stations 0 and 1 showed a higher number of insects due to the freshwater nature of those stations, and Stations 2 through 4 had higher salinities and therefore fewer insect species. Non-insect macroinvertebrates showed fewer changes among stations and were more abundant in Stations 2 through 4.

Historical Comparisons

These data indicated that the water quality of the lower Neches River is similar to the conditions observed in 2003 and indicate a long-term trend of improved water quality when compared to earlier surveys in 1953 and 1973. Additionally, there were no patterns suggestive of impacts due to the saltwater barrier at the time of the survey.

Fish

Fish were collected by seining, trawling, and dip netting at all five stations. All fish were identified to the lowest possible taxonomic level (typically species), and station and year comparisons were based primarily on species richness and abundance.

Comparisons Among Stations in 2021

Over all samples, 18,292 individuals and 66 fish species were collected by seining, trawling and dip netting. A total of 54 species were collected by seining and 29 species were collected by trawling to determine densities. The five most abundant species collected by trawling bottom habitats were Bay Anchovy, Blue Catfish, Channel Catfish, Hogchoker and Shoal Chub. The five most abundant species collected by seining shoreline habitats were Bay Anchovy, Blacktail Shiner, Bullhead Minnow, Weed Shiner and Ribbon Shiner.

Fish abundance and community structure were largely related to the salinity gradient. Along this gradient, Stations 0 and 1 consisted of freshwater and Stations 2, 3 and 4 consisted of brackish water. The composition of the fish communities and individual species differences among stations corresponded to this gradient, with freshwater species more abundant at Stations 0 and 1, as opposed to 2, 3 and 4. Bay Anchovy was the only species with significantly lower abundances at Stations 2 and 3 that did not appear to be related to the salinity gradient.

This study was conducted during a year of typical discharge and found the fish assemblages and species abundances to be similar among Stations 0 and 1, and there were no consistent patterns in the abundance of species that would indicate a difference due to the saltwater barrier at the time of our survey. Lower in the estuary, Stations 2, 3 and 4 had similar salinities and depths. Fish assemblages among these stations were similar, indicating no differences due to industrial inputs or management. However, the abundance of Bay Anchovy was lower in shoreline samples at Stations 2 and 3, relative to other stations, and may reflect increased anthropogenic activity/effects at these stations, or natural variation. It is difficult to discern the driving factor for these decreased abundances without additional sampling.

Historical Comparisons

Some differences in species assemblages among the seven surveys are due to shifts in the estuarine gradient in response to variable freshwater inflows. Taking all survey years together, these data indicate that under typical flows, Stations 1 and 0 represent the freshwater portion of the estuarine gradient, while Stations 2, 3 and 4 occur in the mesohaline to polyhaline portion of the estuary.

For stations where past surveys were conducted, these data indicate that Station 1 has remained in relatively good condition, Station 2 has shown the most improvement, and Stations 3 and 4 have improved as well (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1998, ANSP 2006, this report). The more recent surveys, conducted in 1996, 2003 and 2021 (this report), focused condition assessments on differences in densities of fish species among stations. In these surveys, the primary techniques used to assess densities among stations were seining and trawling. In 1996 and 2003, none of the differences among stations appeared to be related to pollution, and differences were largely related to the salinity gradient (ANSP 1998 and ANSP 2006). In 2021, differences were again largely related to the salinity gradient. However, there were decreased abundances (number of individuals) of Bay Anchovy at Stations 2 and 3 which may reflect increased anthropogenic impacts at these stations or natural variation. Historically, Stations 2 and 3 have received the greatest impact from, and are in closest proximity to, the region's industry.

Conclusions

The current survey assessed the water quality and key ecosystem components of the lower Neches River and their association with industrialized areas (Stations 2,3 and 4) and a saltwater barrier, during a period of typical flow. Major factors found to influence the ecosystem of the lower Neches River at the time of the current survey were salinity and industrial development. The saltwater barrier was open at the time of the survey and did not appear to influence ecosystem components. Under drought conditions, it is likely that the saltwater barrier would influence these components. However, additional sampling during these conditions would be needed to determine the barrier's influence. Combined with historical surveys, these data show a trend of improved water quality and ecosystem integrity in the lower Neches River over the last 68 years. Although improved water quality and ecosystem integrity is apparent at all stations with past monitoring, stations with the most industrial development, Stations 2 and 3, continue to show lower ecosystem integrity relative to other stations. Additionally, as found in other estuarine systems, and as shown over all survey years, the salinity gradient is a major factor governing the distribution and abundance of aquatic communities in the lower Neches River.

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1. INTRODUCTION

1.1 Background

Located in eastern Texas, the Neches River flows through the Eastern Central Texas Plains and South Central Plains before entering the Western Gulf Coastal Plain ecoregion just north of Beaumont, Texas (EPA.gov); Robertson et al. 2018). The Neches River, along with its principal tributary, the Angelina River, drains an area of approximately 25,900 km^2 (Figure 1.1). Continuing through the coastal plain, the Neches River flows into the Sabine Lake bay-system and then into the Gulf of Mexico (Martin et al. 2012; Matlock and Garcia 1983). On the coastal plain, the Neches River is tidally influenced with an amplitude of <0.6 m in Sabine Lake and with water movement largely driven by wind (Matlock and Garcia 1983).

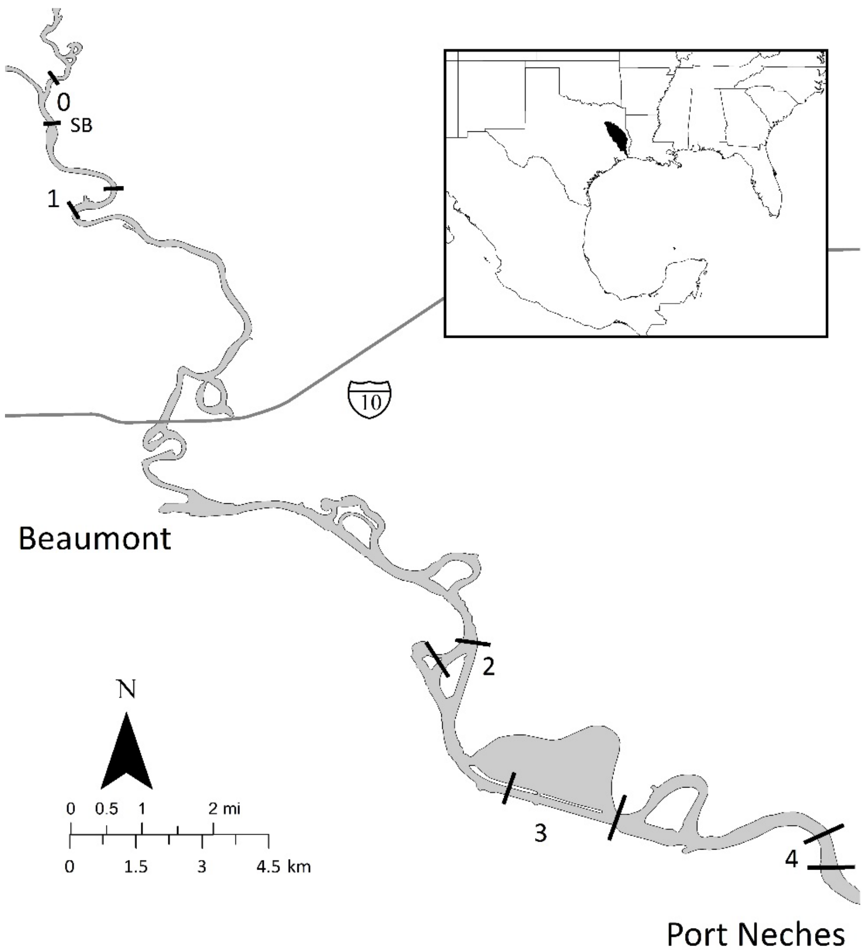

Figure 1.1: Map of the Neches River located in eastern Texas, showing the Neches River watershed (shaded in black), the locations of Stations 0, 1, 2, 3 and 4, the Saltwater Barrier (SB) and major cities. Dark bars indicate approximate station bounds.

Figure 1.2: Floodplain and shoreline vegetation of the lower Neches River in the vicinity of Beaumont and Port Neches, Texas.

The hydrology and general character of the lower Neches River is typical of an estuarine system where a salinity continuum of freshwater (salinity less than 0.5 parts per thousand [ppt]) to polyhaline waters (18 to 30 ppt) changes seasonally and annually to create a dynamic range of environments. In 2003, a permanent saltwater barrier was completed just downstream of the confluence of the Neches River and Pine Island Bayou near Beaumont, Texas (Pizano-Torres et al. 2017). Upriver, the Angelina (a major tributary of the Neches) and Neches River flow are partially regulated by two dams of various sizes. The largest of these is Sam Rayburn Reservoir on the Angelina River, having flood storage capacity which is often utilized when the Neches River is in flood stage. The second, Lake B. A. Steinhagen, is a much smaller reregulation lake with no flood storage capacity. Its primary function is absorbing the pulse releases of storage water from Sam Rayburn Reservoir and releasing it into the Neches River in a more sustained manner. If the upper Neches River is in flood stage, B. A. Steinhagen simply serves as a passthrough structure. These impoundments were collectively created for several purposes (e.g., to control floods, generate hydroelectric power and conserve water for municipal, industrial, agricultural, and recreational uses). Rainfall, dam operations, and the saltwater barrier are the most substantial factors governing river discharge within the Beaumont area.

Manufacturing in the Beaumont area (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. Agriculture includes crops (especially rice) and livestock. The river is dredged up to the Port of Beaumont to create a navigational channel. Improvement of the system for navigation began with the channelization of the offshore bar and the construction of protective jetties about 1883 (Ward 1980). 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. Additionally, dredging and channelization has resulted in digging new channels and cutting off several meanders.

1.2 Historical Surveys

Comprehensive studies of the Neches River were conducted by the Academy of Natural Sciences (the Academy) in August 1953 (ANSP 1954), August 1973 (ANSP 1974), October 1996 (ANSP 1998) and October 2003 (ANSP 2006), 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 (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 survey was an analysis of selected metals in sediments. The primary purpose of the 1973 program was to measure trends by comparing 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 techniques for the algae were like 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. 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 reservoir releases were decreased due to low seasonal water demand, and ambient river temperatures were relatively high. In addition, October in the region sees the lowest monthly rainfall totals on average.

1.3 Current Survey

This report summarizes the findings of studies conducted on the Neches River in Hardin, Jefferson and Orange counties, Texas, during 2021 by the Academy of Natural Sciences of Drexel University for the Lower Neches Valley Authority. The 2021 studies were conducted at two reference stations 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, Texas. Program elements were designed to characterize the biological conditions of the Neches River in areas previously surveyed by the Academy using similar methods and effort to past surveys, and to assess spatial and temporal patterns in chemical and biological indicators of water quality.

1.4 Study Area and Collection

Five portions (Stations 0, 1, 2, 3, and 4) of the lower Neches River from Port Neches to Beaumont, Texas, were surveyed (Figure 1.1). The same stations used during the 1953, 1973, 1996 and 2003 comprehensive surveys were investigated (ANSP 1954, ANSP 1974, ANSP 1998, ANSP 2006). Additionally, a station upstream of the saltwater barrier was included in the 2021 survey to document the freshwater fauna more thoroughly now that the barrier is fully operational. The uppermost station, Station 0, started just upstream of the confluence with Pine Island Bayou and extended downriver to the saltwater barrier, approximately 43 km (26.7 mi) upstream from Sabine Lake. Station 1 started approximately 2.2 km (1.4 mi) downstream of the Saltwater Barrier and extended downriver to a bend that was approximately 1.5 km (0.9 mi) upriver from the Beaumont Country Club. Station 2 began just upriver from Light Number 56 and continued downriver to include the point of Clark Island. Station 3 started approximately in the middle of the right bank of McFadden Bend Cutoff and stretched downriver to just upstream of power lines crossing the river and lying in the region of Light Number 40. The lowermost station, Station 4, began approximately midway between lights numbered 28 and 30 and extended downriver to an area near the canal to Block Bayou, approximately 11 km (6.8 miles) upstream from Sabine Lake. In all, five stations were located along 33 km (20.5 mi) of an estuarine system (Figure 1.1).

Figure 1.3: View from downstream of the saltwater barrier on the lower Neches River.

Each station included a range of habitats, including large backwaters at Stations 1, 2 and 4, and river bends with erosional and depositional areas. River bends provided areas with faster flows overlaying sandy substrates and slower flows (depositional areas) characterized by detritus overlaying silt and clay. Each station included shorelines with bald cypress (*Taxodium distichum*) and emergent vegetation, the most conspicuous of which were the common reed (*Phragmites australis*) and California bulrush (*Scirpus californicus*). Stations 0 and 1 drained a Cypress-Tupelo forest, while the downriver stations drained city, residential, industrial, marsh and pasture habitats. Downriver stations also received more input from saline waters and had a dredged channel. Stations were broadly defined to allow individual investigators the freedom to identify critical habitats for their study organisms. These stations provided comparable habitat to assess patterns in the flora and fauna along the estuarine continuum and allowed for a comprehensive assessment of the lower Neches River ecosystem.

1.5 River Discharge Patterns

Species composition has varied among years, in part reflecting seasonal and annual discharge patterns in the Neches River basin. Daily discharges recorded at Evadale for the 1953, 1973, 1996, 2003, and 2021 surveys are depicted in Table 1.1 and Figure 1.4 and help interpret differences among survey years. 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 was characterized by high spring discharge, but much like 1996, was characterized by low discharge for the remainder of the year. The 1973 discharge was high in the first third of the year and had lower flows thereafter, although in 1973 a late spring spike occurred. The 2021 discharge patterns were most like 1973, with elevated discharge from May through early August. Like 1953 and 1973, 2021 discharge patterns were characterized by elevated discharge in the spring and summer, and decreased discharge during the late-summer to early-fall periods. Like 1973, the generally higher discharges of 2021 favored certain species over those typical in low-flow years (e.g., 1996), and likely diluted some of the chemical constituents of the river and increased others from terrestrial runoff (see Section 2.4 Comparison to Historical Monitoring).

Table 1.1: Neches River mean, minimum and maximum monthly daily discharge (cubic feet per second [cfs]) for 1953, 1973, 1996, 2003 and 2021. Values in bold highlight discharge data for the month that Neches River sampling took place each year.

	1953			1973			1996			2003			2021		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
January	4065	1840	11400	7555	1930	10800	2941	2740	3720	16505	5660	24600	6981	3380	10900
February	6772	3870	16600	11152	4700	17300	2713	2510	3190	8328	3720	21900	6081	4230	9330
March	13787	4960	23800	11922	7190	16100	2666	2500	2870	23561	19200	25900	5554	4340	7380
April	7424	1090	23400	20717	15700	30100	2495	1070	3700	11297	4720	19900	6361	2870	16800
May	46794	11300	80000	18310	12200	22900	1429	1270	1730	3762	2940	5400	23645	10000	42800
June	11200	1150	43900	15484	5660	30600	1537	1130	1930	3851	2830	7740	24200	19800	30400
July	2271	1060	5040	12639	3830	19700	1447	1110	1600	3048	2490	4110	18526	15900	19900
August	**1954**	**1380**	**3580**	**3935**	**1700**	**5920**	825	672	1710	3809	2870	4920	7656	2770	15500
September	1123	840	1500	6772	4220	9910	1712	526	11100	4663	3310	6250	3278	2040	4930
October	471	248	810	8065	4370	10100	**1229**	**484**	**9690**	**2324**	**2140**	**3160**	**1849**	**1250**	**3380**
November	428	403	472	11799	6720	16000	684	510	1910	3375	1790	10700	1645	1140	2370
December	1707	425	5010	15244	8460	19400	2449	857	7000	2683	2060	4460	2113	1720	2860

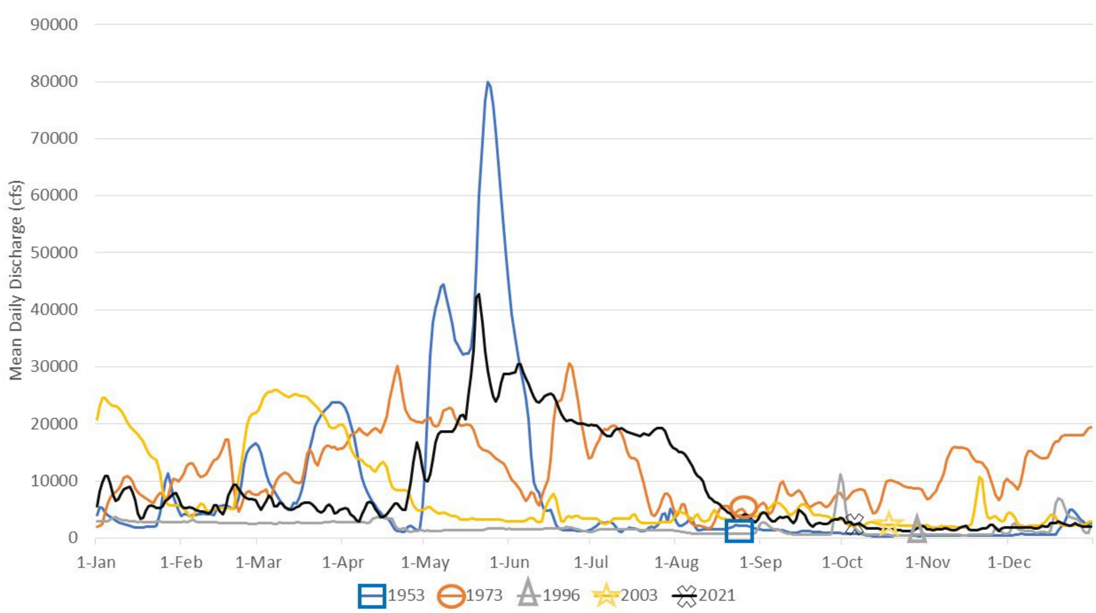

Figure 1.4: Neches River daily discharge (cubic feet per second [cfs]) for 1953, 1973, 1996, 2003 and 2021. Icons for each study are proportional in width to the lengths, in days, of the field effort.

2. ENVIRONMENTAL GEOCHEMISTRY

Abstract

1. The goal of this component of the study was to assess potential differences between reference and exposed stations and, where possible, to compare with applicable water-quality guidelines and standards and to compare results to those of previous studies by the Academy of Natural Sciences (the Academy).
2. Water samples were collected by staff of the Lower Neches Valley Authority (LNVA) in support of the study by the Academy and analyzed by a contract lab.
3. Stations below the saltwater barrier exhibited salinity stratification with depth, and dissolved oxygen concentrations were lowest near the bottom of Stations 2 and 3. Nutrient parameters were variable across stations and dates, with nitrate+nitrite concentrations increasing substantially from the upstream stations to Stations 2 through 4. Contaminants such as volatile organic compounds and trace metals did not appear to be elevated in the water and were close to the detection limits of the methods.
4. When compared to previous surveys, dissolved oxygen levels in the surface waters were similar and above screening levels (except for the 1953 survey). Nutrient parameters were similar or slightly lower, and fecal coliform levels were much lower. Additionally, due to changes in state regulations, *Enterococci* or E. coli measurements should replace fecal coliform measures in the future.
5. Long term trends (in data obtained from the Texas Commission on Environmental Quality [TCEQ]) revealed substantial variability from upstream to downstream stations. Dissolved oxygen saturation values showed a positive trend over the ~40-yr time period, while fecal coliform showed a decrease in concentration. Seasonal flows may impact the trend analysis and should be included in future studies. Note: future studies should replace fecal coliform with E. Coli or Enterococci.
6. Overall, this section of the lower tidal Neches River appears to have slightly better water quality than found in the 2003 survey (ANSP 2006). This may be related to stable and lower flows during this period. Dissolved oxygen concentrations in the near bottom waters (Stations 2 and 3) were low, in-part, due to increased salinity, and can impact the biological community in or near the bottom while nitrate+nitrite concentrations increased downstream of Station 1. This distribution was related to the limited mixing due to density differences between surface and bottom waters. The less dense freshwater on the top and the denser saltwater below causes a density difference that restricts mixing between surface and bottom layers.

2.1 Overall Approach

Chemistry data were collected in October 2021 as part of the Academy's biological survey. Water samples were collected by staff of LNVA in support of the study by ANS and analyzed by A and B Labs in Houston, Texas. Additionally, LNVA provided a complete long-term data set for the period 1981-2021 (from the Texas Commission on Environmental Quality [TCEQ] SWQMIS), which permitted trend analyses for several water-quality parameters. The parameters available among stations varied 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.

2.2 Sampling Methods

Water samples were collected at each of the five sampling stations (Stations 0, 1, 2, 3 and 4) on four consecutive days (Oct. 5 to Oct. 9, 2021). It should be noted that Station 0 is new relative to previous surveys. This station is upstream of the saltwater barrier and was included in the 2021 survey to document the chemistry and freshwater fauna more thoroughly now that the barrier is fully operational. At each station, a water quality meter was used to collect basic water quality parameters (e.g., temperature, specific conductance 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 Oct. 6 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 by the Texas Commission on Environmental Quality (TCEQ), formerly the Texas Natural Resource Conservation Commission.

Table 2.1: Parameters determined in near-surface water samples from the Neches River in 2021. (TR = total recoverable)

Field Measurements	
Dissolved Oxygen	pH
Salinity	Temperature
Specific Conductance	
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
Styrene	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

It should be noted that Segment 601 (Neches River Tidal; below the barrier; Stations 1-4) and Segment 602 (Neches River Below B.A. Steinhagen Lake; above the barrier; Station 0) are officially classified as two different water body types per the Texas Surface Water Quality Standards (30 TAC, Chapter 307). Segment 601 (Neches River Tidal) is considered saltwater, and the screening values associated with this water body would be those for a tidal stream. Segment 602 (Neches River Below B.A. Sternhagen Lake) is upstream of the saltwater barrier and classified as a freshwater stream. In this respect the nutrient and water quality nutrient screening values are different and noted below (State of Texas, 2020)

2.3 Results and Discussion

The following presents the results from the sampling program between Oct. 5 and Oct. 9, 2021, on the tidal and partially non-tidal (i.e., Station 0) Neches River. Results are presented in four sections: basic water quality, solids and nutrients, organic compounds, and selected trace elements.

Basic Water Quality Parameters

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), salinity, specific conductance, and total dissolved solids (TDS). Salinity and temperature ranged from <0.1 to 8.7 ppt and 23.4 to 27.8°C, respectively (see Appendix A.1 for full water quality data). At all sampling times, the specific conductance (and salinity) was lowest at Stations 0 and 1. Due to the low levels of salt at Stations 0 and 1, specific conductance values will be discussed for these stations. Temperature and salinity (and specific conductance) generally increased from Station 0 to Station 4 but with some interesting changes with depth down river (Figures. 2.2 to 2.6). The depth profiles show that at Stations 2 and 3, salinity was higher near the bottom than further downstream at Station 4 (Figures. 2.2 to 2.6). Salinity reached levels >8 ppt near the bottom during the Oct. 5 to Oct. 9 sampling periods and decreased slightly to approximately 5 ppt in the latter two sampling events.

Figure 2.1: LNVA staff collecting a water sample in the field.

There was some water quality difference between Station 0 above the barrier (new for this study) relative to Station 1 below the barrier. While there was some variation during the sampling period, Station 0 conductivities increased with depth, while at Station 1, specific conductance was similar from top to bottom (Figures. 2.2 and 2.3). Similarly, temperature and dissolved oxygen (DO) values decreased with depth at Station 0 and were similar from surface to the bottom at Station 1. For example, DO concentrations at Station 0 were approximately 7 mg/L at the surface decreasing to ~4.5 mg/L (range = 4.3 to 4.8 mg/L) near the bottom, while DO concentrations were similar from surface to bottom at Station 1. Similarly, temperatures at Station 0 were highest near the surface decreasing by approximately 2°C at depths of 6-7 m, while at Station 1, temperatures showed little variation with depth but did vary slightly over the sampling period. The data indicate water column stratification above the saltwater barrier (Station 0), mostly due to temperature variations and greater tidal mixing below the barrier.

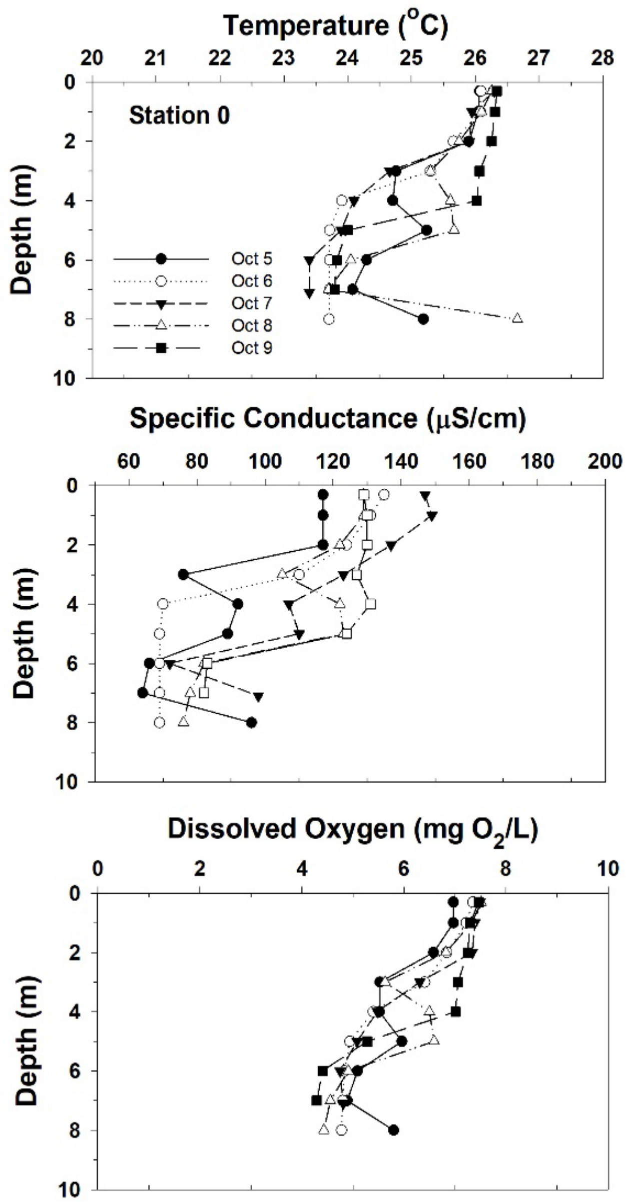

Figure 2.2: Depth profiles of temperature, specific conductance, and dissolved oxygen for Station 0 for the four sampling dates.

The distribution of temperature, salinity and dissolved oxygen with depth and distance downstream from Station 1 are typical of an estuarine environment in coastal Texas (Figures 2.2 to 2.6). In general, temperatures were lowest at the surface increasing with depth, while salinities were lowest near the surface increasing with depth. Since salinity has a larger influence on water density than temperature, given the changes observed, this indicates that the system is a typical lagoonal estuary with the water column normally stratified (i.e., low-density water on top of high-density water near the bottom). The increase in salinity with depth at the downstream Stations 2 and 3 indicates that mixing of surface and bottom waters is limited. The stratification limits

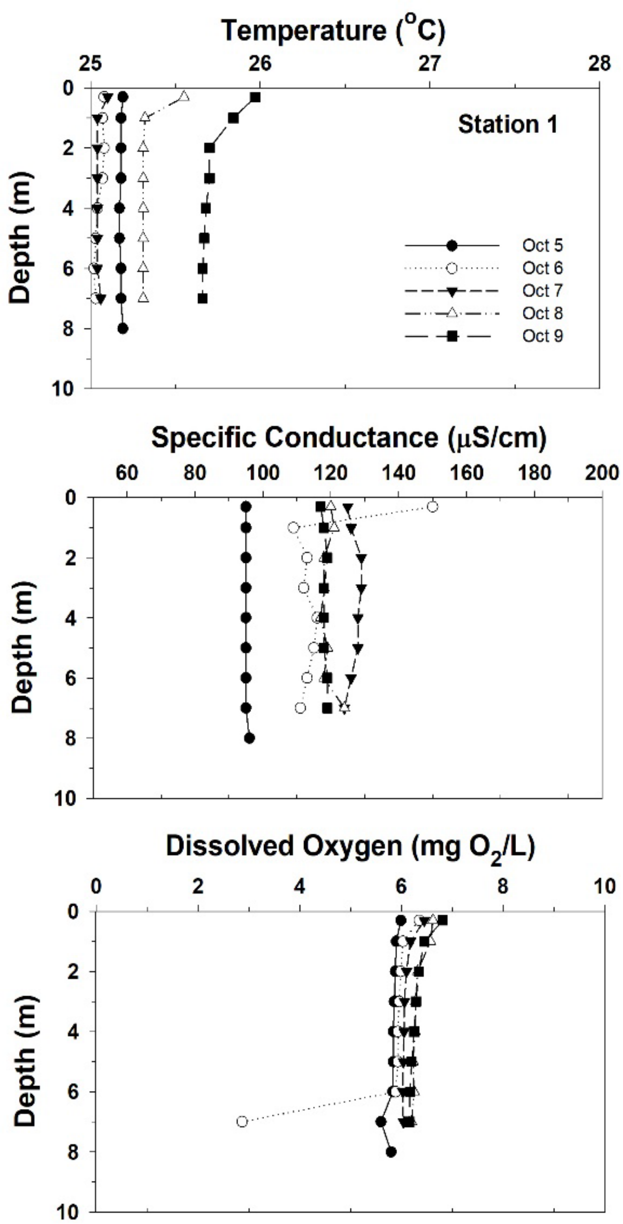

Figure 2.3: Depth profiles of temperature, specific conductance, and dissolved oxygen for Station 1 for the four sampling dates.

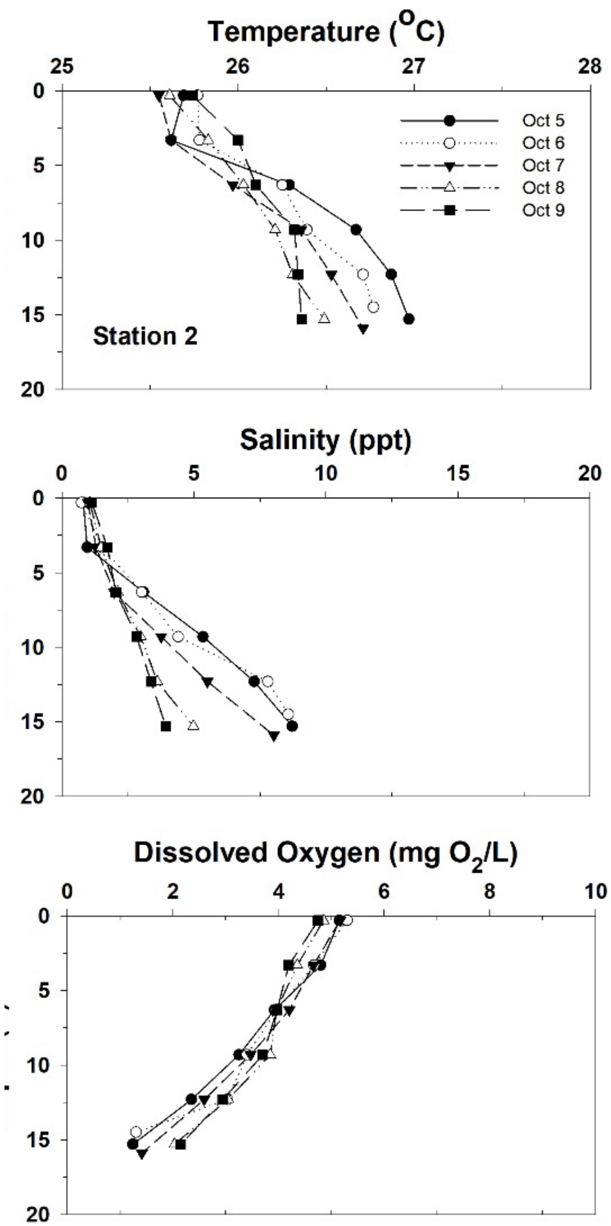

Figure 2.4: Depth profiles of temperature, salinity, and dissolved oxygen for Station 2 for the four sampling dates.

mixing and impacts the distribution of dissolved oxygen (DO) with depth. Oxygen levels were approximately 5 mg/L near the surface decreasing to levels < 3.5 mg/L below 12 m at Stations 2 and 3 and <4.5 mg/L below 12 m at Station 4.

Dissolved oxygen concentrations were compared with the criterion set by the State of Texas (i.e., 3.0 mg O_2/L: TCEQ, 2018). This criterion pertains to samples in the mixed layer (i.e., surface to 6000 µS/cm). Overall, out of 131 samples, none were below the criterion. There were 17 samples with DO concentrations < 3 mg/L from all stations and periods, but these were in higher specific conductance (salinity) waters and were nearer the bottom.

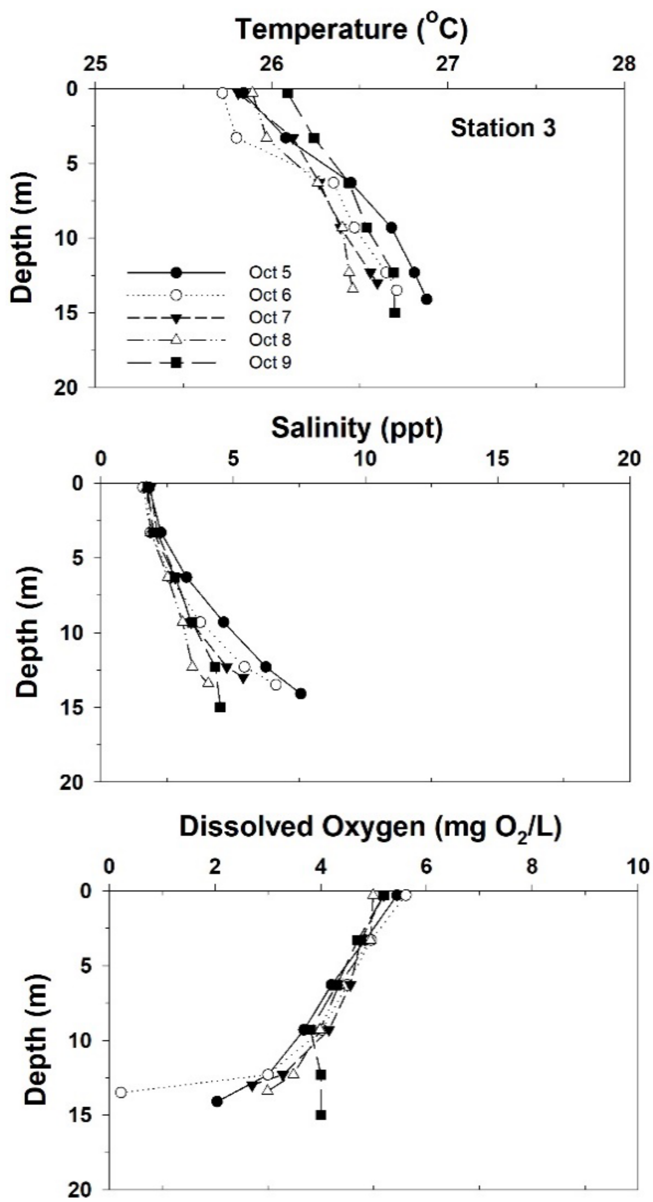

Figure 2.5: Depth profiles of temperature, salinity, and dissolved oxygen for Station 3 for the four sampling dates.

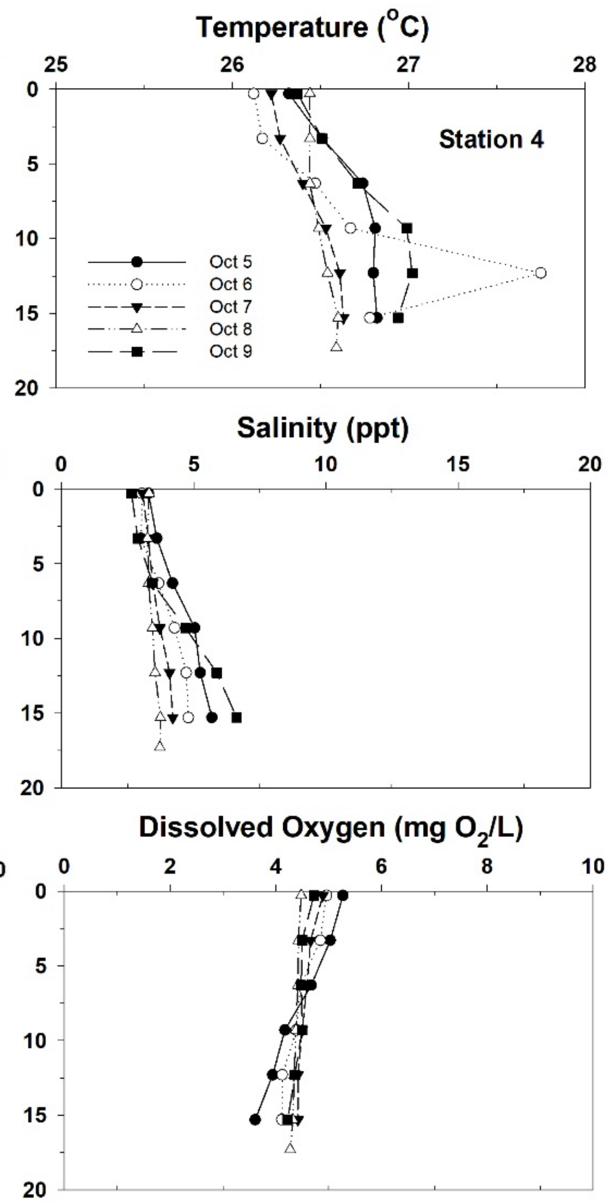

Figure 2.6: Depth profiles of temperature, salinity, and dissolved oxygen for Station 4 for the four sampling dates.

To factor out changes in oxygen solubility due to temperature and salinity, dissolved oxygen saturation (% Sat) was measured. The % Sat ranged from approximately < 1 to 93% (mean = 61±17 % Sat) for all stations and sampling dates (Appendix A.1). Lowest % Sat was measured in the deeper samples from all stations. There was a decrease in surface water % Sat from Station 0 to Station 4, from 90% to approximately 60%, indicating greater microbial activity and oxygen consumption.

The observed DO profiles are the result of a net balance between processes that produce and consume dissolved oxygen as well as mixing with the atmosphere (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 estuary. 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. 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 lower levels and in some cases to concentrations < 2 mg/L DO (Figures. 2.2 to 2.6).

For all stations and sampling periods, pH ranged from 6.4 to 7.8 (mean = 6.9±0.3 pH units). While there was small variability in pH with depth (generally <1 pH unit), lower pH samples (<7) were associated with lower salinities (Appendix A.1) and slightly higher values (7-7.2) in the higher salinity waters. In all cases, pH was within the criteria range set by the State of Texas (i.e., 6.0-8.5; TCEQ, 2018).

Figure 2.7: LNVA staff Dennis Becker, Brielle Patronella and Jeannie Bowlen (left to right) taking water quality measurements.

Water Column Solids, Fecal Coliform, Total Organic Carbon, and Nutrients

Sub-surface water samples (collected ~0.3 m below the surface) for solids (turbidity, total suspended solids, volatile solids), fecal coliform and nutrients were collected Oct. 5 to Oct. 9 at all stations. Data are presented in Appendix A.2.

Total suspended solids (TSS) ranged from approximately 8.5 to 22 mg/L for all time periods and stations (Figure 2.8). Higher concentrations were observed at Station 0 (mean = 16 mg/L) with a slight decrease to Station 3 (mean = 10 mg/L) and a slight increase to a mean of 16 mg/L at Station 4 (Figure. 2.8). The slight decrease in TSS may be a result of the dilution of watershed derived solids with the mixing with coastal waters. Turbidity ranged, on average, from 6 to 31 nephelometric turbidity units (NTU) and was higher in the upper stations with means of 18 and 21 NTU at Stations 0 and 1,

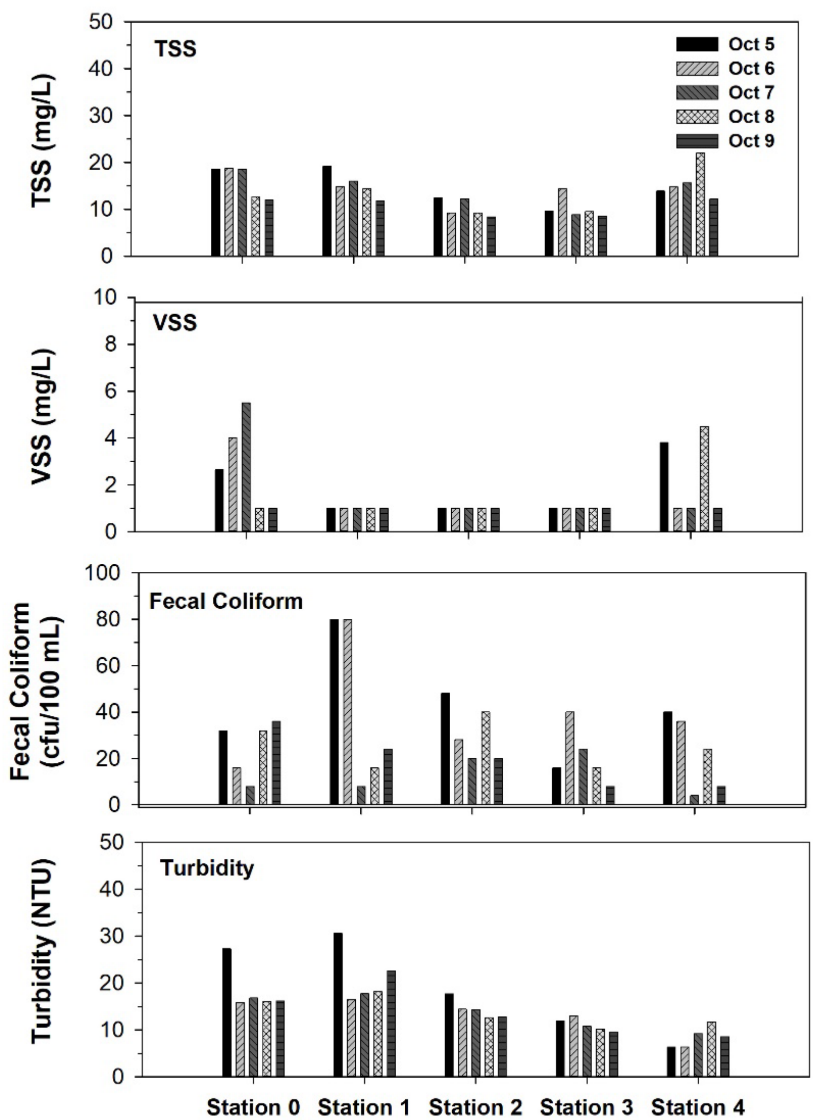

Figure 2.8: Concentrations of total suspended solids, volatile suspended solids, fecal coliform and turbidity in the lower Neches River (Segment 601) for the four sampling dates in 2021.

respectively, decreasing to Station 4 to a mean of 8 NTU (Figure 2.8). Over the four-day sampling period, turbidity decreased slightly at Stations 2 and 3 and were more variable at the other stations. Volatile suspended solids (VSS) ranged from <1 to 5.5 mg/L. The only locations with detectable VSS were Station 0 above the barrier and at Station 4 on two dates (Figure 2.8).

Fecal coliform (FC) amounts were low and variable during the study period and ranged from 4 to 80 colony forming units per 100 milliliters (cfu/100mL) with an overall average of 28 cfu/100ml (Figure 2.8). Highest FC amounts were measured from samples taken at Station 1 on Oct. 5 and Oct. 6 (80 cfu/100ml). It should be noted that either *Enterococci* or *E. coli* bacteria has since replaced fecal coliforms as the bacterial water quality indicator for contact recreational use and should be monitored in the future (LNVA 2004; TCEQ 2018; 2023 personal communication).

Total organic carbon (TOC), the sum of dissolved and particulate organic material, ranged from 6 to 11 mg C/L (mean±SD = 8.0± 1.4 mg C/L; Figure 2.8). In general, TOC concentrations were slightly higher, overall, at Stations 1 and 2 (average of ~9.5 mg C/L) compared to other stations (~6.5-8.0 mg C/L). To note, concentrations of TOC above the saltwater barrier (Station 0; 6.5±0.8 mg C/L) were lowest overall compared to the other stations except for Station 4. At Stations 0 and 1, TOC concentrations decreased slightly over the five-day sampling period, while at Stations 2 to 4, there was a slight increase in TOC levels. For example, at Station 2, TOC levels increased from 8.4 to 9.3 mg C/L from Oct. 5 to Oct. 9, while at Station 1, TOC concentrations decreased from 10.8 to 8.2 mg C/L. There are no water quality criteria from the State of Texas with which to compare these concentrations.

Three forms of nitrogen were measured for this study: dissolved nitrate+nitrite, total Kjeldahl nitrogen (TKN) and ammonium (+ ammonia) (Table 2.1). Dissolved nitrate (nitrate+nitrite) concentrations were always low and near the reporting limit at Stations 0 and 1, averaging <0.02 and 0.049 mg N/L, respectively (Figure 2.9). At both stations, there was a slight decrease in nitrate concentrations from Oct. 5 to Oct. 9. Below the saltwater barrier, concentrations increased downstream substantially and were highest at Station 4 (average±SD; 0.20±0.02 mg N/L) on all sampling days. Total Kjeldahl nitrogen concentrations ranged from <0.20 to 0.45 mg N/L from all stations with only six sampling points above the reporting limit of 0.20 mg N/L (Figure 2.9). Only on the Oct. 6 sampling day were concentrations at all stations above the reporting limit, with concentrations highest at Station 0 and 1 (~0.44 mg N/L) decreasing slightly to Station 4 (0.30 mg N/L). Lastly, dissolved ammonium (+ammonia) concentrations ranged from 0.02 to 0.08 mg N/L (mean±SD = 0.04±0.01 mg N/L). Concentrations were generally similar at each station during the five days but with an overall increase from Oct. 5 to Oct. 9 (Figure 2.9). For example, at Station 0, above the barrier, concentrations increased from 0.02 mg N/L to 0.05 mg N/L from Oct. 5 to Oct. 9; this was similar at the other downstream stations except for Station 4 on Oct. 9.

Dissolved inorganic phosphorus concentrations were below the method detection limit and are reported at 0.03 mg P/L (except for two samples; see Appendix A.2), while total phosphorus concentrations ranged from 0.01 to 0.07 mg P/L (mean = 0.03± 0.02 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 (State of Texas, 2020) is 0.7 mg/L. Concentrations of all forms of phosphorus were below the published screening criterion.

The screening level criteria (SLC) for various nutrients are different for the upstream station (Station 0) compared to the tidal stations (Stations 1-4; State of Texas, 2020). For dissolved nitrate (+nitrite), the SLCs are 1.95 and 1.10 mg N/L for the upstream and

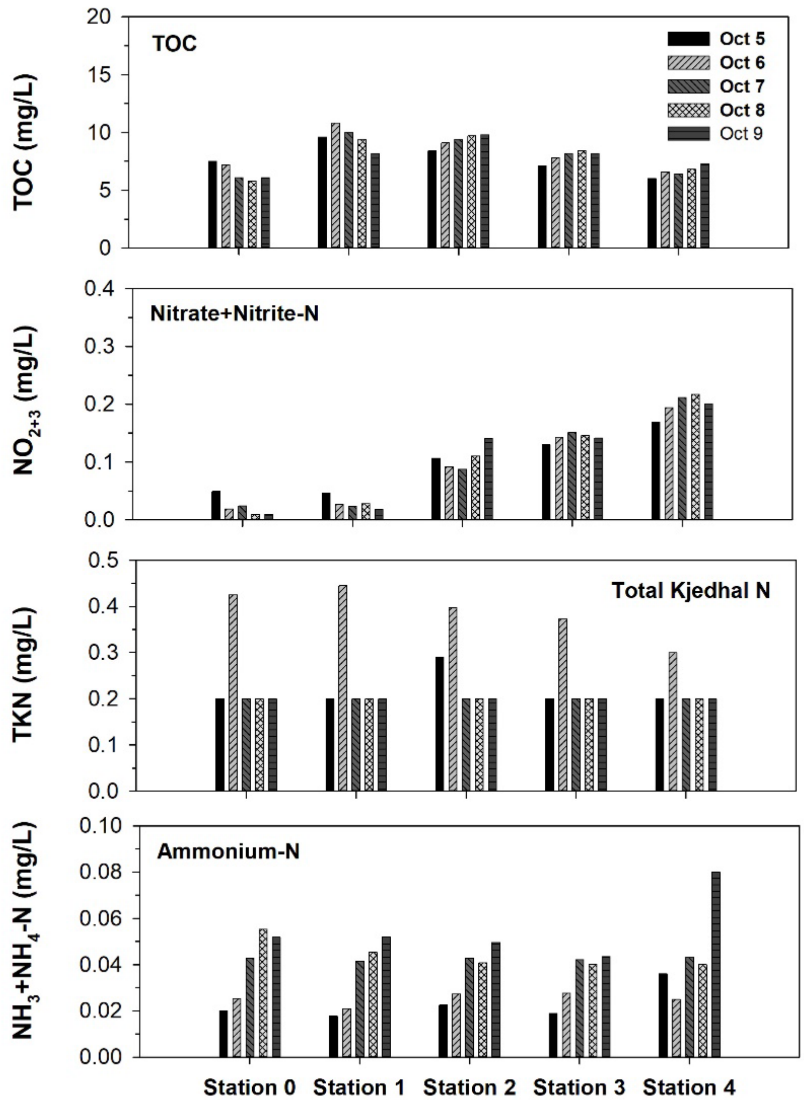

Figure 2.9: Concentrations of total organic carbon, dissolved nitrate+nitrite, total Kjeldahl nitrogen, and dissolved ammonia+ammonium in the partially-tidal and tidal Neches River for the four sampling dates in 2021.

below the barrier stations, respectively, while for dissolved ammonia they are 0.33 and 0.46 mg N/L. For total phosphorus, concentrations vary from 0.69 mg P/L to 0.66 mg P/L for the upstream and downstream (of the barrier) sections.

Selected Organic Compounds

Sub-surface water grab samples were collected on Oct. 6 for 21 selected organic compounds from Stations 0 to 4 including: Styrene, Ethylene Glycol, Methanol, Phenol along with other phenolic compounds including 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. All samples yielded undetectable concentrations (below the practical quantitation limits [PQL]) for all organic parameters as listed in Appendix A.3.

Water Column Trace Metals and Metalloids

In 2021, 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 (TR). Dissolved forms cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), arsenic (As) and total recoverable mercury (Hg) and selenium (Se) were at or below the detection limit of between 0.0006 and 0.002 micrograms per liter (µg/L) for the various metal or metalloids (see Appendix A.4 for trace element data). Only a few samples for dissolved silver (Ag) and aluminum (Al) were above the reporting limits (Figure 2.10) where dissolved Ag was higher at Station 0 and dissolved Al was highest at Station 1, just below the saltwater barrier.

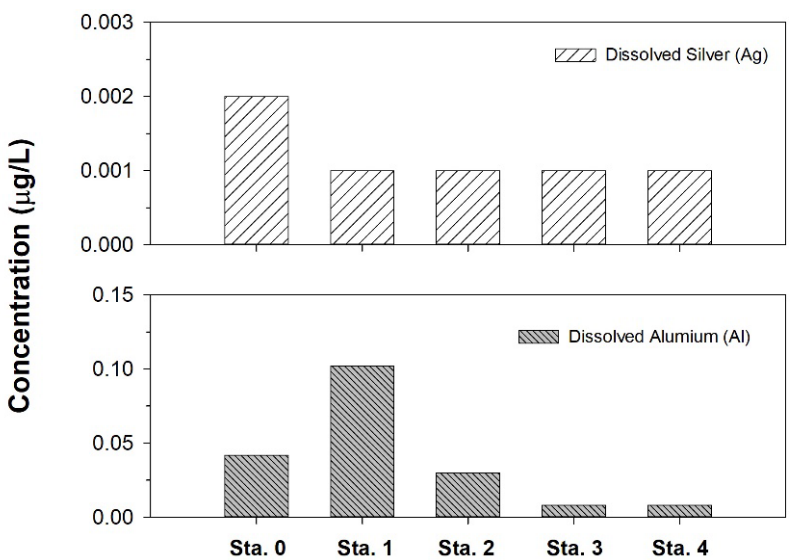

Figure 2.10: Neches River trace element for dissolved aluminum and silver collected on Oct. 6, 2021.

2.4 Comparison to Historical Monitoring

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 (Stations 1 through 4). Chemical monitoring was undertaken in 1973, 1996, 2003 and 2021. In 2021, Station 0 was added to assess water quality above the new saltwater barrier located on the Neches River near Bigner Road in Beaumont, Texas. Since this is a new station (year 1), it was not included in comparison to previous studies. A summary of the surface concentrations from these surveys is presented in Appendices A.5-A.9. Presented are the average, standard error, and minimum and maximum values for each station over four consecutive days, except for 1953 when samples were only collected on one day.

Surface water dissolved oxygen (DO) concentrations measured in the current study are generally similar to those measured in previous studies with some small differences

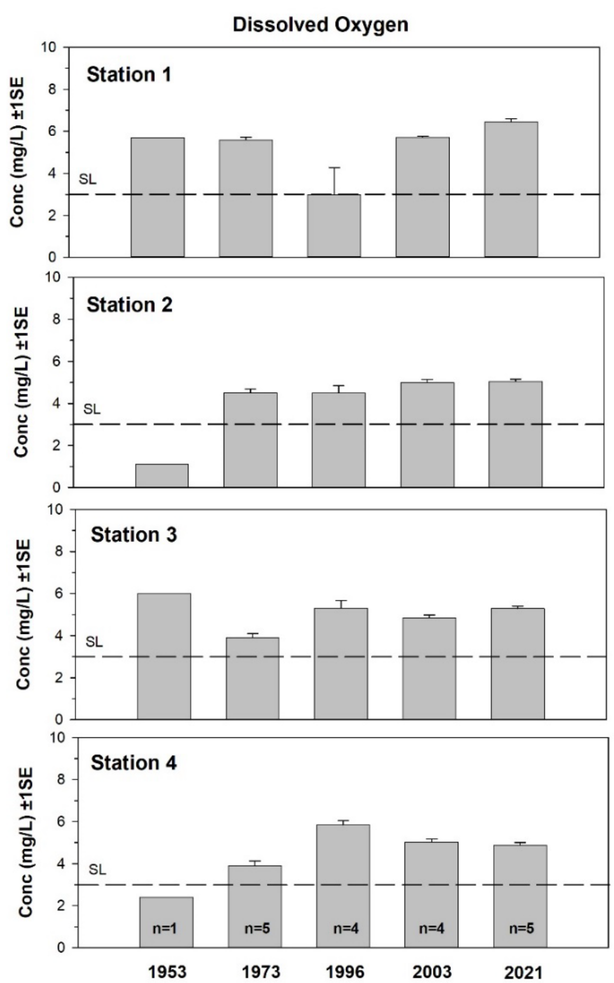

Figure 2.11: Concentrations (average mg/L ± 1SE) of dissolved oxygen from each of the four study periods from 1953 to the present. SL = current screening level; n = number of sample days for each station.

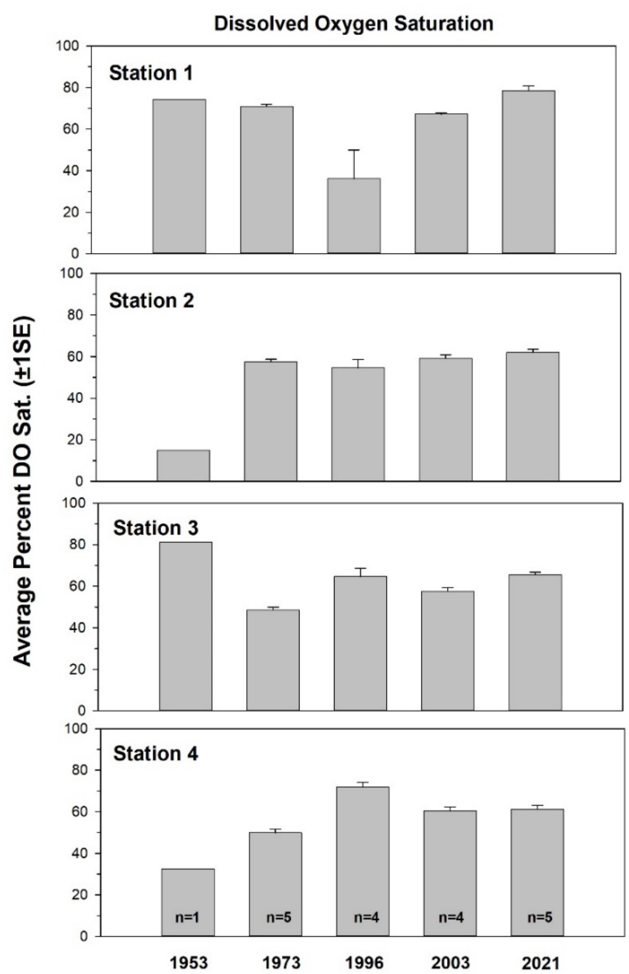

Figure 2.12: Percent dissolved oxygen saturation (average ± 1SE) from each of the four study periods from 1953 to the present. Note: saturation data were not corrected for salinity which, in most cases, was low. n is the number of sample days for each station.

(Figure 2.11). In 1953, surface water concentrations were less than 3 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 (Figure 2.11). 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 Figure 2.12. 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. Concentrations of dissolved oxygen and percent DO in 2021 were like those measured in 1996 and 2003.

Fecal coliform (FC) concentrations exhibited large changes during the five surveys. Other than at Station 1 in 1953, FC average concentrations were significantly higher in 1953 and 1973 than in the 1996, 2003 and 2021 surveys (Figure 2.13). Average concentrations in 1996 and 2003 were similar and still above published screening

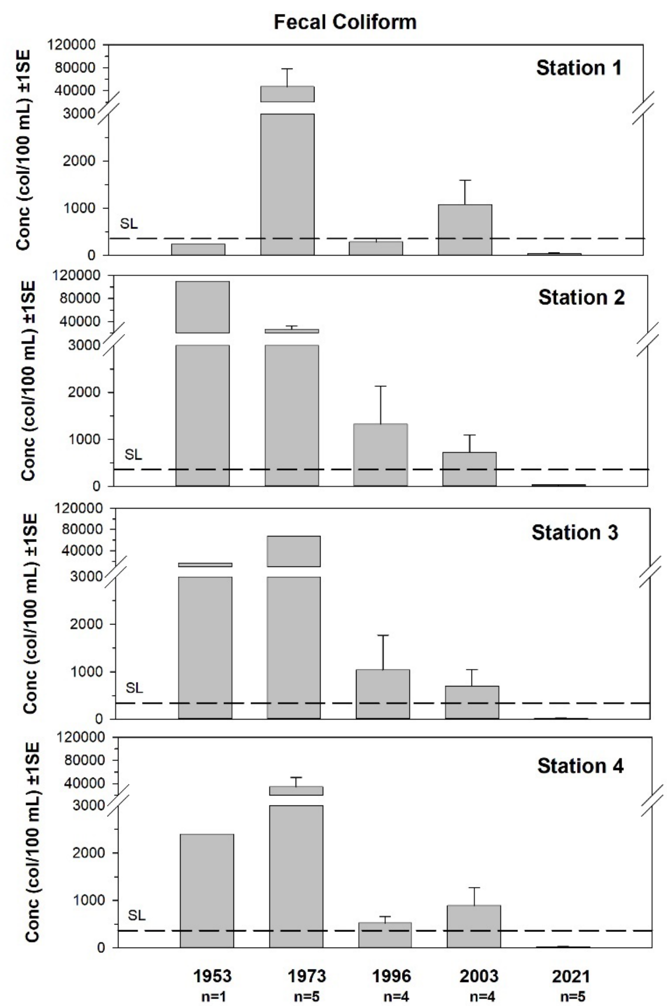

Figure 2.13: Concentrations (average cols./100 ml ± 1SE) of fecal coliform from each of the four study periods from 1953 to the present. SL = current screening level; n is the number of sample days for each station.

criteria of 400 colonies per 100 ml, while in 2021, all samples were well below the screening criteria.

Three different nitrogen forms were measured during the five surveys that allow comparison (Figure 2.14). 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 and were lower in the 2021 survey ranging from 0.02 to 0.08 mg N/L. Dissolved nitrate concentrations in 2003 were at or near the stated DL of 0.04 mg N/L ranging from 0.04 to 0.09 mg N/L (Table 2.3); while in 2021 all concentrations were only slightly higher (~ 0.02 to 0.22 mg N/L). In the 2003 and 2021 surveys, concentrations generally increased downstream to the higher salinity waters. Concentrations in 1973 were generally lower than those detected in either 1953 or 1996.

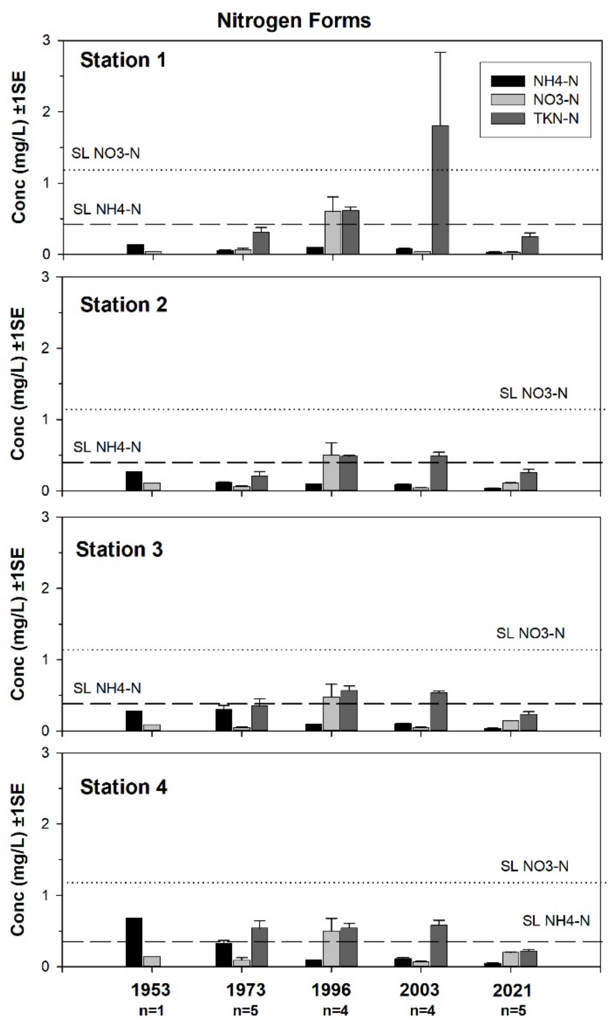

Figure 2.14: Concentrations (average mg/L ± 1SE) of the different nitrogen forms from each of the four study periods from 1953 to the present study. SL = current screening level for ammonia and nitrate. n is the number of sample days for each station.

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 (2.4 mg N/L) and ammonium (0.4 mg N/L; State of TX, 2020). Total Kjeldahl nitrogen (TKN) was not measured in 1953 and on average ranged from 0.2 to 1.80 mg N/L for the other four surveys (Figure 2.14). 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 and were lower in 2021, ranging from 0.2 to 0.44 mg N/L (0.24±0.08 mg N/L).

Phosphorus concentrations are presented for dissolved inorganic phosphorus (also called dissolved orthophosphate, o-PO_4) and total phosphorus (TP) (Figure 2.15). Dissolved orthophosphate samples were below the stated detection limit (0.04 mg P/L) in 2021 (except in two samples), 2003, and 1953 (<0.001 or 0.03 mg P/L). Note that the

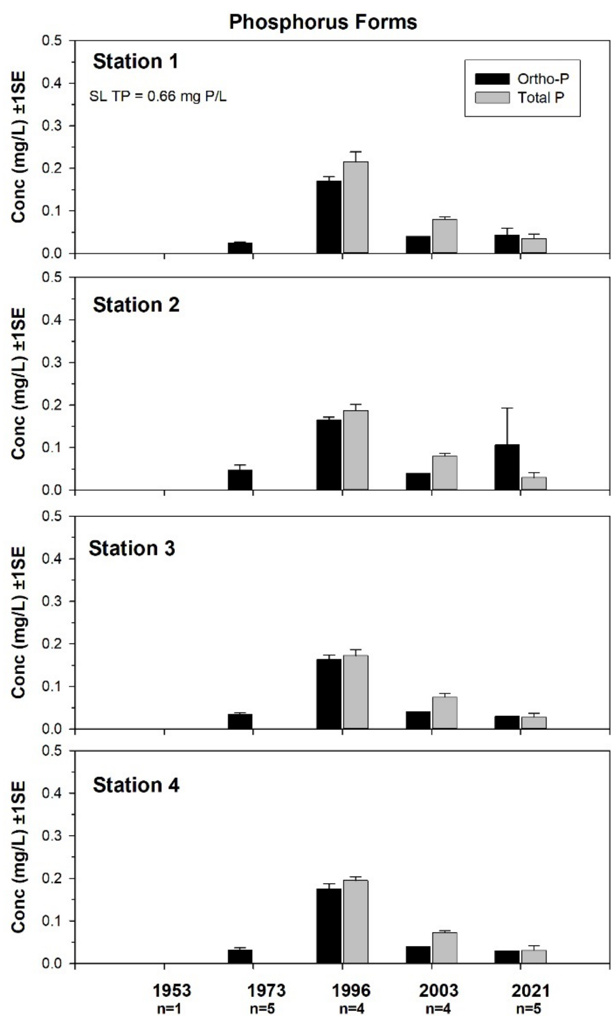

Figure 2.15: Concentrations (average mg/L ± 1SE) of the different phosphorus forms from each of the four study periods from 1953 to the present study. SL = current screening level for TP; n is the number of sample days for each station.

detection limit varied over the different surveys. On average o-PO_4 concentrations were higher in 1996 (~0.17 mg P/L) than in 1973, 2003 and 2021 surveys. Total phosphorus levels, on average, were similar to o-PO_4 concentrations suggesting that a majority of the TP was dissolved inorganic phosphorus. TP had a similar temporal distribution as o-PO_4 with higher concentrations in 1996.

Organic contaminant data were measured in 1996, 2003 and 2021. In all cases, except for ethylene glycol in 2003, concentrations were below the reported method detection limit. In 2003, ethylene glycol was detectable at all stations (see Appendix A.3), however, the data are suspect (see ANS Report, 2006).

Trace element data compiled by LNVA from the period between approximately 1982 and 2021 were obtained and summarized for seven trace metals (Cd, Cr, Cu, Pb, Ni, Ag, and Zn) and two trace metalloids (As and Se) (Table 2.6). Stations 100 and 300 are located roughly 6 river miles and 1 river mile (respectively) downstream from Academy Station 4, Station 500 is less than 1 river mile downstream from Academy Station 2, and Station 800 is roughly midway between Academy Stations 1 and 2.

The period of record was different for each station, with Stations 100 (downstream) and 500 (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. In some cases, the form of the element has changed from total, to total recoverable to dissolved forms, thus limiting overall comparisons. 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 2.6). 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. In 2021, as reported above, only dissolved silver (Ag) and aluminum (Al) were above the detection limit at the upper stations, while total recoverable selenium (Se) was detected at only one station.

Complexity due to changing forms of trace metals measured over time and implementation of cleaner methods (and lower detection levels) hinders the ability to make a clear data comparison over the long-term.

Table 2.2: 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
2021 Study Range**	<0.004	<0.002	<0.004	<0.004 to 0.004	<0.004	<0.004	<0.001 to 0.002	<0.005	<0.006 to 0.01
Number of Samples	5	5	5	5	5	5	5	5	5
Number above DL	0	0	0	2	0	0	4	0	1

* 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

2.5 Long-Term Water Quality Analysis

For long-term analysis of water quality, electronic data were obtained from LNVA (from the TCEQ SWQMIS; A. Bruno and Jeannie Mahan, personal communication in 2003 and 2021, respectively). Data were obtained from Segment 601 of the tidal Neches River for Stations 100, 300, 500 and 800 (Appendix A.10). There were no additional data since the last report for Station 700, 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).

Water Quality Trends

Historical Chemical Data Analyses

In previous reports (ANSP 1998 and ANSP 2006), data from the Neches River were analyzed for temporal variability and change since approximately 1981. In the 2003 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], and dissolved 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) (ANSP 2006). In this report, the period is extended to ~2020, depending on the parameter, and the complete data set was analyzed for temporal changes over this period (i.e., 1981 through ~2020). Figures 2.16 to 2.19 present the long-term data for total phosphorus, dissolved inorganic phosphorus, fecal coliform, dissolved oxygen, oxygen saturation and dissolved ammonia.

Since the earlier data (ANSP 1998 and ANSP 2006) 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 frame (i.e., 1981 to ~2020). We also investigate potential seasonal patterns of variation, which could explain some of the variability in the concentration data.

Methods

We used two linear models to test for temporal changes over time. The first model was a linear regression testing solely for the effect of time on each parameter. The second model was an analysis of covariance (ANCOVA) that tested for seasonal differences over time and therefore accounted for seasonal differences in the parameters. Models were assessed for normality and there were no major violations. Again, for some parameters and locations, there was not enough data for statistical analysis. In addition, over the decades, changing analytical methods (and detection limits) may limit overall results.

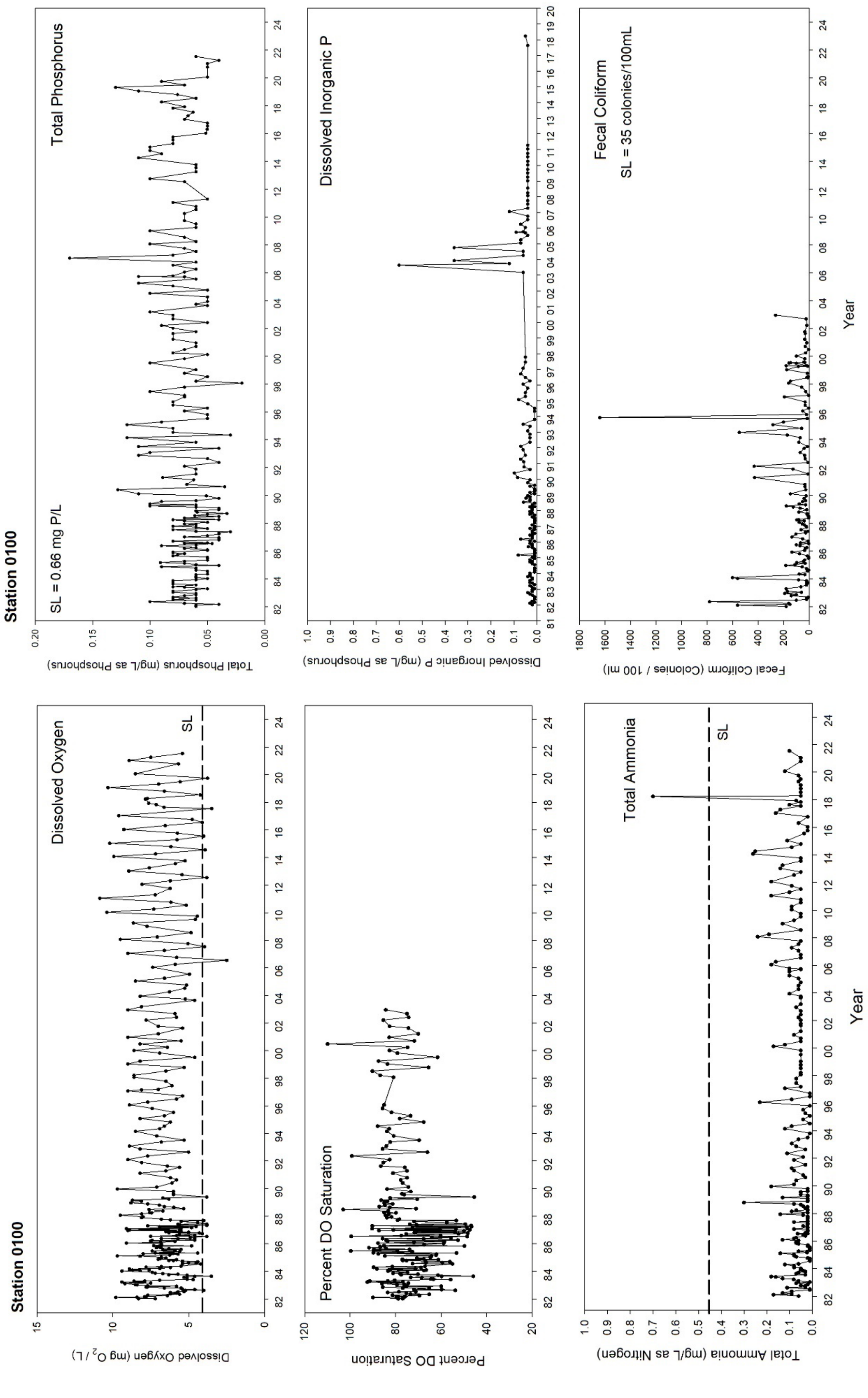

Figure 2.16: Temporal distribution of water quality parameters at Station 100 in the lower tidal Neches River. Dashed line is the screen level (SL) concentration presented by the State of Texas (2020).

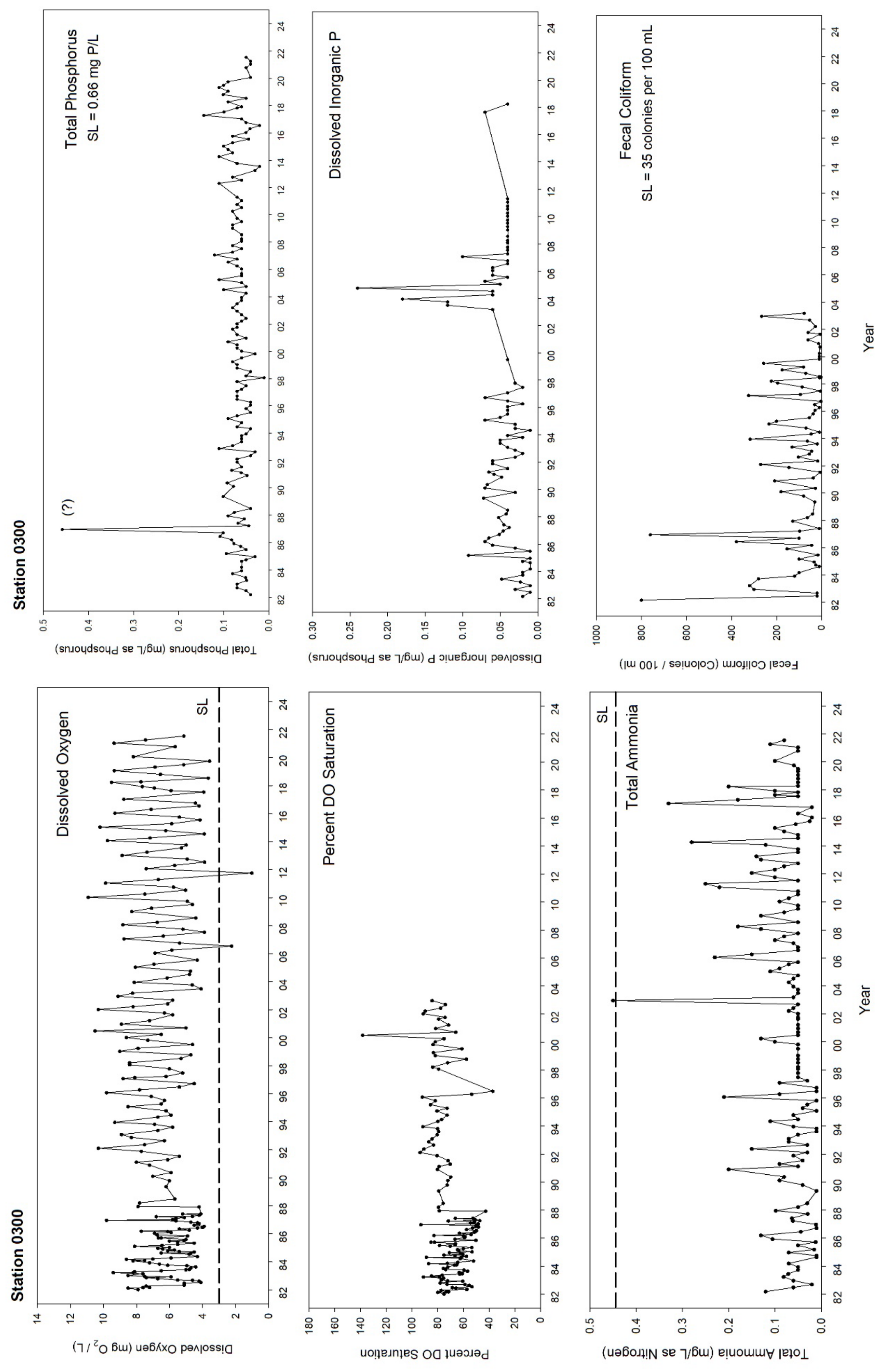

Figure 2.17: Temporal distribution of water quality parameters at Station 300 in the lower tidal Neches River. Dashed line is the screen level (SL) concentration presented by the State of Texas (2020).

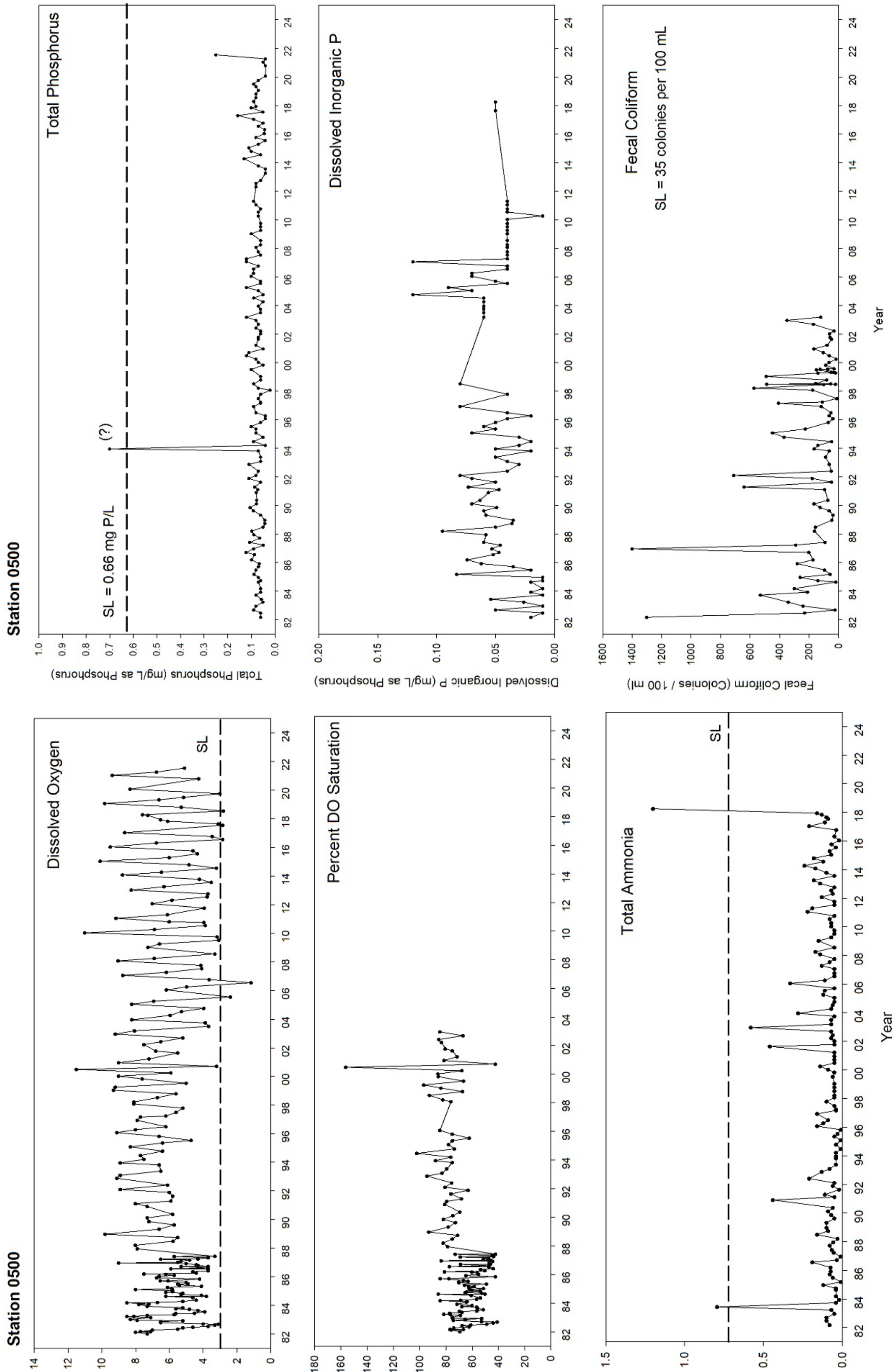

Figure 2.18: Temporal distribution of water quality parameters at Station 500 in the lower tidal Neches River. Dashed line is the screen level (SL) concentration presented by the State of Texas (2020).

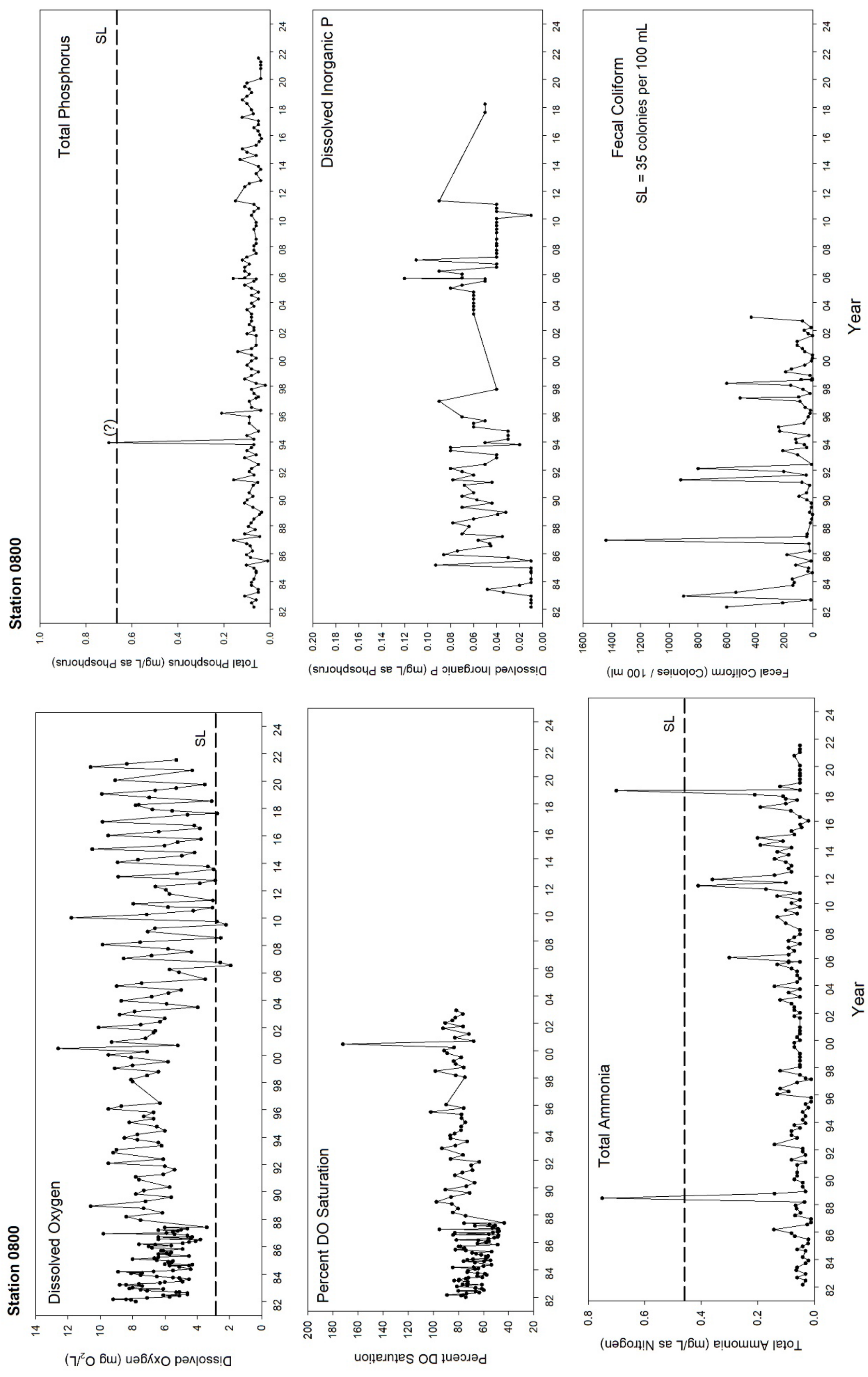

Figure 2.19: Temporal distribution of water quality parameters at Station 800 in the lower tidal Neches River. Dashed line is the screen level (SL) concentration presented by the State of Texas (2020).

Results

Dissolved oxygen (DO) results varied by site and model. For simple models that included only a temporal effect, DO significantly increased over time for TCEQ Station 20774 ($P=0.046$), but did not significantly change for any other station ($P>0.050$). However, in a model that accounted for seasonal variation in DO, we detected a consistent trend at most stations. There was a significant effect of time, season, and an interaction between time and season on DO for stations 100, 300, 500, and 800 ($P<0.050$). Post-hoc results varied by station, but generally DO was the highest in the winter and lowest in the summer and displayed an increasing trend in the winter and spring but a decreasing trend in the summer and fall over time. When seasonal variation was accounted for, there was no significant effect of the time, season, or an interaction on TCEQ Stations 10579 and 20774 ($P<0.050$). As a general trend, DO appears to be increasing in the winter and spring but decreasing in the summer and fall. Past surveys of the Neches River did not evaluate linear trends in DO in mg/L, so we are unable to compare this model to past reports.

Percent oxygen saturation results were very similar between sites and models. For simple models, percent saturation in LNVA Stations 100 ($p=0.003$), 300 ($p<0.001$), 500 ($p<0.001$) and 800 ($p<0.001$) significantly increased from 1982 to 2021. Similarly, when models included a seasonal term there was a significant increase of percent saturation in Stations 300 ($P=0.044$), 500 ($P=0.003$) and 800 ($P=0.015$) over time. Additionally, there was a significant effect of season ($P=0.006$) and an interaction between season and time ($P=0.006$) for Station 500 with percent saturation increasing significantly more in the spring compared to the winter ($P=0.007$) and summer ($P=0.011$). As a general trend, percent saturation appears to be increasing over time regardless of season. These findings are similar to the 2003 report that found an increase in percent saturation at Stations 100, 300, 500 and 800 from 1981 to 2002.

Results for dissolved ammonia+ammonium (termed ammonium or NH_4) concentrations varied depending on the station and model. Simple models indicated small increases of NH_4 concentrations at Stations 100 ($P<0.001$), 300 ($P=0.004$) and 800 ($P=0.012$) over time. However, when we accounted for seasonal variation, there was no significant effect of time or season on stations 300 and 800 ($P>0.050$). There was a significant effect of time, season, and an interaction between season and time for stations 100 and 500 ($P<0.050$). For station 100, NH_4 concentrations were highest in the winter but only significantly differed from summer ($P<0.001$). At station 100, the trend in ammonium concentrations over time significantly differed between the winter and fall ($P=0.002$), but not between other seasons (all $P>0.050$), with NH4 concentrations slightly increasing in the winter but slightly decreasing in the fall. In Station 500, trends were only significantly different between the winter and spring ($P=0.007$), with NH4 concentrations decreasing in the spring and increasing in the winter. The trends for NH4 concentrations showed a lot of variation based on station and model. The 2003 survey found a significant increase in NH4 concentrations over time for station 800, but this was attributed to an increased detection limit after 1997.

The increases in our results are most likely due to the increase in detection limit, though, some seasons did display decreasing trends for Stations 100 and 500.

There were no real evident temporal trends for total phosphorus (TP) in either model. The simple model did detect a slight increase in TP over time in Station 100 ($P=0.008$), but when we accounted for seasonal variation, there was no significant temporal effect for station 100 ($P=0.198$). This is the same as the 2003 report that found no variation in TP over time.

Dissolved orthophosphate (o-PO_4; also called dissolved inorganic phosphorus, DIP) exhibited similar trends in both types of models. In the simple model, DIP showed significant increasing trends for Stations 100 ($P<0.001$), 300 ($P=0.014$) and 800 ($P=0.031$). For models that included a seasonal component, there was a significant effect of time for Stations 100 ($P<0.001$) and 300 ($P<0.001$) but no significant effect of season on DIP ($P>0.050$). Stations 100 and 300 displayed an increasing trend over time in all seasons. Our findings are similar to the 2003 report that found slight increases in DIP for Stations 100, 500, and 800 over time.

Fecal coliform (FC) results generally appeared to decrease over time at some stations. For the simple model, there was a significant decrease in FC concentrations over time at stations 300 ($P=0.012$) and 500 ($P=0.008$). However, when we accounted for seasonal variation, these trends were no longer significant for Station 300 ($P=0.076$) or 500 ($P=0.102$), but there was a significant decrease in FC concentrations for Station 800 over time when accounting for seasonal variation ($P=0.039$). Together these results indicate that FC concentrations are decreasing at some of the stations on the Neches River. These results support the previous findings of the 2003 report that found decreases in FC concentrations at Stations 300 and 500.

Dissolved nitrate (or nitrate+nitrite; NO_3) varied by station and model type. For the simple model there was a significant decreasing trend in NO3 concentrations over time for Station 100 ($P<0.001$). For this model there were no significant trends at the other stations ($P>0.050$). When accounting for seasonal variability there was still a significant decrease in NO3 over time ($P=0.031$) for Station 100, but there was no significant effect of season ($P=0.345$). We were able to detect seasonal trends for Station 20774. There was a significant effect of time ($P=0.006$), season ($P=0.020$), and an interaction between time and season ($P=0.020$) on NO3 concentrations for station 20774. There was a significant difference in the change in NO3 concentrations over time between fall and summer ($P=0.030$) where NO3 concentrations increased over time in the summer but decreased over time in the fall. There were no significant trends for other stations (all $P>0.050$). We are unable to compare these results to the 2003 report because they did not analyze NO3 concentrations using temporal models.

2.6 Study Summary

Basic Water Quality Parameters

The concentration of most parameters in the lower tidal Neches River were below published water quality guidelines from the State of Texas (TCEQ 2000), as found in the 2003 study, specially noted are fecal coliform values and dissolved oxygen concentrations. The distribution of most analytes, while limited with only one station upstream of the saltwater barrier and four stations downstream, indicate no particular source area to the river, suggesting that both inputs from upstream and non-point sources (e.g., urban runoff) are the predominant sources. Interestingly, parameters such as TSS, VSS and turbidity were slightly higher above the barrier (or just below) most likely due to solids retention or new growth from algae (e.g., higher VSS). In addition, fecal coliform, while much lower than in 2003, was elevated at Station 1 for the first two sampling days but then decreased for the last three sampling days. In this regard, there were somewhat stable flows recorded at the barrier prior to the survey and a decrease in discharge during the survey. The stable or lower flows could be associated with lower precipitation and therefore reduced overland runoff, which most likely helped keep parameters lower than in the previous survey.

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 lower levels in the deeper waters 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 < 2 mg/L near the bottom (~10 to 15 m). Two main sources of labile (easily degradable) 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 8 mg C/L (range of 6 to 11 mg C/L), while TKN averaged 0.24 mg N/L (range of 0.2 to 0.4 mg N/L). To note, concentrations of dissolved nitrate+nitrite increased substantially below Station 1 and were highest at Station 4 on all days. These mid to 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). The sampling performed in mid-October of 2021 yielded values that support this use; most likely due to the stable/low flows in the river prior and during the sampling period. 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 five samples, taken during any 30-day period. If ten or fewer samples are analyzed, no more than one sample shall exceed 400 colonies per 100 ml. Fecal coliforms during the current program were well below this standard.

Overall, this section of the lower, tidal Neches River appears to have somewhat better water quality than found in 2003 (ANSP 2006). This may be related to the stable and lower flows during the 2021 survey period. Dissolved oxygen concentrations in the near bottom waters (Stations 2 and 3) are low and can impact the biological community in or near the bottom. This distribution was related to the limited mixing due to density differences between surface and bottom waters. The less dense freshwater on the top and the denser saltwater below causes a density difference that restricts mixing between surface and bottom layers.

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 various autocorrelations. This study deals largely with trends in mean concentrations and variance over an approximately 40-yr time period as these are of general interest to monitoring programs for the Neches River. Analysis of the temporal pattern of the concentration data from the tidal Neches River SWQMIS focused on the identification of several types of trends: linear and changes in variability (i.e., heteroscedasticity) of each parameter over time.

Because there is less historical data for some parameters (e.g., nitrate or nitrate+nitrite) compared to others at specific stations, as well as for trace elements or organic contaminants, a statistically based trend analysis cannot be completed. This is due to a low sampling frequency over a long enough time period. Additionally, changes in sampling methods and, importantly, analytical chemical methods (e.g., detection levels), can hinder a more complete longer-term analysis. Lastly, sources of many chemical constituents can be broadly thought to derive from point (municipal and industrial) and non-point sources, from within the study reach and/or upstream. Non-point source inputs are highly variable and are largely related to overland runoff which may enter the stream at any point throughout the watershed. Determining whether point or non-point sources are the dominant inputs for chemical constituents in a stream requires various flow-related analyses. In this study, flow was not evaluated with changes in parameter concentrations, but it could be done in the future to provide additional information about the Neches River system.

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. Dissolved ammonia concentrations were too variable to derive a statistically based trend. In addition, the changes in detection limits over the decades hinder 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 with TCEQ SWQMIS data, more samples may be needed over smaller spatial extents and at greater frequencies to statistically detect changes over space and time. These data would better enable managers to assess if specific control strategies are sufficient to improve water quality.

3. ALGAL STUDIES

Abstract

1. Positioned at the base of the food web, algae are important primary producers that provide habitat and a nutrient rich food source for other aquatic organisms. Through the process of photosynthesis, algae produce an important byproduct, oxygen, that is essential for all aquatic life. Many algal forms, especially diatoms, are useful bioindicators of environmental conditions as they respond quickly to changes and are sensitive to different water quality parameters.
2. In 2021, algal communities were sampled at five different stations across the Neches River to assess variations in the algal communities as they may relate to changes in water quality. At each station, algae were collected from all available habitats, and to ensure consistency across stations, various collection methods were used. Diatom and soft algae samples were then processed and analyzed for differences among stations, habitat types, and any yearly changes from past surveys.
3. The 2021 survey showed a clear shift in algal communities when comparing the upper stations (Station 0 and 1) to the downstream stations (Stations 2, 3 and 4) with some improvement from Station 3 to 4. Diatom species richness and evenness did not vary too dramatically and overall showed low species evenness across each station.
4. The taxonomic shift seen for 2021 is showing a response to the increase in the salinity gradient downstream and the higher levels of disturbance at Station 3. The overall higher abundances of *Nitzschia* and *Navicula* species since the 1973 survey continues to suggest high sedimentation along the Neches River.
5. The 2021 results are similar to the results from 2003 and continue to show a long-term trend of improved water quality when compared to the 1953 and 1973 surveys. Changes in algal taxa appear to follow changes in the salinity gradient across each station with Station 3 still showing the highest level of disturbance. There does not appear to be an effect of the saltwater barrier. However, there was increased light availability for potential algal growth at Station 1.

3.1 Introduction

In estuary, river and lake ecosystems, algae are located at the base of the food web making them important primary producers. Algae utilize the sun's energy through the process of photosynthesis, producing oxygen that is necessary for all aquatic life. Many algal forms provide a diverse habitat or shelter for macroinvertebrates and small fish, while also being a food source. Along with being an important ecological component, algae, especially diatoms, are utilized as indicators of water quality. Algae have short generation times, allowing them to be quick responders to ecological changes. Diatoms are specifically sensitive to changes in dissolved nutrients, metals and organic compounds.

The purpose of the 2021 algal survey was to 1) characterize the periphyton, or attached algal forms, along the Neches River, 2) compare the differences in taxa among the five stations, and 3) compare the 2021 survey results to the historical surveys performed by the Academy of Natural Sciences.

3.2 Methods

Collections of attached algae – periphyton – were made from all distinctive habitats at the five established stations on the Neches River near Beaumont, Texas. This included the four historic stations (1 through 4) and the new addition of Station 0 for the 2021 survey. To reduce the amount of natural variation among the five 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 pocketknife. 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 diatoms, that were living at the time of collection, as some important diagnostic characteristics of filamentous and fragile forms are lost through preservation. Diatom subsamples were made by separating them from collections with abundant diatoms; these samples were preserved with a few drops of formaldehyde. The remainder of the samples were preserved with formaldehyde (3-5% final concentration).

At the Academy laboratory, diatom collections were prepared by cleaning the siliceous diatom frustules of any organic material and mounting them 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 indefinitely. In addition, a composite slide for each station was made with the combined cleaned frustules from each sample counted.

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 magnification. Further identifications were made by comparing with previous voucher collections (from Academy surveys in 1953, 1956, 1960, 1973, 1996 and 2003) and specimens in the Academy’s Diatom 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 for each station. The composited slide from each station was analyzed using a detailed reading method. The detailed reading method involves identifying and counting between approximately 3,000 and 7,500 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 surveys allowing for comparison of 2021 data with past data (1953, 1973,1996, and 2003). 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 from the algal survey done on the Neches River in 2021 were mostly qualitative in determining relative abundances of the major algal groups and comparisons across the various habitats collected for each station. Evaluation of similar habitats and abundances allows for changes across stations to be noted, and for comparisons to past surveys. Data from the composited diatom samples provided species comparisons and parameters based on a lognormal curve (Table 3.1) and a list of major diatom species (Table 3.2). A full list of abundant algal species observed during the 2021 survey is provided in Appendix B.1. During the period between the 2021 and the 2003 survey, there were multiple algal taxonomic changes made and noted in Appendix B.2.

Table 3.1: Listing of the lognormal curve parameters from composited periphyton samples collected in October 2021 from the Neches River near Beaumont, Texas.

Station	σ2	Dispersion Factor	Position of the Mode	Species in the Mode	Observed Species	Species in Theoretical Universe
0	9.89	0.0219	2.78	36.99	237	291.18
1	10.13	0.0850	2.48	40.82	255	325.22
2	6.54	0.0232	2.26	35.33	184	226.17
3	6.15	0.0600	2.03	38.11	188	236.53
4	6.08	0.0006	2.36	40.85	210	252.11

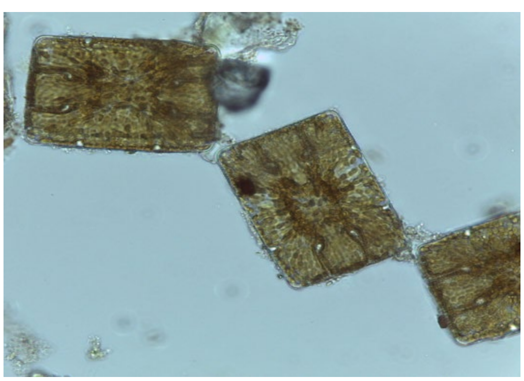

Figure 3.1: Diatom Terpsinoë musica *at 40x magnification, collected at Station 4.*

Figure 3.2: Unidentified raphid, pennate diatom at 40x magnification, collected at Station 2.

Detailed Reading Analysis

Diatom species richness is determined by the number observed species (237, 255, 184, 188, and 210 species at Stations 0, 1, 2, 3 and 4, respectively) (Table 3.1) and a detailed reading analysis which results in plotted lognormal curves. A higher number of species in the mode, shown as the highest point in each station's curve (36.99, 40.82, 35.33, 38.11, and 40.85 species at Stations 0, 1, 2, 3 and 4, respectively), indicates higher species richness. Previous studies have shown that species richness is generally lower in brackish waters than freshwater, but in 2021, there was not a dramatic change in richness between the stations. We can see from Figure 3.3 that the diatom communities at Stations 1 (freshwater) and 4 (brackish), were similar to each other in species richness, and were the highest of all stations (Figure 3.3 and Table 3.1).

The length of the lognormal curve, or number of counted intervals (14, 13, 11, 10 and 11 at Stations 0, 1, 2, 3 and 4, respectively) along with the relative abundance of the most dominant taxa (20.37, 8.35, 17.10, 18.98 and 14.07% at Stations 0, 1, 2, 3 and 4, respectively) (Table 3.2), provides information on how evenly distributed the diatom species are across the Neches River. Looking at the length of the tails in each station's curve in Figure 3.3, we can see that overall, most stations are showing low evenness. However, there is some variation, with Station 0 exhibiting the least even distribution (the curve has the longest tail) and a higher dominance by one single diatom taxa Station 1 also has similarly low evenness but isn't as dominated by a single taxon.

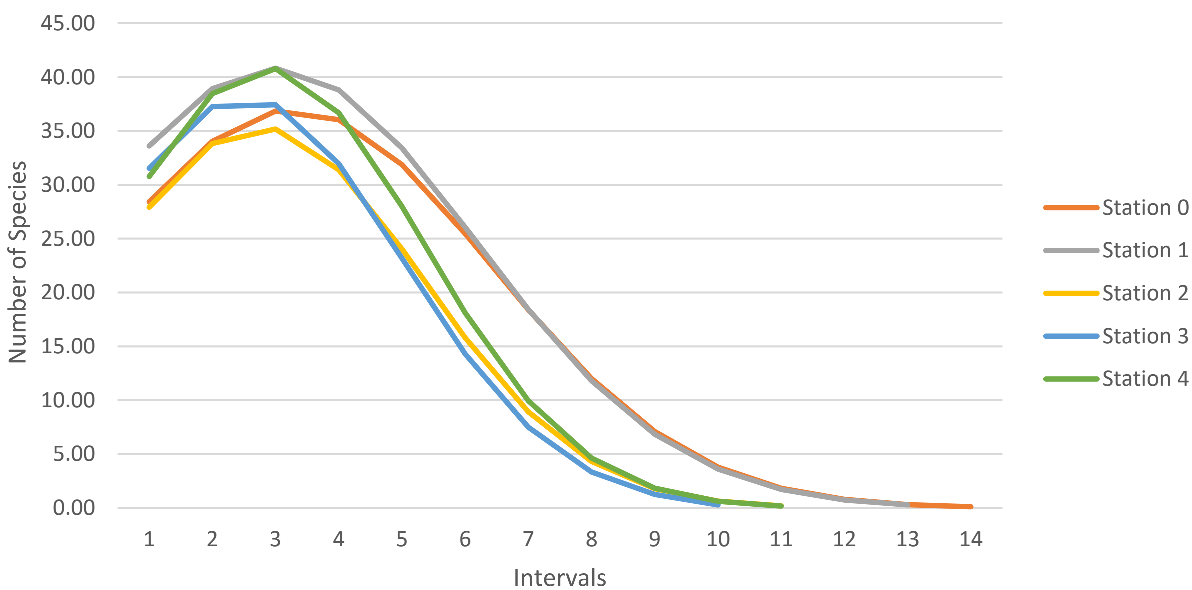

Figure 3.3: Frequency distribution from the detailed reading of diatom species at Stations 0 through 4 on the Neches River, 2021.

Table 3.2: Relative abundances (%) of the most abundant diatoms (<2% relative abundance) from composite periphyton samples for each station. Taxa are provided if their relative abundance is greater than 2% from at least one station.

Diatom Taxa	Station 0	Station 1	Station 2	Station 3	Station 4
Bacillaria paxillifera (O.F.Müller) T.Marsson	1.50	5.05	4.18	---	3.11
Berkeleya rutilans (Trentepohl ex Roth) Grunow	---	---	---	---	2.50
Diadesmis confervacea Kützing	1.03	3.25	0.13	---	---
Fragilaria pararumpens Lange-Bertalot, G. Hofmann & Werum	0.88	4.15	0.11	---	---
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin et Witkowski	---	0.08	2.46	---	0.90
Luticola goeppertiana (Bleisch) Mann	0.06	0.16	2.35	---	---
Navicula canalis Patrick	2.51	1.25	---	---	0.12
Navicula difficillima Hustedt	2.35	1.41	---	---	---
Navicula recens (Lange-Bertalot) Lange-Bertalot	0.30	0.15	3.36	14.18	14.07
Navicula symmetrica Patrick	1.60	2.88	1.23	---	0.37
Navicula vilaplanii (Lange-Bertalot et Sabater) Lange-Bertalot et Sabater	0.97	0.44	0.22	---	2.91
Nitzschia amplectens Hustedt	---	---	13.16	4.32	0.89
Nitzschia clausii Hantzsch	20.37	6.27	6.55	3.86	1.63
Nitzschia filiformis (Smith) Van Heurck	3.83	6.72	2.25	---	2.32
Nitzschia filiformis var. conferta (Richter) Lange-Bertalot	2.28	1.07	4.22	13.43	10.39
Nitzschia frustulum (Kützing) Grunow	4.64	8.35	0.48	---	0.71
Nitzschia inconspicua Grunow	0.41	---	1.68	---	6.53
Nitzschia palea (Kützing) Smith	2.66	1.78	0.12	---	0.71
Nitzschia palea var. debilis (Kützing) Grunow	3.23	1.07	---	---	---
Nitzschia sp.	0.59	3.11	0.02	---	---
Nitzschia sp. 3 ?	2.20	3.82	0.83	---	0.68
Nitzschia sp. 8 ?	---	---	3.68	15.32	0.32
Nitzschia supralitorea Lange-Bertalot	4.64	7.06	12.87	---	1.99
Planothidium delicatulum (Kützing) Round et Bukhtiyarova	0.01	0.03	1.93	---	2.34
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	2.71	0.16	0.21	---	0.03
Pseudostaurosira sp. 2 ?	0.07	---	2.24	---	---
Pseudostaurosiropsis sp. 2 ?	---	---	---	---	2.58
Staurosira construens var. venter (Ehrenberg) Hamilton	0.13	1.78	0.97	---	4.84
Staurosirella sp.	---	---	0.56	---	2.37
Tabularia fasciculata (Agardh) Williams et Round	0.49	0.24	17.10	18.98	13.03

Station 0

Station 0 presented mostly hard pan or clay-like substrate with an abundance of Cyprus trees, multiple submerged logs, and aquatic plant stems for algae colonization. Blue-green and green algae species were found across most habitats at this station, with the yellow-green species, *Vaucheria sp.¸* forming light, velvety patches on submerged logs and the hard pan substrate. The filamentous blue-green, *Phormidium sp.*, formed more abundant mats on all habitats sampled (submerged logs, aquatic plant stems, hard pan and Cyprus tree trunks) and was found to be the most predominate blue-green alga overall. Other abundant blue-green filamentous forms found on the submerged logs included *Oscillatoria sp., Leptolyngbya sp.* and *Nostoc sp.*, along with the green algae *Odeogonium sp.* The hard pan substrate covered the entirety of the Neches River streambed, near the shoreline, and presented four abundant blue-green species at Station 0, including *Phormidum sp., Anabaena sp., Aphanocapsa sp. and Pseudoanabaena sp.*

Individual diatom populations at Station 0 varied across the same habitats as above but were mostly dominated by *Navicula* and *Nitzschia* species. Throughout most of the samples (submerged wood, plant stems and roots, and hard pan), *Nitzschia clausii* dominated, except for macrophytes growing on Cyprus trees that were dominated by *Cocconeis fluviatilis. Nitzschia frustulum* was the next most common species found on floating plant stems and roots, and on macroalgae; these habitats were also associated with less sediment. Higher sedimentation areas were more associated with *Nitzschia clausii* and *Navicula gregaria.* Populations of *Planothidium frequentissimum* and *Diadesmis confervacea* were found on floating plant roots near the shore as well. Overall, samples taken from the hard pan substrate were lower in species diversity (30 and 37 species) than other habitat types, with the macrophyte population being the most diverse at 64 species.

The composited diatom (Bacillariophycaea) sample for Station 0 consisted of 132 abundant species (Table 3.3) (a species is listed if it occurred 6 or more times in the completed detailed reading) with the majority belonging to *Nitzschia* and *Navicula* species (70.7% of the community). *Nitzschia clausii* had the highest abundance at 20% of the community with *Nitzschia frustulum* and *Nitzschia supralitorea* both representing the second highest abundance at 4.64% (Table 3.2). All other species fell below 5% relative abundance for the composite sample at Station 0. *Planothidium frequentissimum* was the only relatively abundant species that did not belong to the *Navicula* or *Nitzschia* group. An analysis of diatom pollution tolerance (Patrick and Palavage, 1994) shows that 25 species are tolerant of pollution and 29 species are characteristically found in natural waters (78 species were not rated) at Station 0.

Table 3.3: Yearly comparisons of the number of abundant species for each algal group collected at the five stations along the Neches River near Beaumont, Texas, in 1953, 1973, 1996 and 2003. Xanthophytes was previously called Chrysophyceae in past reports.

Algal Group	Station 0					Station 1					Station 2					Station 3					Station 4				
	1953	1973	1996	2003	2021	1953	1973	1996	2003	2021	1953	1973	1996	2003	2021	1953	1973	1996	2003	2021	1953	1973	1996	2003	2021
Chlorophyceae (green algae)	---	---	---	---	1	4	4	4	6	1	4	3	5	2	1	1	4	4	5	1	0	3	4	1	3
Xanthophytes (yellow-green algae)	---	---	---	---	1	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Bacillariophyceae (diatoms)	---	---	---	---	132	65	39	68	66	147	10	59	54	37	94	23	56	47	37	91	31	25	50	46	114
Myxophyceae (blue-green algae)	---	---	---	---	3	8	3	5	8	3	5	5	4	6	1	5	5	4	8	4	5	7	3	9	4
Rhodophyceae (red algae)	---	---	---	---	0	0	2	1	1	1	0	0	1	1	0	0	0	1	1	0	0	0	1	1	0
Dinophyceae (dinoflagellates)	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Euglenophyceae (euglenoids)	---	---	---	---	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station 1

The most abundant habitat types at Station 1 were submerged logs, sand and hardpan substrate, Cyprus trees, and macrophytes. At this station, blue-green alga forms were not abundant but still found on most of the habitats sampled. Filamentous *Phormidium sp*. was the most abundant blue-green alga and present across all habitats from submerged logs and Cyprus trees to the sandy sediments. The blue-green species *Leptolyngbya sp.* and *Nostoc sp.* formed mild sheens on submerged logs and Cyprus trees, with blue-green alga forms being the most abundant on both habitat types. A few green alga species *Odeogonium sp., Gleocystis sp.* and *Spirogyra sp.* were found on submerged macrophytes near the shoreline but no other habitats. *Vaucheria sp.* was also found sporadically across Station 1 as macroalgae on submerged logs and sand.

Individual diatom populations at this station were also more dominated by *Navicula* or *Nitzschia* species, but the relative abundance of these two groups was not as consistently high as in Station 0. There were multiple other diatom genera that constituted more of the diatom abundance, such as *Fragilaria pararumpens* and *Bacillaria paxillifera* (Table 3.2) found on floating plant stems and roots, respectively. Sand habitats were more dominated by *Ulnaria sp.* and *Fragilaria pararumpens* than *Navicula* or *Nitzschia* species at this station. However, the hard pan or mud samples taken at this station were dominated by *Nitzschia clausii,* like at Station 0. Submerged wood, macrophytes, and the macroalgae habitats showed a large population of *Nitzschia supralitorea.* This station presented a more even species diversity across each habitat that ranged from 30-60 species with hard pan or mud being the lowest and submerged wood being the highest.

The composited diatom sample for Station 1 consisted of 147 abundant species (Table 3.3) with the majority also belonging to *Nitzschia* and *Navicula* groups (59.0% of the community); *Nitzschia* having the most abundance. *Nitzschia frustulum* composed most of the community at 8.35% and *Nitzschia supralitorea* consisting of 7.06%. *Bacillaria paxillifera* presented 5.05% and *Fragilaria pararumpens* presented 4.15% of the community (Table 3.2). This station presented 29 species that are pollution tolerant, and 30 species are characteristic of natural waters (87 species were not rated) (Patrick and Palavage, 1994).

Station 2

Station 2 kept the consistent habitat of submerged logs, aquatic plants, sand and hard pan, and Cyprus trees. A new and non-natural habitat was also presented here as large, submerged rope. Only the filamentous blue-green *Phormidium sp.* and *Oscillatoria sp.* were identified on the submerged rope but did form some larger masses on other habitat types as well. At this station, *Phormidium sp.* was the only common and abundant blue-green species found, with the overall blue-green species diversity being low (three species). A difference in green alga forms was also observed at Station 2 with *Rhizoclonium sp.* and *Cladophora glomerata* being the two abundant forms. *Cladophora glomerata* was seen in macroalgae form, tangled in tall aquatic plants and grasses off the shoreline of a cove. *Rhizoclonium sp.* was found on more habitat varieties including submerged logs, aquatic plant stems, and the sand and hard pan substrate.


Figure 3.4: Mariena Hurley collecting an algal sample from a submerged log along the Neches River.

The diatom population at Station 2 began to differ from Station 0 and 1 with the *Nitzschia* and *Navicula* populations no longer having the highest relative abundance but still having the most species present. When *Tabularia fasciculata* was present on woody habitats (Cyprus tree roots and submerged sticks/logs), sand, and attached to macroalgae, it was the most common and abundant species. When present on hard pan and submerged macrophytes, it was not the most abundant. *Bacillaria paxillifera* and *Nitzschia supralitorea* were equally as abundant on the macrophyte habitat with *Nitzschia amplectens*, *Nitzschia clausii*, and *Nitzschia palea* being abundant on the hard pan substrate but not on the sand substrate. Rather, samples collected from sand showed an abundance of *Tabularia fasciculata*, possibly presenting a preference in substate type for some species. Generally, *Tabularia fasciculata* did not seem to favor one specific habitat type but when it was present it was abundant with a species abundance of 30% or more. Station 2 also presented a more even species diversity across each habitat ranging from 23-54 species with Cyprus tree roots having the most diversity.

The composited diatom sample for Station 2 consisted of 94 abundant (Table 3.3) species with the majority belonging to *Nitzschia* and *Navicula* species (56.3% of the community). However, for this station the largest population consisted of *Tabularia fasciculata* (17.10%), *Nitzschia amplectens* (13.16%), and *Nitzschia supralitorea* (12.78%) (Table 3.2). There were only 12 species known to be pollution tolerant and 22 species characteristic of natural waters (60 species were not ranked) (Patrick and Palavage, 1994).

Station 3

Station 3 presented more non-natural habitat types (concrete slabs, metal and submerged rope) and surface area with few Cyprus trees, increasing the light intensity for optimal algae growth. Throughout the station, blue-green algal communities were abundant and found in large masses at each sampled habitat, especially on the concrete slabs that lined the right side of the bank. *Phormidium sp.* was the most abundant species collected at each location, including the natural and non-natural habitat types, and the sand and hard pan substrate. Any plant roots or stems also had a higher abundance of *Phormidium sp.* present. Submerged logs had the most diversity of blue-green species with *Phormidium sp.*, *Leptolynbya sp.* and *Coleofasciculus chthonoplastes* present. Only one species of green algae (*Rhizoclonium sp.)* was sampled from the concrete slabs and around plant roots.

Individual diatom populations were not as abundant or diverse at Station 3 compared to other stations and provided less natural habitat varieties for algae colonization. However, Station 3 provided new habitats – submerged rope and concrete blocks – that were not found at Stations 0-2. These were categorized as man-made habitats. Like Station 2, *Tabularia fasciculata* was abundant in nearly every diatom sample analyzed. This species was either the most abundant (submerged wood and plant stems) or the second most abundant (hard pan and man-made habitats) but was not abundant on the sand substrate. *Staurosira construens var. venter* and *Staurosirella sp.* were equally the most abundant on the sandy substrate at roughly 20% relative abundance. Analysis of hard pan showed *Nitzschia palea* as the most abundant, as at Station 2, continuing to present a possible preference in substate type for some species in the Neches River. On man-made substrates (submerged rope and concrete blocks) *Nitzschia filiformis var. conferta* formed the largest population with a presence of *Tabularia fasciculata.* Across each habitat, *Nitzschia* and *Navicula* populations were generally the most common and diverse diatom genera. Overall, Station 3 also showed a lower species diversity among habitats and a lower range, from 17 to 41 different species.

The composited diatom sample for Station 3 consisted of 91 abundant species (Table 3.3) with the majority still belonging to *Nitzschia* and *Navicula* groups (65.8% of the community). *Tabularia fasciculata* also consisted of the highest abundance at 18.98%, followed by *Nitzschia sp8* (15.32%), *Navicula recens* (14.18%), and *Nitzschia filiformis v. conferta* (13.43%) (Table 3.2). Station 3 had 15 species tolerant of pollution and 18 species characteristic of natural waters (57 species were not ranked) (Patrick and Palavage, 1994).

Station 4

Station 4 presented natural and non-natural habitats, which included submerged logs, plant stems and roots, concrete slabs and submerged rope, and hard pan substrate. The submerged logs provided the most diverse habitat with six different blue-green alga species. *Phormidium sp.* was the most abundant followed by *Nostoc sp.*, *Coleofasciculus chthonoplastes* and *Geitlerinema splendidum.* The non-natural substrate of concrete and submerged rope had moderate masses of *Phormidium sp.* along with hard pan on the shoreline. Various plant stems provided habitat to *Phormidium sp.* and *Geitlerinema splendidum.* Three green algae species were sampled across the various habitats with most of the abundance being *Rhizoclonium sp.* At the base of aquatic plant stems and on submerged rope near the shoreline, *Microspora sp.* and *Rhizoclonium sp.* formed smaller mats whereas *Cladophora glomerata* formed macroalgae mats along the station.

The diatom communities at Station 4 varied between the different habitats with no one species dominating multiple habitat types. Man-made habitats were also found at this station but were dominated by *Navicula recens, Nitzschia filiformis var. conferta* and *Tabularia fasciculata,* unlike Station 3 where only *Nitzschia filiformis var. conferta* was abundant. The sand and hard pan substrates differed with *Nitzschia clausii* and *Nitzschia filiformis var. conferta* present on hard pan and *Staurosira construens var. venter* and *Staurosirella sp.* present on the sandy substrates. *Tabularia fasciculata* was not as widespread as at Station 3 but was still present on plant stems, submerged wood, and the man-made areas. *Navicula recens* populations were present here on submerged wood and man-made habitats but not necessarily on heavy sedimented areas. *Navicula* and *Nitzschia* populations were largely abundant at each habitat, except for the sandy substrate. Station 4 also provided less habitat availability with a lower species diversity and range (28 to 49 species).

The composited diatom sample for Station 4 consisted of 114 abundant species (Table 3.3) with the majority belonging to *Nitzschia* and *Navicula* species (53.0% of the community). Most of the community consisted of *Navicula recens* (14.07%), *Tabularia fasciculata* (13.03%) and *Nitzschia filiformis v. conferta* (10.39%) (Table 3.2). This station had 18 species tolerant of pollution and 24 species characteristic of natural waters (72 species were not ranked) (Patrick and Palavage, 1994).

3.4 Discussion

Analysis and comparison of the algal communities along the Neches River utilizes several factors, such as the amount of algae, major groups present and their abundances, species richness, and the amount of dominance by one or more taxa. Areas with an increase in algal growth, especially of blue-green populations, are generally indicative of enrichment at or near that specific location. When looking at overall stream health, algal communities that present a variety of species (high species richness), more even species distribution (low dominance by a single taxa), and a low abundance of blue-green populations are considered healthier streams. All these factors were reviewed to analyze any differences in the algal communities across the five stations sampled during the 2021 survey.

Comparisons Among Stations in 2021

During the 2021 survey, clear differences in diatom and soft-algae taxa were seen between the upper (Stations 0 and 1) and lower stations (Stations 2, 3, and 4) along the Neches River, with the lower stations showing more degradation but there was some improvement in Station 4 when compared to Station 3. Analysis of the chemical data also showed an increase in the salinity gradient from the upper to the lower stations, with Station 0 having a low concentration and being categorized as freshwater and Station 4 having the highest concentration (See section 2. Environmental

Geochemistry). The upper two stations (Stations 0 and 1) were similar to one another in presenting a dominance of a few *Nitzschia* diatom species, mostly *Nitzschia clausii*, across each habitat sampled and a higher species richness of 132 and 147 species for Station 0 and 1, respectively, as compared to the lower Stations 3 and 4. A higher number of these raphid diatoms (*Nitzschia)* tends to indicate higher sediment loading and can be seen as most of the Neches River substrate is sand or hard pan along the banks. The yellow-green alga *Vaucheria sp.* was also only found at Stations 0 and 1 with a presence of the green algae species, *Odeogonium sp.* However, Station 0 did present more apparent blue-green mats of *Phormidium sp.* than seen at Station 1, a higher presence of blue-green taxa tends to indicate lower water quality. The larger presence of blue-green mats at Station 0, may relate to it being located near a boat access point for recreational use. The recreation occurring at Station 0 may also account for Station 1 being presented as the least polluted or disturbed station across the Neches River rather than Station 0 as one may predict. Based on the algal analysis for the 2021 survey, Station 1 is the healthiest station as it has the largest species richness, provides some evenness, and the least presence of blue-green populations.

As we move down the Neches River to Stations 2 and 3, the salinity gradient increases (See section 2. Environmental Geochemistry) and the diatom taxa respond with a clear change in dominance from a few specific *Nitzschia* species to a dominance of *Tabularia fasciculata. Tabularia fasciculata* is known to populate higher salinity environments rather than freshwater environments (Kociolek, P. 2011), as seen in the shift from Stations 0 and 1 to Station 2. Even with this shift, the *Navicula* and *Nitzschia* populations still consisted of about 50-60% of the algal community at Stations 2 and 3, respectively, still suggesting a presence of sediment loading. Diatom species richness also decreased to 94 and 91 species for Stations 2 and 3, respectively, with a drop in species evenness as *Tabularia fasciculata* dominated most of the population at these stations. Dominate green algae populations also change from *Odeogonium sp.* to *Rhizoclonium sp.* and *Cladophora glomerata* at Station 2 with no presence of the yellow-green taxa, *Vaucheria sp.*, at either Station 2 or 3. *Odeogonium sp.* is typical of more freshwater environments and *Cladophora glomerata*, although also seen in freshwater, is considered a nuisance alga and often found in more enriched locations with higher flow (Wehr at al. 2015). Different *Vaucheria* species can be habitat specific and vary with salinity (Wehr at al. 2015). Blue-green populations were more abundant at Stations 2 and 3 than the upper stations with very large mats of *Phormidium sp.* found at Station 3, likely due to an introduction of man-made habitats (submerged rope and concrete blocks) and human or industrial use. Station 3 is a high traffic location for large industrial ships and refinery use that has significantly decreased habitat diversity and canopy cover, allowing for an increase in light availability with increasing in nutrient concentrations. This type of environment can provide better conditions for an increase in blue-green populations that may affect water quality. The man-made habitats of submerged rope and concrete blocks also provided a different habitat for diatom growth as *Nitzschia filiformis var. conferta* was the dominate taxa rather than *Tabularia fasciculata* identified from the more natural habitat types. Based on the algal analysis for the 2021 survey, Station 3 showed the greatest evidence of pollution or disturbance among stations across the Neches River and as each station increased in salinity, species richness decreased.

Lastly, Station 4 was the most downstream location and although used for ship access, it showed some variation and improvement from Station 3 but still differed from the uppermost stations. There was an increase in diatom species richness to 114 species rather than the 91 species seen in Station 3, even with Station 4 having the highest salinity concentration (See section 2. Environmental Geochemistry). Diatom species evenness also increased as there was less dominance of one single taxa and more spread across multiple taxa, but *Tabularia fasciculata* and *Navicula recens* were the two most abundant species. Both prefer higher salinity or brackish waters (Kociolek, P., 2011 and Potapova, M., 2009). Station 4 still provided less habitat diversity than the upper stations and the man-made submerged rope and concrete blocks also provided different habitat with less shade. As with Station 3, *Nitzschia filiformis var. conferta* was abundant on these man-made habitats with a presence of *Navicula recens.* A larger diversity in blue-green species was identified at Station 4 but not at the other four stations, with *Phormidium sp.* still being the most abundant species across each station. The green algae *Rhizoclonium sp.* and *Cladophora glomerata* were found on multiple habitats, similar to Station 2, but the yellow-green alga *Vaucheria sp.* was still not identified below Station 1.

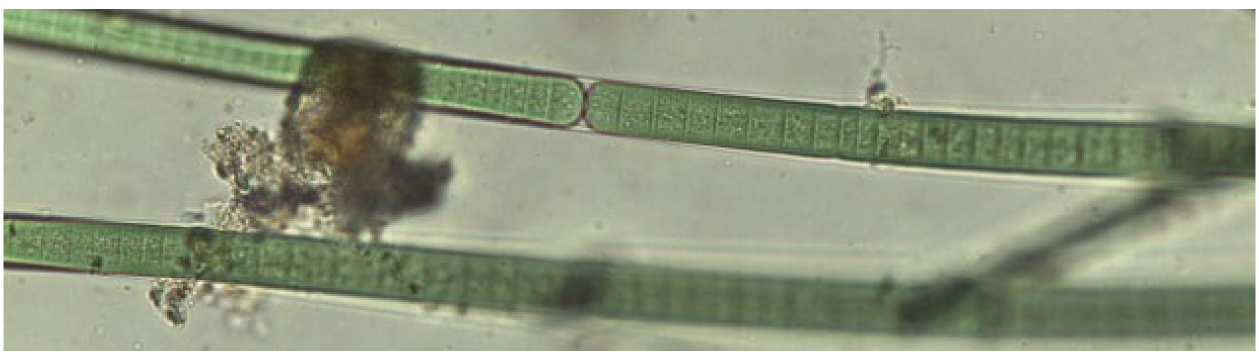

Figure 3.5: Phormidium sp. (blue-green algae) at 40x magnification, collected from Station 2.

Figure 3.6: Macroalgae on hardpan substrate at Station 2 These forms mostly consisted of colonies of Phormidium sp.

Figure 3.7: Macroalgae on hardpan substrate at Station 0. These forms mostly consisted of colonies of Phormidium sp.

Historical Comparisons Among Surveys

When comparing all previous surveys, the algal assemblages followed a similar pattern of taxa changes among stations in response to the salinity gradient and levels of disturbance at Stations 2, 3 and 4 downstream. The presence and abundance of blue-green species also has been indicative of enrichment through all the surveys, where stations with higher blue-green growth tend to be more enriched or disturbed, as seen at Station 3 through many of the surveys. For both the 2003 and current 2021 survey, Station 3 has continued to show more blue-green species richness and abundance but there has not been a dramatic increase in the number of dominant species between surveys. Similarly, species of *Phormidium* are continuing to be a common and dominate blue-green algae among stations, indicating the continued disturbance across most of the Neches River. *Vaucheria sp.* has also been common at Station 1 through many of the surveys but for the 2021 survey, it was identified at Station 2 as well as the newly added Station 0, but continues to not have a presence at Station 3 and 4. Overall, the 2021 survey showed a decrease in the number of dominant blue-green taxa identified at each station but Station 3 still exhibits the most disturbance.

When looking at diatom richness, the 2021 survey is consistent with 2003, and previous years, as the species richness decreases from Station 1 to Station 4 with a slight increase from Station 3 to Station 4. This is likely suggesting a similar salinity gradient and level of disturbance across Neches River among years, meaning Station 1 has been consistently different from Station 4. Station 3 is still noted as the most enriched or disturbed location (least species evenness and richness) and Station 1 as the least polluted (most species evenness and richness) for the 2021 survey. There was also some consistency in the specific diatom taxa identified when comparing the 2003 and 2021 surveys. The percentage of raphid *Nitzschia* and *Navicula* species in 2021, continued to be high ranging from 53-70% with the 2003 survey also ranging from 56-74%, but these populations were lower for the 1973 survey and only ranged from 10-60%. As noted above, a higher number of raphid diatoms tends to indicate higher sediment loads, suggesting an increase in sedimentation to the Neches River since the 1973 survey. Changes in sedimentation can influence algal distributions as some taxa prefer lower or higher sedimentation. The 2021 survey noted changes in diatom taxa between the sand and hard pan substrate, and that the man-made habitats displayed different dominate taxa than the more natural habitats. *Tabularia fasciculata* was another abundant taxa in both the 2003 and 2021 surveys, but for the 2021 survey, *Nitzschia clausii* was greater at Station 1 than *Tabularia fasciculata,* whereas the 2003 survey noted both being abundant at Station 1. Overall, diatom species richness has increased with each survey, except from the 1996 to 2003 surveys. The 2021 survey provided a larger number of species identified which can be indicating increases in water quality, but the significant increase may also be due to changes in taxonomic naming from the previous survey. Over the years, many of the taxonomic species' names used previously have been changed or split into different species names.

For 2021, diatom species evenness has also seen some improvement from the 2003 and previous surveys, with the same trend between stations (Station 1 being most even and Station 3 being least even). This can be seen in the 2021 survey, as Station 1 only had one population that was 8% of the relative abundance, whereas the 2003 survey was 15%. Stations 2 and 3 did not show as much improvement from 2003 as both stations still had a few populations ranging from 13-18% but 2003 had a maximum of 39% that was not found for 2021. Current species evenness has greatly improved, as studies done before 1996 had populations exceeding 50%.

A 2021 review of the algal communities along the Neches River revealed similar results to the 2003 survey with few changes. Conditions continue to show improvement from the earlier 1953 and 1973 surveys with more balanced algal communities, and increases in species richness from the 1996 survey. Stations 2 and 3 continue to show a decrease in species richness, higher dominance of a single diatom taxa, and a higher presence of blue-green algae indicating poorer water quality conditions. Station 1, as with past surveys, presents the most species diversity, evenness, and less presence of blue-green algae. Based on the 2021 survey, conditions along the Neches River continue to show some improvement from past surveys with changes along the estuarine gradient, but Station 3 still presents a high level of disturbance.

4. MACROINVERTEBRATES

Abstract

1. Macroinvertebrates are one of the most utilized bioindicators of environmental changes in aquatic environments (USEPA 2017).
2. Since 1953, the Academy of Natural Sciences has conducted seven aquatic macroinvertebrate assessments along the Neches River (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1974, ANSP 1998, ANSP 2006).
3. In 2021, the Academy of Natural Sciences surveyed macroinvertebrates at five stations to assess the environmental quality in the Neches River; including a station upstream of the saltwater barrier that was constructed in 2003. At each station several qualitative multihabitat methods were utilized. Macroinvertebrates were either hand collected, or a dip net was used to collect detritus; macroinvertebrates were then collected from the material.
4. Macroinvertebrate communities showed a strong response to the salinity gradient present at the time of the survey.
5. Our 2021 results were similar to 2003 in that Station 1 showed a higher number of insects due to the freshwater nature of those stations, and Stations 2 through 4 had higher salinities and therefore fewer insect species. Non-insect macroinvertebrates showed fewer changes among stations and were more abundant in Stations 2 through 4.
6. These data indicated that the water quality of the Neches River is similar to the conditions observed in 2003 and indicate a long-term trend of improved water quality when compared to earlier surveys in 1953 and 1973. Additionally, there were no patterns suggestive of impacts due to the saltwater barrier at the time of the survey. The Neches River remains an important nursery for many estuarine crustaceans, as juvenile shrimps and crabs were abundant at all stations.

4.1 Introduction

Biological inventories are widely recognized as establishing necessary baseline data against which important comparisons 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, and 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 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 (Harrel and Hall 1991, Harrel and Smith 2002, Moring 2003).

This survey was undertaken to (1) provide information on the diversity of organisms in this portion of the Neches River system, (2) compare faunas among the five stations and (3) relate the results with previous surveys by the Academy at or near the same survey stations in 1953 (ANSP 1954), 1956 (ANSP 1958), 1960 (ANSP 1961), 1973 (ANSP 1974), 1996 (ANSP 1998) and 2003 (ANSP 2006).

4.2 Methods

Since macroinvertebrates are a phylogenetically diverse group that exhibit numerous morphologies and behaviors and occupy a range of habitats, they were sampled in several ways. At each station, we identified habitats that were historically sampled and most likely to support a variety of macroinvertebrate communities: macrophytes (aquatic and semi-aquatic plants), mud (including silty depositional areas), sand (including hard pan found under 1-10 cm of sand), logs (as well as woody debris and roots), rip rap (including large pieces of concrete), as well as the lentic (standing water like pools near the shorelines) and lotic (moving water like runs or riffles) areas of the river. Within the defined reach at each station, we stopped at as many different habitat areas as were present and accessible. Approximately six to eight hours 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. GPS coordinates were taken at each stop for future reference. For a full list of all GPS coordinates at each station, see Appendix C.1.


Figure 4.1: Danielle Odom and Cody Malin using dip nets to collect macroinvertebrates in the shallower areas along the right bank at Station 4.

Macrophytes were sampled a few different ways. The most common method was to search through the plant by hand, placing it on a lighter background enabling us to see the macroinvertebrates more easily. Using "Jason's Technique" (named after LNVA Environmental Stewardship Manager Jason Watson), a macrophyte would be banged against the flat front portion of the boat in such a way as to dislodge any organisms that were attached to it. This method was especially useful when searching *Phragmites* roots. Vegetation searched included stems and exposed root mats of common reed, beds of *Schoenoplectus californicus* (California bulrush), root mats of *Eichhornia crassipes* (water hyacinth), and mats of *Salvinia* (watermoss; *S. minima* and *S. molesta*). Lotic and lentic areas of the stream that were wadable (no more than 4 feet deep) were sampled using the dip net method. Dip nets consisted of a Wildco bottom aquatic dip net (#3-425-K10) with an 800 to 900-µm mesh and a dip net with a 3-mm (1/8 in) ace mesh. The bottom aquatic dip net would be placed so that the opening of the net faced upstream, catching the downstream flow. Using our feet, we disturbed the substrate directly in front of the net opening for 30 to 60 seconds, then used the net to scoop up any surrounding macroinvertebrates. In lentic areas, where flow was stagnant, the substrate was disturbed and the net was used to scoop up the detritus and any swimming macroinvertebrates. The number of kicks were recorded at each location and for each habitat (i.e., lentic or lotic). The contents of the dip nets 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. The ace mesh dip net was used in open habitats on the riverbanks and tree roots to collect larger organisms, such as crabs (blue crab [*Callinectes sapidus*] and mud crabs [*Panopeus obesus* and *Rhithropanopeus harrisii*]). Mud, silt, sand and hard pan were placed into a 425- or 500-µm mesh sieve and rinsed in the river to reveal any burrowing organisms. Macroinvertebrates were then handpicked, or forceps were used to collect them. Burrowing intertidal and subtidal forms, such as bivalve mollusks, were collected by hand from the surface of sandy, muddy sand and muddy substrates. Logs were picked through using knives and forceps while a dip net was used to jab under roots and woody debris. Bark was peeled from submerged and beached limbs to remove organisms hiding beneath the bark. Organisms were hand-picked off rip rap and concrete blocks. The net was also placed over the side of the boat as it moved from location to location to capture any fast-moving organisms that were swimming on the surface of the river (e.g. whirligig beetles).

The first Neches survey in 1953 utilized a timed search that was duplicated this year. At each habitat (either macrophytes, mud, sand, logs, rip rap, lentic or lotic), sampling occurred for at least 30 minutes. If, at the end of the 30-minute time span, no new organisms were found, sampling stopped. If new organisms were found, sampling continued for 10 additional minutes. This was repeated until no new organisms were found. To ensure we were capturing the smaller individuals, some material from each habitat was taken back to the Academy laboratory to sort under a microscope. All individuals were sorted out of the detritus. Additionally, nektonic and benthic macroinvertebrate taxa were collected as bycatch while sampling for fishes using a benthic otter trawl and by seining areas of Station 0 through 4 (see section 5. Fish). The contents of the dip nets, otter trawl and seine were rinsed in the river to remove sediment.

Some reference material and detritus, as well as taxa that could not be identified with certainty in the field, were preserved in 70% ethyl alcohol and taken to the Academy laboratory for identification.

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 at several stations. Prostigmata water mites were found in macrophyte samples but were not identified to species. Because of instar stage or condition, some insect specimens could not be identified to species. These are noted in Appendix 8 with an asterisk, and were counted as follows: If a genus contained both an identified species (e.g., *Caenis diminuta*) and an undetermined species (e.g., *Caenis* sp.*) at the same station, the undetermined species was not counted in the station total or survey total, since the undetermined species may be the same as the identified species. If a genus contained both an identified species and an undetermined species from different stations (e.g., *Dineutus serrulatus* from Station 1, *Dineutus* sp. 1* from Station 0), both taxa were counted in the respective station totals, but the undetermined species of *Dineutus* is not counted in the survey total since the undetermined species may be the same as the identified species.

For each habitat and station, relative abundances of all the taxa were noted and the macroinvertebrates later identified to the lowest practical taxon. Relative abundances were defined based on the number of animals observed: rare (1-5 individuals), common (6 to 100) and abundant (101 or more).

Macroinvertebrate data from the previous comprehensive and cursory studies (see section 1.2: Historical Surveys) were compiled and compared with 2021 data to enable a assessment of change over time. 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.

Complete information on station locations and general characteristics of the river at each station are presented in Introduction section 1.4. Locations within stations where macroinvertebrates were collected are outlined in Appendix C.1.

4.3 Results

Results by taxa are presented here for the major groups found in the 2021 survey. For a full list of species at all stations for the current and historical surveys, see Appendix C.2.

Non-Insect Macroinvertebrate Taxa

The lower Neches River macroinvertebrate community was dominated by non-insect taxa from three groups: Annelida, Mollusca and arthropods. These groups were found in the highest abundances in brackish Stations 2 through 4.

Segmented Worms (Annelida)

Three main morphological groups of annelids – oligochaete worms, leeches and polychaete worms – were found in the 2021 survey. Annelids were present at every station except Station 4.

Oligochaete Worms

Because of their small size and 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 substrate material under a microscope. Most specimens in 2021 were found in this way. There were five undetermined species of Lumbriculidae worms, most of which were found at Station 0 on macrophytes (mats of *Salvinia*) and in muddy or sandy habitats. While all

Lumbriculidae species were characterized as common abundance, "Species 2," found only at Station 0, was the most common. Two species of Naididae worms, *Pristina longiseta* and an undetermined species, were found on macrophytes at Station 0.

Leeches

Although leeches are better represented in freshwaters, species are known to occur in brackish and marine waters. Most leeches in 2021 were found via hand collection, but one species was found at Station 3 in the seine collection. Three undetermined species of leech were collected in 2021: "Species 1" was found at Stations 0, 1 and 3; "Species 2" was found only at Station 0; and "Species 3" was found only at Station 1.

Polychaete Worms

The 2021 survey yielded two species of polychaete worms, *Neanthes succinea* and *Laeonereis culveri*. *L. culveri* was found at Station 0 (in mats of *Salvinia*) and Station 3 (in muddy habitats). *N. succinea* was found while sifting mud at Station 0. These species were rare at both stations.

Mollusks (Mollusca)

The 2021 molluscan fauna at the five Neches River stations included six species of bivalves and five species of snails. Snail abundance was characterized between rare and common at all stations, while bivalves were common at most stations. Most species were found at either Station 0 or Station 1 (six species at each station). Atlantic rangia was abundant at every station, but especially abundant at Station 1; an LNVA staff member (Trent Harper) commented, "there's a billion *Rangia*" while searching for bivalves along the right bank of Station 1. In previous survey years, snails were most often found at Station 1, while bivalves were found at a range of stations throughout the Neches River (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1974, ANSP 1998, and ANSP 2006).

Bivalves

Bivalves included four species of clams, one oyster and one species of estuarine mussel. The clams consisted of *Rangia cuneata* (Atlantic rangia), *Rangia flexuosa* (brown rangia), *Corbicula fluminea* (Asian clam) and *Eupera cubensis* (mottled fingernail clam). The oyster species was *Crassostrea virginica* (eastern oyster) and the estuarine dreissenid bivalve was *Mytilopsis leucophaeata* (dark falsemussel). At Station 0, Asian clam was common; many individuals were found in the mud

Figure 4.2: Sifting through detritus at Station 4 for macroinvertebrates.

and muck habitats as well as seine samples. Mottled fingernail clam was common and found in logs, lentic areas and on macrophyte roots. Station 1 supported more bivalves than snails. Two species of *Rangia* were found: a single specimen of brown rangia was collected in a seine sample, and Atlantic rangia was found in the sandy areas of the right bank and in seine samples, where it was common. Dark falsemussel was common in otter trawls and seine samples and was found on some concrete blocks along the left bank. Mottled fingernail clam was found in macrophytes. Atlantic oyster, dark false mussel, Atlantic rangia and an unknown species of *Rangia* (possibly brown rangia but specimen is too small to determine species) were found at Station 4.

Snails

The snails found in the study areas included *Assiminea succinea* (Atlantic assiminea), *Pseudosuccinea columella* (American ribbed fluke snail), *Physella gyrina* (tadpole physa), *Planorbella trivolvis* (marsh ramshorn), and *Ferrissia californica* (fragile ancylid). At Station 0, Atlantic assiminea was moderately common in macrophytes, tadpole physa was rare and American ribbed fluke snail was rare. A species of *Physa* snail and an unknown species of Planorbidae were also found in macrophytes at Station 1. Station 2 had two species of snails, fragile ancylid and an unknown species; both were found on macrophytes in rare abundance. Station 3 was the only station where snails were not found. At Station 4, a single snail species, marsh ramshorn, was found on woody debris.

Arthropods

Throughout this report, the term "arthropods" refers to all non-insect members of Phylum Arthropoda. Though they are members of Phylum Arthropoda, insects (Class Insecta) are evaluated as a separate group because of their importance as indicators of water quality.

Crustaceans (Crustacea)

The 2021 survey found 37 species of crustaceans. Diversity of crustaceans was highest at Station 2 (21 species), and at all stations, the abundance of crustaceans was higher than any other taxa group. This year we collected Cladocera for the first time. As in previous studies, we collected barnacles, isopods, amphipods, mysids, and decapods including shrimps, crayfish and crabs. Decapod shrimps dominated abundance counts for all stations, found commonly along shorelines, otter trawls and seines.

Barnacles

Amphibalanus subalbidus was found in Station 4 in the seine sample, growing on shells of the oyster *Crassostrea virginica*. It was also found in 2003 at Stations 2 through 4 (ANSP 2006).

Isopods

Three species of isopods were collected in 2021: a species of *Caecidotea*, a species in the genus *Lirceus* and the parasitic isopod, *Probopyrus bithynis* found in the gill chambers of *Macrobrachium ohione.* The isopods in genera *Caecidotea* and *Lirceus* were found either in macrophytes or in lentic areas of Station 0.

Amphipods

Thirteen species of amphipods were collected in 2021; most species were common on macrophytes, and most were found at Station 2. Four species in Family Talitridae were only found at Stations 3 and 4 while searching through macrophytes, and one undetermined species from Family Melitidae was only found at Station 3 in macrophytes. Species in Family Gammaridae were found at every station, common in the macrophyte, lentic, seine and otter trawl samples. Species of *Hyalella* (Hyalellidae) were common on macrophytes and found at Stations 0, 1 and 2. *Apocorophium lacustre* (in 2003 *Corophium lacustre*) was found in the lentic areas of Station 0, and in macrophytes at Station 2 and 4. *A. lacustre* is a tube dweller – they construct mucous tubes to which they adhere silt and detritus and may include sand grains, so it was not unusual to find them in lentic areas as well as in and on macrophytes.

Mysids

Taphromysis louisianae, commonly called opossum shrimp, was found in macrophyte detritus from Station 0 and a damaged specimen was collected in an otter trawl from Station 2. In 2003, this species was common in algae over a silt and sand substrate (ANSP 2006).

Decapods

Shrimps, crayfishes and crabs constitute the decapod crustacean fauna and include some of the most familiar species. The shrimps were represented in 2021 by seven species: four species of palaemonid shrimps and three species of penaeid shrimps. Nearly 5,000 shrimp were collected this year; most were collected by shoreline seining or otter trawl in deeper water. Shrimps, regardless of species, were abundant at every station where they were found.

Palaemonid shrimps were found at every station. *Macrobrachium ohione* (Ohio shrimp) was found at every station, in nearly every kind of habitat, but was most abundant at Station 0. This, the largest of the palaemonid shrimps recorded in the survey, is a freshwater species whose larvae require the higher salinity of estuarine waters to complete their life cycle (q.v., Horne and Beisser 1977). An unknown species of *Macrobrachium* was found at every station. It is possible that these specimens are also *M. ohione* and/or another species, but without full grown males, it is difficult to identify them to species. *Palaemon pugio* (daggerblade grass shrimp) was found at Stations 2 through 4, *Palaemon kadiakensis* (Mississippi grass shrimp) at Stations 0, 1 and 4, and *Palaemon intermedius* at Station 4 only. *P. intermedius* had not been seen since 1973 (ANSP 1974).

Over 2,500 individuals of penaeid shrimp were collected at Stations 1 through 4 in 2021. Of the three species of Penaeidae, Atlantic white shrimp (*Litopenaeus setiferus*) has been collected every year since 1956 (Appendix C.2). Brown shrimp (*Penaeus aztecus*) and seabob (*Xiphopenaeus kroyeri*) were very abundant Stations 2 through 4. The presence of so many juveniles and subadult white shrimp indicates the Neches River estuary to be an important nursery ground for this species.

One species of crayfish was collected in 2021 – *Faxonius texanus*, from one of the seine samples collected Station 0. Other specimens were collected at the same time but were too small to identify. A female crayfish was collected in the lentic sample of Station 0 but was unable to be identified to species. All crayfish were rare in the 2021 samples.

Figure 4.3: Juvenile squareback marsh crab found at Station 2.

Four species of crab were collected in 2021: *Callinectes sapidus* (blue crab), *Rhithropanopeus harrisii* (Harris mud crab), *Panopeus obesus* (salt marsh crab) and *Armases cinereum* (squareback marsh crab). Family Ocypodidae was not observed or collected this year. Crabs were found at every station except Station 0. Blue crab and Harris mud crab individuals were characterized as abundant at each location they were found. Individuals ranged in size, indicating several generations with many juveniles present. The presence of so many juveniles and subadult blue crabs indicates the Neches River estuary to be an important nursery ground for this species. Salt marsh crab was found only at Station 2 where 16 individuals were caught in the otter trawl. One squareback marsh crab was found at Station 4 where it was found on some woody debris.

Mites (Arachnida)

Five unknown species of Prostigmata (water mites) were collected during the 2021 survey. All were sorted out of macrophyte detritus brought back to the Academy. Four species were found at Station 0, two species at Station 1, and two species at Station 2

Springtails (Collembola)

Collembola, until recently, were under the umbrella class Insecta as Entognatha but have since been moved to their own taxonomic class "Collembola" (Ruggerio and Gordon 2013). Previous Neches surveys have not listed any species of Collembola. The 2021 survey is listing these species for the first time. At Stations 0 and 1, individuals were observed jumping off logs. A specimen identified in the lab to be a species of Hypogastruridae (genus *Anurida*) was found in *Salvinia*, brought back to the Academy and sorted under a microscope. A springtail from the family Sminthuridae was found on *Salvinia* at Station 2 but was too small to identify to species. The macrophytes at Station 4 had a species of *Semicerura* (Isotomidae).

Additional Non-Insect Macroinvertebrate Taxa Notes

In 2021, no individuals in phyla Porifera (sponges), Ctenophora (comb jellies) or Cnidaria (jellyfishes and hydrozoans) were found. Phylum Platyhelminthes was represented by three specimens of an unknown species of Rhabditophora flatworm found at Station 0. This may have been a species in the genus *Girardia*, considering that *Girardia tigrina* was found at Station 1 in 1973 (ANSP 1974). Taxa lists for these groups from historical surveys can be found in Appendix C.2.

While Academy staff were out collecting on October 8 and 9, 2021, at Stations 0 and 1, LNVA staff collected 128 mussel specimens representing 12 taxa (Table 4.1). These samples were not collected according to the standardized protocols used at other stations (see section 4.2 Methods) and therefore, these mussel species were not counted in the final species list. However, they are valuable additions to the full picture mussel diversity of the Neches River, which is vital to understanding how mussels use the Neches as a nursery. Most species were found at Station 0; only one species, round pearlshell (*Glebula rotundata*), was also found at Station 1. The most common species collected was round pearlshell with 63 individuals at Station 0; this represents nearly 50% of the individuals collected. The second most common bivalve was mapleleaf (*Quadrula quadrula*), with 36 individuals found at Station 0.

Table 4.1: List of mussel species (Phylum Mollusca, Class Bivalvia) collected using non standardized methods during the 2021 Neches River survey.

Family	Species	Station	
		0	1
Mactridae	*Rangia cuneata*	+	
Unionoidae	*Glebula rotundata*	+	+
	Lampsilis teres	+	
	Plectomerus dombeyanus	+	
	Potamilus amphichaenus	+	
	Potamilus fragilis	+	
	Potamilus c.f. fragilis (juvenile)	+	
	Potamilus purpuratus	+	
	Quadrula quadrula	+	
	Tritogonia nobilis	+	
	Unidentified sp. 1 (juvenile)	+	
	Unidentified sp. 2 (juvenile)	+	

Insect (Class Insecta) Taxa

Several insect families were seen for the first time in the 2021 survey: Dipseudopsidae, Polycentropodidae, Saldidae, Hydrometridae, Chrysomelidae, Mesoveliidae, Hydrometridae and Limoniidae. Heptageniidae mayflies were observed this year but have not been seen since 1973 (ANSP 1974, ANSP 1998, ANSP 2006). Taxonomic name changes (Appendix C.3) might account for why some taxa were not seen in 2021. A non-native species of beetle, *Agasicles hygrophila*, was found on macrophytes. This beetle was introduced in the United States to control alligator weed (*Alternanthera philoxeroides*) (Buckingham 2002). See Table 4.2 for a complete list of the insect orders and families found during the 2021 Neches survey.

Table 4.2: All the insect orders and families found in the 2021 Neches River survey.

Order	Families
Odonata	Aeshnidae, Gomphidae, Corduliidae, Libellulidae, Macromiidae, and Coenagrionidae
Ephemeroptera	Baetidae, Ephemeridae, Heptageniidae, and Caenidae
Hemiptera	Gerridae, Veliidae, Belostomatidae, Nepidae, Mesoveliidae, Salididae, Hydrometridae, and Naucoridae
Megaloptera	Corydalidae
Lepidoptera	Crambidae
Trichoptera	Dipseudopsidae and Polycentropodidae
Coleoptera	Noteridae, Haliplidae, Dytiscidae, Gyrinidae, Elmidae, Scirtidae, Curculionidae, Chrysomelidae, and Hydrophilidae
Diptera	Chironomidae, Culicidae, Tabanidae, Limoniidae, and Ceratopogonidae

Odonata

In 2021, 14 species of Odonata nymphs were collected; most were found at Station 0. Cyrano darner (Aeshnidae: *Nasiaeschna pentacantha*) was found in a mat of *Salvinia* at Station 0 and in lentic areas of Station 1. In lentic areas of Station 0, a prince baskettail (Corduliidae: *Epitheca princeps*), and several *Erythemis* (Libellulidae) were collected. *Erythemis* were also collected on macrophytes at Station 2 and 4. A smoky shadowdragon (*Neurocordulia molesta*) was found in one of the otter trawls from Station 0. Station 0 seines revealed Gomphidae dragonflies in the genera *Dromogomphus* and *Stylurus*, a species of *Macromia* (Macromiidae), as well as an emerald (Corduliidae: *Somatochlora* sp.). Lentic areas of Station 1 had 2 species of Coenagrionidae in the genera *Ischnura* and *Neoerythromma*. Macrophytes from Station 2 had four species of narrow winged damselflies (Coenagrionidae) in the genera *Leptobasis*, *Enallagma*, *Nehalennia* and the species *Hesperagrion heterodoxum* (Painted Damsel).

Adult dragonflies were seen at several stations; while these species are not in the final taxa list, their presence is worth noting. At Station 2, flying along the shoreline and lighting upon tree limbs was a blue dasher (*Pachydiplax longipennis*). Mating Rambor's forktail damselflies (*Ischnura ramburii*) were seen flitting along the sandy beach near location 4. A third species of dragonfly, in the family Libellulidae, was also observed. A male red tailed pennet (*Brachymesia furcata*) was seen on the shoreline at Station 4 perching on dead tree branches. Another adult Libellulidae was observed at Station 4.

Ephemeroptera

Six species of mayflies were collected in 2021. Station 0 yielded a high abundance of *Hexagenia* mayflies in the silty depositional areas as well as the otter trawl and seine collections; there were twice as many individuals than any other type of mayfly. Heptageniidae mayflies (genera *Stenacron* and *Stenonema*) were found on rip rap along the right bank. *Hexagenia* mayflies were also found in seines from Station 1. Two species of Caenidae mayflies, *Caenis diminuta* and *Caenis punctata*, were found in the lentic areas and on macrophytes at Station 1. Station 2 had *Caenis* species in the mud and on macrophytes, as well as a species of *Callibaetis*. No mayflies were found at Station 3 or 4 in 2021.

Hemiptera

Ten species of Hemiptera from eight families were found during the 2021 survey. Most species of Hemiptera were found at Stations 0, 1 and 2. Hemiptera were rare at Station 0, but common at Station 1. Nearly all species were found in lentic portions of the river, along margins or in pools floating on the surface; most specimens were collected by sweeping the kick net through the surface of the water or sorting through macrophytes. The most common Hemiptera encountered along the Neches was a species of *Mesovelia* and a species of *Pelocoris*; both species were found along shorelines. A species of *Pelocoris* was found at every Station except 4, in lentic kick net collections. Water scorpions (Nepidae: *Ranatra* sp.) were caught in the backwater at Station 1, otter trawl and macrophytes at Station 2, and on *Salvinia* at Station 4. A species of marsh treader (Hydrometridae) was found on a log at Station 0. The *Pentacora* species of shore bug (Saldidae) was found at Station 1 in a kick net sweep from the shoreline. All giant water bugs in the species *Belastoma* (Belastomatidae) were found on mats of *Salvinia*. Water striders (Gerridae) and riffle bugs (Veliidae) were rare at Stations 0, 1 and 2.

Megaloptera and Lepidoptera

Two orders were represented in the 2021 survey by single families. The only Megalopteran was a dobsonfly (Corydalidae: *Chauliodes*) found in a kick net sweep along the shoreline at Station 1. Lepidopterans were represented by some individuals of Salvinia stem-borer moth (Crambidae: *Samea multiplicalis*) which were common at Stations 0 and 1 in mats of Salvinia.

Trichoptera

Caddisflies are rare along the Neches. 2021 saw two families of caddisflies not collected before in Academy surveys, and both were rare. An individual of the species *Phylocentropus* (Dipseudopsidae) was collected in mud along the shoreline at Station 0. *Polycentropus* (Polycentropodidae) was found in a kick net collection of a lentic habitat at Station 0. Historically, only a few individuals from a few families have been found. Moring (2003) found a significantly higher abundance of caddisflies above the confluence of Pine Island Bayou, including all the families found in 2021.

Figure 4.4: Phylocentropus *(Family Dipseudopsidae)*

Coleoptera

In 2021, nine families of beetles were found along the Neches (more than in any other Academy survey). Beetles were most common at Station 0 in 2021, with seven families representing 12 species. The most abundant type of beetle was the whirligig beetle (Gyrinidae); they were observed at every station, and large swarms were observed swimming past the boat at Stations 0 and 1. Most other species of beetles were rare, with only one to two individuals representing a taxon. As was the case with most other insect taxa, most species were found in mats of *Salvinia*. Scirtidae larvae (*Cyphon* and *Scirtes* spp.) were rare and found clinging to *Salvinia* leaves at Station 0. A species of burrowing water beetle (Noteridae: *Hydrocanthus*) was found at every station except Station 4.

Figure 4.5: Whirligig beetles (Gyrinidae) caught off the side of the boat at Station 1.

Diptera

Dipterans collected in 2021 were found mostly at Station 0. Chironomidae were the most common (49 individuals) at Station 0, found mostly in the macrophyte detritus that was brought back to the Academy and sorted. Seven species of midges (Chironomidae: Tanypodinae, Orthocladiinae and Chironomini), two species of mosquito (Culicidae), one species of horse fly (Tabanidae: *Chlorotabanus crepuscularis*), one species of cranefly (Limoniidae: *Limonia* sp.), and one species of biting midge (Ceratopogonidae: *Dasyhelea* sp.) were found at Station 0. Chironomidae was the only family found at the other stations. Most species were found in macrophytes. Two species of Chironomidae were found at Station 1, one species at Station 2 and Station 4, and no species were found at Station 3.

4.4 Discussion

Richness tells us how many species are present in any given environment. Abundance tells us if a species or taxonomic group is common or rare and how the species are distributed in an environment, including stream ecosystems. Examined together, these two metrics allow for an understanding of biodiversity and other aspects of stream health. Whereas insect diversity is a significant part of the freshwater fauna, in estuarine and marine habitats macroinvertebrate niches are filled by crustaceans, and insects are less common to rare depending on the salinities and season. In general, the more varied the available habitats are, the more biodiversity we see. For example, macrophytes, especially mats of *Salvinia*, supported the highest diversity of insects. Acting like small islands throughout the Neches, they enabled certain taxa to thrive in areas where they would otherwise be unable to. Both richness and abundance were calculated for the 2021 survey to highlight how communities change as the Neches moves from a freshwater ecosystem (Stations 0 and 1) to a brackish one (Stations 2, 3 and 4), look for possible anthropogenic or industrial impacts, and discern any trends over time.

Comparisons Among Stations in 2021

During the October 2021 survey, 59 species of insects and 63 species of non-insect macroinvertebrates were obtained. The species richness at each station (Figure 4.6) shows that more species are found at Stations 0 and 1 compared to Stations 2 through 4. There are more species at Station 0 than any other station. This is the station beyond the saltwater barrier and with the least amount of industrial development.

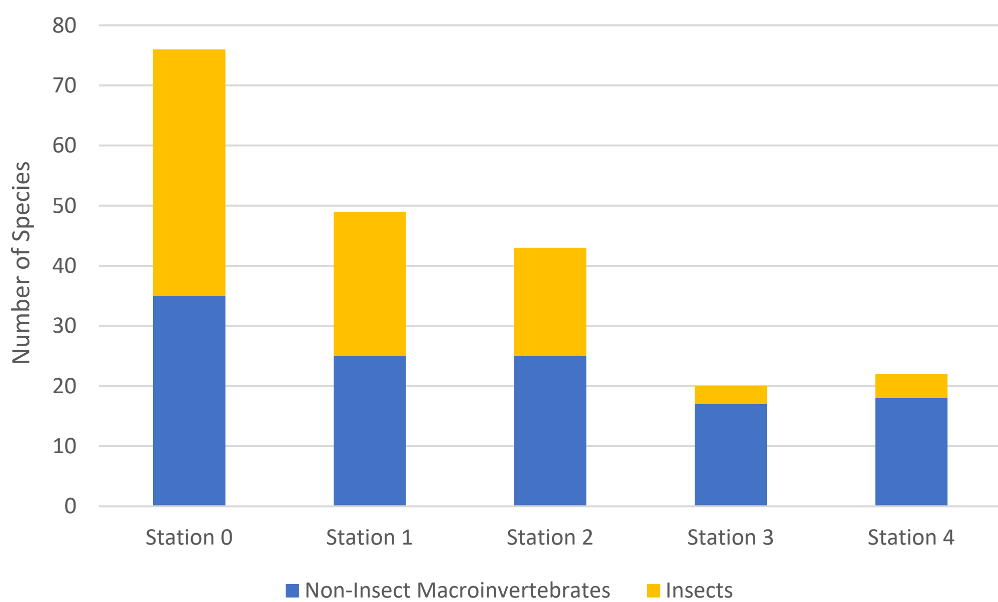

Figure 4.6: Total macroinvertebrate species collected at all stations along the Neches River in October 2021.

Station 1 has more species than Station 2 but they differ in the kinds of animals present. Station 1 has a similar number of non-insect species as insect species (25 and 24, respectively), but Station 2 has about a third fewer insect species than non-insect species (18 to 25, respectively). Stations 3 and 4 show the lowest richness of any of the stations. Looking at species richness at each station by taxa group (Figure 4.7), we can see that the number of arthropod species (crustaceans, mites and springtails) at Stations 3 and 4 is about four times the number of insect species, which could be a response to the increased salinity as we move downstream.

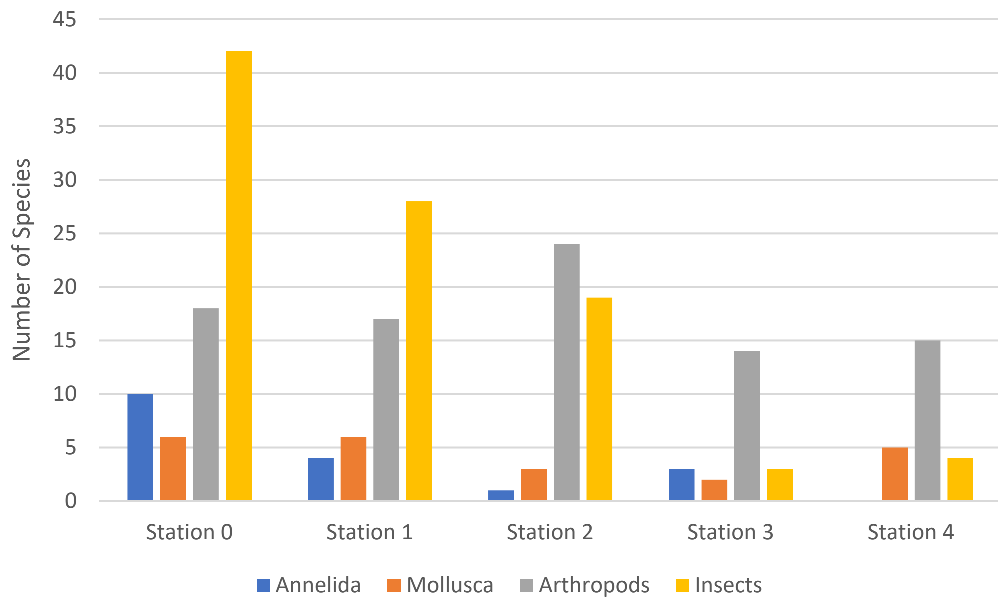

Figure 4.7: Number of macroinvertebrate species (richness) by taxa group at each station for the October 2021 Neches River survey.

Based on the composition of macroinvertebrate communities at each station in 2021, a faunal division is present between the freshwater and brackish stations. Stations 0 and 1 are considered freshwater, while Stations 2 through 4 are in the channelized portion of the river and bear higher salinity (see 2. Environmental Geochemistry). Overall, the total numbers of macroinvertebrate species decreased between Stations 0 and 1 and the downriver Stations 2 through 4, primarily reflecting the larger freshwater insect component at Stations 0 and 1 and the increase in salinity at Stations 2 through 4 (Figures 4.6 and 4.7). Looking at only insects, which prefer fresh water, richness decreased from the freshwater portion of the system at Stations 0 (41 species) and 1 (24 species) to the brackish waters further downriver (18, 3 and 4 species at Stations 2 through 4, respectively).

The faunal change from freshwater to brackish stations can be further discerned by looking at where different taxa groups were most abundant (Figure 4.8). Most of the insects and annelids (groups who prefer fresh water) were found at Stations 0, 1 and 2.

Odonata, Ephemeroptera and Diptera were found most often at Station 0. Hemipterans were found most often at Stations 1 and 2 floating on mats of watermoss. Station 0 was the location where most of the annelids, mollusks and other arthropods were found.

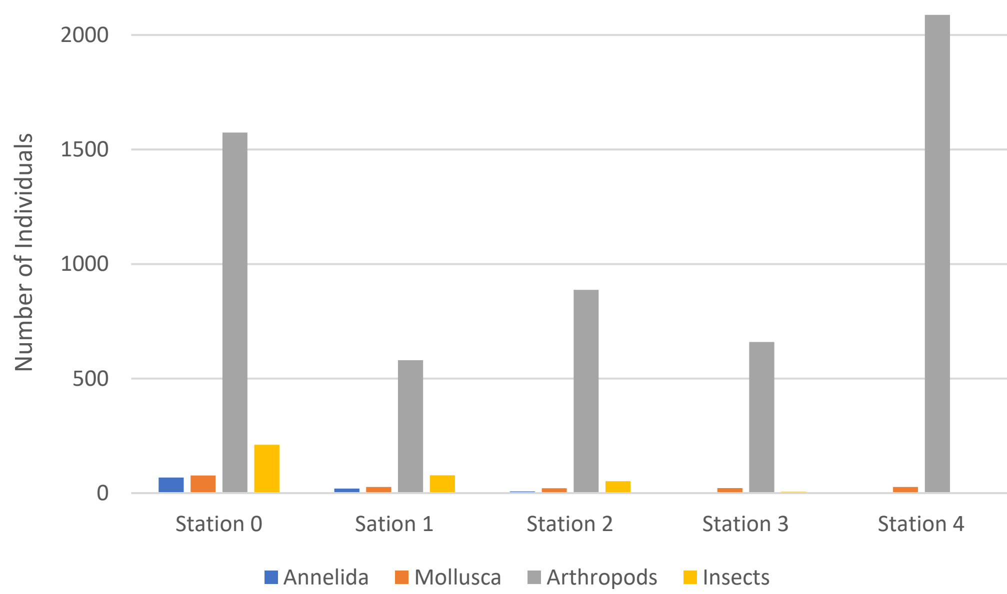

Figure 4.8: *Macroinvertebrate abundance by taxa group at each station for the October 2021 Neches River survey.*

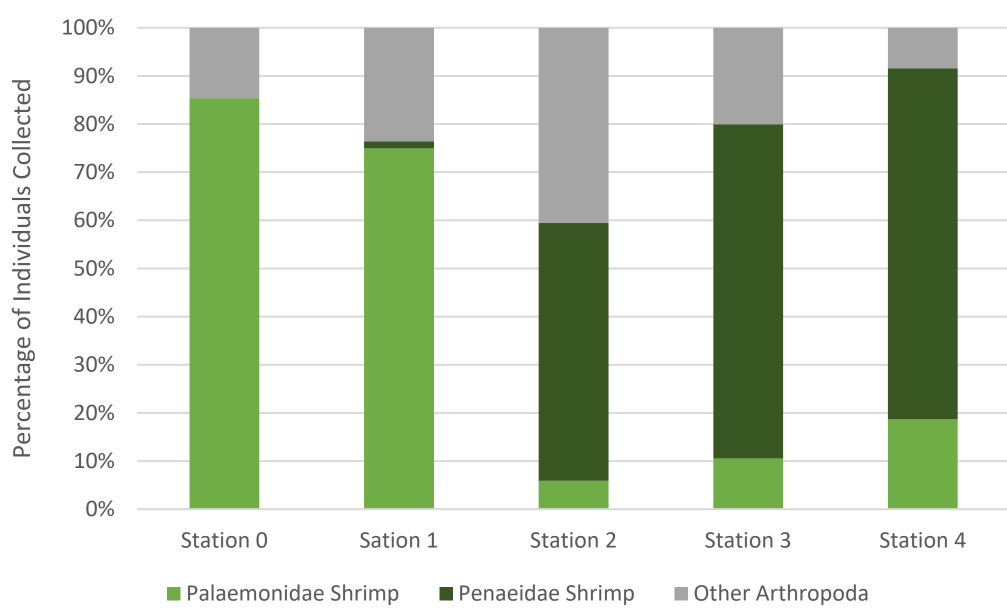

Figure 4.9: *Abundance of Palaemonidae and Penaeidae shrimps compared to all other arthropod taxa per station, as a percentage of the total amount collected within that station.* The presence of many juvenile shrimps of these families (as well as blue crab) suggests that the lower Neches River estuary is an important nursery ground for commercially important species.


Figure 4.10: Palaemonid shrimp at Station 0.

Most of the crustaceans, a group with more salt-loving taxa, were found in Stations 1 through 4, the exception being Palaemonid shrimps who were found in high numbers even at Station 0, and the barnacles (Balanomorpha) that were only found at Station 4. Isopods and Amphipods were most common at Station 2. It is clear from Figure 4.8 that most of the individuals collected during the 2021 survey were arthropods; at every station, shrimp species make up most of the individuals, even though there are only a few species. This is highlighted in Figure 4.9, which shows that the arthropod communities at Stations 0 and 1 were dominated by Palaemonid shrimps while Stations 2, 3 and 4 were mostly Penaeids. Many of the shrimp were juveniles. In addition to Atlantic white shrimp (Family Penaeidae), the lower Neches River estuary provides nursery grounds for juveniles of at least one other species of commercially important decapod crustacean, the blue crab.

Station Specific Fauna and Ranges

Looking at whether some species were restricted in their range to either the freshwater or brackish stations further illustrates the salinity gradient present in the Neches.

Freshwater Stations

At Stations 0 and 1 in 2021, 30 species of insects and 24 species of non-insect macroinvertebrates were found that did not range downriver to Stations 2 through 4 (Table 4.3). While Stations 0 and 1 were similar in salinity, they exhibited some differences in their community compositions. Station 0 exhibited more species unique to the freshwater stations than did Station 1. Also, there were far more individuals of these taxa at Station 0 overall compared to Station 1: 169 insect specimens compared to 27, and 181 non-insect macroinvertebrate specimens compared to 28. Of the 74 species that were limited to the freshwater stations, only 8 species were found at both Station 0 and Station 1.

At Station 0, the salinity-restricted insect community consisted of six species of Odonata, three species of mayfly, two species of Hemiptera, a single species of Pyralid moth, two species of caddisflies, eight species of beetle and eight species of flies. Of these, the *Hexagenia* species of mayfly was the most abundant overall (over 100 individuals observed). The non-insect macroinvertebrates that were present included six species of annelid worms, five species of mollusks and nine species of arthropods. The most abundant of these was an invasive species of bivalve, *Corbicula fluminea*. At Station 1, there were half as many species of both Odonates and beetles than at Station 0, and only one species of fly compared to eight. Station 1 also had fewer species of non-insect macroinvertebrates: two species of annelid worm, two species of mollusks and three species of arthropods.

The absence of these taxa at downriver stations 2, 3, and 4 is indicative of their limited tolerance for higher salinity waters and reflects the strong macroinvertebrate community response to the salinity gradient observed in 2021.

Table 4.3: Macroinvertebrate taxa found only at freshwater *Stations 0 and 1 during the 2021 Neches River survey.*

Non-Insect Macroinvertebrates			Station 0	Station 1
Class Rhabditophora			+	
Phylum Annelida		Hirudinea sp. 2	+	
		Hirudinea sp. 3		+
		Lumbriculidae sp. 2	+	
		Lumbriculidae sp. 3	+	+
		Lumbriculidae sp. 4	+	
		Naididae sp. 1	+	
		Neanthes succinea	+	
		Pristina longiseta	+	
Phylum Mollusca		*Assiminea succinea*	+	
		Corbicula fluminea	+	
		Eupera cubensis	+	+
		Physella gyrina	+	
		*Physella sp.**		+
		Pseudosuccinea columella	+	
Phylum Arthropoda	Order Trombidiformes	Prostigmata sp. 1	+	+
		Prostigmata sp. 3	+	
		Prostigmata sp. 4	+	
	Order Collembola	*Anurida sp.*	+	
	Suborder Cladocera	*Daphnia sp.*		+
		Holopedium sp.	+	
	Order Isopoda	*Caecidotea sp.*	+	
		Lirceus sp.	+	
		Probopyrus sp.		+
	Order Decapoda	*Orconectes texanus*	+	
	Order Mysida	*Taphromysis louisianae*	+	

Table 4.3 (continued): Macroinvertebrate taxa found only at freshwater *Stations 0 and 1 during the 2021 Neches River survey.*

Insects		Station 0	Station 1
Order Odonata	*Dromogomphus sp.*	+	
	Epicordulia princeps	+	
	Ischnura sp.		+
	Macromia sp.	+	
	Nasiaeschna pentacantha	+	+
	Neoerythromma sp.		+
	Neurocordulia molesta	+	
	Somatochlora sp.	+	
Order Ephemeroptera	*Caenis diminuta*		+
	Caenis punctata		+
	Hexagenia sp.	+	+
	Stenocron sp.	+	
	Stenonema sp.	+	
Order Hemiptera	Hydrometridae Unknown sp.	+	
	Pelocoris biimpressus		+
	Pentacora sp.		+
	Rhagovelia sp.	+	+
Order Megaloptera	*Chauliodes sp.*		+
Order Lepidoptera	*Samea multiplicalis*	+	+
Order Trichoptera	*Phylocentropus sp.*	+	
	Polycentropus sp.	+	
Order Coleoptera	*Agasicles hygrophila*		+
	Berosus sp.	+	
	Copelatus sp.	+	
	Cyphon sp.	+	
	Dineutus serrulatus		+
	Gyretes sinuatus		+
	Lissorhoptrus simplex		+
	Neoporus sp.	+	
	Peltodytes sp.	+	
	Scirtes sp.	+	
	Stenelmis sp.	+	
	Suphisellus sp.	+	
Order Diptera	*Anopheles sp.*	+	
	Chlorotabanus crepuscularis	+	
	Culex sp.	+	
	Dasyhelea sp.	+	
	Goeldichironomus devineyae	+	
	Goeldichironomus fluctuans	+	
	Limonia sp.	+	
	Polypedilum illinoense grp.	+	
	Tribelos fuscicorne		+

Brackish Stations

The brackish water species found only at Stations 2 through 4 are listed in Table 4.4. The 20 species of non-insect macroinvertebrates unique to the brackish stations included eastern oyster, *Rangia* clams, the barnacle *A. subalbidus*, eight species of amphipods, shrimps (*Palaemon intermedius*, Atlantic seabob and daggerblade grass shrimp) and crabs (salt marsh mud crab and squareback marsh crab). Primarily a freshwater group, 20 insect species were collected in 2021 at Stations 2 through 4, but only eight species were found only at those stations, specifically, at Station 2. Most of the insects found only in the brackish stations were damselflies (four species of Coenagrionidae), and true bugs (three species: one water strider, one small water strider and one giant water bug). Many of the insects collected from the brackish stations were found in mats of *Salvinia* that had floated downriver from upriver tributaries. With increasing salinities, crustaceans typically replace insects. In 2021, three times as many crustacean species were unique to the brackish water Stations 2, 3 and 4 (15) than were unique to freshwater Stations 0 and 1 (five) (Tables 4.3 and 4.4).

Table 4.4: Macroinvertebrate taxa found only at brackish Stations 2 through 4 during the 2021 Neches River survey.

		Non-Insect Macroinvertebrates			Station		
					2	3	4
Phylum Annelida	Subclass Oligochaeta	Order Lumbriculida		Lumbriculidae sp. 5		+	
Phylum Mollusca				*Rangia sp.**			+
				Crassostrea virginica			+
				Ferrissia californica	+		
				Planorbella trivolvis			+
Phylum Arthropoda		Order Collembola		*Semicerura sp.*			+
Subphylum Crustacea		Order Balanomorpha	Family Balanidae	*Amphibalanus subalbidus*		+	
		Order Amphipoda	Family Gammaridae	*Gammarus mucronatus*	+		
				Gammarus tigrinis	+		
				Gammaridae sp.*		+	
			Family Corophiidae	*Paracorophium sp.*	+		
			Family Talitridae	*Speziorchestia grillus*		+	
				Platorchestia platensis			+
				Orchestia sp.			+
				Talitroides sp.		+	
			Family Melitidae	Melitidae sp.		+	
		Order Decapoda	Family Palaemonidae	*Palaemon pugio*	+	+	+
				Palaemon intermedius			+
			Family Penaeidae	*Xiphopenaeus kroyeri*	+		
			Family Panopeidae	*Panopeus obesus*	+		
			Family Sesarmidae	*Armases cinereum*			+
		Order Mysida	Family Mysidae*		+		
		Insects					
		Order Odonata	Family Coenagrionidae	*Enallagma sp.*	+		
				Hesperagrion heterodoxum	+		
				Leptobasis sp.	+		
				Nehalennia sp.	+		
		Order Ephemeroptera	Family Baetidae	*Callibaetis sp.*	+		
		Order Hemiptera	Family Gerridae	*Rheumatobates sp.*	+		
			Family Veliidae	*Platyvelia sp.*	+		
			Family Belostomatidae	*Belostoma sp.*	+		

Only three of the 122 taxa collected in the Neches River ranged across all stations. These were the Atlantic rangia, Ohio shrimp and one species of whirligig beetle, *Gyrinus minutus.* Atlantic rangia (estuarine) and Ohio shrimp (brackish) are typically found throughout the lower Neches River and are tolerant of a wide range of salinities, while the whirligig beetle is a common freshwater species. *Rangia* clams were common to abundant, found most often in the sandy areas accessible at lower tides. Thousands of individuals of Ohio shrimp were observed or collected, most often caught in seine and otter trawls. The beetles were abundant at every station and found primarily in large congregations swimming on the surface of the water.

These examinations and comparisons of species richness and abundance at each station indicate a strong response of the benthic community to a gradient of salinity extending from freshwater Stations 0 and 1 to brackish water Stations 2, 3 and 4. The findings also correlate to stations where there is city, residential and/or industrial development. This demonstrates that in the Neches River, biodiversity is at its highest in areas of the river where salinity and development are at their lowest.

Figure 4.11: Danielle Odom (back left) and Tanya Dapkey (front right) scraping woody debris for macroinvertebrates at Station 1.

Historical Comparisons Among Surveys

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 fall 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.

Comparisons among the five major Academy surveys (2021, 2003, 1996, 1973 and 1953) and the two cursory surveys (1956 and 1960) 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 in 2021 was similar to 2003, 1973 and 1953, with the exception of a large storm in May (Figure 1.4).

In most years, Academy surveys have found that Stations 0 and 1 are freshwater, while Stations 2 through 4 are brackish (see section 2. Environmental Geochemistry). However, in 1996, due to a drought, higher salinity waters extended further upstream than usual, resulting in brackish water at Station 1, depending upon depth.

The 122 taxa of macroinvertebrates collected in the October 2021 survey is similar to 2003 (119), but represents a substantial increase from older surveys, even when considering that a station was added in 2021 (Table 4.5). Differences in species totals between 2003 and 1996 reflect variations in salinity patterns in the river. The

Figure 4.12: Jason Watson (left), Mike Foster (center) and Mariena Hurley (right) looking for macroinvertebrates and algae.

Figure 4.13: Belostomatidae (giant water bug) nymph found at Station 2.

differences between the 1996, 2003 and 2021 surveys and the earlier surveys of 1953, 1956 and 1960 and 1973 indicate improvements in water quality in the lower Neches River.

Figure 4.14 shows the four major macroinvertebrate groups found in the Neches: Annelida (worms), Mollusca (bivalves and gastropods), arthropods (crabs, shrimps), and insects. Low numbers of macroinvertebrates found in 1953, 1973 and 1996 compared to the 2003 and 2021 surveys, suggest improvements in water quality. Across all surveys, most species of insects are found at Stations 0 and 1, reinforcing that those stations typically consist of freshwater.

Table 4.5: Number of insect vs. non-insect macroinvertebrate species from all five major surveys.

	Non-Insects	Insects	Total
1953	16	7	23
1973	21	32	53
1996	44	14	58
2003	52	67	119
2021	63	59	122

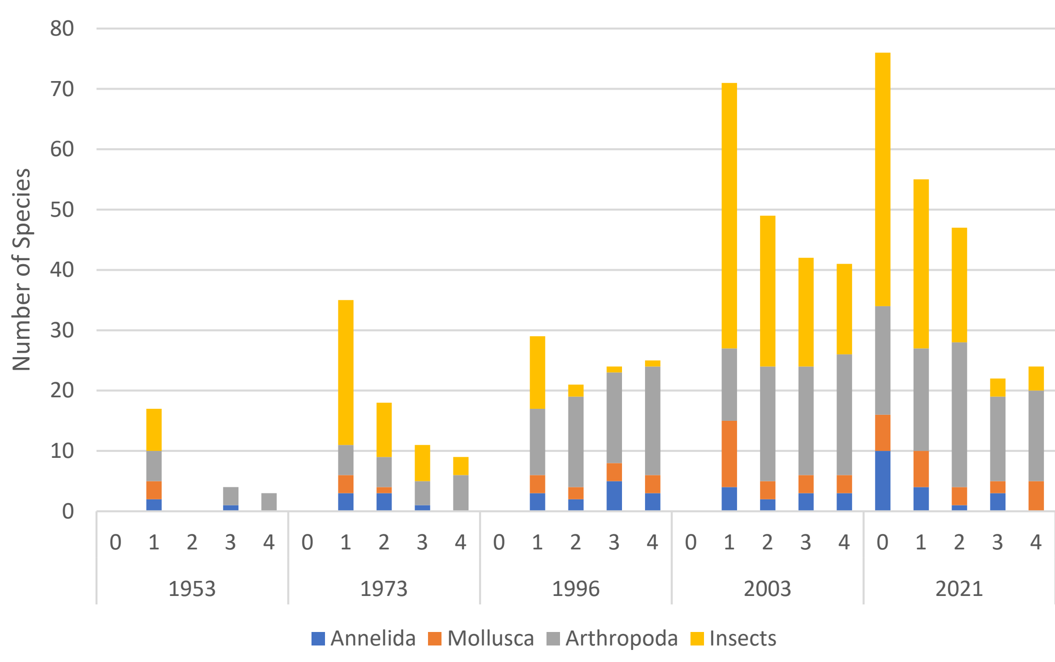

Figure 4.14: Species diversity of the four major macroinvertebrate groups in the Neches River for five Academy surveys over a period of 68 years.

Historical patterns in insects

A comparison of the species composition among the years generally shows a trend towards greater number of insect species over time (Table 4.5, Figure 4.15). 2021 did see fewer insect species than 2003, but not substantially different. 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 (Figure 1.4). Influxes of freshwaters escalate insect drift rates and lower salinity regimes are 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. Between 2003 and 2021, numbers of insect species decreased at nearly every station, but the addition of Station 0 in 2021 kept the total number of insect species similar to 2003. Changes in the number of insect species between 2003, 1973 and 1953 suggest improvements in water quality.

Comparing the number of insect species between Station 1 and Stations 2 through 4 reveals a significant decrease; this reduction is a common pattern found in all major surveys except 1953 (no insects were collected at the three downriver stations). This pattern of more insects at Station 1 (and now Station 0 as well) strongly influences the higher numbers of macroinvertebrate species at Station 1 that is found among all surveys (Figure 4.14). Stations 0 and 1 represent 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.

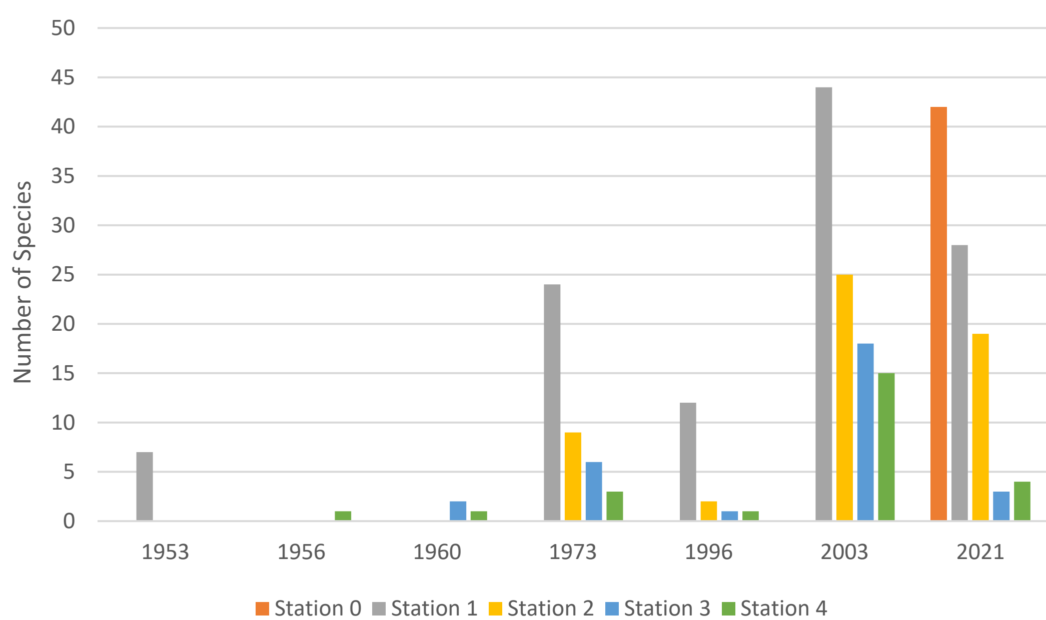

Figure 4.15: Insect species found at every station during all Academy Neches River surveys.

Historical patterns in non-insect macroinvertebrates

Unlike the insect fauna, no strong difference in the number of non-insect macroinvertebrate species was recorded in 2021 and 2003 among Stations 1 through 4 (2021: 25, 25, 18 and 17 species at Stations 1 through 4, respectively; 2003: 28, 23, 23 and 26 species at Stations 1 through 4, respectively). Similar species numbers were also evident among stations in 1996, with a slight increase in richness 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). Salinity concentrations at the three downriver stations characterized the shallow waters as brackish in 1996, 2003 and 2021. The more brackish waters in 1996 resulted in the presence of species at one or more of the downriver stations not found in 2003 or 2021, including jellyfishes, several shrimps and an ectoproct (see Appendix C.2). 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 higher 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 the pattern observed during 1996, 2003 and 2021 surveys 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.

Figures 4.17, 4.18 and 4.19 show all non-insect species found at all stations for every Academy survey conducted since 1953. Over the years, species numbers for all three groups (annelids, mollusks and arthropods) increases, as does the number of species in Station 1. The number of arthropod species is most diverse at Station 2 through 4 (Figure 4.19).

Figure 4.16: Crab found at Station 2.

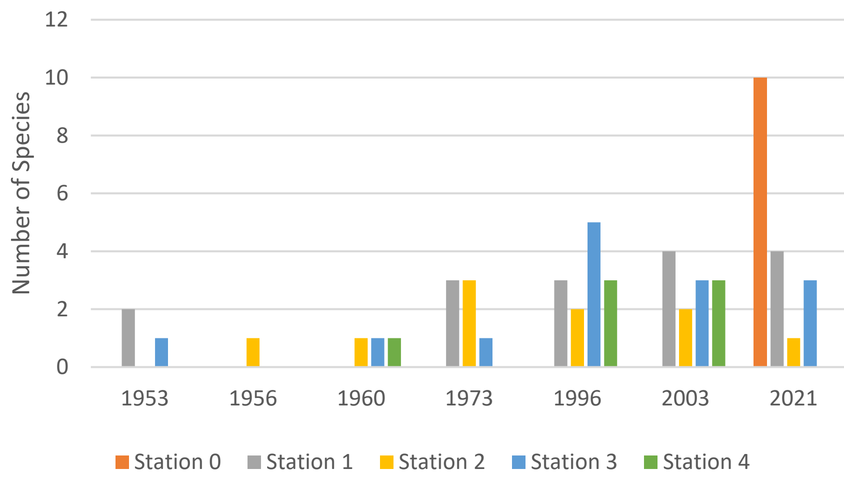

Figure 4.17: Annelida species found at every station during all the Academy Neches River surveys.

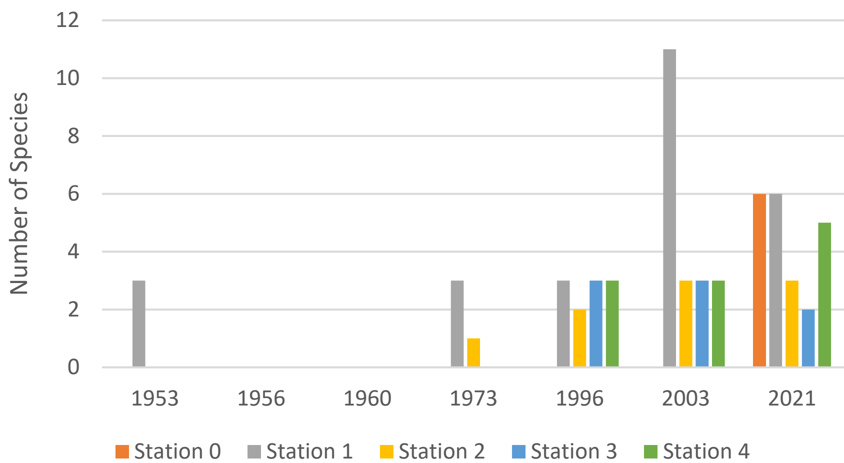

Figure 4.18: Mollusca species found at every station during all the Academy Neches River surveys.

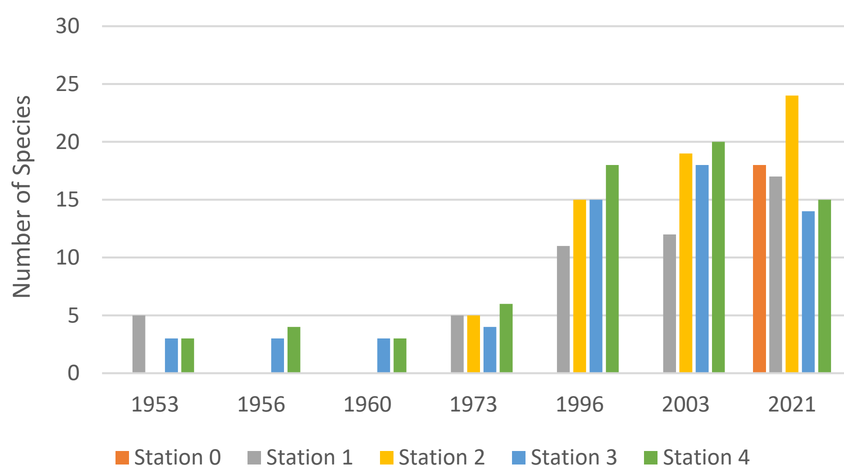

Figure 4.19: Arthropod species found at every station during all the Academy Neches River surveys.

Historical comparisons among Stations

At Station 1 in 2021, fewer species were collected than in 2003. 2021 had 49 total species, (25 non-insects and 24 insects), while 2003 had 66 species of macroinvertebrates (28 non-insects/38 insects). 2003 species counts are roughly double what was collected in 1996 (32 species: 20 non-insects/12 insects). Because 1996 was a drought year, and as such, the number of non-insect species (which were thriving as tidally influenced brackish water made its way further upstream), is a better comparative measure of differences in the macroinvertebrate fauna between these years: there were 28 species in 2003 and 20 in 1996. Freshwater discharges are responsible for slightly more than three times as many species of insects recorded in 2003 (38) versus 1996 (12). The 23 species of insects in 1973 is more than three times the number that appeared in the 1953 survey (7) which indicates an improvement in water quality, as insects are a pollution-sensitive taxon.

In 2021, the Station 2 macroinvertebrate fauna was nearly the same as 2003 (Appendix C.2). Differences in the Station 2 fauna between the recent surveys (2021 and 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 5 survey years shows a steady improvement from 1953 through 2003 and 2021 (1953–0, 1973–10, 1996–22, 2003-23 and 2021–25). The insect biota among the five survey years showed marked changes between 2021, 2003 and 1996 (18 species in 2021, 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 captured by the 1996 survey and improvements in water quality from 1953 to 1973, and more pronounced improvement between 1973 and recent surveys of 2003 and 2021.

In 2021, only 20 species of macroinvertebrates were collected at Station 3 – half of what was collected in 2003. In 2003, 40 species of macroinvertebrates were collected at Station 3, including 23 taxa of non-insects and 17 insect species. The drop in species in 2021 could indicate environmental disturbance. In 2003, the salinity at Station 3 was 0.56 ppt, but in 2021 the salinity jumped to 1.76 ppt. This could be a temporary increase from a storm event or a saltwater intrusion. It is difficult to discern the cause without additional or more frequent sampling. Overall, differences observed over the survey years are most likely the result of salinity fluctuations and improvements in water quality from 1953 to 2021.

Station 4 saw a similar drop in the number of macroinvertebrates compared to 2003. Twenty-two total macroinvertebrates species were found, 17 non-insects and 4 insects. Salinity was also significantly higher than in 2003, with an average value of 3.07 ppt compared to 1.29 ppt (over twice what it was the previous survey). The total number of species in 2003 (41 species) represents a steady increase from the 4 species in 1953, 9 in 1973 and 30 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 (1, 2 and 3), the 2003 results also reflect changes in the insect fauna from 2021, 2003 and 1996 (4, 15 and 2 insect species, respectively) compared to 1973 and 1953 (3 and 0 species). Contrasts among these years are a result of salinity pattern differences and slight to significant improvement in water quality between 1953 and 1973 and between 1973 and 2003, respectively.

Collectively, across all survey years,, improvement in water quality of the lower Neches River can be seen in the macroinvertebrate community between 1953 and 1973 and more substantially between 1973 and the recent surveys of 1996, 2003, and 2021.

5. FISH

Abstract

1. The saltwater barrier, its operation, and changing seasonal weather patterns are major factors influencing discharge and water quality characteristics in the estuary. When there are extended low flows in the Neches River, salinity below the barrier increases, and dissolved organic matter from local industry may accumulate. Furthermore, drought conditions in the Neches River estuary may negatively affect biotic communities by favoring species tolerant of low dissolved oxygen, high concentrations of dissolved organic compounds, and saline conditions below the saltwater barrier. Additionally, in the Neches River estuary, salinity concentrations are dynamic and range from freshwater to brackish/polyhaline water, and can be a major determinant of fish distribution. Differences in fish assemblages and individual species densities are often used as indicators of water quality and pollution. For example, fish may respond to low dissolved oxygen caused by pollution by leaving the affected area, thus resulting in lowered densities for that area. There may also be natural causes for lowered densities (e.g., seasonal movements).
2. We used a benthic otter trawl to sample bottom channel habitats and a bag seine to sample shoreline habitats. Seines were pulled along the inner and outer bends of the river, in areas with sand or sand/silt/detritus substrate. Analysis of covariance (ANCOVA) was used to assess spatial differences in the abundance of the more common individuals collected by trawling and seining. Canonical correspondence analysis (CCA) was used to assess spatial differences in the fish community and to characterize important environmental gradients. Additional qualitative samples were collected to characterize site richness but were not used in statistical analyses.
3. In 2021, we found that differences were largely related to an estuarine gradient. Along this gradient, Stations 0 and 1 consisted of freshwater and Stations 2, 3, and 4 consisted of brackish water. CCAs showed fish assemblages to be more similar according to these freshwater and brackish water station groupings. Individual species differences also followed this pattern, with freshwater obligates generally having significantly higher abundances in freshwater Stations 0 and 1, as opposed to 2, 3 and 4. Bay Anchovy was the only species with significantly lower abundances in shoreline samples at Stations 2 and 3 that did not appear to be related to the estuarine gradient. However, in bottom habitats assessed by trawling, Bay Anchovy abundance was not significantly different among stations.
4. Our study was conducted during a year of typical discharge and found the fish assemblages and species abundances to be similar among Stations 0 and 1. Stations 0 and 1 were similar in fish community structure and there were no consistent patterns in the abundance of species that would indicate a difference due to the saltwater barrier at the time of our survey. Lower in the estuary, Stations 2, 3 and 4 had similar salinities and depths. Fish assemblages among these stations were similar, indicating no differences due to industrial inputs or management. Historically, Stations 2 and 3 have received the greatest impact from, and are in closest proximity to, the region's industry. The decreased abundance of Bay Anchovy in shoreline samples at Stations 2 and 3 may reflect increased industrial inputs/anthropogenic effects at these stations, or natural variation. It is difficult to discern the driving factor for these decreased abundances without additional sampling.

5.1 Introduction

The 2021 fish survey of selected portions of the Lower Neches River was the seventh in a series of Academy studies since 1953. Comprehensive surveys, during which collections were made at Stations 1 to 4, were conducted during 1953, 1973, 1996 and 2003. Cursory surveys of only Stations 2, 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 over this time (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1974, ANSP 1998, ANSP 2006).

The main goals of the 2021 survey were to 1) determine the occurrence and abundance of fishes in bottom and shoreline habitats, 2) assess spatial differences in the fish community among five stations, and 3) compare the findings of this survey to historical Academy surveys.

5.2 Methods

Fish Data Collection

Bottom habitats were sampled using a 3.7-m (12-ft) benthic otter trawl with a 0.32-cm (0.125-in) mesh inner liner. Trawls were towed in an upstream direction for typically 5 minutes and at a speed of 2.5-3 knots. Trawl catch per unit effort (CPUE) was standardized as the number of fish per 5 minutes of trawling. Shoreline 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. Seines were pulled along inner and outer bends of the river, in areas with sand or sand/silt/detritus substrate, and in approximately equal numbers for each bend type (i.e., inner and outer). 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 along 20-m of shoreline and was typically pulled in a downstream direction with the flow. Seine CPUE was standardized as the number of fish per seine haul. In one station, 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. No extra weight was attached to this seine and this sample was used for qualitative purposes. Additional qualitative samples were also collected with a fine mesh dip net in conjunction with the macroinvertebrate sampling. Correspondingly, macroinvertebrates collected during seining and trawling were included in the macroinvertebrate assessment (see section 4. Macroinvertebrates). Associated temperature (°C), salinity (ppt), dissolved oxygen (mg/L) and pH were taken at the surface (0.5 m depth) and at depth of the individual trawls, and at the surface during seining using a Yellow Springs Instruments ProPlus multimeter.

All fish collected were identified, enumerated, and either released in the field or preserved with 10% buffered formalin for subsequent laboratory identification. Released fish were measured in total length to the nearest millimeter. In the Academy 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. Selected fish were measured in total lengths to the nearest millimeter. Size ranges were measured for some of the more common species.

Texas Parks and Wildlife Department (TPWD) Data

Bag seine data from Sabine Sampling Grids 298 and 306 for the period 2003-2021 were acquired from Mark Fisher of TPWD (Appendix D.1). TPWD sampled shoreline habitats with an 18.3-m x 1.8-m (60-ft x 6-ft) bag seine with 1.3-cm (0.5-in) mesh. Seine CPUE was standardized as the number of fish per 0.03 hectares (300 m^2). The TPWD standardized 0.03-hectare sample area was sampled over the course of one day.

Multiple samples taken during the fall (September, October and November) were averaged to calculate CPUE for assessing annual trends at each sampling grid.

Nomenclature and Archival

All fish were identified using standard references. The common and scientific names of fishes used were consistent with Page et al. (2013) and selected fish specimens were curated into the permanent fish collection of the Academy of Natural Sciences. For historical comparisons, species identifications were taken from reports of the previous surveys (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1974, ANSP 1998 and ANSP 2006). Some names are changed because of taxonomic revisions of the groups. Specifically, since the 2003 survey, the genera of some species changed, including Hardhead Catfish, *Arius felis* to *Ariopsis felis*; Darter Goby, *Gobionellus boleosoma* to *Ctenogobius boleosoma*; and Freshwater Goby, *Gobionellus shufeldti* to *Ctenogobius shufeldti*.

Data Analysis

Analysis of covariance (ANCOVA) was used to assess differences in the abundance of the more common individuals collected by trawling and seining. Additionally, canonical correspondence analysis (CCA) was used to assess spatial differences in the fish community and to characterize important environmental gradients (e.g., species association to salinity). All CCAs were performed in CANOCO (version 5; ter Braak and Smilauer 2012). All data were transformed to improve normality of the data (logarithm, square-root and logit transforms were used as appropriate). An alpha of 0.05 was used for all analyses.

5.3 Results

Overall

Across Stations 0, 1, 2, 3 and 4, 38 seine samples were taken in shoreline habitats and 29 trawl samples were taken in bottom habitats to quantify fish densities and to characterize fish assemblages. Additional qualitative samples were taken with a 50-ft seine (one sample of 100 meters of shoreline at Station 2), by trawling (one sample at Station 3 that became entangled on the bottom), and by dip netting (one at each station by the macroinvertebrate team). Over all samples (quantitative and qualitative), 18,292 individuals and 66 species were collected (Table 5.1). A total of 19 species were collected by dip netting (Table 5.2). A total of 54 species were collected by seining and 29 species were collected by trawling to determine densities (these data do not include qualitative samples; Tables 5.3 and 5.4).

Table 5.1: Common name, scientific name, and abbreviation of fishes caught in 2021 Neches River survey. N= total number collected by all techniques.

Family	Scientific Name	Common Name	Abbreviation	N
Achiridae	*Trinectes maculatus*	Hogchoker	TRMAC	771
Atherinopsidae	*Labidesthes sicculus*	Brook Silverside	LASIC	14
	Membras martinica	Rough Silverside	MEMAR	31
	Menidia beryllina	Inland Silverside	MEBER	253
Belonidae	*Strongylura marina*	Atlantic Needlefish	STMAR	1
Catostomidae	*Ictiobus bubalus*	Smallmouth Buffalo	ICBUB	1
	Moxostoma poecilurum	Blacktail Redhorse	MOPOE	1
Centrarchidae	*Lepomis macrochirus*	Bluegill	LEMAC	4
	Lepomis megalotis	Longear Sunfish	LEMEG	195
	Lepomis microlophus	Redear Sunfish	LEMIC	33
	Lepomis miniatus	Redspotted Sunfish	LEMIN	33
	Micropterus punctulatus	Spotted Bass	MIPUN	19
	Micropterus salmoides	Largemouth Bass	MISAL	7
	Pomoxis nigromaculatus	Black Crappie	PONIG	1
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	DOCEP	6
	Dorosoma petenense	Threadfin Shad	DOPET	3
Cynoglossidae	*Symphurus plagiusa*	Blackcheek Tonguefish	SYPLA	1
Cyprinidae	*Cyprinella lutrensis*	Red Shiner	CYLUT	7
	Cyprinella venusta	Blacktail Shiner	CYVEN	1562
	Hybopsis amnis	Pallid Shiner	HYAMN	25
	Lythrurus fumeus	Ribbon Shiner	LYFUM	384
	Macrhybopsis hyostoma	Shoal Chub	MAHYO	167
	Notropis texanus	Weed Shiner	NOTEX	691
	Notropis volucellus	Mimic Shiner	NOVOL	15
	Opsopoeodus emiliae	Pugnose Minnow	OPEMI	9
	Pimephales vigilax	Bullhead Minnow	PIVIG	918
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead Minnow	CYVAR	1
	Lucania parva	Rainwater Killifish	LUPAR	35
Dasyatidae	*Dasyatis sabina*	Atlantic Stingray	DASAB	1
Eleotridae	*Dormitator maculatus*	Fat Sleeper	DOMAC	19
	Eleotris amblyopsis	Largescaled Spinycheek Sleeper	ELAMB	1
Engraulidae	*Anchoa mitchilli*	Bay Anchovy	ANMIT	11381
Fundulidae	*Fundulus chrysotus*	Golden Topminnow	FUCHR	3
	Fundulus grandis	Gulf Killifish	FUGRA	7
	Fundulus jenkinsi	Saltmarsh Topminnow	FUJEN	1
	Fundulus notatus	Blackstripe Topminnow	FUNOTA	148
	Fundulus pulvereus	Bayou Killifish	FUPUL	1
Gobiidae	*Ctenogobius boleosoma*	Darter Goby	GOBOL	29
	Ctenogobius shufeldti	Freshwater Goby	GOSHU	21
	Gobioides broussonetii	Violet Goby	GOBRO	6
	Gobionellus oceanicus	Highfin Goby	GOOCE	1
	Gobiosoma bosc	Naked Goby	GOBOS	3
	Microgobius gulosus	Clown Goby	MIGUL	7
Ictaluridae	*Ictalurus furcatus*	Blue Catfish	ICFUR	487
	Ictalurus punctatus	Channel Catfish	ICPUN	457
Lepisosteidae	*Atractosteus spatula*	Alligator Gar	ATSPA	1
	Lepisosteus oculatus	Spotted Gar	LEOCU	2

Table 5.1 (continued): Common name, scientific name, and abbreviation of fishes caught in 2021 Neches River survey. N= total number collected by all techniques.

Family	Scientific Name	Common Name	Abbreviation	N
Mugilidae	*Mugil cephalus*	Striped Mullet	MUCEP	9
Paralichthyidae	*Citharichthys spilopterus*	Bay Whiff	CISPI	13
Percidae	*Ammocrypta vivax*	Scaly Sand Darter	AMVIV	13
	Etheostoma chlorosoma	Bluntnose Darter	ETCHL	15
	Etheostoma proeliare	Cypress Darter	ETPRO	1
	Percina sciera	Dusky Darter	PESCI	3
Poeciliidae	*Gambusia affinis*	western Mosquitofish	GAAFF	307
	Heterandria Formosa	Least Killifish	HEFOR	3
	Poecilia latipinna	Sailfin Molly	POLAT	5
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum	APGRU	37
	Cynoscion arenarius	Sand Seatrout	CYARE	46
	Cynoscion nebulosus	Spotted Seatrout	CYNEB	6
	Cynoscion species	Seatrout species	CYNOSCION	1
	Leiostomus xanthurus	Spot	LEXAN	9
	Menticirrhus littoralis	Gulf Kingfish	MELIT	1
	Micropogonias undulatus	Atlantic Croaker	MIUND	31
	Stellifer lanceolatus	Star Drum	STLAN	4
Sparidae	*Archosargus probatocephalus*	Sheepshead	ARPRO	2
	Lagodon rhomboides	Pinfish	LARHO	2
Sygnathidae	*Syngnathus scovelli*	Gulf Pipefish	SYSCO	20

Table 5.2: Total numbers of fish species collected as bycatch while conducting macroinvertebrate sampling by dip netting. See Section 4. Macroinvertebrates section for methods. There was no bycatch of fish at Station 3.

Scientific Name	Common Name	Station			
		0	1	2	4
Anchoa mitchilli	Bay Anchovy	1	7	12	3
Ctenogobius boleosoma	Darter Goby				1
Cynoscion arenarius	Sand Seatrout				1
Cyprinella venusta	Blacktail Shiner	9	6		
Dormitator maculatus	Fat Sleeper		2	2	
Fundulus chrysotus	Golden Topminnow			1	
Fundulus grandis	Gulf Killifish				1
Fundulus notatus	Blackstripe Topminnow	3	1		
Fundulus pulvereus	Bayou Killifish			1	
Gambusia affinis	western Mosquitofish	1	2	8	3
Heterandria formosa	Least Killifish	3			
Lepomis megalotis	Longear Sunfish			6	
Lepomis microlophus	Redear Sunfish			1	
Lepomis miniatus	Redspotted Sunfish	1	2	1	
Lucania parva	Rainwater Killifish			2	
Lythrurus fumeus	Ribbon Shiner	4	1		
Menidia beryllina	Inland Silverside			1	
Poecilia latipinna	Sailfin Molly			3	2
Syngnathus scovelli	Gulf Pipefish			1	

Table 5.3: Mean catch per unit effort (CPUE; number caught per 20 m of shoreline) and standard deviation (SD) of fish species collected with a 20 ft bag seine during the 2021 Neches River survey. The number of samples per station are given in parentheses.

Scientific Name	Common Name	Station									
		0 (N=7)		1 (N=7)		2 (N=8)		3 (N=8)		4 (N=8)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocrypta vivax	Scaly Sand Darter	0.00	0.00	1.71	2.93	0.00	0.00	0.00	0.00	0.00	0.00
Anchoa mitchilli	Bay Anchovy	178.00	184.94	343.57	180.11	23.88	22.62	160.50	436.00	610.13	1289.77
Atractosteus spatula	Alligator Gar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.35
Citharichthys spilopterus	Bay Whiff	0.00	0.00	0.00	0.00	0.38	0.74	0.00	0.00	0.13	0.35
Ctenogobius boleosoma	Darter Goby	0.00	0.00	0.00	0.00	1.00	1.60	0.50	0.53	1.38	2.50
Ctenogobius shufeldti	Freshwater Goby	0.00	0.00	0.43	0.53	0.00	0.00	0.00	0.00	0.00	0.00
Cynoscion arenarius	Sand Seatrout	0.00	0.00	0.00	0.00	0.13	0.35	0.75	0.71	1.50	2.39
Cynoscion nebulosus	Spotted Seatrout	0.00	0.00	0.00	0.00	0.38	0.74	0.13	0.35	0.25	0.46
Cyprinella lutrensis	Red Shiner	0.57	1.13	0.43	0.79	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinella venusta	Blacktail Shiner	68.43	98.76	152.00	126.09	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinodon variegatus	Sheepshead Minnow	0.00	0.00	0.00	0.00	0.13	0.35	0.00	0.00	0.00	0.00
Dasyatis sabina	Atlantic Stingray	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.35	0.00	0.00
Dormitator maculatus	Fat Sleeper	0.00	0.00	0.00	0.00	1.88	4.16	0.00	0.00	0.00	0.00
Dorosoma cepedianum	Gizzard Shad	0.29	0.76	0.43	1.13	0.00	0.00	0.00	0.00	0.00	0.00
Dorosoma petenense	Threadfin Shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.71
Eleotris amblyopsis	Largescaled Spinycheek Sleeper	0.00	0.00	0.00	0.00	0.13	0.35	0.00	0.00	0.00	0.00
Etheostoma chlorosoma	Bluntnose Darter	1.14	1.77	1.00	1.41	0.00	0.00	0.00	0.00	0.00	0.00
Etheostoma proeliare	Cypress Darter	0.14	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fundulus chrysotus	Golden Topminnow	0.00	0.00	0.00	0.00	0.25	0.46	0.00	0.00	0.00	0.00
Fundulus grandis	Gulf Killifish	0.00	0.00	0.00	0.00	0.50	1.07	0.00	0.00	0.25	0.46
Fundulus jenkinsi	Saltmarsh Topminnow	0.00	0.00	0.00	0.00	0.13	0.35	0.00	0.00	0.00	0.00
Fundulus notatus	Blackstripe Topminnow	15.71	15.64	4.86	7.06	0.00	0.00	0.00	0.00	0.00	0.00
Gambusia affinis	western Mosquitofish	16.29	22.01	17.43	23.65	6.38	10.08	0.50	0.76	0.13	0.35
Gobioides broussonetii	Violet Goby	0.14	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gobiosoma bosc	Naked Goby	0.00	0.00	0.00	0.00	0.25	0.46	0.13	0.35	0.00	0.00
Hybopsis amnis	Pallid Shiner	2.00	3.21	0.43	0.79	0.00	0.00	0.00	0.00	0.00	0.00
Ictalurus furcatus	Blue Catfish	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.07	0.00	0.00
Ictalurus punctatus	Channel Catfish	0.00	0.00	0.14	0.38	0.00	0.00	4.00	4.04	0.13	0.35
Labidesthes sicculus	Brook Silverside	1.43	2.94	0.43	0.79	0.00	0.00	0.00	0.00	0.00	0.00
Lagodon rhomboides	Pinfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.35
Leiostomus xanthurus	Spot	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.76	0.13	0.35
Lepisosteus oculatus	Spotted Gar	0.00	0.00	0.14	0.38	0.13	0.35	0.00	0.00	0.00	0.00
Lepomis macrochirus	Bluegill	0.00	0.00	0.57	1.13	0.00	0.00	0.00	0.00	0.00	0.00
Lepomis megalotis	Longear Sunfish	13.86	16.79	7.57	7.28	3.63	9.10	0.00	0.00	0.00	0.00
Lepomis microlophus	Redear Sunfish	0.71	1.25	0.86	1.57	2.50	4.66	0.00	0.00	0.00	0.00
Lepomis miniatus	Redspotted Sunfish	1.00	1.41	0.00	0.00	2.50	4.38	0.13	0.35	0.00	0.00
Lucania parva	Rainwater Killifish	0.00	0.00	0.00	0.00	4.13	8.56	0.00	0.00	0.00	0.00
Lythrurus fumeus	Ribbon Shiner	44.57	52.47	9.57	20.07	0.00	0.00	0.00	0.00	0.00	0.00
Membras martinica	Rough Silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.71	3.63	7.13
Menidia beryllina	Inland Silverside	0.00	0.00	0.00	0.00	4.00	3.55	4.50	5.73	23.00	32.34
Menticirrhus littoralis	Gulf Kingfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.35
Microgobius gulosus	Clown Goby	0.00	0.00	0.00	0.00	0.75	2.12	0.00	0.00	0.00	0.00
Micropogonias undulatus	Atlantic Croaker	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.46	0.00	0.00
Micropterus punctulatus	Spotted Bass	0.86	1.07	1.57	1.13	0.13	0.35	0.00	0.00	0.00	0.00
Micropterus salmoides	Largemouth Bass	0.14	0.38	0.71	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Moxostoma poecilurum	Blacktail Redhorse	0.00	0.00	0.14	0.38	0.00	0.00	0.00	0.00	0.00	0.00
Notropis texanus	Weed Shiner	38.71	39.44	59.86	95.51	0.00	0.00	0.00	0.00	0.00	0.00
Opsopoeodus emiliae	Pugnose Minnow	0.86	1.46	0.43	0.79	0.00	0.00	0.00	0.00	0.00	0.00
Percina sciera	Dusky Darter	0.29	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pimephales vigilax	Bullhead Minnow	80.71	87.06	40.71	24.20	0.00	0.00	0.00	0.00	0.00	0.00
Pomoxis nigromaculatus	Black Crappie	0.00	0.00	0.14	0.38	0.00	0.00	0.00	0.00	0.00	0.00
Symphurus plagiusa	Blackcheek Tonguefish	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.35	0.00	0.00
Syngnathus scovelli	Gulf Pipefish	0.00	0.00	0.00	0.00	2.00	5.26	0.38	0.52	0.00	0.00
Trinectes maculatus	Hogchoker	4.00	6.51	1.71	2.75	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.4: Mean catch per unit effort (CPUE; number caught per 5 min of trawling) and standard deviation (SD) of fish species collected with a 3.7 m benthic otter trawl during the 2021 Neches River survey. The number of samples per station are given in parentheses.

Scientific Name	Common Name	Station 0 (N=6) Mean	SD	1 (N=5) Mean	SD	2 (N=6) Mean	SD	3 (N=6) Mean	SD	4 (N=6) Mean	SD
Ammocrypta vivax	Scaly Sand Darter	0.00	0.00	0.20	0.45	0.00	0.00	0.00	0.00	0.00	0.00
Anchoa mitchilli	Bay Anchovy	19.50	47.77	14.00	25.14	1.83	1.72	25.00	48.10	162.00	312.98
Aplodinotus grunniens	Freshwater Drum	4.45	10.42	2.46	2.29	0.00	0.00	0.00	0.00	0.00	0.00
Archosargus probatocephalus	Sheepshead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.82
Citharichthys spilopterus	Bay Whiff	0.00	0.00	0.00	0.00	0.17	0.41	0.17	0.41	0.83	0.75
Ctenogobius boleosoma	Darter Goby	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.82	0.33	0.52
Ctenogobius shufeldti	Freshwater Goby	0.00	0.00	3.40	4.77	0.00	0.00	0.00	0.00	0.00	0.00
Cynoscion arenarius	Sand Seatrout	0.00	0.00	0.20	0.45	0.67	0.52	1.50	1.76	1.83	2.64
Cynoscion species	Seatrout species	0.00	0.00	0.00	0.00	0.17	0.41	0.00	0.00	0.00	0.00
Dorosoma cepedianum	Gizzard Shad	0.17	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dorosoma petenense	Threadfin Shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.41
Gobioides broussonetii	Violet Goby	0.00	0.00	1.09	1.24	0.00	0.00	0.00	0.00	0.00	0.00
Gobionellus oceanicus	Highfin Goby	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.41	0.00	0.00
Hybopsis amnis	Pallid Shiner	0.67	1.63	0.80	1.10	0.00	0.00	0.00	0.00	0.00	0.00
Ictalurus furcatus	Blue Catfish	22.26	26.69	53.07	32.45	9.00	17.41	5.50	10.43	0.33	0.52
Ictalurus punctatus	Channel Catfish	28.48	45.67	38.80	45.45	1.50	3.67	8.83	13.83	0.00	0.00
Ictiobus bubalus	Smallmouth Buffalo	0.00	0.00	0.20	0.45	0.00	0.00	0.00	0.00	0.00	0.00
Leiostomus xanthurus	Spot	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.82	0.33	0.82
Lepomis megalotis	Longear Sunfish	0.00	0.00	2.00	4.47	0.00	0.00	0.00	0.00	0.00	0.00
Lepomis microlophus	Redear Sunfish	0.17	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macrhybopsis hyostoma	Shoal Chub	3.05	4.70	29.40	47.44	0.00	0.00	0.00	0.00	0.00	0.00
Micropogonias undulatus	Atlantic Croaker	0.00	0.00	0.00	0.00	0.67	1.21	1.67	2.66	0.67	0.82
Micropterus punctulatus	Spotted Bass	0.17	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Micropterus salmoides	Largemouth Bass	0.00	0.00	0.20	0.45	0.00	0.00	0.00	0.00	0.00	0.00
Notropis texanus	Weed Shiner	0.17	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Notropis volucellus	Mimic Shiner	2.50	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percina sciera	Dusky Darter	0.00	0.00	0.20	0.45	0.00	0.00	0.00	0.00	0.00	0.00
Pimephales vigilax	Bullhead Minnow	6.00	14.70	6.40	12.70	0.00	0.00	0.00	0.00	0.00	0.00
Stellifer lanceolatus	Star Drum	0.00	0.00	0.00	0.00	0.17	0.41	0.00	0.00	0.50	1.22
Trinectes maculatus	Hogchoker	56.38	63.59	75.78	102.87	0.17	0.41	0.50	0.55	0.00	0.00

Figure 5.1: Fisheries team retrieving the net at the end of a trawl sample.

Water Quality and Depth Measurements

Water quality parameters and depth were measured during sampling to account for the variation in the fish assemblage that may be due to these parameters, allowing for a better understanding of the variation in fish assemblages due to stations alone (Table 5.5). Trawling depth was not significantly different among stations. However, all water quality parameters were found to have at least one significant difference among stations. Salinity and specific conductance were significantly lower at Station 0 and 1 than at Stations 2, 3 and 4. The pH was significantly lower at Station 0 than Stations, 1, 2, 3 and 4. Water temperature showed a decreasing trend with upstream position. Specifically, water temperature was significantly lower at Station 0 than Stations 2, 3 and 4. Additionally, water temperatures at Stations 0 and 1 were not significantly different; nor were Stations 1 and 2 significantly different from each other. Dissolved oxygen at Station 1 was significantly greater than Station 2. There were no other significant differences in dissolved oxygen among stations. Water quality data collected while seining showed a similar pattern but were not statistically analyzed due to a low number of unique measurements (i.e., one water quality measurement was assigned to adjacent seine samples if they were a few meters apart). Overall, water quality measurements used to assess the fish assemblage generally reflected an estuarine gradient of saltier and warmer waters lower in the estuary, and freshwaters of cooler temperature in the upper estuary.

Table 5.5: Summary of water quality and depth measurements associated with fish trawl and seine sampling in the 2021 Neches River survey. Sample depth refers to the typical depth in which a sample was taken. Mean values are shown except for maximum (max) and mini minimum (min) sample depth measures. Water quality measurements associated with trawling were taken approximately 0.50 m from the bottom. Measures associated with seining were taken approximately 0.30 m below the surface. N = number of unique measurements.

Technique	Station	Sample Depth (m)	Max Sample Depth (m)	Min Sample Depth (m)	D.O. (mg/L)	D.O. (%)	Salinity (ppt)	Specific Cond. (µS/cm)	pH	Water Temp. (°C)	N
Trawling	0	5.9	7.9	3.1	4.42	53.10	0.04	92	6.46	24.42	6
	1	4.8	6.4	2.4	5.69	69.28	0.05	107	6.77	25.36	5
	2	7.4	13.7	3.1	2.86	35.93	3.30	6028	6.80	26.15	6
	3	8.3	13.1	3.1	3.60	40.02	3.92	5727	6.87	26.67	6
	4	7.2	15.2	3.1	4.58	58.35	3.84	7004	6.99	26.58	6
Seining	0	NA	NA	NA	6.92	87.20	0.06	122	7.29	27.45	2
	1	NA	NA	NA	5.38	65.13	0.05	106	7.03	26.50	3
	2	NA	NA	NA	4.19	52.77	1.11	2173	6.83	26.77	3
	3	NA	NA	NA	6.24	79.94	1.54	2982	7.20	27.56	5
	4	NA	NA	NA	6.36	83.15	3.36	6194	7.21	27.98	4

The low pH observed at Station 0 while trawling may reflect low pH inputs from Pine Island Bayou that stem from its relatively higher amounts of decaying organic material. On Oct. 9, 2022, the day of sampling Station 0, pH ranged from 6.3 to 6.4 at the Continuous Water Quality Monitoring Network (CWQMN) station on Pine Island Bayou near the Highway 69 bridge at LNVA's BI canal pump station (this is upstream of Station 0). Due to available habitat suitable for sampling at Station 0, trawling was focused on the junction pool while seining was focused on the left bank (looking downstream) of the junction pool and just upstream from the confluence of Pine Island Bayou on the Neches River. The pH values recorded while seining where much higher and characterized surface waters, but nevertheless, were more indicative of the waters of the Neches River upstream of the confluence with Pine Island Bayou. These data likely reflected the incomplete mixing of Pine Island Bayou and Neches River waters at Station 0.

Shoreline Habitats – Fish Community Assessment

Canonical correspondence analysis (CCA) was used to assess the relative differences in fish assemblages among stations and to assess the association of fish with environmental gradients (i.e., salinity, water temperature, dissolved oxygen and pH) for fish collected by seining shoreline habitats. Station (0, 1, 2, 3, 4) explained 37.3% of the variation in the fish assemblages collected by seining (Figure 5.2). CCA of seining CPUE showed a clear difference among groups of stations with Stations 0 and 1 forming one group and Stations 2, 3 and 4 forming a second group (Figure 5.2). Stations closer and/or overlapping each other indicated more similar fish assemblages (Figure 5.2). Fishes most closely associated with a particular station appeared closer to the symbol for that station (Figure 5.3). For example, fishes NOTEX (Weed Shiner), LYFUM (Ribbon Shiner), and CYVEN (Blacktail Shiner) were most closely associated with

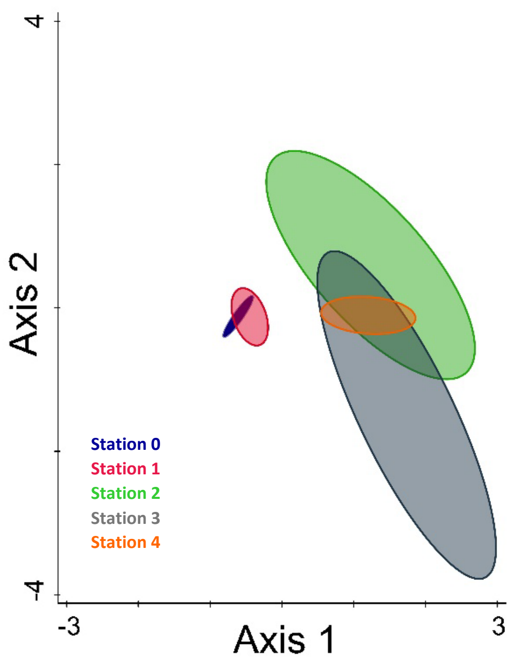

Figure 5.2: CCA of fish assemblages collected by seining. Ellipses represent the dissimilarity of fish assemblages collected within each station. Ellipses closer together and/or overlapping indicate more similar fish assemblages.

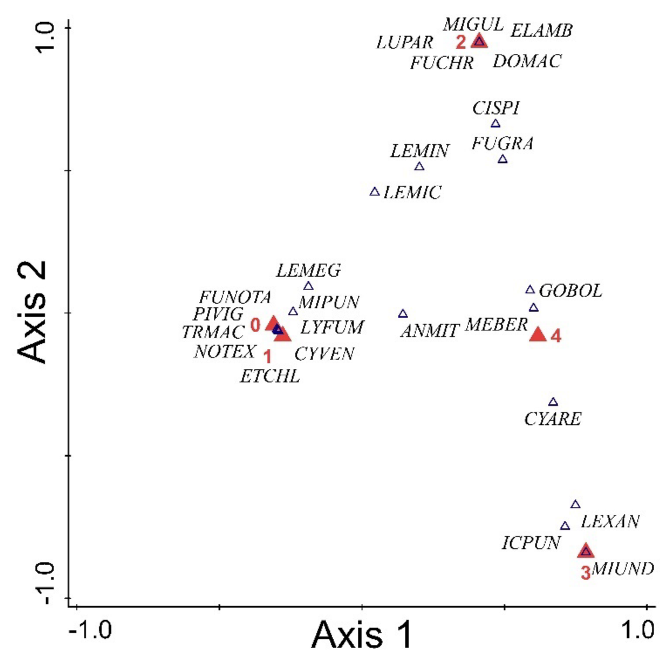

Figure 5.3: CCA of fish assemblages collected by seining. Station centroids are indicated with red triangles. Stations closer together and/or overlapping indicate more similar fish assemblages. Fish species appear closer to the station or stations to which they were most associated. See Table 5.1 for species and common names that correspond to species codes. Note: not all species shown.

Stations 0 and 1, while fishes MEBER (Inland Silverside), GOBOL (Darter Goby), and CYARE (Sand Seatrout) were more closely associated with Station 4 (Figure 5.3). AMNIT (Bay Anchovy) was found at all stations in similar numbers, hence, it was located in between all stations (Figure 5.3).

Water quality parameters measured during seining included salinity, temperature, dissolved oxygen, specific conductance and pH. Specific conductance and pH were removed from CCA analyses due to each having a high variance inflation factor (VIF) with other parameters. A high VIF (e.g., >20) indicated high correlation with other variables, so not including these parameters in the CCA analyses resulted in little loss of information or explanatory power. Additionally, CCA analyses were intended to be descriptive of known environmental gradients (e.g., fish species turnover or change with increasing salinity). In a CCA model where stations are not included, salinity, water temperature and dissolved oxygen explained 25.7% of the variation in the fish assemblages collected by seining (Figure 5.4). Salinity was most closely associated with the first axis which explained 17.8% of the variation in the fish assemblage. Temperature and dissolved oxygen were the principal factors explaining variation along the second axis, which explained the remaining 5.2% of the variation in fish assemblages (Figure 5.4).

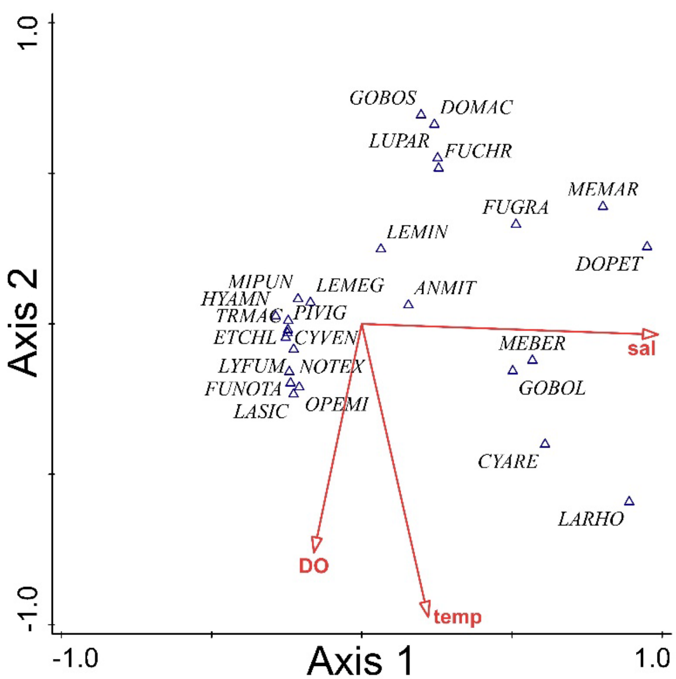

Figure 5.4: CCA of fish assemblages collected by seining. Red arrows show environmental gradients along which fish species were ordered. Blue triangles indicate position of fish species in ordination space and relation to environmental gradients. See Table 5.1 for species and common names that correspond to species codes. DO= dissolved oxygen, temp=temperature, sal=salinity. Note: not all species shown.

Figure 5.5: Terry Corbett holding a gar collected by seining.

Shoreline Habitats – Individual Species Patterns

The five most abundant species collected by seining shoreline habitats were Bay Anchovy, Blacktail Shiner, Bullhead Minnow, Weed Shiner and Ribbon Shiner. In shoreline samples, Bay Anchovy was the only species to occur at all five stations. In an ANCOVA model that included temperature as a significant covariate, Bay Anchovy CPUE was significantly lower at Stations 2 and 3 than at 0, 1 and 4. The decreased CPUE of Bay Anchovy at Stations 2 and 3 may reflect the increased industrial inputs at these stations or natural variation. It is difficult to discern the driving factor for these decreased abundances without additional sampling. Blacktail Shiner, Bullhead Minnow, Weed Shiner and Ribbon Shiner are freshwater species and therefore only occurred at Stations 0 and 1. Blacktail Shiner CPUE was significantly greater at Stations 0 and 1 than at Stations 2, 3 and 4. Additionally, Station 1 was significantly greater than Station 0. There were no significant covariates for Blacktail Shiner CPUE. Likewise, Bullhead Minnow CPUE was significantly greater at Stations 0 and 1 than at Stations 2, 3 and 4. There were no significant covariates for Bullhead Minnow CPUE. In an ANCOVA model that included temperature and dissolved oxygen as a significant covariates, Weed Shiner CPUE was significantly greater at Stations 0 and 1 than at Stations 2, 3 and 4. In a model without covariates the same station differences were found. Lastly, Ribbon Shiner CPUE was significantly greater at Station 0 than Stations 2, 3, and 4. Stations 0 and 1 did not differ, nor did Station 1 differ from 2, 3 and 4. There were no significant covariates for Ribbon Shiner CPUE.

Differences in seining CPUE among stations largely reflected an estuarine gradient with freshwater species Blacktail Shiner, Bullhead Minnow, Weed Shiner and Ribbon Shiner present only at upstream Stations 0 and 1, and the estuarine Bay Anchovy present at all stations. Other less abundant species collected by seining followed a similar distributional pattern (Table 5.1). Additionally, one Saltmarsh Topminnow (*Fundulus jenkinsi*) was collected at station 2 (Table 5.1 and 5.3). The Saltmarsh Topminnow record is noteworthy as it has a state conservation rank of S1, “critically imperiled”. Additional assessment of this species’ distribution may be warranted.

Bottom Habitats – Fish Community Assessment

Canonical correspondence analysis (CCA) was used to assess the relative differences in fish assemblages among stations and to assess the importance of environmental gradients (i.e., salinity, water temperature, dissolved oxygen, depth and pH) for fish collected by trawling bottom habitats. Station (0, 1, 2, 3, 4) explained 30.5% of the variation in the fish assemblages collected by trawling (Figures 5.6 and 5.7). The CCA of trawling CPUE placed the stations in a similar order to what was shown by the CCA of seining CPUE (Figure 5.2 and Figure 5.6). However, when compared to the CCA of seining CPUE, the CCA of trawling CPUE indicated that the bottom fish assemblages were more variable and less dissimilar, with Station 2 overlapped by the grouping of Stations 0 and 1. Following the same pattern demonstrated by the CCA of seining CPUE, Stations 3 and 4 remained grouped together and distinctly different from Stations 0

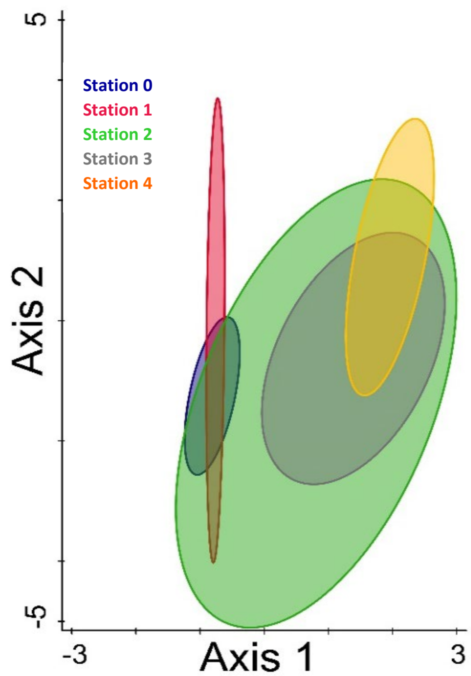

Figure 5.6: CCA of fish assemblages collected by trawling. Elipses represent the dissimilarity of fish assemblages collected within each station. Elipses closer together and/or overlapping indicate more similar fish assemblages.

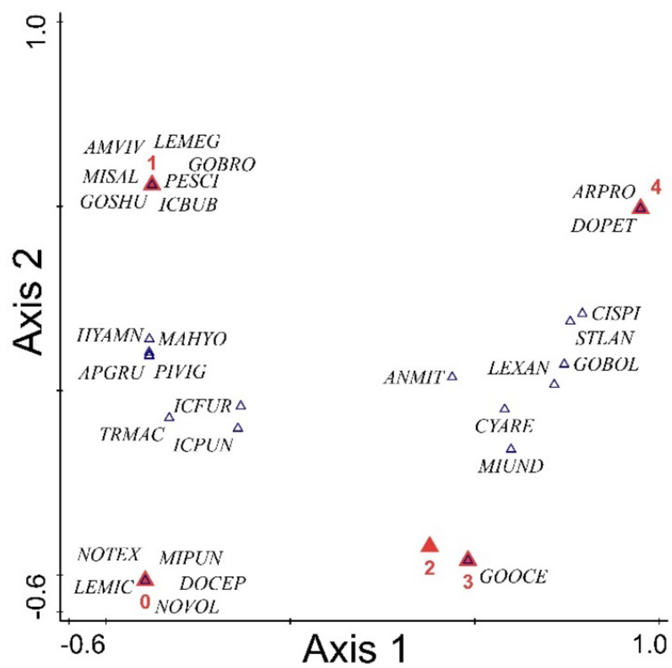

Figure 5.7: CCA of fish assemblages collected by trawling. Station centroids are indicated with red triangles. Stations closer together and/or overlapping indicate more similar fish assemblages. Fish species appear closer to the station or stations to which they were most associated. See Table 5.1 for species and common names that correspond to species codes.

and 1 (i.e., groups of ellipses not overlapping in Figure 5.6). Fishes most closely associated with a particular station appeared closer to the symbol for that station (Figure 5.7). For example, fishes TRMAC (Hogchoker), APGRU (Freshwater Drum) and ICFUR (Blue Catfish) were most closely associated with station 0 and 1, while fishes ANMIT (Bay Anchovy), CYARE (Sand Seatrout) and MIUND (Atlantic Croaker) were closely associated with stations 2, 3 and 4 (Figure 5.7).

In addition to trawling depth, water quality parameters measured during trawling included salinity, temperature, dissolved oxygen, specific conductance and pH (Table 5.5). Specific conductance and pH were removed from CCA analyses due to each having a high variance inflation factor (VIF) with other parameters. A high VIF (e.g., >20) indicated high correlation with other variables, so not including these parameters in the CCA analyses resulted in little loss of information or explanatory power. As with the CCA of seining CPUE, CCA analyses were intended to be descriptive of known environmental gradients (e.g., fish species turnover or change with increasing salinity). In a CCA model where stations are not included, salinity, water temperature, depth and dissolved oxygen explained 34.4% of the variation in the fish assemblages collected by seining (Figure 5.8). Salinity and temperature were most closely associated with the first axis which explained 20% of the variation in the fish assemblage. Depth and dissolved oxygen were the principal factors explaining variation along the second axis, which explained an additional 7.7% of the variation in fish assemblage (Figure 5.8).

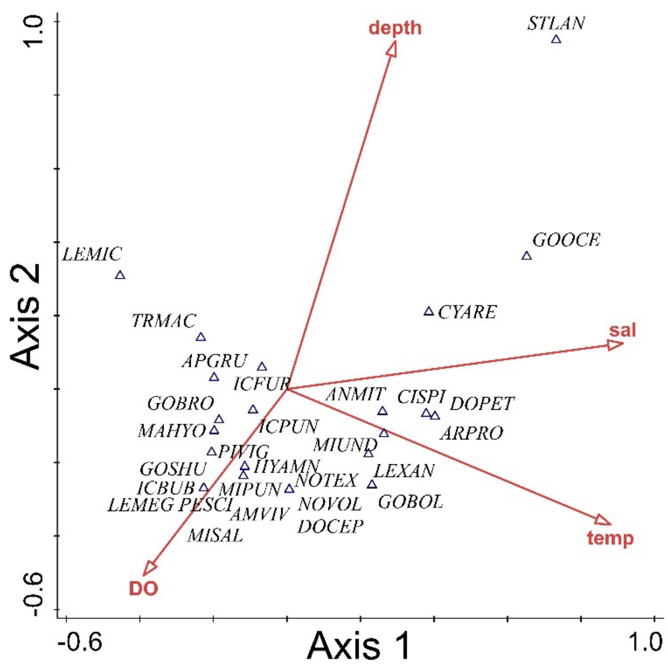

Figure 5.8: CCA of fish assemblages collected by trawling. Red arrows show environmental gradients along which fish species were ordered. Blue triangles indicate position of fish species in ordination space and relation to environmental gradients. See Table 5.1 for species and common names that correspond to species codes. DO=dissolved oxygen, temp=temperature, sal=salinity, depth=depth of trawl sample.

Figure 5.9: Hogchoker collected by trawling.

Bottom Habitats – Individual Species Patterns

The five most abundant species collected by trawling bottom habitats were Bay Anchovy, Blue Catfish, Channel Catfish, Hogchoker and Shoal Chub. Bay Anchovy and Blue Catfish were the only two species to occur at all 5 stations. Shoal Chub, a freshwater species, only occurred at Stations 0 and 1, and Channel Catfish and Hogchoker occurred at all stations except Station 4, a distribution typical of their salinity tolerances. In an ANCOVA model that included depth and salinity as significant covariates, Blue Catfish CPUE was significantly greater at Station 1 than Stations 2, 3 and 4. Additionally, Blue Catfish CPUE at Station 0 was greater than Stations 3 and 4 but not Station 2, and Stations 0 and 1 did not differ. A model of Blue Catfish CPUE without covariates resulted in the same station differences. In an ANCOVA model that included significant covariates, temperature, pH and weakly insignificant dissolved oxygen (p=0.055), Hogchoker CPUE was significantly greater at Stations 0 and 1 than at 2, 3 and 4 (note that a model of Hogchoker CPUE without covariates resulted in the same stations differences). There were no differences in Bay Anchovy, Channel Catfish and Shoal Chub CPUE among stations.

Differences in trawling CPUE among stations, much like seining CPUE, largely reflected an estuarine gradient with freshwater species Shoal Chub present only at upstream

Stations 0 and 1, Channel Catfish and Hogchoker occurring at most stations, and the estuarine Bay Anchovy and salt tolerant Blue Catfish present at all stations. Other less abundant species collected by trawling followed a similar distributional pattern (Table 5.4).

Texas Parks and Wildlife Department (TPWD) Data

We assessed bag seine data from Sabine Sampling Grids 298 and 306 for the period 2003-2021 by inspecting mean fall CPUE to identify annual trends at each sampling grid. Grids 298 and 306 were downstream of our stations and in higher salinity waters. Seine data from grids 298 and 306 revealed three notable patterns in species abundances. In grid 298, since 2015, Atlantic Croaker have been collected in the fall for each year for which there were data. Prior to 2015, Atlantic Croaker was collected in the fall only twice (in 2008 and 2011). Seine data from grid 306 showed a similar pattern for Atlantic Croaker with this species present in collections in 6 of 7 years for which there were data since 2013 and occurring in 1 of 8 years prior. Although, abundances are patchy, in grid 298, Bay Anchovy was absent from collections in 2008 and prior and was collected in 5 of the 9 years following. While in grid 306, Bay Anchovy was absent in all collections from 2008 to 2014 and present in all other years. Lastly, in grid 298, White Mullet have occurred in collections in 7 of 10 years since 2008 and was absent from collections in 2003 to 2007. White Mullet was rarely collected in grid 306. Collections among sampling grids for Bay Anchovy and White Mullet may reflect annual shifts in distribution in the estuary due to salinity, temperature, discharge and other factors. The patterns for these species were not consistent across grids 298 and 306. However, the increased occurrence of Atlantic Croaker in recent years at grids 298 and 306 is an interesting finding and appears to be a stronger trend. Nevertheless, it is unclear what factors are driving the increased occurrence of Atlantic Croaker.

Figure 5.10: David Keller, Kathleen Jackson and Haden Burks (left to right) process fish collected at Station 0.

5.4 Discussion

Overall, our findings demonstrate that the Neches River estuary supports a wide variety of fish species in shoreline and bottom habitats, and that salinity is the primary determinant of fish species occurrence and abundance in this portion of the estuary. Similarity in fish assemblages among stations, and the occurrence and abundance of most species was driven by a salinity gradient that extended from the lowermost Station 4 to the uppermost Station 0. Freshwater Stations 0 and 1, and brackish Stations 2, 3 and 4 were least similar in fish community structure and often differed in individual species abundances (CPUE).

Fish Community Patterns

Shoreline and bottom sampling of the fish community revealed similar patterns and associations to environmental determinants, with salinity being a major driver of fish species composition among stations. The CCAs of fish assemblages collected by trawling bottom habitats showed more overlap among stations, indicating lesser differences among stations when compared to the fish assemblages collected by seining shoreline habitats, which indicated a distinct difference among the freshwater Stations 0 and 1 and brackish Stations 2, 3 and 4. One reason why trawling bottom habitats showed similar but less distinct separation among freshwater and brackish stations may be due to more saline tolerant species being collected in bottom habitats combined with lower richness observed for this sampling method. Specifically, although Bay Anchovy was collected in both bottom and shoreline sampling, bottom sampling collected much more Hogchoker, Blue Catfish and Channel Catfish – species with broader salinity tolerances. In comparison, shoreline sampling collected many more freshwater obligates (species intolerant of saline/brackish conditions), particularly at Stations 0 and 1.

Individual Species Patterns

Differences in trawling CPUE among stations largely reflected an estuarine gradient, with the freshwater reliant Shoal Chub present only at upstream Stations 0 and 1, Channel Catfish and Hogchoker occurring at most stations, and the estuarine Bay Anchovy and salt tolerant Blue Catfish present at all stations. Four of the five most abundant fish species collected in shoreline habitats were freshwater obligates that only occurred at Stations 0 and 1. Of the five most abundant species collected in shoreline habitats, Bay Anchovy was the only species that occurred in all stations, again demonstrating its tolerance for a broad range of salinities.

Historical Comparisons Among Surveys

Some differences in species assemblages among the seven surveys (conducted in 1953, 1956, 1960, 1973, 1996, 2003 and 2021) are due to shifts in the estuarine gradient in response to variable freshwater inflows (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1998, ANSP 2006, this report). For example, many freshwater species were absent in the 1996 survey but were present in earlier surveys and the surveys that followed in

2003 and 2021 (ANSP 1998, ANSP 2006, this report). Correspondingly, several estuarine species were common in the 1996 survey but have otherwise been uncommon in the surveys before and after. Prior to the 2021 survey, many of the records of freshwater species were from Station 1 (ANSP 1954, ANSP 1974, ANSP 1998, ANSP 2006). In 2021, Station 1 and Station 0 (not previously surveyed) provided most of the freshwater species. Taking all survey years together, these data indicate that under typical flows, Stations 1 and 0 represent the freshwater portion of the estuarine gradient, while Stations 2, 3 and 4 occur in the mesohaline to polyhaline portion of the estuary (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1998, ANSP 2006, this report).

Figure 5.11: Sheepshead collected while trawling on the lower Neches River.

Some of the among-year differences reflect sampling effort and techniques. In particular, the 1956 and 1960 surveys did not include sampling at Station 1, and rotenone, a chemical piscicide, was used in 1953, 1956 and 1960 surveys (not permitted by the state in later surveys) (ANSP 1954, ANSP 1958, ANSP 1961). Additionally, in the 2021 survey, a new station, Station 0, was added upstream of Station 1. During the 1953 survey, 38 species were taken using stationary fyke (hoop) nets, seining, wire basket traps and rotenone. The number of species collected at each station was: Station 1, 33 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 (ANSP 1954). In the 1956 survey, the number of species collected at each station were as follows: Station 2, 0 species; Station 3, 10 species; and Station 4, 10 species. During this survey, Station 4 appeared to have higher abundances of fish when compared to Station 3. Also, note that Station 2 did not appear to support fish during the 1956 survey (ANSP 1958). During the 1960 survey, no fish were collected at Station 2, while Station 3 yielded 16 species, and Station 4 had 20 species. Again, during this survey, station 4 appeared to support higher densities of fish when compared to Station 3 (ANSP 1961). During the 1973 survey, 33 species were collected in all: 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; 1-inch stretch mesh was used for trawling and seining (ANSP 1974). The 1996, 2003 and 2021 surveys found high numbers and a greater variety of estuarine species at Stations 2, 3 and 4. Finer mesh nets were used for seining and trawling in these surveys (ANSP 1998, ANSP 2006, see methods above). Bay Anchovy, which was uncommon in the early surveys, was abundant in the three most recent surveys (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1998, ANSP 2006, this report). The use of finer mesh nets may have resulted in increased catches of Bay Anchovy. However, Bay Anchovy is likely to be caught by seines which were used in the early surveys, so the change is probably not related to technique differences. The change in the occurrence of Bay Anchovy in the lower Neches River reflects an increase in water quality, at least in part.

For stations where past surveys were conducted, these data indicate that Station 1 has remained in relatively good condition, Station 2 has shown the most improvement, and Stations 3 and 4 have improved as well (ANSP 1954, ANSP 1958, ANSP 1961, ANSP 1998, ANSP 2006, this report). For example, the 1953 survey found that Station 2 did not support fish and identified oil slicks, high temperature and low dissolved oxygen as likely causes. Similar conditions were observed at Stations 3 and 4 but to a lesser extent (ANSP 1954). The 1956 survey found no fish at station 2 and again, identified high temperatures and low dissolved oxygen as likely culprits (ANSP 1958). The 1960 survey found Stations 3 and 4 made some improvement but Station 2 remained unchanged or was further degraded, supporting "practically no aquatic life." Considerable amounts of oil were present at Station 2, on the water surface and substrate (ANSP 1961). The 1973 survey showed much improvement, with Station 2 having 16 species, and Stations 3 and 4 improving as well. However, at Stations 2, 3 and 4, fish life appeared to be restricted to upper oxygenated waters as evidenced by the absence of fish in trawl samples. Station 1 remained in good condition at this time. Overall, the 1973 survey showed much improved water quality at Stations 2, 3 and 4, when compared to the 1953 survey (ANSP 1954 and ANSP 1974). Surveys from 1973 and earlier primarily relied on fish species presence and site richness to infer or assess condition, hence, abundance or density information was not collected and is not available for comparison with more recent surveys that focused on those ecological characteristics. Nevertheless, in 1996, 51 species were collected, with 29 species collected at Station 1; 20 species collected at Station 2; 16 species collected at Station 3; and 22 species collected at Station 4. In 1996, at all stations, richness increased relative to the species richness observed in 1973 (ANSP 1974 and ANSP 1998). Furthermore, the 1996 survey indicated continued improvement at Stations 2, 3 and 4, as demonstrated by an increased variety of estuarine species at these stations (ANSP 1998). Similarly, in 2003, 51 species were collected and none of the patterns among stations appeared to be related to pollution (ANSP 2006). Likewise, in 2021, 66 species were collected with no patterns in richness (number of species) appearing to be related to pollution. In 2021, trawling produced 13, 16, 9, 10 and 10 species at Stations 0, 1, 2, 3 and 4 respectively. Seining produced 22, 25, 22, 16 and 15 species at stations 0, 1, 2, 3 and 4, respectively.

The more recent surveys, conducted in 1996, 2003 and 2021 (this report), focused condition assessments on differences in densities (CPUE) of fish species among stations. In these surveys, the primary techniques used to assess densities among stations were seining and trawling. In 1996 and 2003, none of the differences among stations appeared to be related to pollution, and differences were largely related to the estuarine gradient (ANSP 1998 and ANSP 2006). In 2021, differences were again, largely related to an estuarine gradient. However, there were decreased abundances (number of individuals) of Bay Anchovy at Stations 2 and 3 which may reflect increased industrial/anthropogenic impacts at these stations or natural variation. It is difficult to discern the driving factor for these decreased abundances without additional sampling. TPWD data indicated spatial variation and inconsistent patterns for Bay Anchovy among grids 298 and 306, however it is unclear if this was due to natural variation. TPWD seine data from grids 298 and 306 were collected using 0.5 inch mesh, a much larger size then the 0.125 inch mesh used by the Academy. Although, TPWD seine data may be useful for assessing larger Bay Anchovy, this monitoring program is likely missing smaller sized individuals, and therefore may not be as informative for assessing spatial and temporal patterns in Bay Anchovy. Future assessment of Bay Anchovy should use mesh sizes suitable for capturing the full size range of Bay Anchovy.

Management Implications

From a management perspective, the saltwater barrier and its operation are a major factor controlling discharge and water quality characteristics in the estuary. When there is a lack of precipitation resulting in low flows in the Neches River, salinity may increase below the barrier, and the lack of instream flow can allow dissolved organic matter from local industry to accumulate (Pizano-Torres, et al., 2017). These drought conditions may negatively affect biotic communities by favoring species tolerant of low DO, high concentrations of dissolved organic compounds, and saline conditions below the saltwater barrier (Pizano-Torres, et al., 2017). Additionally, Pizano-Torres, et al. (2017) found species richness decreased when the barrier was closed, presumably due to low flows and/or drought conditions. However, our study was conducted during a year of typical discharge and found the fish communities and species abundances to be similar among Stations 0 and 1. Station 0 was the upper most station and was located upstream of the saltwater barrier while Station 1 was located downstream. Both stations had similar water quality and depths and were found along the freshwater portion of the salinity gradient, a major determinant of fish species occurrence and abundance in the estuary (this report; see above). One exception to the similar water quality observed at these stations was that Station 0 was in closer proximity to Pine Island Bayou, a fact that presumably affects that station's water quality more so than downstream Station 1. Stations 0 and 1 were similar in fish community structure and there were no consistent patterns in the abundance of species that would indicate a difference due to the saltwater barrier at the time of our survey. Additionally, species richness at Station 1 fluctuates among Academy surveys and is most associated with among survey variation in the salinity gradient. Academy surveys show that many species were absent in 1996, a high salinity year, but were present in surveys before and after 1996 (see Historical Comparisons Among Surveys section above). However, the minimum time needed for freshwater species to recolonize areas previously inundated with higher salinity waters is unclear and species specific.

Lower in the estuary, Stations 2, 3 and 4 had similar salinities and depths. The fish communities among these stations were similar, indicating no differences due to industrial inputs or management. However, in shoreline samples, Bay Anchovy abundance was significantly lower at Stations 2 and 3 than at 0, 1 and 4. In contrast, in bottom habitats assessed by trawling, Bay Anchovy abundance was not significantly different among stations. Historically, Stations 2 and 3 have received the greatest impact from, and are in closest proximity to, the region’s industry. The decreased CPUE of Bay Anchovy in shoreline samples at Stations 2 and 3 may reflect increased industrial inputs or anthropogenic effects at these stations relative to other stations, or natural variation. It is difficult to discern the driving factor for these decreased abundances without additional sampling.

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APPENDIX A: ENVIRONMENTAL GEOCHEMISTRY

Appendix A.1: Basic water quality measurements taken in October 2021.

October 5, 2021

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (mS)	TDS (mg/L)
Station 0							
0.3	26.1	6.9	7.0	86.1	0.05	117	76
1.0	26.1	6.9	7.0	86.0	0.05	117	76
2.0	25.9	6.9	6.6	81.2	0.05	117	76
3.0	24.8	6.9	5.5	66.2	0.04	76	49
4.0	24.7	6.7	5.5	66.9	0.04	92	62
5.0	25.2	6.6	6.0	72.4	0.04	89	56
6.0	24.3	6.5	5.1	60.6	0.03	66	42
7.0	24.1	6.4	4.9	58.1	0.03	64	42
Station 1							
0.3	25.2	7.8	6.0	73.2	0.04	95	62
1.0	25.2	7.3	5.9	71.7	0.04	95	62
2.0	25.2	7.2	5.9	71.4	0.04	95	62
3.0	25.2	7.1	5.9	71.1	0.04	95	62
4.0	25.2	7.0	5.8	70.9	0.04	95	62
5.0	25.2	7.0	5.8	70.9	0.04	95	62
6.0	25.2	6.8	5.8	70.8	0.04	95	62
7.0	25.2	6.8	5.6	68.6	0.04	95	62
8.0	25.2	6.7	5.8	70.5	0.04	96	62
Station 2							
0.3	25.7	7.4	5.2	63.5	0.81	1606	1045
3.3	25.6	7.2	4.8	59.0	0.96	1901	1234
6.3	26.3	7.0	3.9	49.3	3.09	5717	3721
9.3	26.7	7.1	3.3	41.7	5.34	9566	6212
12.3	26.9	7.0	2.4	30.5	7.28	12653	8232
15.3	27.0	7.2	1.2	15.1	8.72	15030	9771
Station 3							
0.3	25.8	7.7	5.4	67.3	1.83	3494	2271
3.3	26.1	7.5	4.8	60.4	2.27	4289	2786
6.3	26.5	7.3	4.2	53.1	3.24	5967	3882
9.3	26.7	7.2	3.7	47.0	4.64	8372	5440
12.3	26.8	7.2	3.0	38.4	6.24	11209	7284
14.1	26.9	7.1	2.0	26.8	7.56	13200	8576
Station 4							
0.3	26.3	7.3	5.3	66.6	3.29	6047	3940
3.3	26.5	7.2	5.0	63.7	3.61	6612	4309
6.3	26.7	7.3	4.7	59.7	4.20	7706	4986
9.3	26.8	7.3	4.2	53.7	5.04	9055	5870
12.3	26.8	7.4	3.9	50.9	5.25	9410	6109
15.3	26.8	7.3	3.6	46.3	5.69	10075	6558

October 6, 2021

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (mS)	TDS (mg/L)
Station 0							
0.3	26.1	7.2	7.4	90.8	0.06	135	87
1.0	26.1	7.2	7.2	89.1	0.06	131	85
2.0	25.7	7.1	6.8	83.9	0.06	124	81
3.0	25.3	6.9	6.4	77.7	0.05	110	67
4.0	23.9	6.5	5.4	63.6	0.03	70	45
5.0	23.7	6.6	4.9	58.4	0.03	69	45
6.0	23.7	6.5	4.8	57.2	0.03	69	45
7.0	23.7	6.4	4.8	56.7	0.03	69	45
8.0	23.7	6.4	4.8	56.5	0.03	69	45
Station 1							
0.3	25.1	6.9	6.4	76.8	0.05	150	72
1.0	25.1	6.8	6.0	73.1	0.05	109	71
2.0	25.1	6.9	6.0	72.5	0.05	113	74
3.0	25.1	6.9	6.0	72.3	0.06	112	81
4.0	25.0	6.8	5.9	71.9	0.05	116	76
5.0	25.0	6.9	5.9	71.7	0.05	115	74
6.0	25.0	6.9	5.9	71.4	0.05	113	73
7.0	25.0	6.9	2.9	34.0	0.05	111	73
Station 2							
0.3	25.8	7.0	5.3	65.2	0.74	1492	966
3.3	25.8	7.0	4.7	57.5	1.52	2951	1916
6.3	26.3	7.0	4.0	49.7	3.02	5670	3650
9.3	26.4	7.1	3.4	43.3	4.40	7785	5078
12.3	26.7	7.2	3.0	27.0	7.80	13740	8837
14.5	26.8	7.2	1.3	17.2	8.57	14778	9611
Station 3							
0.3	25.7	7.2	5.6	69.1	1.60	3438	2232
3.3	25.8	7.2	5.0	61.4	1.88	2594	2335
6.3	26.4	7.2	4.5	56.6	2.64	4954	3218
9.3	26.5	7.2	4.0	50.9	3.76	6881	4468
12.3	26.7	7.2	3.0	39.5	5.43	9556	6287
13.5	26.7	7.3	0.2	0.8	6.62	11600	7518
Station 4							
0.3	26.1	7.0	5.0	62.2	3.04	5632	3661
3.3	26.2	7.0	4.8	60.8	3.01	5721	3728
6.3	26.5	7.1	4.5	56.7	3.67	6738	4366
9.3	26.7	7.1	4.4	54.9	4.28	7756	5041
12.3	27.8	7.2	4.1	52.8	4.72	8513	5530
15.3	26.8	7.2	4.1	52.8	4.80	8645	5621

October 7, 2021

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (mS)	TDS (mg/L)
Station 0							
0.3	26.3	7.1	7.5	92.4	0.07	147	95
1.0	26.0	7.1	7.4	91.1	0.07	149	94
2.0	25.9	7.0	7.3	89.4	0.06	137	87
3.0	24.7	6.8	6.3	76.9	0.06	123	81
4.0	24.1	6.6	5.5	64.5	0.05	107	69
5.0	23.9	6.5	5.1	61.2	0.05	110	72
6.0	23.4	6.4	4.8	55.6	0.03	72	47
7.1	23.4	6.4	4.8	55.4	0.05	98	65
Station 1							
0.3	25.1	6.7	6.5	78.0	0.06	125	81
1.0	25.0	6.7	6.2	74.8	0.06	126	82
2.0	25.0	6.7	6.1	73.8	0.06	129	85
3.0	25.0	6.7	6.1	73.4	0.06	129	84
4.0	25.0	6.7	6.1	73.3	0.06	128	83
5.0	25.0	6.7	6.0	73.1	0.06	128	83
6.0	25.0	6.7	6.0	73.0	0.06	126	82
7.0	25.1	6.7	6.0	73.2	0.06	124	80
Station 2							
0.3	25.6	6.8	5.2	63.2	0.98	1911	1249
3.3	25.6	6.8	4.7	57.4	1.29	2516	1637
6.3	26.0	6.9	4.2	52.1	1.97	3807	2450
9.3	26.4	7.0	3.5	43.8	3.76	7072	4563
12.3	26.5	6.9	2.6	32.8	5.51	9765	6363
15.9	26.7	7.0	1.4	18.2	8.02	13986	9082
Station 3							
0.3	25.8	6.7	5.2	64.1	1.87	3585	2332
3.3	26.1	6.9	4.8	59.5	2.13	4026	2620
6.3	26.3	7.0	4.6	57.4	2.84	5289	3434
9.3	26.4	7.0	4.2	52.4	3.41	6197	4061
12.3	26.6	7.0	3.3	41.6	4.76	8538	5559
13.0	26.6	7.1	2.7	34.5	5.38	9575	6231
Station 4							
0.3	26.2	7.0	4.9	61.3	3.07	5650	3670
3.3	26.3	7.0	4.7	58.8	3.28	6048	3935
6.3	26.4	7.0	4.6	58.1	3.45	6367	4132
9.3	26.5	7.0	4.5	58.3	3.72	6844	4432
12.3	26.6	7.0	4.4	56.3	4.09	7443	4831
15.3	26.6	7.1	4.4	56.4	4.21	7640	4966

October 8, 2021

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (mS)	TDS (mg/L)
Station 0							
0.3	26.3	7.2	7.5	93.0	0.06	129	84
1.0	26.1	7.2	7.3	90.6	0.06	129	84
2.0	25.8	7.0	6.8	83.1	0.06	122	80
3.0	25.3	6.8	5.6	68.2	0.05	105	66
4.0	25.6	6.9	6.5	79.9	0.06	122	79
5.0	25.7	6.9	6.6	80.8	0.06	123	80
6.0	24.1	6.4	4.9	58.4	0.04	82	54
7.0	23.7	6.4	4.6	53.6	0.04	78	51
8.0	26.7	6.4	4.4	52.2	0.03	76	50
Station 1							
0.3	25.6	6.9	6.6	80.9	0.06	120	78
1.0	25.3	6.8	6.6	79.8	0.06	121	79
2.0	25.3	6.8	6.3	76.8	0.05	118	77
3.0	25.3	6.8	6.3	76.3	0.05	118	77
4.0	25.3	6.7	6.3	76.2	0.05	117	76
5.0	25.3	6.8	6.2	75.9	0.05	119	77
6.0	25.3	6.9	6.3	76.0	0.05	118	77
7.0	25.3	6.8	6.2	75.5	0.05	124	78
Station 2							
0.3	25.6	6.7	4.9	59.6	1.06	2093	1360
3.3	25.8	6.8	4.4	53.7	1.48	2884	1871
6.3	26.0	6.8	4.0	49.3	2.11	3997	2597
9.3	26.2	6.9	3.8	48.3	2.98	5507	3585
12.3	26.3	6.9	3.0	38.4	3.61	6623	4303
15.3	26.5	6.9	2.0	25.9	4.98	8945	5803
Station 3							
0.3	25.9	6.9	5.0	61.9	1.7	3313	2152
3.3	26.0	6.9	4.9	61.5	1.9	3603	2342
6.3	26.3	6.9	4.3	54.6	2.5	4750	3088
9.3	26.4	6.9	4.0	50.3	3.1	5742	3730
12.3	26.4	6.9	3.5	43.7	3.5	6299	4118
13.4	26.5	6.9	3.0	37.8	4.1	7349	4799
Station 4							
0.3	26.4	7.0	4.5	56.6	3.31	6084	3966
3.3	26.4	7.0	4.4	56.1	3.25	6013	3909
6.3	26.4	7.0	4.4	55.9	3.29	6094	3955
9.3	26.5	7.0	4.4	55.5	3.44	6368	4122
12.3	26.5	7.0	4.4	55.2	3.54	6526	4232
15.3	26.6	7.0	4.3	55.0	3.74	6858	4455
17.3	26.6	7.0	4.3	54.3	3.72	6805	4425

October 9, 2021

Depth (m)	Temp (°C)	pH	DO (mg/L)	% Sat	Sal (ppt)	Cond (mS)	TDS (mg/L)
Station 0							
0.3	26.3	7.3	7.5	92.7	0.06	129	84
1.0	26.3	7.3	7.3	90.7	0.06	130	85
2.0	26.3	7.3	7.3	89.7	0.06	130	84
3.0	26.1	7.2	7.1	87.0	0.06	127	83
4.0	26.0	7.2	7.0	86.4	0.06	131	86
5.0	24.0	6.6	5.3	63.6	0.06	124	81
6.0	23.8	6.6	4.4	52.1	0.04	83	54
7.0	23.8	6.6	4.3	50.8	0.04	82	53
Station 1							
0.3	26.0	6.9	6.8	84.2	0.05	117	76
1.0	25.8	6.9	6.5	79.0	0.05	118	77
2.0	25.7	6.9	6.3	77.7	0.05	119	77
3.0	25.7	7.0	6.3	77.1	0.05	118	77
4.0	25.7	7.0	6.3	76.6	0.05	118	77
5.0	25.7	7.1	6.2	75.9	0.05	118	77
6.0	25.7	7.0	6.2	75.6	0.05	119	77
7.0	25.7	7.0	6.2	75.5	0.05	119	77
Station 2							
0.3	25.7	7.0	4.8	58.6	1.13	2147	1140
3.3	26.0	6.9	4.2	52.0	1.72	3302	2146
6.3	26.1	7.0	4.0	49.5	2.04	3865	2515
9.3	26.3	7.1	3.7	46.5	2.83	5364	3423
12.3	26.3	7.1	2.9	37.0	3.37	6214	4038
15.3	26.4	7.0	2.2	27.2	3.93	7140	7140
Station 3							
0.3	26.1	6.9	5.2	64.8	1.8	3377	2198
3.3	26.2	6.9	4.7	59.1	2.0	3776	2455
6.3	26.4	7.0	4.3	53.9	2.8	5225	3392
9.3	26.5	7.0	3.8	48.6	3.5	6348	4123
12.3	26.7	7.1	4.0	50.8	4.3	7831	5090
15.0	26.7	7.1	4.0	50.7	4.5	8175	5315
Station 4							
0.3	26.4	6.9	4.7	59.3	2.65	4966	3227
3.3	26.5	6.9	4.5	57.3	2.89	5381	3500
6.3	26.7	7.0	4.5	57.0	3.44	6297	4094
9.3	27.0	7.1	4.5	58.1	4.69	8512	5526
12.3	27.0	7.2	4.4	56.5	5.87	10430	6775
15.3	26.9	7.2	4.2	54.9	6.62	7572	7572

Appendix A.2: Solids, nutrients and bacteria levels in Segment 601 of the lower Neches River in October 2021.

	TSS (mg/L)	VSS (mg/L)	Turbidity (FTU)	Fecal Coliform (cols./ 100mL)	TOC (mgC/L)	NO_3-N (mgN/L)	TKN (mgN/L)	NH_4-N (mgN/L)	TP (mgP/L)	o-PO_4 (mgP/L)
Oct. 5, 2021										
Station 0	18.6	2.7	27.3	32	7.5	0.05	<0.2	0.02	<0.01	<0.03
Station 1	19.2	<1	30.6	80	9.6	0.05	<0.2	0.02	0.02	<0.03
Station 2	12.5	<1	17.7	48	8.4	0.11	0.29	0.02	<0.01	0.41
Station 3	9.6	<1	11.9	16	7.1	0.13	<0.2	0.02	<0.01	<0.03
Station 4	13.9	3.8	6.3	40	6.0	0.17	<0.2	0.04	<0.01	<0.03
Oct. 6, 2021										
Station 0	18.8	4.0	15.8	16	7.2	0.02	0.43	0.03	0.06	<0.03
Station 1	14.9	<1	16.4	80	10.8	0.03	0.45	0.02	0.06	0.10
Station 2	9.3	<1	14.4	28	9.1	0.09	0.40	0.03	0.07	<0.03
Station 3	14.5	<1	13.0	40	7.8	0.14	0.37	0.03	0.05	<0.03
Station 4	14.8	<1	6.3	36	6.6	0.19	0.30	0.02	0.05	<0.03
Oct. 7, 2021										
Station 0	18.6	5.5	16.8	8	6.1	0.02	<0.2	0.04	0.03	<0.03
Station 1	16.1	<1	17.7	8	10.0	0.02	<0.2	0.04	0.03	<0.03
Station 2	12.3	<1	14.3	20	9.4	0.09	<0.2	0.04	0.03	<0.03
Station 3	8.9	<1	10.8	24	8.2	0.15	<0.2	0.04	0.02	<0.03
Station 4	15.7	<1	9.2	4	6.4	0.21	<0.2	0.04	0.03	<0.03
Oct. 8, 2021										
Station 0	12.6	<1	16.1	32	5.8	<0.01	<0.2	0.06	0.01	<0.03
Station 1	14.5	<1	18.1	16	9.4	0.03	<0.2	0.05	0.05	<0.03
Station 2	9.3	<1	12.6	40	9.7	0.11	<0.2	0.04	0.03	<0.03
Station 3	9.6	<1	10.2	16	8.4	0.15	<0.2	<0.04	0.04	<0.03
Station 4	22.0	4.5	11.7	24	6.8	0.22	<0.2	<0.04	0.06	<0.03
Oct. 9, 2021										
Station 0	12.1	<1	16.2	36	6.1	<0.01	<0.2	0.05	<0.01	<0.03
Station 1	11.9	<1	22.6	24	8.2	0.02	<0.2	0.05	<0.01	<0.03
Station 2	8.5	<1	12.7	20	9.8	0.14	<0.2	0.05	<0.01	<0.03
Station 3	8.6	<1	9.6	8	8.2	0.14	<0.2	0.04	<0.01	<0.03
Station 4	12.2	<1	8.6	8	7.3	0.20	<0.2	0.08	<0.01	<0.03

Appendix A.3: Volatile organic compounds (mg/L) in Neches River water on Oct. 6, 2021. All concentrations are below the PQL.

Station	1,3-Butadiene	Acetone	Styrene	Ethylene Glycol	Methanol
0	<0.00072	<0.00298	<0.00069	<5.00	<0.36
1	<0.00072	<0.00298	<0.00069	<5.00	<0.36
2	<0.00072	<0.00298	<0.00069	<5.00	<0.36
3	<0.00072	<0.00298	<0.00069	<5.00	<0.36
4	<0.00072	<0.00298	<0.00069	<5.00	<0.36

Station	Phenol	2-Chlorophenol	2-Methylphenol	4-Methylphenol	2-Nitrophenol	2,4-Dimethylphenol	2,4-Dichlorophenol	2,6-Dichlorophenol
0	<0.00044	<0.0005	<0.001	<0.002	<0.00113	<0.00053	<0.00069	<0.004
1	<0.00044	<0.0005	<0.001	<0.002	<0.00113	<0.00053	<0.00069	<0.004
2	<0.00044	<0.0005	<0.001	<0.002	<0.00113	<0.00053	<0.00069	<0.004
3	<0.00044	<0.0005	<0.001	<0.002	<0.00113	<0.00053	<0.00069	<0.004
4	<0.00044	<0.0005	<0.001	<0.002	<0.00113	<0.00053	<0.00069	<0.004

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
0	<0.00053	<0.00079	<0.00085	<0.00141	<0.00113	<0.002	<0.00066	<0.0005
1	<0.00053	<0.00079	<0.00085	<0.00141	<0.00113	<0.002	<0.00066	<0.0005
2	<0.00053	<0.00079	<0.00085	<0.00141	<0.00113	<0.002	<0.00066	<0.0005
3	<0.00053	<0.00079	<0.00085	<0.00141	<0.00113	<0.002	<0.00066	<0.0005
4	<0.00053	<0.00079	<0.00085	<0.00141	<0.00113	<0.002	<0.00066	<0.0005

Appendix A.4: Neches River trace element total recoverable data collected on Oct. 6, 2021 (D = dissolved fraction. TR = total recoverable).

Station	D Ag (mg/L)	D Al (mg/L)	D Cd (mg/L)	D Cr (mg/L)	D Cu (mg/L)	D Ni (mg/L)	D Pb (mg/L)	D Zn (mg/L)	D As (mg/L)	TR -Hg (mg/L)	TR-Se (mg/L)
0	0.002	0.042	<0.002	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<6E-05	<0.006
1	0.001	0.102	<0.002	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<6E-05	<0.006
2	<0.001	0.030	<0.002	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<6E-05	<0.006
3	0.001	<0.008	<0.002	<0.004	0.004	<0.004	<0.004	<0.005	<0.004	<6E-05	0.01
4	0.001	<0.008	<0.002	<0.004	0.004	<0.004	<0.004	<0.005	<0.004	<6E-05	<0.006

Appendix A.5: Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, collected in 1993 by LNVA and the Academy.

Parameter	Salinity	Temp	pH	DO	DO	PO4-P	TKN	NH4-N	NO3-N	Fecal Coliform	Sp. Cond.	TP	TSS	TOC
Unit	ppt	°C	unitless	mg/L	% Sat	mg P/L	mg N/L	mg N/L	mg N/L	cols./100 ml	uS/cm	mg P/L	mg/L	mg C/L
Station 1: Surface	NA	29.2	6.9	5.7	74	0.001	NA	0.14	0.04	240	4300	NA	NA	NA
Station 2 Surface	NA	31.5	7.1	1.1	15	0.001	NA	0.27	0.11	110000	104000	NA	NA	NA
Station 3: Surface	NA	31.5	7.2	6.0	81	0.001	NA	0.28	0.09	17000	106000	NA	NA	NA
Station 4: Surface	NA	31.6	7.3	2.4	33	0.001	NA	0.68	0.14	2400	122000	NA	NA	NA

%DO Sat calculated from raw data.
NA = Not Analyzed or Sampled
Temp is from Bottom samples.
n = 1

Appendix A.6: Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, collected in 1973 by LNVA and the Academy.

Parameter	Salinity	Temp	pH	DO	DO	o-PO4	TKN	NH4-N	NO3-N	Fecal Coliform	Sp. Cond.	TP	TSS	TOC
Unit	ppt	°C	unitless	mg/L	% Sat	mg P/L	mg N/L	mg N/L	mg N/L	cols./100 ml	uS/cm	mg P/L	mg/L	mg C/L
Station 1: Surface														
Mean	NA	27.7	6.6	5.6	71	0.03	0.31	0.06	0.07	47260	278	NA	NA	NA
SE		0.4	0.0	0.1	1	0.002	0.07	0.01	0.02	31021	42			
Min		26.5	6.5	5.2	65	0.02	0.10	0.05	0.04	4500	132			
Max		28.5	6.7	5.8	75	0.03	0.50	0.08	0.12	170000	360			
Station 2 Surface														
Mean	NA	28.1	6.7	4.5	57	0.05	0.21	0.12	0.06	26400	2008	NA	NA	NA
SE		0.3	0.0	0.2	1	0.01	0.07	0.01	0.01	6038	231			
Min		27.0	6.6	4.0	50	0.02	0.12	0.10	0.02	15000	1380			
Max		29.0	6.8	5.0	65	0.08	0.46	0.14	0.10	48000	2800			
Station 3: Surface														
Mean	NA	26.6	6.7	3.9	49	0.03	0.35	0.30	0.05	67200	3040	NA	NA	NA
SE		1.7	0.0	0.2	1	0.00	0.10	0.06	0.01	29060	246			
Min		20.0	6.7	3.4	37	0.02	0.10	0.10	0.01	22000	2300			
Max		29.0	6.8	4.6	60	0.04	0.55	0.43	0.08	170000	3800			
Station 4: Surface														
Mean	NA	28.2	6.8	3.9	50	0.03	0.54	0.33	0.09	34300	3880	NA	NA	NA
SE		0.4	0.0	0.2	2	0.01	0.11	0.04	0.03	16563	339			
Min		27.0	6.8	3.4	43	0.02	0.37	0.23	0.02	8500	3200			
Max		29.0	6.8	4.6	60	0.49	0.74	0.41	0.19	99000	5100			

%DO Sat calculated from raw data.
NA = Not Analyzed or Sampled
Date is composite of low and high tide samples
n = 5

Appendix A.7: Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, collected in 1996 by LNVA and the Academy.

Parameter	Salinity	Temp	pH	DO	DO	o-PO4	TKN	NH4-N	NO3-N	Fecal Coliform	Sp. Cond.	TP	TSS	TOC
Unit	ppt	°C	unitless	mg/L	% Sat	mg P/L	mg N/L	mg N/L	mg N/L	cols./100 ml	uS/cm	mg P/L	mg/L	mg C/L
Station 1: Surface														
Mean	3.7	21.6	6.7	3.0	36	0.17	0.62	0.10	0.60	289	NR	0.22	5.8	8.1
SE	1.5	0.5	0.1	1.3	14	0.01	0.05	0.00	0.20	72		0.02	0.5	0.3
Min	0.3	20.2	6.0	0.1	3	0.14	0.54	0.10	0.30	122		0.15	5.0	7.3
Max	8.3	23.0	7.0	6.5	73	0.19	0.72	0.10	1.20	465		0.25	7.0	8.8
Station 2: Surface														
Mean	9.9	22.1	6.9	4.5	55	0.17	0.49	0.10	0.50	1327	NR	0.19	8.3	4.5
SE	1.2	0.32	0.06	0.35	4	0.01	0.02	0.00	0.18	805		0.01	1.0	0.3
Min	6.1	21.1	6.8	2.4	30	0.15	0.45	0.10	0.20	166		0.15	6.0	4.0
Max	15.1	23.4	7.2	6.1	72	0.18	0.54	0.10	1.00	3600		0.21	11.0	5.1
Station 3: Surface														
Mean	10.3	21.9	7.0	5.3	65	0.16	0.57	0.10	0.48	1036	NR	0.17	8.8	4.4
SE	1.2	0.3	0.1	0.3	4	0.0	0.1	0.0	0.2	735		0.01	0.6	0.1
Min	7.6	21.2	6.9	3.8	46	0.14	0.45	0.10	0.20	44		0.15	7.0	4.2
Max	15.6	23.5	7.4	6.6	79	0.18	0.74	0.10	1.00	3200		0.21	10.0	4.5
Station 4: Surface														
Mean	12.2	21.7	7.2	5.8	72	0.18	0.54	0.10	0.50	524	NR	0.20	13.3	3.6
SE	1.5	0.4	0.1	0.2	2	0.01	0.06	0.00	0.18	135		0.01	1.0	0.0
Min	9.0	20.8	7.0	5.0	62	0.15	0.40	0.10	0.20	185		0.18	11.0	3.5
Max	17.2	23.3	7.5	6.5	78	0.20	0.68	0.10	1.00	780		0.21	16.0	3.7

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
n = 4

Appendix A.8: Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, collected in 2003 by LNVA and the Academy.

Parameter	Salinity	Temp	pH	DO	DO	o-PO4	TKN	NH4-N	NO3-N	Fecal Coliform	Sp. Cond.	TP	TSS	TOC
Unit	ppt	°C	unitless	mg/L	% Sat	mg P/L	mg N/L	mg N/L	mg N/L	cols./100 ml	uS/cm	mg P/L	mg/L	mg C/L
Station 1: Surface														
Mean	0.01	23.5	6.40	5.71	67	0.04	1.80	0.08	0.04	1086	60	0.08	22.5	12.7
SE	0.01	0.1	0.04	0.06	1	0.000	1.03	0.00	0.00	514	2	0.01	3.3	1.0
Min	0.00	23.3	6.33	5.59	66	0.04	0.42	0.07	0.04	283	54	0.07	15.0	10.1
Max	0.03	23.6	6.50	5.86	69	0.04	4.81	0.09	0.04	2560	65	0.09	31.0	14.9
Station 2: Surface														
Mean	0.29	23.8	6.69	4.99	59	0.04	0.49	0.09	0.05	720	575	0.08	14.0	10.9
SE	0.04	0.0	0.10	0.14	2	0.000	0.05	0.01	0.00	376	95	0.01	2.4	1.1
Min	0.20	23.8	6.50	4.73	56	0.04	0.40	0.08	0.04	83	365	0.07	10.0	8.3
Max	0.40	23.9	6.94	5.30	63	0.04	0.62	0.11	0.05	1716	825	0.10	21.0	13.2
Station 3: Surface														
Mean	0.53	23.9	6.82	4.84	58	0.04	0.54	0.11	0.05	696	1053	0.08	14.8	9.9
SE	0.13	0.0	0.11	0.14	2	0.000	0.02	0.00	0.01	350	257	0.01	2.8	1.1
Min	0.30	23.8	6.56	4.66	56	0.04	0.49	0.10	0.04	167	618	0.06	10.0	7.3
Max	0.91	24.0	7.08	5.25	63	0.04	0.58	0.11	0.07	1683	1789	0.09	22.0	12.1
Station 4: Surface														
Mean	1.29	24.2	6.89	5.03	60	0.04	0.58	0.11	0.07	895	2533	0.07	11.8	8.2
SE	0.26	0.1	0.06	0.16	2	0.000	0.07	0.02	0.01	373	467	0.00	1.9	0.8
Min	0.80	24.0	6.73	4.74	57	0.04	0.48	0.08	0.06	133	1665	0.06	8.0	6.5
Max	2.01	24.4	6.99	5.47	66	0.04	0.79	0.17	0.09	1867	3819	0.08	15.0	10.1

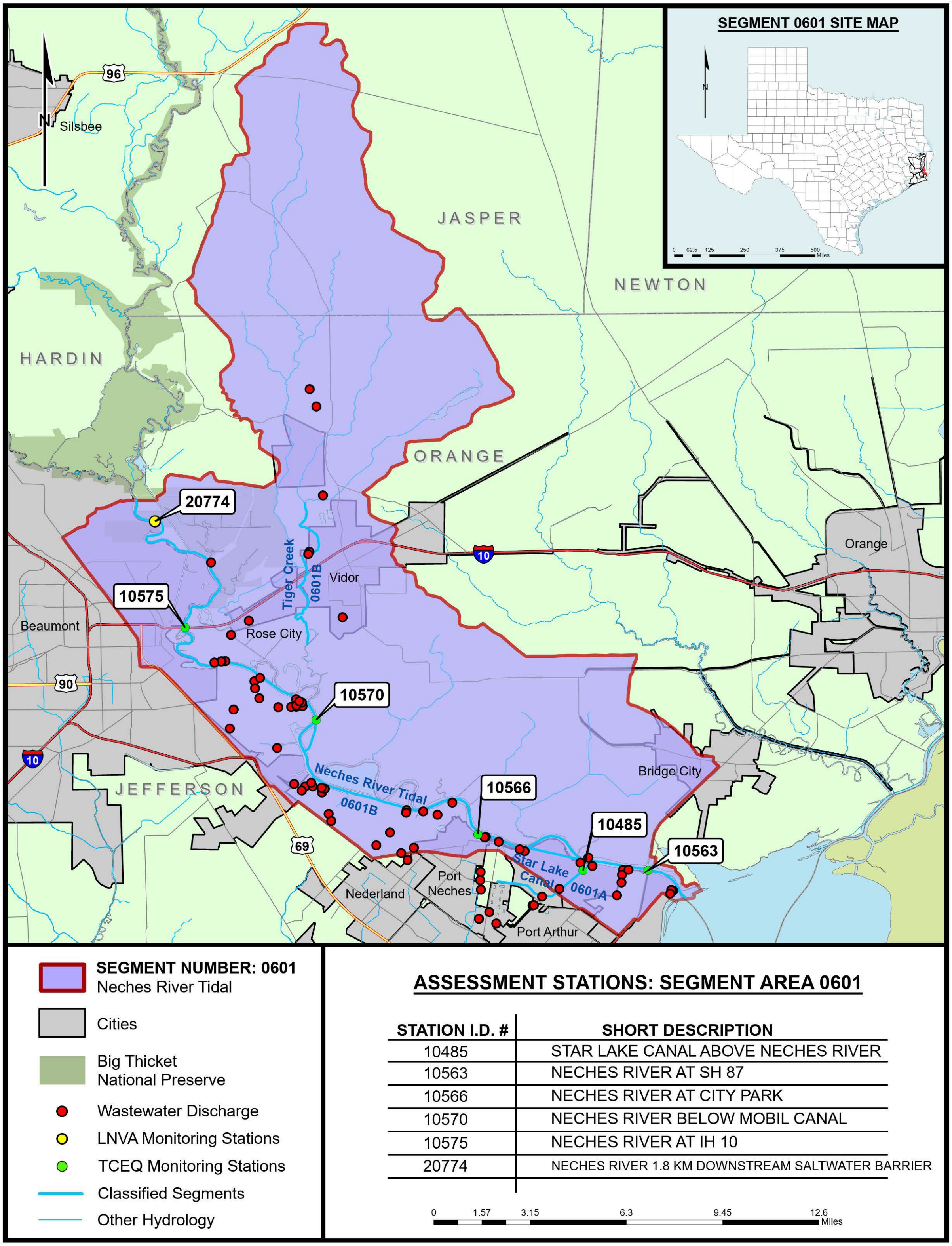
Samples collected once per day from 11 to 14 October 2003
NH4-N at the DL of 0.04 mg N/L
n = 4

Appendix A.9: Average, minimum and maximum concentrations of water column solids, fecal coliform and nutrients in the Neches River, collected in 2021 by LNVA and the Academy.

Parameter	Salinity	Temp	pH	DO	DO	o-PO4	TKN	NH4-N	NO3-N	Fecal Coliform	Sp. Cond.	TP	TSS	TOC
Unit	ppt	°C	unitless	mg/L	% Sat	mg P/L	mg N/L	mg N/L	mg N/L	cols./100 ml	uS/cm	mg P/L	mg/L	mg C/L
Station 0: Surface														
Mean	0.06	26.2	7.1	7.36	91	0.03	0.25	0.04	0.02	25	131	0.02	16.1	6.5
SE	0.00	0.1	0.1	0.11	1	0.00	0.05	0.01	0.01	6	5	0.01	1.7	0.4
Min	0.05	26.1	6.9	6.97	86	0.03	0.20	0.02	0.01	8	117	0.01	12.1	5.8
Max	0.07	26.3	7.3	7.51	93	0.03	0.43	0.06	0.05	36	147	0.06	18.8	7.5
Station 1: Surface														
Mean	0.05	25.4	7.0	6.44	79	0.04	0.25	0.04	0.03	42	121	0.04	15.3	9.6
SE	0.00	0.2	0.2	0.15	2	0.02	0.05	0.01	0.01	18	10	0.01	1.3	0.5
Min	0.04	25.1	6.7	5.99	73	0.03	0.20	0.02	0.02	8	95	0.01	11.9	8.2
Max	0.06	26.0	7.8	6.81	84	0.10	0.45	0.05	0.05	80	150	0.06	19.2	10.8
Station 2: Surface														
Mean	0.94	25.7	7.0	5.04	62	0.11	0.26	0.04	0.11	31	1850	0.03	10.3	9.3
SE	0.08	0.0	0.1	0.12	1	0.09	0.04	0.01	0.01	6	145	0.01	0.9	0.3
Min	0.74	25.6	6.7	4.75	59	0.03	0.20	0.02	0.09	20	1492	0.01	8.5	8.4
Max	1.13	25.8	7.4	5.30	65	0.41	0.40	0.05	0.14	48	2147	0.07	12.5	9.8
Station 3: Surface														
Mean	1.76	25.9	7.1	5.28	65	0.03	0.23	0.03	0.14	21	3441	0.03	10.2	7.9
SE	0.05	0.1	0.2	0.12	1	0.00	0.04	0.01	0.00	6	52	0.01	1.2	0.3
Min	1.60	25.7	6.7	4.99	62	0.03	0.20	0.02	0.13	8	3313	0.01	8.6	7.1
Max	1.87	26.1	7.7	5.61	69	0.03	0.37	0.04	0.15	40	3585	0.05	14.5	8.4
Station 4: Surface														
Mean	3.07	26.3	7.0	4.86	61	0.03	0.22	0.04	0.20	22	5676	0.03	15.7	6.6
SE	0.13	0.1	0.1	0.15	2	0.00	0.02	0.01	0.01	8	225	0.01	1.9	0.2
Min	2.65	26.1	6.9	4.48	57	0.03	0.20	0.02	0.17	4	4966	0.01	12.2	6.0
Max	3.31	26.4	7.3	5.27	67	0.03	0.30	0.08	0.22	40	6084	0.06	22.0	7.3

Samples collected once per day from 5 to 9 October 2021
Note: Some values were set at their DL =
NH4-N at the DL of 0.04 mg N/L
N03-N at the DL of 0.01 mg N/L
TKN-N at the DL of 0.2 mg N/L
Ortho-P at the DL of 0.03 mg P/L
TP at the DL of 0.01 mg P/L
n = 5

Appendix A.10: Map of TECQ SWQMIS monitoring stations in segment 0601 used for long-term analysis of water quality.



STATION I.D. #	SHORT DESCRIPTION
10485	STAR LAKE CANAL ABOVE NECHES RIVER
10563	NECHES RIVER AT SH 87
10566	NECHES RIVER AT CITY PARK
10570	NECHES RIVER BELOW MOBIL CANAL
10575	NECHES RIVER AT IH 10
20774	NECHES RIVER 1.8 KM DOWNSTREAM SALTWATER BARRIER

APPENDIX B: ALGAL STUDIES

Appendix B.1: Listing of the most common algae species from the composite samples from the October 2021 survey on the Neches River near Beaumont, TX. A diatom species is common if it has a valve count of six or more.

	Station				
Taxon Name	0	1	2	3	4
Bacillariophyta (Diatoms)					
Achnanthes brevipes Agardh					+
Achnanthes curvirostrum Brun				+	+
Achnanthes reversa Lange-Bertalot et Krammer					+
Achnanthidium exiguum (Grunow) Czarnecki					+
Achnanthidium minutissimum (Kützing) Czarnecki	+	+			
Achnanthidium spp.	+	+			
Amphipleura pellucida (Kützing) Kützing	+				
Amphora copulata (Kützing) Schoeman et Archibald		+	+	+	+
Anaulus balticus Simonsen				+	
Aulacoseira ambigua (Grunow) Simonsen	+	+			+
Aulacoseira granulata (Ehrenberg) Simonsen	+	+			
Aulacoseira granulata var. angustissima (Müller) Simonsen	+	+			
Aulacoseira pusilla (Meister) Tuji et Houki	+	+			
Aulacoseira tenella (Nygaard) Simonsen		+			
Bacillaria paxillifera (O.F.Müller) T.Marsson	+	+	+	+	+
Berkeleya rutilans (Trentepohl ex Roth) Grunow				+	+
Brachysira spp.	+				
Caloneis bacillum (Grunow) Cleve	+	+		+	+
Caloneis hyalina Hustedt	+				
Capartogramma crucicula (Grunow ex Cleve) Ross	+	+	+	+	+
Catenula adhaerens (Mereschkowsky) Mereschkowsky					+
Pinnularia krockii (Grunow) Hustedt		+			
Chamaepinnularia mediocris (Krasske) Lange-Bertalot	+				
Chamaepinnularia sp.					+
Cocconeis fluviatilis Wallace	+	+	+	+	+
Cocconeis placentula Ehrenberg		+	+	+	+
Craticula accomoda (Hustedt) Mann		+			
Craticula molestiformis (Hustedt) Mayama	+				
Cyclostephanos tholiformis Stoermer, Håkansson et Theriot	+	+	+		
Cyclotella atomus Hustedt	+	+			
Cyclotella gamma Sovereign			+		
Cyclotella meneghiniana Kützing	+	+	+	+	+
Cyclotella striata (Kützing) Grunow				+	+
Cymatosira belgica Grunow				+	+
Cymbella tumida (Brébisson ex Kützing) Van Heurck	+	+			
Denticula subtilis Grunow		+			+
Diadesmis confervacea Kützing	+	+	+		+
Diploneis abscondita Lange-Bertalot and Fuhrmann	+	+	+	+	
Diploneis elliptica (Kützing) Cleve		+		+	+
Diploneis puella (Schumann) Cleve	+	+	+	+	+
Diploneis puellafallax Lange-Bert. and Fuhrmann		+			
Diploneis smithii (Brébisson) Cleve				+	+
Diploneis sp. 1 ?			+	+	+
Diploneis sp. 2 ?	+	+	+	+	+
Discostella stelligera (Cleve et Grunow) Houk et Klee	+	+			
Encyonema silesiacum (Bleisch) Mann	+	+			
Encyonopsis sp.					+
Entomoneis alata (Ehrenberg) Ehrenberg			+		+
Eunotia bilunaris (Ehrenberg) Souza		+			
Eunotia formica Ehrenberg	+				

Appendix B.1 (continued): Listing of the most common algae species from the composite samples from the October 2021 survey on the Neches River near Beaumont, TX. A diatom species is common if it has a valve count of six or more.

	Station				
Taxon Name	0	1	2	3	4
Eunotia incisa Smith ex Gregory				+	
Eunotia minor (Kützing) Grunow	+	+			
Eunotia sp.	+				
Eunotia spp.		+			
Fallacia latelongitudinalis (Patrick) Potapova		+			
Fallacia lenzii (Hustedt) Lange-Bertalot		+			
Fallacia pygmaea (Kützing) Stickle et Mann		+			
Fallacia subhamulata (Grunow) Mann		+			
Fallacia tenera (Hustedt) Mann	+	+	+	+	+
Fragilaria cassubica Witkowski et Lange-Bertalot					+
Fragilaria pararumpens Lange-Bertalot, G. Hofmann & Werum	+	+	+		
Fragilaria saxoplanctonica Lange-Bertalot et Ulrich	+	+			
Fragilaria sp.		+			
Fragilaria vaucheriae (Kützing) Petersen	+				
Frustulia crassinervia (Brébisson) Lange-Bertalot et Krammer	+	+	+		
Frustulia inculta Siver, Pelczar et Hamilton	+	+			
Frustulia latita Graeff et Kociolek	+	+			
Geissleria lateropunctata (Wallace) Potapova et Winter	+	+			
Gogorevia exilis (Kütz.) Kulikovskiy and Kociolek	+			+	
Gomphonema affine Kützing			+		
Gomphonema innocens Reichardt		+			
Gomphonema louisiananum Kalinsky	+	+			
Gomphonema naviculoides W. Smith	+	+			
Gomphonema parvulum (Kützing) Kützing	+	+	+	+	+
Gomphonema sp.	+				
Gomphonema spp.		+			
Gomphonitzschia sp.				+	+
Gomphosphenia lingulatiformis (Lange-Bertalot et Reichardt) Lange-Bertalot	+	+	+	+	+
Gyrosigma acuminatum (Kützing) Rabenhorst	+	+			
Gyrosigma nodiferum (Grunow) Reimer	+	+			
Gyrosigma obscurum (Smith) Griffith et Henfrey		+			
Gyrosigma sciotoense (Sullivant) Cleve	+	+	+	+	+
Gyrosigma sp.					+
Halamphora coffeaeformis (Agardh) Levkov					+
Halamphora holsatica (Hustedt) Levkov			+	+	+
Halamphora latecostata Stepanek et Kociolek					+
Halamphora montana (Krasske) Levkov					+
Hippodonta capitata Authority (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	+	+	+		
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin et Witkowski		+	+	+	+
Hippodonta lueneburgensis (Grunow) Lange-Bertalot, Metzeltin et Witkowski		+			
Hippodonta pseudacceptata (Kobayasi) Lange-Bertalot			+	+	+
Humidophila contenta (Grunow) Lowe, Kociolek, Johansen, Van de Vijver, Lange-Bertalot et Kopalová	+	+	+		
Luticola goeppertiana (Bleisch) Mann	+	+	+	+	
Luticola mutica (Kützing) Mann		+	+	+	+
Luticola sp.					+
Luticola stigma (Patrick) Johansen		+			
Madinithidium flexuistriatum Desrosiers, Witkowski & Riaux-Gobin			+		
Mayamaea sp	+	+			
Melosira moniliformis (Müller) Agardh					+

Appendix B.1 (continued): Listing of the most common algae species from the composite samples from the October 2021 survey on the Neches River near Beaumont, TX. A diatom species is common if it has a valve count of six or more.

	Station				
Taxon Name	0	1	2	3	4
Melosira varians Agardh	+	+			
Navicula aleksandrae Lange-Bertalot, Bogaczewicz-Adamczak et Witkowski			+	+	+
Navicula amphiceropsis Lange-Bertalot et Rumrich	+				
Navicula antverpensis Van de Vijver et Lange-Bertalot		+			+
Navicula canalis Patrick	+	+		+	+
Navicula cari Ehrenberg					+
Navicula cryptocephala Kützing	+	+	+		
Navicula cryptotenella Lange-Bertalot	+	+	+	+	+
Navicula difficillima Hustedt	+	+			
Navicula eidrigiana Carter					+
Navicula erifuga Lange-Bertalot	+	+		+	+
Navicula escambia (Patrick) Metzeltin et Lange-Bertalot	+	+		+	+
Navicula germainii Wallace	+	+	+		
Navicula gregaria Donkin	+	+	+	+	+
Navicula kotschyi Grunow			+	+	+
Navicula lanceolata (Agardh) Kützing		+			
Navicula libonensis Schoeman				+	
Navicula longicephala Hustedt	+	+			
Navicula luciae Witkowski et Lange-Bertalot			+	+	+
Navicula microcari Lange-Bertalot				+	
Navicula namibica Lange-Bertalot et Rumrich			+	+	+
Navicula notha Wallace	+	+			
Navicula peregrina (Ehrenberg) Kützing			+		
Navicula pseudolanceolata Lange-Bertalot				+	+
Navicula recens (Lange-Bertalot) Lange-Bertalot	+	+	+	+	+
Navicula rostellata Kützing	+	+			
Navicula salinarum Grunow	+				
Navicula salinicola Hustedt		+		+	+
Navicula sp.	+		+	+	+
Navicula sp. 1 ?	+	+			
Navicula sp. 2 ?	+	+			
Navicula sp. 3 ?	+	+			
Navicula supergregaria Lange-Bertalot et Rumrich		+	+		
Navicula symmetrica Patrick	+	+	+	+	+
Navicula vilaplanii (Lange-Bertalot et Sabater) Lange-Bertalot et Sabater	+	+	+	+	+
Navicula viridula (Kützing) Kützing		+			
Nitzschia acicularis (Kützing) Smith	+	+			
Nitzschia acidoclinata Lange-Bertalot	+				
Nitzschia adamata Hustedt			+	+	+
Nitzschia amphibia Grunow	+	+	+		+
Nitzschia amplectens Hustedt			+	+	+
Nitzschia angustatula Lange-Bertalot		+			
Nitzschia biacrula Hohn et Hellerman	+	+			
Nitzschia brevissima Grunow ex Van Heurck		+	+	+	+
Nitzschia clausii Hantzsch	+	+	+	+	+
Nitzschia dissipata (Kützing) Grunow	+	+			+
Nitzschia filiformis (Smith) Van Heurck	+	+	+	+	+
Nitzschia filiformis var. conferta (Richter) Lange-Bertalot	+	+	+	+	+
Nitzschia fonticola (Grunow) Grunow	+	+			
Nitzschia frustulum (Kützing) Grunow	+	+	+	+	+

Appendix B.1 (continued): Listing of the most common algae species from the composite samples from the October 2021 survey on the Neches River near Beaumont, TX. A diatom species is common if it has a valve count of six or more.

	Station				
Taxon Name	0	1	2	3	4
Nitzschia gracilis Hantzsch	+	+			
Nitzschia incognita Legler et Krasske		+	+	+	+
Nitzschia inconspicua Grunow	+	+	+	+	+
Nitzschia kurzeana Rabenhorst	+		+	+	+
Nitzschia lacuum Lange-Bertalot	+				
Nitzschia lanceolata Smith	+	+			
Nitzschia liebethruthii Rabenhorst				+	
Nitzschia lorenziana Grunow	+	+			
Nitzschia microcephala Grunow		+	+	+	+
Nitzschia minuta Bleisch	+				
Nitzschia nana Grunow ex Van Heurck	+	+	+	+	+
Nitzschia obtusa Smith		+		+	+
Nitzschia palea (Kützing) Smith	+	+	+	+	+
Nitzschia palea var. tenuirostris Grunow	+	+		+	
Nitzschia palea var. debilis (Kützing) Grunow	+	+			
Nitzschia paleacea Grunow				+	+
Nitzschia pusilla Grunow	+				
Nitzschia recta Hantzsch ex Rabenhorst	+	+	+		+
Nitzschia reversa Smith		+			
Nitzschia rosenstockii Lange-Bertalot			+	+	+
Nitzschia scalpelliformis Grunow					+
Nitzschia sigma (Kützing) Smith	+	+	+		+
Nitzschia sigmoidea (Nitzsch) Smith	+	+			
Nitzschia sociabilis Hustedt	+	+	+	+	+
Nitzschia soratensis Morales et Vis				+	+
Nitzschia sp.	+	+			
Nitzschia sp. 3 ?	+	+	+	+	+
Nitzschia sp. 8 ?			+	+	+
Nitzschia spp.	+	+			
Nitzschia subacicularis Hustedt	+	+	+		
Nitzschia subcohaerens v. scotica (Grunow) Van Heurck				+	+
Nitzschia supralitorea Lange-Bertalot	+	+	+	+	+
Nitzschia tubicola Grunow		+			
Nitzschia valdestriata Aleem et Hustedt					+
Nitzschia vidovichii (Grunow) Grunow				+	+
Nupela sp.	+				
Nupela wellneri (Lange-Bertalot) Lange-Bertalot					+
Parlibellus crucicula (Smith) Witkowski, Lange-Bertalot et Metzeltin			+	+	+
Pinnularia anglica Krammer		+			
Pinnularia marchica Schönfelder		+			
Pinnularia sp. 1 ?	+				
Pinnularia sp. 2 ?		+			
Pinnularia spp.		+			
Placoneis sp.	+				
Planothidium biporomum (Hohn et Hellerman) Lange-Bertalot	+				
Planothidium delicatulum (Kützing) Round et Bukhtiyarova			+	+	+
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	+	+	+		
Planothidium granum (Hohn et Hellerman) Lange-Bertalot			+	+	+
Planothidium incuriatum Wetzel, Van de Vijver and Ector	+				
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot			+		

Appendix B.1 (continued): Listing of the most common algae species from the composite samples from the October 2021 survey on the Neches River near Beaumont, TX. A diatom species is common if it has a valve count of six or more.

	Station				
Taxon Name	0	1	2	3	4
Planothidium lemmermannii (Hustedt) Morales			+	+	+
Planothidium potapovae C.E.Wetzel and Ector	+				
Planothidium sp. 1 ?			+		
Platessa bahlsii Potapova					+
Platessa conspicua (Mayer) Lange-Bertalot			+		
Pleurosigma salinarum (Grunow) Grunow			+		
Pleurosira laevis (Ehrenberg) Compère			+	+	+
Pseudostaurosira sp.		+			
Pseudostaurosira sp. 2 ?	+		+		
Pseudostaurosira trainorii Morales		+	+		
Pseudostaurosiropsis sp. 2 ?				+	+
Rhopalodia acuminata Krammer		+	+	+	
Rhopalodia constricta (Smith) Krammer	+				+
Rhopalodia operculata (Agardh) Håkansson	+				
Sellaphora atomoides (Grunow) Wetzel et Van de Vijver	+				
Sellaphora laevissima (Kützing) Mann	+				
Sellaphora nigri (De Notaris) Wetzel et Ector	+	+			
Sellaphora pupula (Kützing) Meresckowsky	+	+			
Sellaphora saugerresii (Desmazieres) Wetzel et Mann	+	+			
Sellaphora seminulum (Grunow) Mann			+		
Sellaphora sp.	+	+			
Sellaphora sp. 1 ?	+				
Sellaphora subfasciata (Patrick) Potapova	+	+			
Seminavis strigosa (Hustedt) Danielidis et Economou-Amilli			+	+	+
Shionodiscus oestrupii (Ostenfeld) Alverson, Kang et Theriot			+	+	+
Sieminskia zeta (Cleve) Metzeltin et Lange-Bertalot				+	+
Simonsenia delognei (Grunow) Lange-Bertalot		+		+	+
Staurosira construens var. venter (Ehrenberg) Hamilton	+	+	+	+	+
Staurosirella martyi (Héribaud) Morales et Manoylov		+	+	+	+
Staurosirella pinnata (Ehrenberg) Williams et Round			+	+	+
Staurosirella sp.			+	+	+
Stenopterobia delicatissima (Lewis) Van Heurck	+				
Surirella lacrimula English				+	
Surirella ovalis Brébisson					+
Surirella stalagma Hohn et Hellerman	+	+			
Surirella tenera Gregory	+				
Synedra delicatissima Smith		+			
Synedra goulardi Brébisson ex Cleve and Grunow	+	+			
Tabularia fasciculata (Agardh) Williams et Round	+	+	+	+	+
Tabularia tabulata (Agardh) Snoeijs			+	+	+
Terpsinoe musica Ehrenberg	+		+		
Thalassiosira eccentrica (Ehrenberg) Cleve				+	
Thalassiosira lacustris (Grunow) Hasle	+	+	+		
Tryblionella apiculata Gregory			+		+
Tryblionella balatonis (Grunow) Mann	+				
Tryblionella calida (Grunow) Mann		+	+		+
Tryblionella cf perversa (Grunow) Mann		+			
Tryblionella debilis Arnott ex OMeara		+			
Tryblionella hungarica (Grunow) Frenguelli	+	+	+		
Tryblionella levidensis Smith	+	+			

Appendix B.1 (continued): Listing of the most common algae species from the composite samples from the October 2021 survey on the Neches River near Beaumont, TX. A diatom species is common if it has a valve count of six or more.

	Station				
Taxon Name	0	1	2	3	4
Tryblionella salinarum (Grunow) Pelletan			+		+
Tryblionella sp.	+	+	+		+
Ulnaria sp		+			
Ulnaria sp. 1 ?		+			
Ulnaria sp. 2 ?		+			
Ulnaria spp.	+				
Chlorophyceae (Green Algae)					
Characium sp.	+				
Cladophora glomerata (Linnaeus) Kützing	+		+		+
Closterium sp.		+			
Cosmarium sp.	+				
Gloeocystis sp.	+	+			
Microspora sp.			+	+	+
Mougeotia sp.			+		
Oedogonium sp.	+	+	+	+	+
Pediastrum sp.		+			
Rhizoclonium sp.			+	+	+
Scenedesmus ecornis (Ralfs) Chodat	+		+		
Scenedesmus quadricauda (Turpin) Brébisson	+	+			
Scenedesmus sp.	+				
Spirogyra sp.	+	+	+		
Myxophyceae (Blue-Green Algae)					
Anabaena sp.	+	+			+
Aphanocapsa sp.	+	+	+	+	+
Aphanothece sp.	+	+	+		
Calothrix sp.	+	+		+	+
Chlorogloeopsis sp	+	+			
Chroococcus sp.				+	+
Coleofasciculus chthonoplastes (Thuret ex Gomont) M.Siegesmund, J.R.Johansen & T.Friedl	+	+		+	+
Cylindrospermopsis spp.	+	+			
Cylindrospermum sp.	+	+			
Geitlerinema splendidum (Greville) Anagnostidis			+	+	+
Hassallia sp.	+	+			
Homoeothrix (Tapinothrix) janthina (Bornet et Flahault) Starmach				+	+
Komvophoron sp.	+	+		+	+
Leptolyngbya sp.	+	+	+	+	+
Lyngbya martensiana Meneghini ex Gomont	+	+			
Lyngbya sp.		+		+	
Merismopedia sp.			+		
Merismopedia tenuissima Lemmermann	+		+	+	+
Nostoc sp.	+	+	+	+	+
Oscillatoria sp.	+	+	+	+	+
Phormidium sp.	+	+	+	+	+
Pseudanabaena sp.	+	+	+	+	+
Spirulina sp.	+				+
Xanthophytes (Yellow-Green Algae)					
Vaucheria sp.	+	+	+		+
Rhodophyceae (red algae)					
Compsopogon sp.		+			

Appendix B.2: List of taxonomic changes between algal surveys conducted in 2003 and 2021. Most changes represent new taxon designations (i.e., taxonomy updates) along with taxa that have been combined or separated.

Name used in 2021	Name used in 2003
Bacillaria paxillifera (O.F.Müller) T.Marsson	*Bacillaria paradoxa* Gmelin
Discostella stelligera (Cleve et Grunow) Houk et Klee	*Cyclotella stelligera* (Cleve et Grunow) Van Heurck
Gogorevia exilis (Kütz.) Kulikovskiy and Kociolek	*Achnanthidium exiguum* (Grunow) Czarnecki
Halamphora montana (Krasske) Levkov	*Amphora montana* Krasske
*Hippodonta pseudacceptata (*Kobayasi) Lange-Bertalot	*Navicula perminuta* Grunow
Navicula escambia (Patrick) Metzeltin et Lange-Bertalot	*Navicula schroeteri var. escambia* Patrick
Navicula metareichardtiana Lange-Bertalot & Kusber	*Navicula reichardtiana* Lange-Bertalot
Nitzschia inconspicua Grunow	*Nitzschia inconspicua* Grunow
Nitzschia palea var. debilis (Kützing) Grunow	*Nitzschia palea* (Kützing) Smith
Nitzschia palea var. tenuirostris Grunow	*Nitzschia palea* (Kützing) Smith
Nitzschia soratensis Morales et Vis	*Nitzschia inconspicua* Grunow
Placoneis symmetrica (Hustedt) Lange-Bertalot	*Navicula constans var. symmetrica* Hustedt
Planothidium lemmermannii (Hustedt) Morales	*Achnanthes lemmermannii* Hustedt
Planothidium potapovae Wetzel & Ector	*Planothidium rostratum* (Østrup) Lange-Bertalot
Platessa conspicua (Mayer) Lange-Bertalot	*Achnanthes conspicua* Mayer
Ulnaria acus (Kützing) Aboal	*Synedra acus* Kützing
Ulnaria ulna (Nitzsch) Compère	*Synedra ulna* (Nitzsch) Ehrenberg
Coleofasciculus chthonoplastes (Thuret ex Gomont) M.Siegesmund, J.R.Johansen & T.Friedl	*Microcoleus chthonoplastes* (Thuret) Gomont

APPENDIX C: MACROINVERTEBRATES

Appendix C.1: Macroinvertebrate sampling locations and detailed descriptions for all stations.

	Latitude	Longitude	Notes
Station 0, Location 1	30.15623333	-94.11323333	Left Bank, closest to the salt water barrier
Station 0, Location 2	30.15778333	-94.11423333	Left Bank
Station 0, Location 3	30.15918333	-94.11475	Left Bank
Station 0, Location 4	30.16163333	-94.11375	Left Bank
Station 0, Location 5	30.16105	-94.11471667	Confluence
Station 0, Location 6	30.16006667	-94.1159	Right Bank, past the confluence
Station 0, Location 7	30.15798333	-94.11561667	Right Bank, rip rap and rocks, close to the salt water barrier
Station 1, Location 1	30.14245	-94.1014	Right Bank
Station 1, Location 2	30.139786	-94.106384	Backwater
Station 1, Location 3	30.137774	-94.103846	Left bank
Station 1, Location 4	30.138655	-94.101668	Left bank, location too deep, cut bank. Side Pond found here
Station 1, Location 5	30.13923	-94.103653	Right bank, sand area revealed after the tide
Station 2, Location 1	30.05455	-94.03036667	Right bank
Station 2, Location 2	30.047	-94.0355	Multiple locations within backwater by Clark Island
Station 2, Location 3	30.04556667	-94.03203333	Right bank
Station 2, Location 4	30.04941667	-94.02675	Left bank, sandy shore where seining occurred
Station 3, Location 1	30.0125	-93.99996667	Right Bank
Station 3, Location 2	30.01636667	-94.01481667	Right Bank, further upstream from location 1
Station 3, Location 3	30.01456667	-93.99815	Left Bank
Station 4, Location 1	30.005922	-93.957303	Right Bank
Station 4, Location 2	30.008103	-93.957588	Right Bank
Station 4, Location 3	30.010389	-93.95864	Last stop on the Right Bank
Station 4, Location 4	30.011808	-93.955277	First stop along the Left Bank near the canal
Station 4, Location 5	30.010732	-93.95469	Other side of the canal along the Left Bank
Station 4, Location 6	30.009612	-93.954311	Left Bank
Station 4, Location 7	30.008118	-93.954018	Final stop along the Left Bank

Station 0

Seven locations were sampled along the reach for Station 0: four locations along the left bank, one at the confluence of the Neches River and Pine Island Bayou, and two along the right bank. One was a depositional sandy bank where *Schoenoplectus californicus* (California bulrush), *Alternanthera philoxeroides* (alligator weed), genus *Cladium* (saw grasses), *Pontederia cordata* (water pickerel) and *Eichhornia crassipes* (water hyacinth) were sampled. Knees and roots of *Taxodium distichum* (bald cypress) were sampled with a knife and dip net, as well as hand-picked. Most locations contained driftwood, exposed roots and various water plants that were all hand-picked. A dip net was used along the side of the boat along the right bank in areas that were too deep (7 to 8 feet) to navigate by foot. At the confluence, a depositional area allowed for dip net sampling of the sand, mud and hard pan. The right bank had some rip rap that enabled hand picking of macroinvertebrates. At nearly every sampling location, mats of *Salvinia* (*S. minima* and *S. molesta*) were sampled. Detritus was collected at the confluence, woody debris from the left bank, and mats of *Salvinia* from

Appendix C.1 (continued): Macroinvertebrate sampling locations and detailed descriptions for all stations.

both banks. The detritus was brought back to the Academy laboratory for further picking.

Station 1

Five locations were chosen for sampling at Station 1. The shallow water sampling sites were along a depositional right bank (downstream orientation) of the river in a region with a narrow-flooded spit of land that separated the main channel from a large backwater. Sampling occurred on both sides of this peninsula and upriver on the channel side. Numerous macrophytes were sampled within the backwater including California bulrush, water hyacinth, *Phragmites*, *Salvinia* and various sedges of the genus *Carex*. Macrophytes were shaken onto the boat surface to dislodge macroinvertebrates for hand-picking. In addition to 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. One location along the left bank was too deep to sample outside of the boat so detritus was taken into the boat for hand-picking. At this location a side pond was discovered, and several macroinvertebrates were taken for identification. The organisms in the side pond were not counted in the total species count since the pond was not connected to the river itself and as such was not part of the study area. For a list of side pond species, see Appendix C.4. The last location, along the right bank, was visited later in the day when the tide went out which allowed for collection of clams along the sandy areas.

Station 2

Station 2 began at an area downriver from Light 54 to a region upriver of Light 56. Within these limits, four locations were chosen. 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 right bank shoreline north of Clark Island near Light 51 was sampled in two locations, and substrates here consisted of muddy sand and depositional silt. Macrophytes within the backwater near Clark Island included stands of California bulrush (*Schoenoplectus californicus*), water hyacinth (*Eichhornia crassipes*), *Phragmites*, sedges (genus *Carex*), cattails (Typhaceae family), coontail (*Ceratophyllum demersum*), *Salvinia* (*S. minima and S. molesta*), and some lily pads (Nymphaeaceae family). Macrophytes were hand-picked as well as shaken onto the boat surface to dislodge macroinvertebrates.

Station 3

Three locations were chosen at Station 3. Station 3 was sampled along the right bank, from approximately the middle of McFadden Bend Cutoff to just upriver from Light 40. The left bank was sampled along the east side of the Reserve Fleet area 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

Appendix C.1 (continued): Macroinvertebrate sampling locations and detailed descriptions for all stations.

were present. Most sandy areas had only 1 cm of sand, with hard pan below it. Macrophytes included water hyacinth (*Eichhornia crassipes*), Phragmites, and an undetermined rush (Juncaceae family). Macrophytes were shaken onto the boat surface to dislodge macroinvertebrates for hand-picking. The left bank had more organisms than the right bank, and there was more trash and rip rap along the right bank.

Station 4

Station 4 samples were taken at seven locations, primarily from left bank habitats between 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. The right bank had regions that lacked a sand beach, and substrates consisted of clay, firm mud, and detrital mixtures. Macrophytes included water hyacinth (*Eichhornia crassipes*) and stands of *Phragmites.*

Appendix C.2: Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Non-Insect Macroinvertebrates	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
Porifera		Spongillidae	*Trochospongilla horrida*																								+			
			Undetermined sp.						+				+				+										+			
Ctenophora			*Beroe sp.*											+	+	+														
			Undetermined sp.									+																		
Cnidaria			Undetermined sp. A											+	+	+														
			Undetermined sp. B										+	+	+	+														
Platyhelminthes		Dugesiidae	*Girardia tigrina*														+													
	Class Rhabditophora		Undetermined sp.	+																										
Annelida	Sub-Class Oligochaeta	Naididae	*Brachiura sowerbyi*						+																					
			Naididae sp. 1	+																										
			Pristina longiseta	+																							+			
			Stylaria sp. (in algae collections)																								+			
			Undetermined sp.						+									+												
			Undetermined sp. A										+																	
			Undetermined sp. B										+		+															
		Lumbriculidae	*Lumbriculus variegatus*						+				+			+														
			Lumbriculidae sp. 1	+	+	+																								
			Lumbriculidae sp. 2	+																										
			Lumbriculidae sp. 3	+	+																									
			Lumbriculidae sp. 4	+																										
			Lumbriculidae sp. 5				+																							
	Sub-Class Hirudinea		Hirudinea sp. 1	+	+		+																							
			Hirudinea sp. 2	+																										
			Hirudinea sp. 3		+																									
		Glossiphoniidae	*Helobdella triserialis*						+																					
		Piscicolidae	*Myzobdella lugubris*							+	+	+			+															
	Class Polychaeta	Nereidae	*Ceratonereis tridentata*															+	+											
			Laeonereis culveri	+			+										+	+												
			Neanthes succinea	+						+	+	+		+	+	+														
			Nereis sp.																							+				
			Undetermined sp.																			+	+							
		Pilargidae	*Parandalia americana*												+															
		Serpulidae	*Ficopomatus miamiensis*								+	+		+	+	+														

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	**Class/Order**	**Family**	**Non-Insect Macroinvertebrates**	**2021**					**2003**				**1996**				**1973**				**1960**			**1956**			**1953**			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
Mollusca	Class Bivalvia	Unionidae	*Fusconaia askewi*						+																					
			Quadrula apiculata						+																					
			Undetermined sp.																								+			
		Pisidiidae	*Eupera cubensis*	+	+				+																					
			Musculium securis						+																					
			Undetermined sp.*		+																									
		Dreissensiidae	*Mytilopsis leucophaeata*		+		+	+		+	+	+	+	+	+	+	+										+			
		Mactridae	*Rangia cuneata*	+	+	+	+	+	+	+	+	+	+	+	+	+	+										+			
			Rangia flexuosa		+	+																								
			*Rangia sp.**					+																						
		Ostreidae	*Crassostrea virginica*					+								+														
		Cyrenidae	*Polymesoda caroliniana*							+	+				+															
		Corbiculidae	*Corbicula fluminea*	+																										
	Gastropoda	Hydrobiidae	*Amnicola limosus*						+																					
			Pyrgophorus spinosus						+																					
			Undetermined sp.						+									+												
		Planorbidae	*Ferrissia californica*			+																								
			Planorbella trivolvis					+	+																					
			*Planorbidae sp.**		+	+																								
		Ancylidae	*Hebetoncylus excentricus*						+																					
		Lymnaeidae	*Pseudosuccinea columella*	+													+													
		Physidae	*Physella gyrina*	+					+			+	+																	
			*Physella sp.**		+	+																								
		Assimineidae	*Assiminea succinea*	+																										
Arthropoda	Suborder Prostigmata		Prostigmata sp. 1	+	+																									
			Prostigmata sp. 2	+		+																								
			Prostigmata sp. 3	+																										
			Prostigmata sp. 4	+																										
			Prostigmata sp. 5		+	+																								
	Order Collembola	Neanuridae	*Anurida sp.*	+																										
		Sminthuridae	*Sminthurida sp.*			+																								
		Isotomidae	*Semicerura sp.*					+																						

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Non-Insect Macroinvertebrates	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
Sub-phylum Crustacea	Subclass Copepoda		Copepoda sp.		+	+																								
	Suborder Cladocera	Holopediidae	*Holopedium sp.*	+																										
		Daphniidae	*Daphnia sp.*		+																									
	Order Ostracoda		Ostracoda sp. 1	+	+	+																								
			Ostracoda sp. 2	+	+	+																								
			Undetermined sp.																								+			
	Order Balanomorpha		Undetermined sp.																			+				+				
		Balanidae	*Amphibalanus improvisus*																								+			
			Amphibalanus subalbidus				+			+	+	+																		
			Balanus eburneus											+	+	+														
			Balanus sp.																				+							
	Order Isopoda		Undetermined sp.			+	+																							
		Asellidae	*Caecidotea sp.*	+									+																	
			Lirceus louisianae						+																					
			Lirceus sp.	+																										
		Sphaeromatidae	*Sphaeroma terebrans*							+	+	+		+	+	+														
		Cymothoidae	Undetermined sp.												+															
		Ligiidae	*Ligia exotica*									+																		
		Idoteidae	*Edotia triloba*									+																		
		Bopyridae	*Probopyrus bithynis*						+																					
			Probopyrus floridensis						+																					
			Probopyrus sp.		+																									
	Order Amphipoda	Gammaridae	*Gammarus fasciatus*																								+			
			Gammarus nr. mucronatus							+	+	+																		
			Gammarus mucronatus			+				+	+	+		+	+	+														
			Gammarus tigrinus			+			+	+	+	+	+																	
			Gammarus sp.	+	+	+				+	+	+					+	+	+											
			Gammaridae sp.				+																							
		Hyalellidae	*Hyalella azteca*		+	+			+	+	+	+	+			+	+													
			*Hyalella sp.**	+	+	+																								
		Corophiidae	*Apocorophium lacustre*	+		+		+		+							+													
			Apocorophium louisianum													+														
			Paracorophium sp.			+																								
		Aoridae	*Grandidierella bonnieroides*							+	+	+		+																

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Non-Insect Macroinvertebrates	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
		Talitridae	*Orchestia sp.*					+																						
			Platorchestia platensis					+		+	+	+		+	+	+														
			Speziorchestia grillus				+																							
			Talitroides sp.				+																							
		Melitidae	*Melita nitida*							+	+	+																		
			Melitidae sp.				+																							
	Order Decapoda	Palaemonidae	*Macrobrachium ohione*	+	+	+	+	+	+	+			+	+	+	+	+													
			*Macrobrachium sp.**	+	+	+	+	+																						
			Palaemon intermedius					+												+										
			Palaemon kadiakensis	+	+			+	+				+																	
			Palaemon pugio			+	+	+		+	+	+		+	+	+		+		+							+		+	
		Penaeidae	*Litopenaeus setiferus*		+	+	+	+		+	+	+	+	+	+	+		+	+	+		+	+		+	+				
			Penaeus aztecus		+	+	+	+														+	+		+	+				+
			Xiphopenaeus kroyeri			+								+	+	+														
		Portunidae	*Callinectes sapidus*		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					+	+			+	+
		Ocypodidae	*Leptuca spinicarpa*							+	+	+		+	+	+														
			Minuca minax																	+									+	+
			Undetermined sp.																						+					
		Panopeidae	*Panopeus obesus*			+																								
			Rithropanopeus harrisii		+	+	+	+		+	+	+		+	+	+		+	+	+							+			
		Sergestidae	*Acetes americanus*											+	+	+														
		Callichiridae	*Lepidophthalmus jamaicense*													+														
		Cambaridae	*Faxonius texanus*	+																										
			Procambarus angelinae										+																	
			Procambarus clarkii						+				+																	
			Cambaridae sp. 1*	+																										
		Sesarmidae	*Armases cinereum*					+		+	+	+		+	+	+														
			Sesarma reticulatum								+																			
	Order Mysida		Undetermined sp.			+																								
		Mysidae	*Americamysis almyra*							+	+	+	+	+	+	+														
			Taphromysis louisianae	+					+				+																	
	Order Tanaidacea	Leptocheliidae	*Hargeria rapax*									+				+														
	Class Arachnida	Arrenuridae	*Arrenurus sp.*						+																					
		Unionicolidae	*Unicola sp.*						+																					

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Insects	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
	Order Odonata	Aeshnidae	*Nasiaeschna pentacantha*	+	+				+																					
			Nasiaeschna sp.														+	+												
		Gomphidae	*Aphylla williamsoni*						+																					
			Arigomphus maxwelli						+																					
			Dromogomphus sp.	+																										
			Stylurus sp.	+		+																								
		Macromiidae	*Macromia taeniolata*						+																					
			Macromia sp.	+					+																					
		Corduliidae	*Epicordulia princeps*	+					+																					
			Epitheca nr. cynosura						+																					
			Neurocordulia molesta	+																							+			
			Somatochlora sp.	+																										
		Libellulidae	*Erythemis simplicicollis*							+	+	+																		
			Erythemis sp.	+	+	+		+		+					+															
			Libellula auripennis						+																					
			Miathyria marcella									+																		
			Pachydiplax longipennis						+																					
			Sympetrum sp.															+												
			Undetermined sp.		+																									
		Coenagrionidae	*Enallagma signatum*						+																					
			Enallagma sp.			+											+	+												
			Hesperagrion heterodotum			+																								
			Ischnura posita									+																		
			Ischnura ramburii							+																				
			Ischnura sp.		+						+																			
			Leptobasis sp.			+																								
			Nehalennia sp.			+																								
			Neoerythromma sp.		+																									
	Order Ephemeroptera	Baetidae	*Callibaetis sp.*			+			+	+	+	+																		
			Cloeon sp.														+													
			Procloeon sp.						+				+																	
			Undetermined sp.																			+								

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Insects	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
		Ephemeridae	*Hexagenia bilineata*																								+			
			Hexagenia sp.	+	+				+																					
		Caenidae	*Caenis diminuta*		+																									
			Caenis nr. *diminuta*						+	+																				
			Caenis sp.		+	+						+					+	+												
			Undetermined sp.*		+	+																								
		Leptohyphidae	*Tricorythodes sp.*						+								+													
		Heptageniidae	*Stenocron sp.*	+																										
			Stenonema carolina														+													
			Stenonema integrum														+													
			Stenonema sp.	+																										
	Order Hemiptera	Hydrometridae	Undetermined sp.	+																										
		Gerridae	*Rheumatobates sp.*			+			+				+				+													
			Undetermined sp.							+																				
		Veliidae	*Microvelia sp.*						+	+																				
			Platyvelia sp.			+			+																					
			Rhagovelia sp.	+	+																									
		Nepidae	*Ranatra buenoi*						+																		+			
			Ranatra sp.		+	+		+	+								+	+												
		Belostomatidae	*Belostoma lutarium*														+		+											
			Belostoma sp.			+			+	+	+	+	+																	
			Undetermined sp.		+																									
		Corixidae	*Palmacorixa buenoi*						+																					
			Trichocorixa sp.								+	+	+			+														
		Mesoveliidae	*Mesovelia sp.*	+	+	+																								
		Notonectidae	*Buenoa sp.*								+	+																		
		Naucoridae	*Plecoris biimpressus*		+																									
			Pelocoris femoratus															+												
			*Pelocoris sp.**	+	+	+	+			+	+	+																		
		Saldidae	*Pentacora sp.*		+																									
	Order Megaloptera	Sialidae	*Sialis* sp.						+																					
		Corydalidae	*Chauliodes rastricornis*														+													
			Chauliodes sp.		+																									

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Insects	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
	Order Lepidoptera	Crambidae	*Crambus* sp.							+	+																			
			Samea multiplicalis	+	+																									
	Order Trichoptera	Dipseudodopsidae	*Phylocentropus sp.*	+																										
		Polycentropodidae	*Polycentropus sp.*	+																										
		Hydropyschidae	*Macrostemum sp.*														+													
		Leptoceridae	*Leptocella sp.*														+													
			Nectopsyche sp.						+																					
			Oecetis sp.						+																					
		Psychomyiidae	*Psychomyia sp.*																								+			
	Order Coleoptera		Undetermined sp.																				+							
		Haliplidae	*Peltodytes dunavani*								+																			
			Peltodytes sexmaculatus						+																					
			Peltodytes sp.	+									+																	
		Dytiscidae	*Copelatus sp.*	+																										
			Desmopachria sp.								+																			
			Hydroporus clypealis														+													
			Laccophilus sp.														+	+		+										
			Neoporus sp.	+																										
			Uvarus sp.		+	+																								
			Uvarus sp. 1										+																	
			Uvarus sp. 2										+																	
		Noteridae	*Hydrocanthus atripennis*								+																			
			Hydrocanthus sp.	+	+	+	+			+		+	+																	
			Suphisellus puncticollis									+					+		+	+										
			Suphisellus sp.	+									+																	
		Gyrinidae	*Dineutus serrulatus analis*														+													
			Dineutus serrulatus		+																									
			Dineutus sp.										+																	
			*Dineutus sp. 1**	+	+																									
			*Dineutus sp. 2**	+																										
			Gyrinus analis														+													
			Gyrinus minutus	+	+	+	+	+																						
			Gyrinus sinuatus		+																									

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Insects	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
		Hydrophilidae	*Berosus sp.*	+						+																				
			Enochrus sp.														+													
			Tropisternus sp.									+																		
		Elmidae	*Stenelmis fuscata*														+													
			Stenelmis sp.	+																										
		Scirtidae	*Cyphon sp.*	+													+													
			Scirtes sp.	+																										
		Curculionidae	*Bagous sp.*														+													
			Lissorhoptrus simplex		+																									
		Chrysomelidae	*Agasicles hygrophila*		+																									
	Order Diptera	Tabanidae	*Chlorotabanus crepuscularis*	+																										
			Tabanus atratus														+													
		Limoniidae	*Limonia sp.*	+																										
		Culicidae	*Aedes sp.*							+																				
			Anopheles sp.	+						+																				
			Culex sp.	+						+																				
		Ceratopogonidae	*Bezzia/Palpomyia*							+																				
			Dasyhelea sp.	+							+																			
			Probezzia sp.						+																		+			
		Chironomidae	*Ablabesmyia mallochi*						+																					
			Ablabesmyia ramphe grp.						+																					
			Ablabesmyia sp.						+																					
			Chironomus attenuatus															+												
			Chironomus (C.) decorus grp.							+																				
			Chironomus sp.							+																				
			Cladopelma sp.						+																					
			Clinotanypus sp.						+																					
			Coelotanypus sp.						+																					
			Cricotopus sp.																+											
			Cryptochironomus sp.						+																		+			
			Dicrotendipes modestus						+											+										
			Dicrotendipes neomodestus							+	+	+																		
			Dicrotendipes sp.	+				+																						

Appendix C.2 (continued): Macroinvertebrate taxa list for all Academy surveys of the lower Neches River from 1953 to 2021 (current survey). The cursory studies in 1956 and 1960 are shaded in grey, and encompassed Stations 2 through 4 only.

Phylum	Class/Order	Family	Insects	2021					2003				1996				1973				1960			1956			1953			
				0	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	2	3	4	1	2	3	4
		Chrionomidae (continued)	*Endochironomus nigricans*																+											
			Endochironomus sp.							+			+																	
			Epoicocladius flavens						+																					
			Fissimentum sp.						+																					
			Glyptotendipes																+								+			
			Goeldichironomus devineyae	+																										
			Goeldichironomus fluctuans	+																										
			Labrundinia neopilosella							+																				
			Larsia decolorata							+	+																			
			Parachironomus															+												
			Polypedilum halterale grp.							+																				
			Polypedilum illinoense grp.	+					+	+	+						+		+											
			Polypedilum scalaenum grp.								+	+																		
			Polypedilum sp.										+																	
			Procladius (Holotanypus) sp.						+																					
			Procladius sp.						+																					
			Stictochironomus caffrarius grp.						+																					
			Tanytarsus sp. K Epler						+																					
			Tanytarsus sp. H Epler							+	+	+																		
			Tanytarsus sp. E Epler								+																			
			Tanytarsus sp. F Epler							+																				
			Tribelos fuscicorne		+				+																					
			Unicola sp.						+																					
			Undetermined sp.																			+								
			Undetermined sp. A*	+	+	+																								
			Undetermined sp. B*	+																										
			Undetermined sp. C*	+																										

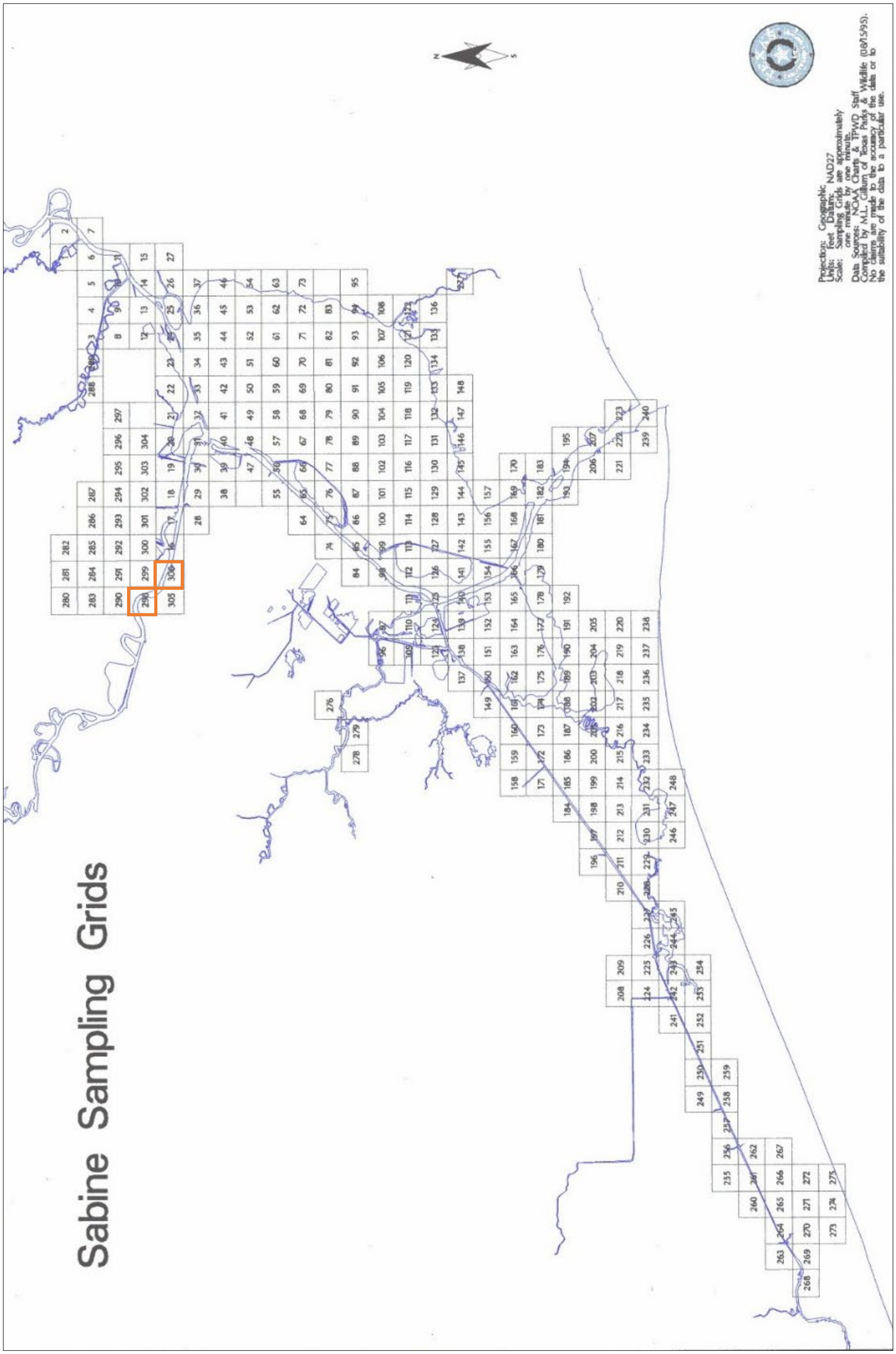
Appendix C.3: Taxonomic order, family and species name changes in macroinvertebrates over the past 65 years.

Year	Previous Name	Valid Name
1953	Mytilopsis leucophaeatus	Mytilopsis leucophaeata
1973	Archoophora	Rhabitiphora
1973	Ceratonereis tridentata	Websterinereis tridentata
1973	Congeria leucophaeta	Mytilopsis leucophaeata
all years	Tricorythodidae	Leptohyphidae
1973	Stenonema integrum	Stenonema mexicanum integrum
1973	Macronemum	Macrostemum
1973	Leptocella	Nectopsyche
1973	Hydroporus clypealis	Neoporus clypealis
1973	Cyphon	Elodes
1996	Ectoprocta	Bryozoa
1996	Pilargiidae	Pilargidae
1996	Pelecypoda	Bivalvia
1996	Penaeus setiferus	Litopenaeus setiferus
1996	Procambarus angelinae	Procambarus nechesae
2003	Pyralidae	Crambidae
2003	Brachiura sowerbyi	Branchiura sowerbyi
2003	Hebetoncylus excentricus	Hebetancylus excentricus
2003	Sphaerium securis	Musculium securis
2003	Desmopachia	Desmopachria
2003	Mysidopsis almyra	Americamysis almyra
2003	Leptochelia rapax	Hargeria rapax

Appendix C.4: Macroinvertebrate species found in the side pond at Station 1. Most of these species were not found anywhere else, notably, a gravid female and a few males in the genus Cambarellus (Crambidae), a species of Boyeria (Aeshnidae) dragonfly, and two genera of water striders (Aquarius and Metrobates).

Taxa Name	Side Pond Station 1
Non-Insect Macroinvertebrates	
Phylum Annelida	
Subclass Oligochaeta	+
Phylum Arthropoda	
Subphylum Crustacea	
Order Isopoda	
Family Asellidae	
Caecidotea sp.	+
Order Decapoda	
Family Cambaridae	
Cambarellus sp.	+
Insects	
Order Odonata	
Family Aeshnidae	
Boyeria sp.	+
Order Hemiptera	
Family Gerridae	
Metrobates	+
Aquarius	+
Order Coleoptera	
Family Hydrophilidae	
Enochrus	+

APPENDIX D: FISH



Appendix D.1: Map from Texas Parks and Wildlife Department showing the location of Sabine Sampling Grids 298 and 306 (outlined in orange).