Cow Bayou Tidal (Segment 0511)
Use Attainability Analysis

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Executive Summary

Tidal streams are important components of aquatic ecosystems, residing between the freshwater drainage upstream and the estuary below. Water quality management of these streams has been difficult since these systems are naturally variable over time and space. Assessments of several tidal streams have revealed dissolved oxygen (DO) measurements which are not meeting state water quality standards. This study was designed to address the impairment in the study streams, but in a larger sense to advance the understanding of the water quality, flow, and biological communities of tidal streams so that they can be effectively protected and managed.

Three tidal streams which have been identified as not meeting dissolved oxygen criteria, and therefore potentially not supporting aquatic life uses, are Cow Bayou Tidal, Garcitas Creek Tidal and Tres Palacios Creek Tidal. A reference stream approach was chosen to frame this study so two additional streams were added to the study design – Lost River and West Carancahua Creek. This report will address only results from the field effort on the upper coast (Cow Bayou Tidal and Lost River).

Cow Bayou Tidal (Orange County) and Lost River (Chambers and Liberty counties) are tidally-influenced streams in southeastern Texas. Cow Bayou's watershed is roughly twice the size of Lost River's watershed. Cow Bayou is surrounded by municipalities and rural development, and receives a number of industrial and domestic wastewater discharges, while Lost River has a relatively undeveloped watershed, much of which lies within the floodplain of the Trinity River. Habitat and land cover analysis reveal that Cow Bayou Tidal is subject to much greater human influence than Lost River.

During the course of the study many episodes of low DO were measured in the waters of Cow Bayou Tidal, especially at the uppermost end of the sampling reach. Lost River did not exhibit DO problems during the study. Based on land use, habitat, point and nonpoint sources of pollution, historical data and previous studies, Cow Bayou Tidal receives much more human impact than Lost River. While natural conditions such as stream width and hydrology may contribute to low DO in Cow Bayou Tidal, controllable anthropogenic impacts should be addressed with a TMDL study.

Nekton communities (mainly fish and shrimp) of both streams showed good diversity of aquatic species. There were 89 species collected in Cow Bayou and 69 species collected in Lost River over the course of the study. As of the last sampling trip, new species were still appearing in the collection. Invertebrate sampling revealed a diversity of taxa, most of which were colonizing and pioneering organisms or stress-tolerant forms. The analysis presented in this report did not show clear differences in the biological data between Cow Bayou and Lost River. Further work is necessary to determine whether the biological communities are impaired by water quality or other conditions, as obvious patterns have not yet emerged that integrate freshwater and estuarine biology. There is no evidence collected in this study or in previous studies to suggest that Cow Bayou

Tidal is incapable of supporting the designated high aquatic life use. We recommend that Cow Bayou Tidal remain designated with a high aquatic life use.

Future aquatic life assessments in tidal streams should consider the high degree of variability in these systems. Multiple gear types, both active and passive, are required to adequately sample the nekton community. Even with the intensive effort undertaken for this study, new species were still being collected on the last sampling trip. Seasonal changes influence collections as well and seasonality must be considered in the design of any biological study of tidal streams.

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List of Acronyms

AbsQ	Total Discharge
ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
ALU	Aquatic Life Use
ANOVA	Analysis of Variance
ANOSIM	Analysis of Similarity
AWRL	Ambient Water Reporting Limit
CB	Cow Bayou Tidal
$CBOD_5$	Five-day Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
CFS	Cubic Feet Per Second
CPUE	Catch Per Unit Effort
DO	Dissolved Oxygen
EMAP	United States Environmental Protection Agency's Environmental Mapping and Assessment Program
EPA	United States Environmental Protection Agency
ft	Feet
GPS	Global Positioning System
HUC	Hydrologic Unit (Code)
IBI	Index of Biotic Integrity
IH	Interstate Highway
km	Kilometer
L	Liter
lbs	Pounds
LDEQ	Louisiana Department of Environmental Quality
LIMS	Laboratory Information Management System
LR	Lost River
LSD	Least Significant Difference
m	Meter

MANOVA	Multivariate Analysis of Variance
MDL	Method Detection Limit
MDS	Multidimensional Scaling
mg	Milligram
NCDC	National Climatic Data Center
OP	ortho-Phosphorus
OSS	On-site Sewerage System
PCS	Permit Compliance System
PVC	Polyvinyl Chloride
Q	Flow
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SD	Standard Deviation
SH	State Highway
SIMPER	Similarity Percentages
SWQM	Surface Water Quality Monitoring
SWQMP	Surface Water Quality Monitoring Procedures
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality, formerly the Texas Natural Resource Conservation Commission and the Texas Water Commission
TDS	Total Dissolved Solids
TIGER	Topologically Integrated Geographic Encoding and Referencing
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TP	Total Phosphorus
TPWD	Texas Parks and Wildlife Department
TRACS	Texas Regulatory and Compliance System
TRRC	Texas Railroad Commission
TSS	Total Suspended Solids

TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
UAA	Use Attainability Analysis
USGS	United States Geological Survey
VSS	Volatile Suspended Solids
WC	West Carancahua Creek

Introduction

Tidal streams are important components of coastal ecosystems. Tidal streams serve as nursery grounds for many types of fish and shellfish, including important commercial and sport species. Texas Parks and Wildlife Department (TPWD) is the agency with primary responsibility for protecting the state's fish and wildlife resources (Texas Parks and Wildlife Code §12.0011(a)), and it is charged with providing information on fish and wildlife resources to any local, state, and federal agencies or private organizations that make decisions affecting those resources (Texas Parks and Wildlife Code §12.0011(b)(3)). As tidal streams become healthier, the health of Texas bays and estuaries, and the Gulf of Mexico, will also be improved.

Most tidal streams in Texas have been designated to support "high" aquatic life use (ALU), and some have been designated "exceptional." Aquatic life use attainment in Texas waterbodies is primarily assessed by evaluating ambient dissolved oxygen concentrations. High ALU in salt water or tidal streams is linked to a 4.0 mg/l mean dissolved oxygen criteria (exceptional ALU is linked to 5.0 mg/l). Designated ALUs are primarily protected by requiring wastewater and stormwater discharges to be of sufficient quality to maintain the appropriate dissolved oxygen levels in the receiving stream. Numerous tidal streams in Texas have been assessed as not meeting the ALU because of low dissolved oxygen measurements, especially during the summer months. This assessment results in inclusion on the list of impaired waters and initiates the Total Maximum Daily Load (TMDL) process. As a first step in the TMDL process, it is necessary to assess the waterbody, and determine if the impairment is genuine, and if so, whether or not it is caused by pollutants. Although there is no generally accepted methodology for assessing the biological health of tidal streams, some experts feel that these tidal streams support healthy aquatic communities despite the documented incidents of depressed dissolved oxygen. If so, that suggests that it may not be appropriate to list streams for non-attainment of the ALU simply on the basis of low dissolved oxygen measurements.

The Texas Commission on Environmental Quality (TCEQ) selected three tidal streams listed for aquatic life impairment (DO exceedances) as subjects for this study. Those streams are Cow Bayou Tidal, Tres Palacios Creek Tidal, and Garcitas Creek Tidal. The project was approached by dividing the effort between upper coast (Cow Bayou Tidal), and middle coast (Tres Palacios Creek Tidal, and Garcitas Creek Tidal) since these two regions of the coast are geographically distant from each other and differ in annual precipitation, geology, and habitat. This report constitutes the use attainability analysis for Cow Bayou Tidal, Segment 0511, hereafter referred to as Cow Bayou.

Problem Statement

Based on DO exceedances, Cow Bayou Tidal was selected for study. The purpose of this study is to determine whether the existing designation of high aquatic life use is attainable in Cow Bayou Tidal, and to provide the data necessary for preparation of a use attainability analysis.

The ability of a water body to support a desired use is an integral consideration in the state and federal water quality standards review and revision process. When a water body is not capable of attaining all the uses included in Section 101(a)(2) of the Clean Water Act or where the level of protection necessary to achieve those uses is not being or cannot be met, 40 Code of Federal Regulations (CFR) Part 131 provides a scientific procedure to select and apply segment-specific use criteria. The procedure, known as a use attainability analysis, is consistent with the intent of Sections 26.023 and 26.026 of the Texas Water Code. The regulation specifies that one or more of the following six conditions may be used for determining if a designated use is unattainable:

1) Naturally occurring pollutant concentrations prevent the attainment of the use; or
2) Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of a sufficient volume of effluent without violating State water conservation requirements to enable uses to be met; or
3) Human caused conditions or sources of pollution prevent the attaining of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4) Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5) Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and other factors, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6) Controls more stringent than the technology-based requirements established by Section 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact. [40 CFR 131.10(g)].

Objectives

A reference stream approach was selected to frame this study. The intention was to select a stream with minimal human influence to compare with the study stream, which is presumed to be potentially impaired based on a water quality assessment. This is difficult to do on the Texas coast, where natural resources on land and in water have historically been exploited in various ways by a growing human population, such as for energy production, navigation, and urbanization. Several reconnaissance trips were made to the southeast Texas area and Louisiana to assess potential reference streams. Surveys were made by boat on these streams, where instantaneous field measurements, maximum channel depth, photographs, and other observations were made to aid in decision-making. Lost River (Chambers/Liberty counties) was selected as the reference stream for Cow Bayou. The main factor which influenced this decision was to find a stream which had minimal human influence. A secondary consideration was the salinity regime of Cow Bayou, which is relatively fresh most years since it does not drain directly to a bay. A summary of the considerations for the streams surveyed is presented in Table 1.

Table 1.—Characteristics of Cow Bayou and tidal streams considered for selection as a reference stream for Cow Bayou.

Stream Name	Segment Number	Sp. Cond. (mmhos/cm)	Riparian Habitat	Instream Habitat	Land Uses	303(d) Listings	Percentage Channelized or Ditched	Depth range (feet)
Cow Bayou	0511	0.2-1.2	Forested	Clay/silt/ sand	Urban, industrial, oil field, homes	FY 00 - low DO, bacteria, low pH	40	8-15
Johnson Bayou	Louisiana	4.2-7.2	Marsh	Sand	National Wildlife Refuge	Not assessed per LDEQ	40	8
East Fork Double Bayou	2422	7.2-23.1	Forested	Sand/clay	Homes, rangeland, local park	FY 02 - West Fork Double Bayou has a concern for low DO	20	7-15
Oyster Bayou	2423A	0.4-17.7	Forested/ marsh	Sand/silt	National Wildlife Refuge, rangeland	none	30	8-10
Spindletop Bayou	2423	21.3-23.0	Forested/ marsh	Sand/silt	Homes, cropland	none	90	7-10
Pine Island Bayou	607	0.1-0.4	Forested	Sand/silt	National Forest, homes	FY 00 - low DO (lower 6 miles) and low pH (lower 43 miles) (other impairments upstream), FY 02 - low DO	unknown	7-20
Old River	801	0.46-1.17	Forested/ residential	Sand/silt	Riverside homes	none	0	5-9
Lost River	801	0.38-0.82	Forested/ marsh	Sand/silt	Small oil field -no signs of pollution	none	0	4-7
Hackberry Bayou	Too small and limited boat access							
Turtle Bayou	Too small and limited boat access							
Cotton Bayou	Too small relative to Cow Bayou							
Armand Bayou	Listed for low dissolved oxygen							
Halls Bayou	Too far west from Cow Bayou							
Taylor Bayou	Too much human influence							

Study Area

Cow Bayou

Description of Water Body

Cow Bayou (Segment 0511) is a tidally-influenced stream in southeastern Texas. It is formed by the junction of Gum Slough and Dognash Gully, rising eleven miles south of Buna in southeastern Jasper County, and runs south-southeast for thirty miles to its mouth on the Sabine River, at Bridge City in Orange County (Handbook of Texas 2006a). With the development of rice farms in Orange County during the early twentieth century, Cow Bayou was used as a source of water for irrigation canals. The bayou, which is intermittent in its upper reaches, was long an important avenue of transportation and saw extensive barge traffic by 1911. In 1963 Congress approved a measure to improve the bayou by constructing a channel 100 feet wide and thirteen feet deep for 7.7 miles from its mouth to Orangefield, where a large (300' x 500' x 13') turning basin was projected. However, a number of oil wells at Orangefield blocked the right-of-way, and only the first seven miles of channel was dredged. In 1967 planners deemed the channel adequate for navigation and flood control, even without the turning basin (Handbook of Texas 2006a).

The tidally-influenced portion of Cow Bayou is defined by the Texas Surface Water Quality Standards (TSWQS) as Segment 0511, and is the subject of this report. Cow Bayou begins just upstream of IH-10 and ends at the confluence with the Sabine River. It lies mostly within the boundaries of Orange County. The lower part of Cow Bayou was channelized in the early 1950’s for navigation, leaving numerous side channels and oxbows. The upper portion of its watershed is densely forested and relatively lightly populated. The lower portion is home to the communities of Bridge City and Orange.

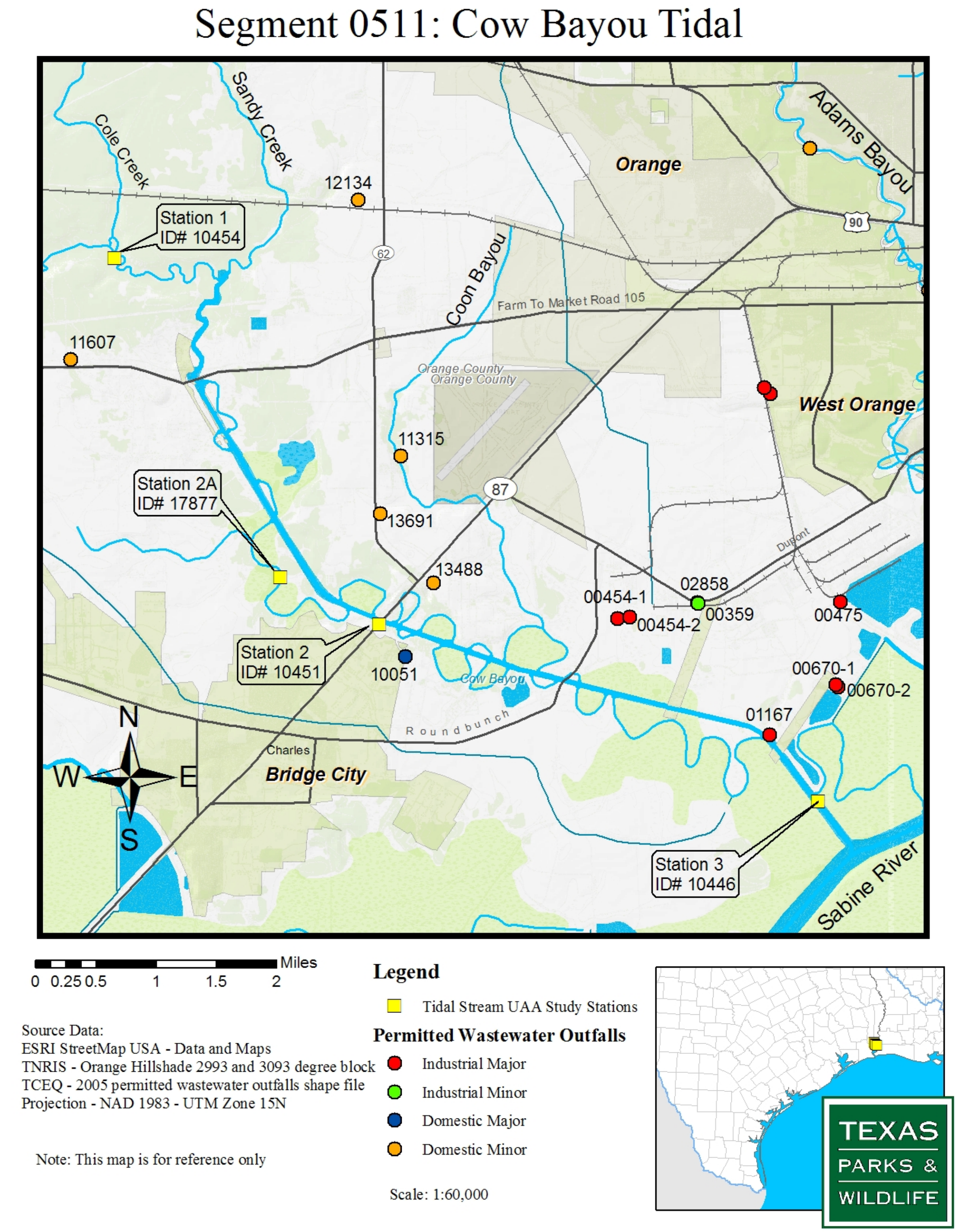
Designated Uses and Criteria

Water quality standards include designated uses for a water body, specific numerical criteria for certain water quality parameters, and narrative criteria. The TSWQS are set by the TCEQ and approved by the EPA. The TCEQ has established aquatic life uses and associated criteria for all waters of the state. The numeric criterion for dissolved oxygen is a surrogate or indirect measure of whether the aquatic life use is being maintained. Adequate dissolved oxygen is necessary for a healthy aquatic community. Most aquatic organisms become stressed if oxygen levels below 2 mg/l persist for very long.

The designated uses for Cow Bayou, Segment 0511, are contact recreation and high aquatic life use (Texas Natural Resource Conservation Commission 2000b: 30 Texas Administrative Code (TAC) §307.10(1)). The dissolved oxygen criteria for a tidal water body with a high aquatic life use are a daily average of 4 mg/l, and a daily minimum of 3 mg/l (30 TAC §307.7(b)(3)(A)(i)). The daily average is evaluated as a mean across 24 hours. Since most data collected at fixed monitoring stations are instantaneous measurements, direct comparison to the 24-hour criteria is not possible. For Cow Bayou, 4.0 mg/l is used as the single measurement screening level to evaluate whether the high aquatic life use is being met (TCEQ 1999b). The dissolved oxygen criteria only apply in the “mixed surface layer,” which in tidally-influenced water bodies is defined as “the portion of the water column from the surface to the depth at which the specific conductance is 6,000 umhos/cm greater than the specific conductance at the surface” (TCEQ 1999b). However, the TSWQS at 30 TAC 307.9(c)(3)(C) also specify that a composite sample from the mixed surface layer be used to determine standards attainment when stratification is caused by temperature (density stratification).

Permitted Discharges

In the watershed of Cow Bayou, there are six industrial permittees, consisting of four EPA-designated major and two minor facilities (Table 2). There are ten domestic permittees, one EPA-designated major facility (City of Bridge City) and the rest minor facilities (one of these is a land application permit therefore no discharge is authorized to waters of the State). Locations of outfalls are depicted in Figure 1.



Source Data:
ESRI StreetMap USA - Data and Maps
TNRIS - Orange Hillshade 2993 and 3093 degree block
TCEQ - 2005 permitted wastewater outfalls shape file
Projection - NAD 1983 - UTM Zone 15N

Note: This map is for reference only

Figure 1.—Map of Cow Bayou showing wastewater outfalls in the watershed.

Table 2.—Wastewater permits in Segment 0511, Cow Bayou. Source: TCEQ Permit Compliance System (PCS) database accessed on 24 Oct 2005.

Permit No.	Category	Major/ Minor	Type of Outfall	Permittee Name	Outfall Number	Wastewater Type
WQ0000359-000	Industrial	Major	Discharge	Chevron Phillips Chemical	001	stormwater, process and utility wastewater
WQ0000454-000	Industrial	Major	Discharge	Firestone Polymers LLC	001	
WQ0000454-000	Industrial	Major	Discharge	Firestone Polymers LLC	002	industrial stormwater
WQ0000670-000	Industrial	Major	Discharge	Honeywell International	001	
WQ0000670-000	Industrial	Major	Discharge	Honeywell International	002	industrial stormwater
WQ0001167-000	Industrial	Major	Discharge	Lanxess Orange Plant	001	stormwater, process and utility wastewater, sanitary waste
WQ0001167-000	Industrial	Major	Discharge	Lanxess Orange Plant	002	emergency outfall - process, utility, and sanitary wastewater, stormwater
WQ0002835-000	Industrial	Minor	Discharge	Texas Polymer Services	001	industrial stormwater
WQ0002835-000	Industrial	Minor	Discharge	Texas Polymer Services	002	stormwater, utility wastewater, washdown, sanitary waste
WQ0002835-000	Industrial	Minor	Discharge	Texas Polymer Services	003	water treatment waste, industrial stormwater
WQ0002858-000	Industrial	Minor	Discharge	PrintPack Inc.	001	utility wastewater, sanitary waste, industrial stormwater
WQ0002858-000	Industrial	Minor	Internal	PrintPack Inc.	101	sanitary waste
WQ0010051-001	Public Domestic	Major	Discharge	City of Bridge City	001	sanitary waste
WQ0010051-001	Public Domestic	Major	Internal	City of Bridge City	101	combined peak flow + treatment plant
WQ0010808-001	Private Domestic	Minor	Discharge	Jasper County WCID #1	001	sanitary waste

Permit No.	Category	Major/ Minor	Type of Outfall	Permittee Name	Outfall Number	Wastewater Type
WQ0011315-001	Private Domestic	Minor	Discharge	Smith Jr., Edward Ned/ Bayou Pines Park	001	sanitary waste
WQ0011316-001	Private Domestic	Minor	Retention	Peveto, Horace Marion/ Oak Leaf Mobile Home Park	001	sanitary waste
WQ0011316-001	Private Domestic	Minor	Soil	Peveto, Horace Marion/ Oak Leaf Mobile Home Park	101	sanitary waste
WQ0011316-001	Private Domestic	Minor	Soil	Peveto, Horace Marion/ Oak Leaf Mobile Home Park	201	sanitary waste
WQ0011316-001	Private Domestic	Minor	Soil	Peveto, Horace Marion/ Oak Leaf Mobile Home Park	301	sanitary waste
WQ0011457-001	Private Domestic	Minor	Discharge	TxDOT/ Orange Co. Comfort Station	001	sanitary waste
WQ0011607-001	Public Domestic	Minor	Discharge	Orangefield ISD	001	sanitary waste
WQ0011916-001	Private Domestic	Minor	Discharge	PCS Development Co./ Park View	001	sanitary waste
WQ0012134-001	Public Domestic	Minor	Discharge	Sabine River Authority/ Plant #1	001	sanitary waste
WQ0013488-001	Private Domestic	Minor	Discharge	Gulflander Partners Group/ Sunrise East Apts.	001	sanitary waste
WQ0013691-001	Private Domestic	Minor	Discharge	Blacksher Development Corp./ Waterwood Estates	001	sanitary waste

The industrial majors include Chevron Phillips Chemical, Firestone Polymers LLC, Honeywell International, and Lanxess Orange Plant. Chevron is a chemical plant. Firestone produces polymers used in tires and other applications. Honeywell produces a variety of specialty materials including plastics. Lanxess makes polybutadiene rubber and technical rubber products. The industrial minors are Texas Polymer Services and PrintPack Incorporated. Most of the industrial dischargers have permit limits for oxygen-demanding substances in their wastewater. Permit limits and self-reporting data for 2003 through 2004 are displayed in Table 3 for the primary outfalls and Table 4 for outfalls predominantly carrying stormwater.

Table 3.—Industrial dischargers main outfalls – Permitted flow and self-reporting data (average of daily averages) for industrial dischargers in the watershed of Cow Bayou Segment 0511. Self-report data was obtained for 1 Jan 2003 through 31 Dec 2004. NA denotes not applicable.

Permit No.	Name of Permittee	Outfall No.	Permitted Flow (MGD)	Actual Flow (MGD)	BOD5 (lbs./day)	COD (lbs./day)	Oil and Grease (lbs./day)	Oil and Grease (mg/l)
WQ0000359-000	Chevron Phillips Chemical	001	3.15	0.88	19.7	192.3	15.8	NA
WQ0000454-000	Firestone Polymers LLC	001	1.00	0.82	46.3	300	15.50	NA
WQ0000670-000	Honeywell International	001	1.4	0.4	10.8	149.2	NA	0.30
WQ0001167-000	Lanxess Orange Plant	001	5.2	4.4	83.1	899.3	NA	72.20
WQ0002835-000	Texas Polymer - utility ww etc.	002	NA	0.162	13.7	NA	NA	3.40
WQ0002858-000	PrintPack internal outfall - sanitary waste	101	0.015	0.0056	4.4	NA	NA	NA

Table 4.—Industrial dischargers stormwater outfalls - self-reporting data (average of daily averages) for industrial dischargers in the watershed of Cow Bayou Segment 0511. Self-report data was obtained 1 Jan 2003 through 31 Dec 2004. NDR denotes no discharge reported and NA denoted not applicable.

Permit No.	Permittee Name	Outfall No.	COD grab (mg/l)	pH min. grab	pH max. grab	Oil and Grease grab (mg/l)	TOC grab (mg/l)	Flow (MGD)
WQ0000454-000	Firestone - stormwater	002	27.3	7.4	7.9	1.3	NA	NA
WQ0000670-000	Honeywell - stormwater	002	NA	6.4	6.8	2.8	21	1.12
WQ0001167-000	Lanxess - emergency outfall	002	NA	NDR	NDR	NDR	NDR	NDR
WQ0002835-000	Texas Polymer Services - stormwater	001	NA	6.8	8.5	2.4	4.5	0.012
WQ0002835-000	Texas Polymer - stormwater etc.	003	NA	6.8	8.0	2.4	7.1	0.043
WQ0002858-000	PrintPack Inc.	001	32.9	7.1	7.5	6.3	NA	0.038

The city of Bridge City is the only major domestic discharger in the watershed of Cow Bayou. Permit limits and self-report data from this plant and the numerous smaller dischargers are displayed in Table 5.

Self-reporting data from 1 Jan 2003 through 31 Dec 2004 was examined for violations of permits (Table 6).

Table 5.—Domestic dischargers – permit limits for CBOD or BOD and TSS and self-reporting data (average of daily averages) for domestic dischargers in the watershed of Cow Bayou Segment 0511. Self-report data was obtained for 1 Jan 2003 through 31 Dec 2004. NA denotes not applicable.

Permit No.	Name of Permittee	Flow (MGD)	Permit Limits ($CBOD_5$ or BOD_5 in mg/l, TSS in mg/l)	$CBOD_5$ (lbs./day)	$CBOD_5$ (mg/l)	BOD_5 (lbs./day)	BOD_5 (mg/l)	TSS (lbs./day)	TSS (mg/l)
WQ0010051-001	City of Bridge City	0.92	10, 15	NA	NA	30.1	3.7	43.0	5.7
WQ0010808-001	Jasper County WCID #1	0.16	30, 90	9.4	7.5	NA	NA	29.1	20.8
WQ0011315-001	Smith Jr., Edward Ned/ Bayou Pines Park	.0017	30, 90	NA	NA	0.2	16.6	0.6	NA
WQ0011457-001	TxDOT/ Orange Co. Comfort Station	.0037	20, 20	NA	NA	0.2	5.8	0.6	15.4
WQ0011607-001	Orangefield ISD	.015	20, 20	NA	NA	0.3	2.0	0.5	3.8
WQ0011916-001	PCS Development Co./ Park View	.007	20, 20	NA	NA	0.1	2.6	0.9	15.2
WQ0012134-001	Sabine River Authority/ Plant #1	.0011	20, 20	NA	NA	.02	2.3	.04	4.1
WQ0013488-001	Gulflander Partners Group/ Sunrise East Apts.	.0706	20, 20	NA	NA	.5	6.0	.80	9.5
WQ0013691-001	Blacksher Development Corp./ Waterwood Estates	.012	20, 20	NA	NA	0.9	13.2	1.3	18.0

Table 6.—Exceedances of wastewater permit limits of dischargers in the Cow Bayou watershed, based on self-reporting data from 1 Jan 2003 through 31 Dec 2004.

Parameter	Units	Effluent Limit	Frequency	Sample Type	Average	N	Number of Exceedances
BOD5 - daily avg	mg/l	20	1 / week	grab	13.7	24	4
BOD5 - daily avg	mg/l	20	weekly	grab	13.2	18	3
BOD5 - daily max	lbs/day	175	2 / week	composite	83.5	24	1
BOD5 - daily max	mg/l	26	1 / week	grab	36.3	24	11
BOD5 - daily max	mg/l	25	2 / week	composite	8.8	23	1
CL_2 residual - minimum	mg/l	1	1 / week	grab	1.6	22	4
Flow - gpm	gpm	2,896	1 / month	totalizer	2443	23	1
Oil and grease - daily max	mg/l	15	1 / week	grab	6.2	24	1
pH - maximum	SU	9	continuous	continuous	8.2	24	1
pH - maximum	SU	9	1 / week	grab	8.1	24	2
pH - maximum	SU	9	1 / week	grab	8.0	24	1
pH - maximum	SU	9	1 / month	grab	7.9	24	2
pH - minimum	SU	6	1 / week	grab	6.8	24	1
pH - minimum	SU	6	1 / week	grab	6.9	24	2
TOC - daily max	mg/l	70	1 / week	grab	26.0	23	2
TSS - daily avg	mg/l	20	1 / week	grab	15.4	23	5
TSS - daily avg	lbs/day	1.8	1 / week	grab	0.6	23	1
TSS - daily avg	mg/l	20	1 / week	grab	15.2	24	7
TSS - daily avg	mg/l	20	weekly	grab	18.0	18	9
TSS - daily max	mg/l	719	2 / week	composite	286.7	24	2
TSS - daily max	lbs/day	1,954	2 / week	composite	451.0	24	1
TSS - daily max	mg/l	19	1 / week	grab	34.8	24	6
TSS - daily max	mg/l	90	1 / week	grab	67.7	17	2

Nonpoint Sources

Numerous nonpoint sources occur in the Cow Bayou watershed, as referenced by previous studies of the area. The most common problem that can affect DO as well as other water quality constituents is untreated or partially treated wastewater. A Sabine River Authority study attributed much of the nonpoint source pollution in the Cow Bayou watershed to on-site wastewater treatment systems which were described as inadequate for the soil type and amount of rainfall in the area (SRA 1999). The study states that on-site sewage systems in the area "have historically functioned poorly if at all." The Orange County TMDL report presented at a stakeholder meeting on July 25, 2006, lists septic systems as a large contributor to oxygen demand in Cow Bayou (Parsons 2006).

Another significant source is agriculture, especially in the upper to middle part of the segment which is less urbanized. As noted in the land cover results and discussion below, a large proportion of the Cow Bayou watershed is classed as "grassland," which may be intensively managed for grazing of cattle or horses and can result in increased nutrient and sediment loads.

The Orange Oil Field is another potential source of nonpoint impacts. The field was discovered in 1913 and developed in subsequent years (Handbook of Texas 2006b). The Orange Oil Field is located in the vicinity of City of Orangefield and Cow Bayou near Farm to Market 105 in Orange County. It supports crude oil and natural gas wells. In 2003 and 2004 the Orange Oil Field produced 94,481 barrels and 175,984 barrels, respectively, of crude oil (Texas Railroad Commission (TRRC) 2006). The field also produced 14,428 barrels and 11,623 barrels of condensate in 2003 and 2004 from natural gas wells.

Summary of Historical Data

Previous Studies

TCEQ's predecessor agencies conducted two intensive surveys of Cow Bayou, one in 1982 and one in 1986 (Kirkpatrick 1988, Kirkpatrick 1985). Data collection efforts focused on hydrology, field water quality measurements, and water chemistry (lab analyses for several parameters). Fourteen stations were sampled, twelve of which were within the designated boundaries of the segment. One of the remaining stations was in Cow Bayou upstream of the tidal segment, and the other was in the Sabine River just below the confluence with Cow Bayou. No biological sampling was undertaken for either survey. Both surveys noted low dissolved oxygen levels in the upper portion of Cow Bayou (from IH-10 to just below the confluence with Cole Creek). The 1982 study attributed that condition to natural phenomena, namely the sluggish hydrology of the stream, since no major wastewater discharges occur in the upper portion of the bayou. The 1986 study found similar results, with low dissolved oxygen conditions present in approximately the same reach of stream. The 1986 study included measurements of primary productivity and sediment oxygen demand, made to better characterize the cause of the low dissolved oxygen. Results of the study indicated that sediment oxygen demand was highest and primary productivity was lowest in the area affected by low dissolved oxygen. The study's author concluded that these factors, in addition to the narrow sluggish configuration of the stream, were major contributors to low dissolved oxygen and all factors were attributable to natural conditions.

In 1987 TPWD River Studies staff conducted a fisheries use attainability study for Cow Bayou, in conjunction with a use attainability analysis (UAA) being prepared by TCEQ. The UAA was never finalized, but the results of the fisheries survey are available in a River Studies report (Linam and Kleinsasser 1987). Four stations, all within the boundaries of Segment 0511, were sampled for habitat, field water quality parameters, and fish. Seining and gill netting were used to sample the fish community. Results of the fish collections were evaluated using a number of methods, including the calculation of species diversity, index of similarity, and condition factor; and the evaluation of species richness, number of pollution intolerant species, proportion of the population comprised of pollution tolerant individuals, proportion of diseased fish, and trophic structure. Results were also compared to the Index of Biotic Integrity (IBI; Karr et al. 1986). The station furthest upstream (IH-10) was rated "good" based on Karr's IBI. The other three stations (Hwy. 87, Round Bunch Road, and Sabine River confluence) were all ranked "fair" to "good." The authors concluded that Cow Bayou holds the potential for a diverse and healthy fish community.

The Sabine River Authority conducted a special water quality study on Cow Bayou which was published in 1999. The study surveyed nine sites on Cow Bayou or its tributaries (including four sites upstream of tidal influence) and 15 wastewater treatment plant outfalls. Stream sites and some of the wastewater discharge sites were sampled quarterly for field water quality and water samples collected for lab analyses of several parameters. Field water quality and fecal coliform bacteria were measured weekly after each quarterly sampling event at those sites for a total of five consecutive weeks. Sampling was also conducted during significant rainfall events following spells of dry weather. Additional dissolved oxygen readings were taken at selected stream sites within two hours of sunrise and near midnight. Vertical salinity profiles were made at selected sites, and ambient toxicity samples were collected at three sites. Flow was measured at small tributaries to Cow Bayou. Black Bayou in Louisiana was used as a reference stream to which the water quality measurements were compared. A rapid bioassessment based on fish collections was performed at three of the sites which are upstream of the tidally-influenced portion of Cow Bayou. Little Cow Creek (Newton County) was used as a reference stream for the rapid bioassessment.

Results from the dissolved oxygen measurements showed low dissolved oxygen conditions in the upper portion of Cow Bayou (at the FM 1442 north crossing). During rainfall events, additional sites in the upper portion of Cow Bayou exhibited low dissolved oxygen conditions. The report's authors attributed most of the oxygen problems to nonpoint source pollution "such as on-site septic systems and other human activities." Measurements taken near sunrise indicated very low dissolved oxygen conditions at a site further downstream (Round Bunch Road), where average dissolved oxygen values were generally not a problem.

The rapid bioassessment found that the fish community had an IBI ranking between intermediate and limited (Karr et al. 1986). The report's authors stated, "The results from the main-stem indicate biological conditions are well below what should be present in the stream." Dissolved oxygen criteria were met during three out of four seasonal sampling events at only five of the nine sites sampled for the study. At one of the other four sites, the criterion was not met during any of the four sampling events. Separately, nine sites were sampled near sunrise to evaluate critical minimum values. The dissolved oxygen measurements ranged from 0.19 to 3.22 mg/l.

The introduction to the study states, "Tidal waterbodies typically have limited assimilative capacity, because of low flows and high dissolved solids. These conditions are made worse by the Subwatershed's high turbidity due to a heavy clay substrate and a large amount of detritus from the deciduous trees common in the area." The study's authors concluded that dissolved oxygen in Cow Bayou is naturally limited by the tidal nature of the system and turbidity, but is also being impacted negatively by point and nonpoint sources. In comparing the dissolved oxygen data to Black Bayou, they found that extreme lows in dissolved oxygen were not typically present there, even following rainfall events. There the mean value was 6.3 mg/l and was less than 4 mg/l only once out of 31 sampling events. The study's authors attribute much of the nonpoint source pollution in the Cow Bayou watershed to on-site wastewater treatment systems which they say are inadequate for the soil type and amount of rainfall in the area, and advocate a regional wastewater treatment system.

Concerns about low DO, bacteria, and low pH led TCEQ to initiate a TMDL in Adams Bayou (segment 0508), Cow Bayou (segment 0511) and their tributaries (including Cow Bayou above tidal.) Data collection for this project, including storm water sampling and intensive surveys, was completed in 2004. Water quality modeling has been completed, and a final report is in preparation. In July 2006 at the Orange County TMDL Stakeholders Advisory Group and Technical Advisory Group, Meeting #10, modeling results were presented (Parsons 2006). These results indicated that below IH-10, about 1390 lbs/day of biochemical oxygen demand is added to Cow Bayou, with the primary sources being failing septic systems and point sources. Smaller contributions came from forest and pasture. Modeling showed that about 168 lbs/day of ammonia-nitrogen is added daily to Cow Bayou below IH-10, with the primary sources being failing septic systems and point sources. The model was quite successful in calculating daily average and daily minimum dissolved oxygen levels. The DO results were fairly insensitive to modeling variables near the mouth of Cow Bayou, and much more sensitive in the upper tidal reaches, where there is less reaeration and where sediment begins to fall out. It was found that, approximately one-third of the time, Cow Bayou above tidal does not flow, but is an intermittent stream with perennial pools. Based on this, it was suggested that a criteria adjustment may be appropriate in this reach. Overall, it was determined that a 69% load reduction would be needed to achieve the DO standard.

Review of Water Quality Data

Water quality data from the Surface Water Quality Monitoring (SWQM) portion of Texas Regulatory and Compliance System (TRACS) was reviewed for the period of record. The focus was on dissolved oxygen measurements, since low oxygen is the reason this water body was suspected to be impaired. The data used in the assessment to list Cow Bayou as impaired for dissolved oxygen was also reviewed separately.

2000 303(d) Listing of Cow Bayou

Cow Bayou was listed in 2000 for not meeting the aquatic life use. The procedures for evaluating surface water data to determine whether uses and criteria were being met is described in “2000 Guidance for Screening and Assessing Texas Surface and Finished Drinking Water Quality Data” (TCEQ 2000a). Under this guidance, dissolved oxygen data from the five-year period of record (1994 -1999) was compared to the criterion, to determine whether the aquatic life use was being met. Two types of data could be used to assess use support – instantaneous or routinely collected data and 24-hour or intensively collected data. With instantaneous data, at least nine values were required to evaluate whether the criterion was being met, with use being fully, partially, or not met based on the percentage of measurements not meeting the instantaneous screening level (4.0 mg/l in the case of Cow Bayou). With 24-hour data, at least five sets of measurements were required to evaluate whether the criterion was being met. Use attainment was evaluated based on the percentages of means and minimum values from those data sets which met the average and minimum criteria established under the TSWQS.

For the 2000 assessment, 208 dissolved oxygen measurements from four stations were evaluated; from upstream to downstream these were: station 10457 (IH 10), station 13781 (FM 1442 north crossing), station 10453 (FM 105), and station 10449 (FM 1442 downstream crossing/Round Bunch Road). All were instantaneous measures of dissolved oxygen. Table 7 summarizes the results of the assessment.

Table 7.—Mean dissolved oxygen, number of samples, number of violations of criteria and percentage of samples which exceeded the criteria. Water quality data assessed for the 2000 Water Quality Inventory and 303(d) List.

Station ID	Mean DO (mg/l)	N	Number of Exceedances	%
10457	4.0	23	12	52
13781	3.8	50	29	58
10453	4.3	71	31	44
10449	5.5	64	15	23

Unlike the Intensive Surveys of the 1980s, these data revealed low dissolved oxygen conditions throughout the water body (not just in the upstream portion). However there were higher percentages of violations of the criterion in the two upstream stations (52% and 58% of the measurements in 10457 and 13781, respectively), which are located in the part of Cow Bayou which historically has had low dissolved oxygen.

Cow Bayou was also assessed as not supporting the contact recreation use due to elevated fecal coliform densities, and only partially supporting general uses in the upper 14 miles of the segment, due to low pH values.

Summary of SWQM TRACS Historical Data

A raw data report of all SWQM data on Cow Bayou (Segment 0511) was obtained for the period of record ending with June 21, 2002. Over the period of record, water quality data has been collected at 13 different stations on Segment 0511. The two stations which have been most frequently monitored over time are Station ID 10449 (FM 1442 downstream crossing) and Station ID 10453 (FM 105). The data set begins in 1969 and monitoring took place somewhere on Segment 0511 at least once every year since then, and frequently on a monthly basis.

Since DO is the parameter of most concern for this study, an analysis was made of instantaneous DO measured at 0.3 meters or less from the surface (to approximate the mixed surface layer). The mean DO for 545 measurements was 5.5 mg/l, and values ranged from 0.4 to 12.1 mg/l. Figure 2 shows the mean DO and standard deviations for these data by station. From FM 105 downstream DO values generally remain high. Upstream of FM 105 depressed DO can be seen. For all four stations between IH-10 and FM 105, the mean DO is below 4 mg/l. DO averages above 4 mg/l at all other stations.

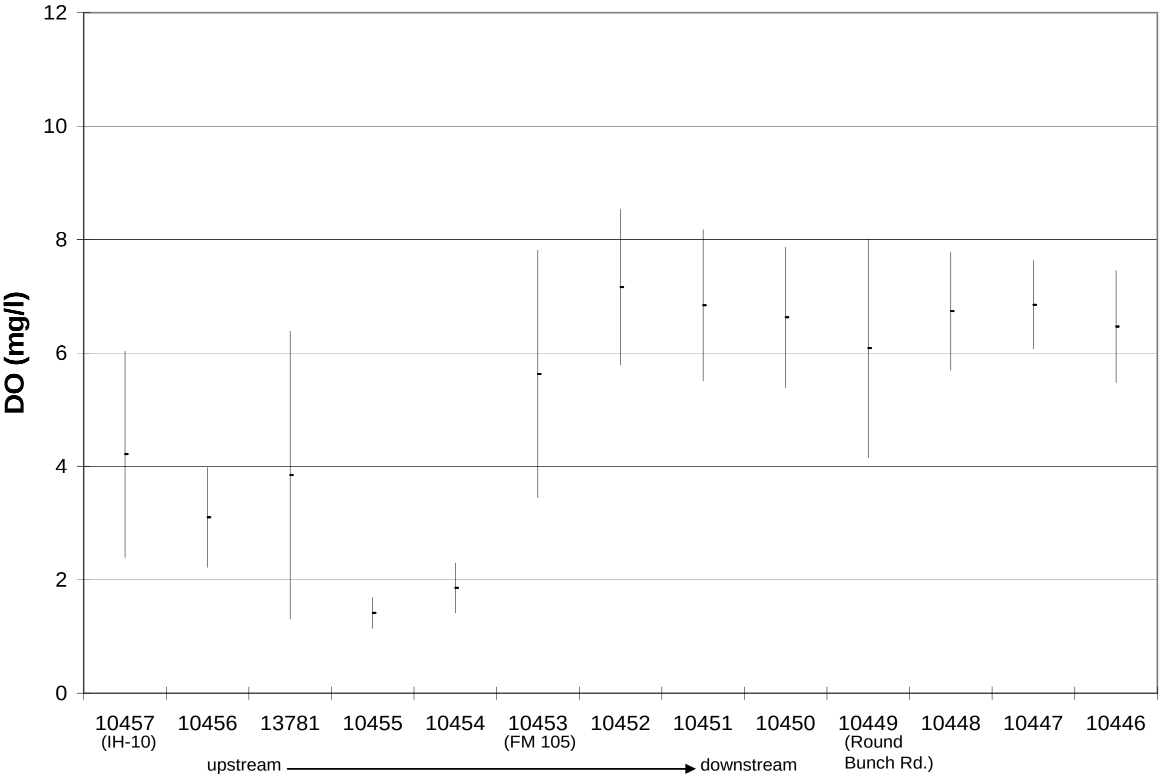


Figure 2.—Mean surface (≤ 0.3 m) dissolved oxygen measurements and standard deviations in Cow Bayou for the period of record by station.

Lost River

Description of Water Body

Lost River is a small tidally-influenced stream which originates in Liberty County and flows about six miles to its mouth in Old River Lake (Chambers County) just north of IH-10. Lost River is largely surrounded by a bottomland forest dominated by bald cypress (*Taxodium distichum*). There are numerous side channels and interconnections with other surface water. There is a dirt dam at the upper end of Lost River which was constructed to prevent saltwater intrusion to public drinking water supplies upstream. When the Trinity River is over bank, river water washes in around the sides of the dirt dam into Lost River.

Designated Uses and Criteria

Lost River is an unclassified stream with many hydrologic connections to the Trinity River Tidal (Segment 0801) and Trinity Bay (Segment 2422). Both segments 0801 and 2422 are designated high ALU with a 4.0 dissolved oxygen criterion.

Permitted Discharges

There are no permitted discharges directly to Lost River. Permitted discharges in the vicinity of Lost River (segments 0801 and 2422) were plotted to verify that none were likely to directly affect Lost River (Figure 3).

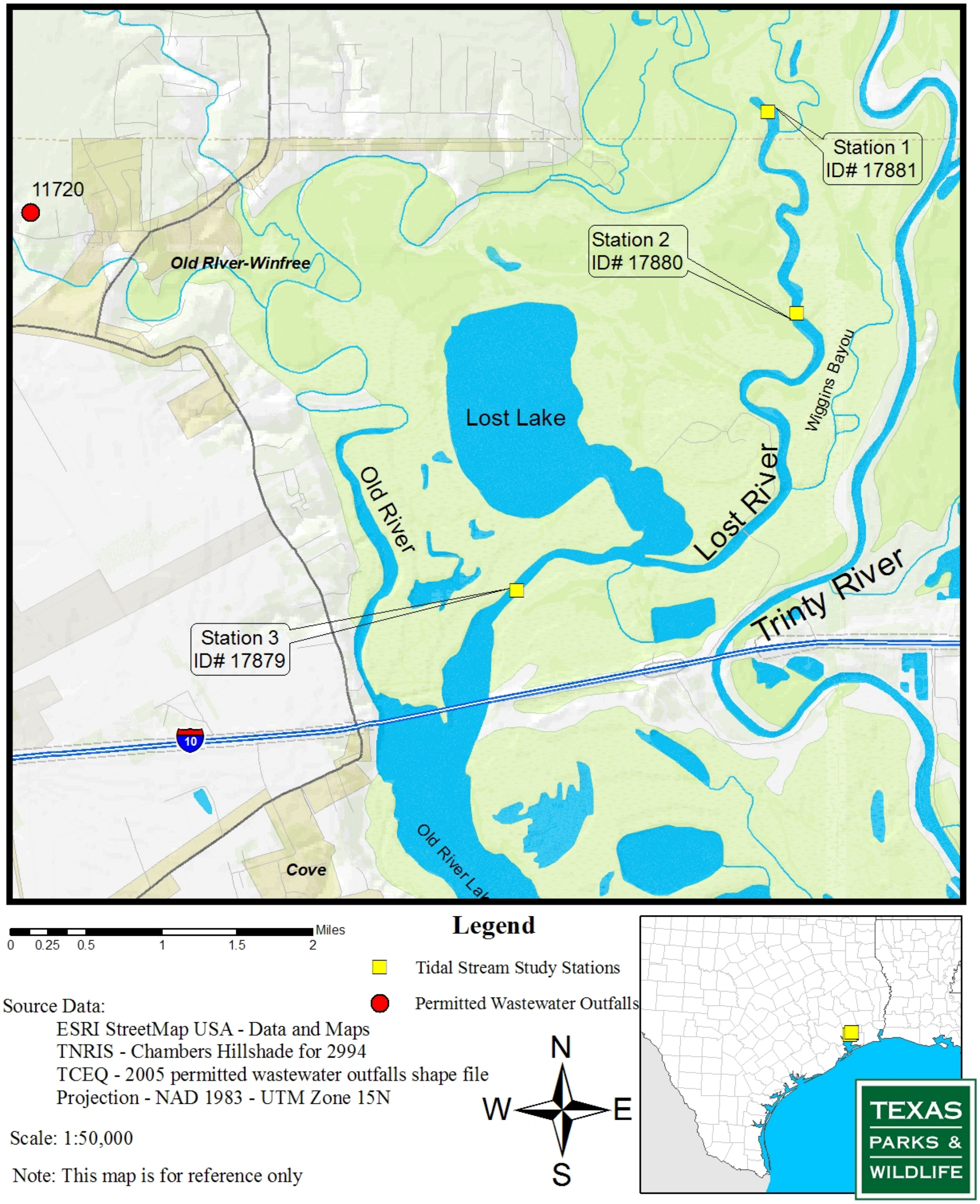
Nonpoint Sources

There are very few signs of human habitation in the vicinity of Lost River. The Lost Lake Oil Field is located east of Lost Lake and west of Lost River in Chambers County. It supports natural gas and crude oil wells. In 2003 and 2004 the Lost Lake Oil Field produced 11,032 and 7,825 barrels of crude oil, respectively (TRRC 2006). There was no natural gas production data reported.

Summary of Historical Data

There is no historical SWQM data in the TRACS database on Lost River, the reference stream for Cow Bayou. Lost River has not been sampled by TPWD’s River Studies Team.

Segment 0801: Lost River - Trinity River Tidal



Legend

🟨 Tidal Stream Study Stations

● Permitted Wastewater Outfalls

Source Data:
ESRI StreetMap USA - Data and Maps
TNRIS - Chambers Hillshade for 2994
TCEQ - 2005 permitted wastewater outfalls shape file
Projection - NAD 1983 - UTM Zone 15N

Scale: 1:50,000

Note: This map is for reference only

Figure 3.—Map of Lost River showing wastewater outfalls in the vicinity.

Methods

General Considerations

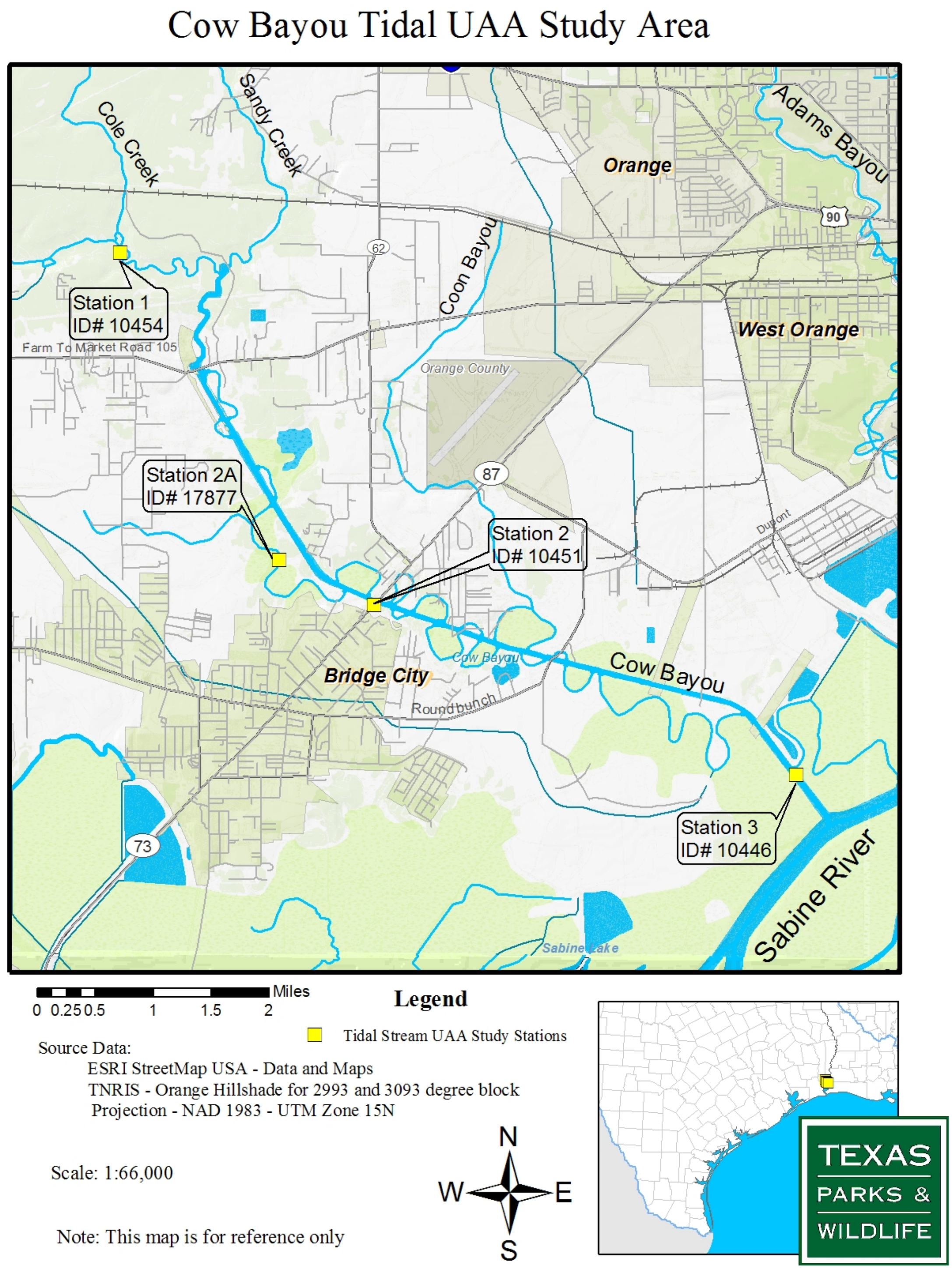
Details about methods and quality assurance/quality control measures used in this study are contained in the project Quality Assurance Project Plan (QAPP; TPWD 2003a). This methods section is intended to provide a quick reference for purposes of this report, and to supplement the QAPP.

Station Selection Criteria and Station Descriptions

A minimum of three monitoring stations were selected for each of the streams. Stations were chosen to capture variability along the salinity gradient from upstream to downstream (for example, CB 1 was the upstream-most station on Cow Bayou and CB 3 was nearest the mouth). On Cow Bayou, an additional station was added, CB 2A, in order to compare the natural channel to the dredged channel. Where possible, stations were selected to correspond to existing SWQM stations. Where stations corresponding to study objectives did not exist, new stations were established by submitting station location requests to TCEQ. Table 8 gives station location descriptions and Figure 4 and Figure 5 depict station locations for the two streams.

At Cow Bayou, the downstream station (CB 3) was selected to provide a station close to the mouth of the stream. This station is located in the channelized portion of Cow Bayou. The middle station (CB 2) was selected at the approximate mid-point of the tidally influenced reach, and is also located in the channelized portion of the stream. An advantage of this station is the large amount of historical water quality data that already exists for this site. Another station (CB 2A) was selected to allow comparison between the original stream channel and the channelized portion. This additional station is near the middle station, but in the original natural stream channel, and is connected with the channelized portion. The upstream station (CB 1) is in the upper end of the reach, above the channelized portion. The station was chosen to reflect the upstream end of Cow Bayou, which rarely receives saltwater intrusion. It is in a part of Cow Bayou that has experienced historical dissolved oxygen depressions. Segment 0511 extends for several miles above CB 1, but the upper end of the Segment was not sampled for this study. Station CB 1 represents a portion of Cow Bayou that is almost always fresh, and it was thought that little additional information would be added by sampling areas further upstream which were not very different from CB 1 in terms of habitat. The upstream reach of Cow Bayou also begins to narrow considerably, and is much less accessible for sampling.

Photographs of study stations are in Appendix B. These photos were all taken looking upstream.



Source Data:
ESRI StreetMap USA - Data and Maps
TNRIS - Orange Hillshade for 2993 and 3093 degree block
Projection - NAD 1983 - UTM Zone 15N

Scale: 1:66,000

Note: This map is for reference only

Figure 4.—Map of Cow Bayou showing locations of stations used in this study.

At Lost River, three stations were sited by placing the downstream station near the mouth of Lost River at Old River Lake, the upstream station near the upper end of Lost River where it is blocked by an earthen dam, and middle station about halfway between.

Table 8.—Station location descriptions for Cow Bayou and Lost River.

TPWD Station ID	TCEQ Station ID	Relative Position	TCEQ Station Descriptions
CB 1	10454	Upper	Cow Bayou Tidal 50 yds (45.7 m) downstream of Cole Creek confluence
CB 2	10451	Middle	Cow Bayou Tidal at SH 87
CB 2A	17877	Middle	Cow Bayou Tidal approximately 2.2 km upstream of SH 87 in original stream channel northeast of Bridge City
CB 3	10446	Lower	Cow Bayou Tidal 2400 ft (732 m) upstream of Sabine River confluence
LR 1	17881	Upper	Lost River 40 m upstream of Chambers County line approximately 5.4 km upstream of John Wiggins Bayou confluence
LR 2	17880	Middle	Lost River approximately 2.6 km upstream of confluence with John Wiggins Bayou northeast of Lost Lake oil field
LR 3	17879	Lower	Lost River at confluence with Old River Lake approx. 1.3 km upstream of IH-10

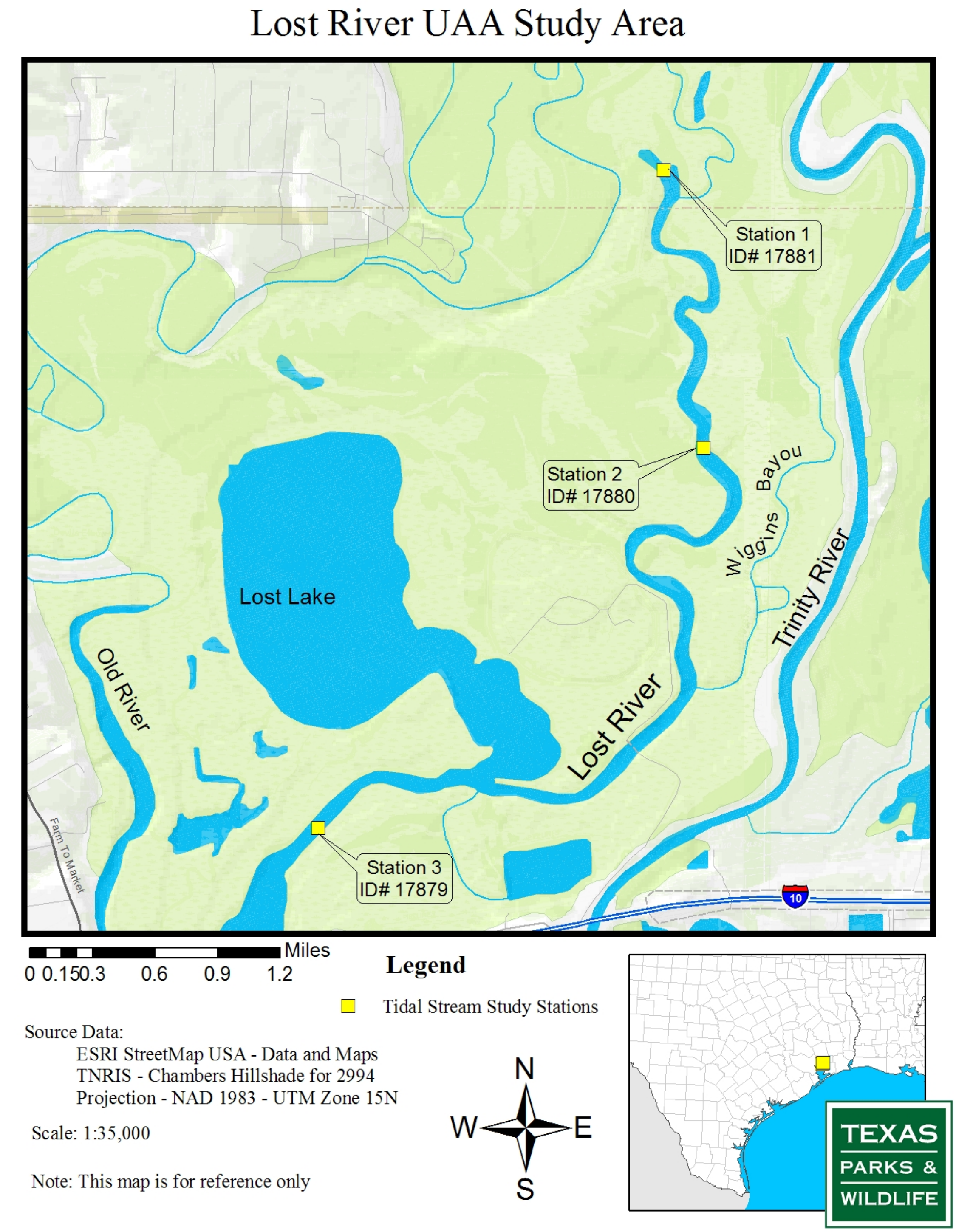


Figure 5.—Map of Lost River showing locations of stations for this study.

Frequency of Sampling

Physicochemical, water chemistry, flow, nekton and aquatic insect data were collected in Cow Bayou and Lost River six times annually for two consecutive years. Sampling occurred twice each in spring, summer, and fall of 2003 and 2004. Sediment and benthic data were collected three times annually for two consecutive years, once each in spring, summer and fall of 2003 and 2004.

To aid in interpretation of results efforts were made to collect data in as small a window of time as possible. For each station all biological samples, water and sediment chemistry, flow data and physicochemical measurements were collected within the same week. The one exception is the November 2004 trip, when datasondes collected data at LR 1 and LR 2 the week before the other sampling was conducted.

Hydrology

Stream flow data was collected using a relatively new method employing acoustic Doppler technology, which measures water motion by transmitting sound through the water column at a fixed frequency and then measuring the Doppler-shifted echoes. The echoes are influenced by backscatter from scatterers (plankton and sediment) in the water and are converted to along-beam (acoustic) velocity components. There are two main methods of deploying these instruments. The first involves mounting the instrument to a boat and making transects across an area of interest. The second involves mounting the instrument on a fixed structure, either on the river bed looking up or submerged at the river's edge looking sideways.

Boat-mounted SonTek River Surveyor acoustic Doppler current profilers (3 MHz; ADCP) were used to record instantaneous measurements of velocity and discharge in the stream channel. The bottom-mounted, up-looking SonTek Argonaut XR acoustic Doppler velocimeter (ADV) was used to measure stream flow direction and velocities over periods of time to include at least one complete tidal cycle. Both instruments use the same technology and provide a detailed level of cross-sectional data that is unprecedented in the history of stream flow data collection. Additionally, documents on appropriate techniques for use and analyses of these data have been made available from the United States Geological Survey (USGS) testing and open file reports (e.g., Rantz et al. 1982, Morlock 1996, Norris 2001, Morlock and Fisher 2002). Since different companies have different nomenclature for these instruments and since some instruments can be used in both roles, in this document the boat-mounted current profilers are referred to as ADCP and the stationary up-looking velocimeters as ADV.

When performing water-current surveys covering large areas, or when monitoring river discharge, it is often convenient to use a boat-mounted system (Figure 6). Following the USGS basic stream flow protocol for collecting flow data with boat-mounted ADCPs

(Norris 2001), the TPWD recorded instantaneous measurements of velocity and calculated volume transport at each of the stations for most sampling events occurring between April 2003 and November 2004. Flow measurements taken in April and May 2003 were made using RD Instruments Rio Grande ADCPs. These meters apply the same technology to measure flows as the SonTek ADCPs, which are the source of most data for this project. The only important difference is that software used by the RDI ADCP generated data files differing in format from the majority of data reported in this study.

Figure 6.—Boat-mounted River Surveyor (ADCP) configuration that was used to collect flow data on Cow Bayou and Lost River beginning with the August 2003 trip.

When operating from a moving platform, an ADCP measures relative currents. As such, it is important to measure independently the speed of the platform so that it can be subtracted from the instrument's measure of raw current. This procedure then establishes residual water currents relative to the fixed Earth. It is generally desirable to perform these calculations in real-time (SonTek 2005a). This usually is done either by the ADCP tracking the river bed (bottom-tracking) or by using differential GPS. Both techniques require driving the platform or boat along transects across an area of interest. During which time, velocities are measured in 'depth bins,' which are accumulated to give total stream discharge for a stream cross-section. Hence, this technique can obtain very accurate instantaneous flow discharge measurements over a large area.

The USGS protocol recommends performing four transects in close succession at a site to establish accuracy of the stream discharge measurements. For typical streams under steady-flow conditions, the USGS expects replicate measurements of total discharge to differ by no more than 5% (Norris 2001). Expectations for this kind of agreement are unrealistic for tidal streams. Within a tidal stream segment, there is continual variation in the forces acting on stream waters. This complicates the implicit assumption that the four transects replicate flow. In tidal waters, the USGS therefore suggests reducing the time variant element in estimates of flow by using individual transects as representative measures of discharge (Norris 2001). This is in contrast to their recommendation to conduct more than four transects in turbulent water, but recognizes the difficulty of measuring discharge under rapidly changing conditions. Clearly, there is no standard methodology for tidal streams, but by conducting four or more transects the range of variability can be documented for future use in determining an appropriate methodology.

Table 9 documents the number of transects conducted during each sampling event. Field conditions and scheduling problems occasionally interfered with meeting the objective of performing four transects. Cases with more than four transects reflect additional effort to ensure accurate measurements. All measurements of discharge for replicate transects were compared to assess typical variability in flow data during a sampling event. For each site and sampling event, ADCP transects were summarized and compared on the basis of total discharge (AbsQ). Total discharge is a function of the velocities measured by the instrument and a volume transport estimated in the cross-sectional areas where the instrument cannot record data.

Table 9.—Number of ADCP transects conducted at study sites during 2003 and 2004. NA denotes missing data.

Study Stream	Station Name	2003						2004					
		April	May	June	Aug	Sept	Nov	March	May	June	Aug	Sept	Nov
Lost River	LR 1	4	4	4	4	2	4	4	4	6	4	4	NA
	LR 2	NA	4	4	4	1	3	4	4	4	4	4	NA
	LR 3	4	5	6	4	1	4	4	4	4	4	4	4
Cow Bayou	CB 1	4	4	4	4	4	4	4	6	NA	4	4	4
	CB 2A	4	5	4	4	4	4	4	4	NA	4	4	4
	CB 2	3	4	4	4	4	4	4	4	NA	4	3	4
	CB 3	4	4	4	4	4	4	4	4	NA	4	4	4

ADCPs and ADVs cannot measure flow across the entire width of the channel. The ADCP technology and methods of deployment prevent measuring flow near the surface and bottom layer, as well as any portion of the channel too shallow for boat access. These non-measured areas must therefore be estimated. Discharge in the surface and bottom layers is estimated according to a power equation by the ADCP software. Discharge along the stream edges also is estimated according to an equation that the user selects based on the expected angle (steep or shallow) of the bank. In this equation, the distance between the last good measurement and the edge of the bank is necessary to accurately estimate flow along the non-measured edges. In large channels and rivers, the non-measured portion of the channel may be very small. For small streams and shallow bayous, the non-measured portion may be relatively large compared to the area directly measured. For comparison among the streams in this study, this is not likely to be a problem; however, the difference between measured and estimated discharge is documented.

Time-series data is invaluable when investigating flow regimes affected by tidal currents and freshwater inflow, such as in these tidally influenced study streams. To measure variations in velocity and direction of stream discharge over time, up-looking ADVs (SonTek Argonaut XR) were installed at the middle station in each of the study streams, for a total of five deployed instruments. Although ADVs were not deployed at upstream and downstream stations, the general impact of tidal ebb and flood on stream flow discharge was expected to be relatively greater at the downstream station and relatively weaker at the upstream station.

ADVs represent flow by averaging velocity across the water column from surface to bottom. They are usually either mounted on river beds looking upward or submerged at one edge of the river looking sideways. These instruments measure a cone-shaped segment of the water column over a user defined start and end distance. The cone is divided into ‘bins’ that are then averaged to obtain a measure of current velocity. Since ADVs can be installed for extended periods of time, they are useful for obtaining flow history at a site.

The Doppler technology employed by the ADV instruments is reliable for low flow situations, as is found in many coastal streams, because there is no minimum velocity detection level (SonTek 2005b). However as with any technique, there are concerns for establishing the accuracy and reliability of the data. One of the main drawbacks of these instruments is that based on the river profile and size there may be significant parts of the water column that are not captured by the cone of measurement. Although velocity measurements given by the ADV are reliable, measures of stream discharge may be inaccurate for this reason, though reliable estimates can be obtained by applying the ADV velocity data to a rating curve generated by ADCP data. Rating curves are determined from measures of stream discharge collected by an ADCP for various flow regimes. The USGS uses this technique for their stream gage program. Additionally, the USGS has established a considerable body of literature documenting and testing appropriate practices for using ADVs and analyzing associated data (e.g., Lipscomb 1995, Norris 2001). However, much of the literature concerns non-tidally influenced streams and it is not known how well these procedures work in tidal streams. Rating curves were not constructed for this study.

Analysis of Flow Data by Texas Water Development Board

Raw data files were received from field operators with non-standardized names. In order to facilitate data analyses and for archival purposes, all files were renamed following a standard convention to enable accurate identification. Field sheets accompanying the data provided definitive connection between the data file and field effort.

SonTek ADCP data was processed and exported through SonTek's River Surveyor and ViewADP software. The ViewADP software provides information about conditions during the time of data collection, as well as a graphic display of discharge rates across the river cross-section and quantitative measurements of river discharge and velocity. The ViewADP software is limited in its ability to conduct more complex analysis. Basic discharge data was calculated then processed and analyzed using other scripts and FORTRAN programs.

In April and May 2003, stream discharge data was collected using an ADCP from RD Instruments. Processing of this data is similar to the procedure described above for the SonTek ADCP, except that the transect summaries of discharge are given by RDIs WinRiver software. Processing with WinRiver also yields voluminous transect-specific data tables which can be processed to provide additional details about flow variation with depth and across the transect profile.

SonTek ADV time-series velocity data was processed and exported using the SonTek ViewArgonaut software, similar to the procedure used for ADCP data. The ViewArgonaut software provides information about stream conditions during sampling including discharge summaries and velocity data. As with ViewADP, the ViewArgonaut software has limited ability for analyzing the data. Therefore, additional data processing was conducted using other scripts and FORTRAN programs.

Typically, ADCP data are used to provide a rating curve enabling stream flow discharge volume to be calculated from the time-series velocity data recorded by the ADV. This way a time series discharge measurement can be calculated for a particular location on the river. The UAA work was not designed to provide that information. However, because in most cases ADV and ADCP data overlapped in time, there may be data sets which can be used to suggest rating curves.

Bi-directional flows occur when both tidal and freshwater currents are equally strong and when channel depth is greater than the depth of mixing near the surface layer. Under these conditions, an inverse, or upstream, current may form along the stream bottom during flood tide. This strong salt wedge creates a vertical flow structure with the denser saltwater flowing upstream as less dense freshwater flows downstream. ADCP data from all events at all stations were examined for evidence of bi-directional flow. To detect bi-directional flows, average magnitude and direction of flow within each bin were plotted. In this format, evidence of bi-directional flows is indicated by at least a 120° change in the direction of water flow between adjacent bins.

ADV velocity data provide a time series of average velocity for a segment of the water column. There are several methods that can be used to separate tidal currents from measured non-tidal currents, thus providing an indication of water movement resulting from tidal action as opposed to stream discharge and wind driven currents. The sub-tidal component is also called the residual or non-tidal component in time series analysis. In general, the accuracy of analysis, whether spectral, harmonic, or filtering, is dependent upon the length of measurement and the sampling interval. A longer time-series of data collection yields more accurate results. Because of the limited record of flow data, this study used a filtering method to quantify the tidal and residual currents, rather than the more commonly used method of harmonic analysis. Moreover, the filtering method was applied only to those data sets containing more than 60 hours of continuous measurement. This requirement was necessary to establish confidence limits for residual currents and for characteristics of the low-pass filter used here.

Several kinds of low-, high-, and band pass filters may be used to distinguish between tidal and non-tidal signals in the data. Following Doodson (1928), a low pass filter (Doodson X0) was used to extract the non-tidal components of flow from raw measurements. The Doodson X0 filter is a symmetric convolution low pass filter which does not lead to distortion due to time lag and is commonly used in oceanography. This technique is capable of quantifying the magnitude of non-tidal currents associated with freshwater and wind driven currents in tidally influenced areas. The classic method of averaging data for 24 hours to remove the tidal signal does not give accurate residual currents in tidally influenced areas, because the 24 hour average cuts off all frequencies that are multiples of one cycle per day. Therefore, it lets through a fair percentage of other tidal constituents. As a consequence, to determine pure residual flow a simple summation of data for 24 hours may result in a 15 - 20% error in the estimate of tidal currents. The low pass filtering method used herein has a 5% residual error for each component of velocity.

Assurance of Data Quality

The quality of flow measurements collected during a sampling event at each station was established by ensuring that replicate transects yielded discharge values within a 5% level of agreement. For each replicate transect *i*, agreement (A_i) between separate estimates of flow (Q_i) was determined by calculation of relative error and is expressed as:

Equation 1.

$$A_i = \frac{\left|\hat{Q} - Q_i\right|}{\hat{Q}}$$

where $\hat{Q}$ is the mean flow value from all of the measurements made at a station during a sampling event, and Q_i is the flow measurement for transect *i*. Per USGS recommendation (Norris 2001), a transect measurement is considered "Good" when its calculated relative error is less than 5%. Additionally, a mean flow measurement for a sampling event is considered "Good" when all flows used in calculating the mean have relative errors less than 5%. Table 10 provides an example of transect agreements for data recorded in June 2003. As mentioned before, the expectation that transects should agree within 5% may be unrealistic for tidal streams, so the categorization of transects as "Good" or "Bad" must be interpreted with this in mind. In general, replicate measurements of flow have better agreement when discharge is high than when it is low.

Table 10.—Example transect agreements for replicate transects measuring volume transport in study streams during June 2003. Quality assurance is based on ADCP field measurements of flow (Q) and is not based on total flow (AbsQ), which would include estimates of flow along the surface, bottom, right and left banks. Transects with less than 5% relative error are defined as "Good" (Norris 2001).

Study Stream	Site	Year	Month	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
Cow Bayou	CB 1	2003	June	106	103.0	2.9%	Good
				84		18.4%	Bad
				98		4.9%	Good
				124		20.4%	Bad
	CB 2	2003	June	528	526.3	0.3%	Good
				500		5.0%	Bad
				556		5.7%	Bad
				521		1.0%	Good
	CB 2A	2003	June	40	29.8	34.5%	Bad
				11		63.0%	Bad
				18		39.5%	Bad
				50		68.1%	Bad
	CB 3	2003	June	1,074	1,075.0	0.1%	Good
				1,053		2.0%	Good
				1,182		10.0%	Bad
				991		7.8%	Bad
Lost River	LR 1	2003	June	31	31.7	2.1%	Good
				30		5.3%	Bad
				34		7.4%	Bad
	LR 2	2003	June	105	103.5	1.4%	Good
				85		17.9%	Bad
				108		4.3%	Good
				116		12.1%	Bad
	LR 3	2003	June	1,154	1,040.0	11.0%	Bad
				1,004		3.5%	Good
				1,063		2.2%	Good
				939		9.7%	Bad

Velocity vectors were displayed in time-series plots, which visually demonstrated the dynamics of flow in these tidal streams showing both daily variation and inflow events. Measurement velocities were given in northward, eastward and upward components. Resultant velocity vectors were calculated using standard geometric methods. All velocity plots indicated north, and for all sites upstream currents were represented by vectors pointing northward and downstream currents were represented by vectors pointing southward.

For those events in which sufficient data were collected (>60 hours of continuous measurement), tidal flow and residual flows were extracted from the raw time-series data (Figure 27, for example). The accuracy of ADV measurements is ±0.5 cm/s, which is suitable for this analysis as flows with velocities less than 0.5 cm/s were not considered in the analyses presented herein.

Instream and Riparian Habitat

Habitat data were collected in the spring (April and May) of 2003. Habitat characteristics were surveyed according to methods outlined in the U. S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) document entitled, "Field Operations and Methods Manual for Non-Wadeable Streams" (Lazorchak et al. 2000) except where noted. Habitat classification was conducted once for each stream (Cow Bayou and Lost River) at 3 or 4 sampling reaches per stream. Each sampling reach was subsampled at 11 transects (Lazorchak et al. 2000), and the transect locations were recorded using global positioning system (GPS). For a more detailed description of the methodology used to sample each of the following variables refer to Lazorchak et al. (2000).

Variables measured included:

- a thalweg (i.e., maximum depth) profile along the length of each stream sampling reach that included an estimate of bottom substrate type and channel habitat type
- an estimate of littoral (i.e., channel bank) depth and substrate type along the margin of the channel at each transect location
- an estimate of the coverage of large woody debris in each channel reach
- a measurement of channel physical characteristics which included channel wetted width, presence of bars or islands and their width if present, bankfull width, bankfull height, channel incised height, and bank angle/degree of bank undercutting;
- an estimate of canopy cover along channel banks using a densiometer;
- another measure of riparian vegetative structure involving separate visual estimates of canopy, understory and groundcover vegetation;
- an estimate of fish cover and aquatic vegetation within the channel
- an estimate of the degree of human influence in the immediate sampling area around transects

The portions of the EMAP methodology pertaining to “legacy trees,” invasive/alien plant species, and measurement of channel sinuosity were not included in this study. Densiometer measurements were taken following the manufacturer’s instructions rather than the method suggested by Lazorchak et al. (2000). Measurements of channel margin depth and substrate type were estimated using a polyvinyl chloride (PVC) pole along banks where the water was too deep to reach the bottom. Because coastal streams have a very low gradient, channel slope as discussed in Lazorchak et al. (2000) was not measured. The presence of power lines was also added to the portion of the method measuring human influence.

Land cover

The watershed for each stream was delineated from remotely sensed imagery, USGS 8-digit HUCs and field data. The land cover map was clipped to the boundary of the watershed and the total area in each land cover class was calculated. The percent cover for each land cover class was calculated. The difference between the reference stream and each study stream was then calculated.

A stream buffer analysis was conducted to better understand land use immediately proximate to the waterbodies. The center of channel was delineated from remotely sensed imagery for each stream, this included secondary and in some cases major tertiary contributory streams. A 200-meter buffer was then created using the stream centerlines. This buffer was used to clip the land cover map. The total area for each land cover class within the buffer area was then calculated. The percent cover for each land cover class was calculated. The difference between the reference stream and each study stream was then calculated.

An urban index analysis was also conducted. TIGER Roads files developed by the United States Census Bureau were clipped to the study area boundaries. The roads were then converted from vector to raster format (15 m cell). Rasterized roads were then reclassified to binary (where road = 1, other = no data).The rasterized binary roads were then merged with the Urban Class from the land cover classification. Raster masks from study area boundaries were created. The merged Roads/Urban Class files were then masked to the study area boundaries.

A neighborhood analysis was then conducted on the masked Roads/Urban Class files where:

- Field = value
- Statistic = Sum
- Neighborhood = rectangle
- Height = 450 m
- Width = 450 m
- Output cell = 30 m

Output files from the neighborhood analysis were reclassified using a five-class natural breaks classification. For Cow Bayou Basin and Lost River Basin the lowest class per neighborhood was thrown out and the remaining four classes were reclassified as low, medium, medium-high, and high.

Water and Sediment Quality

Multiparameter logging sondes of various types, including YSI 600, In Situ Trolls, and Hydrolab Minisondes, were deployed at each sampling station each trip. Temperature, dissolved oxygen, specific conductance, and pH were measured every half-hour for 24 hours.

Water samples were collected at each sampling station and analyzed for the following parameters:

- Ammonia-nitrogen
- Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)
- Chloride
- Chlorophyll *a*
- Nitrate
- Nitrite
- ortho-Phosphorus
- Pheophytin *a*
- Sulfate
- Total Dissolved Solids (TDS)
- Total Kjeldahl Nitrogen (TKN)
- Total Organic Carbon (TOC)
- Total Phosphorus
- Total Suspended Solids (TSS)
- Volatile Suspended Solids (VSS)

Sediment

In conjunction with benthic infauna sampling (that is, once each in spring, summer, and fall for both 2003 and 2004), sediment samples were collected at each sampling station and analyzed for total organic carbon, percent solids and grain size. Samples were composites of surface sediments from five grabs collected with an Ekman dredge. Samples were placed into glass jars which were kept on ice in coolers until arrival at the TCEQ Laboratory.

Sediment samples were analyzed for the following parameters:

- Grain size

- Percent solids
- Percent gravel
- Percent clay
- Percent silt
- Percent sand
- TOC

Field Sampling Procedures

Sampling procedures for field and conventional chemical parameters are documented in the TCEQ *Surface Water Quality Monitoring Procedures Manual* (1999b) unless otherwise noted. Specifically, field sampling procedures followed Chapter 2, "Field Measurements and Sample Collection," pages 2-5 through 2-16 with for field techniques for collecting samples and using multiprobe instruments. Water sampling followed Chapter 4, "Water Sample Collection," pages 4-1 through 4-2.

Figure 7.—Michael Weeks collecting a water sample on one of the middle coast tidal streams, 5 Aug 2003.

Sample Characteristics

Water samples were collected before any other work was done at each sample location site to minimize potential human influence on the sample. The samples were collected at a depth of approximately 0.3 m from the surface of the water column. An additional sample was collected approximately 0.3 m above the bottom. A Van Dorn bottle or similar sampling gear was used to collect the water sample at depth. Water collected at depth was not analyzed for chlorophyll *a* and pheophytin *a*. Sample collection at depth began in April 2003 for the mid coast and May 2003 for the upper coast.

Table 11 gives sample volume, container types, minimum sample volume, preservation and holding time requirements for water chemistry samples collected in this study.

Table 11.—Field sampling and handling procedures for water samples.

Parameter	Container	Preservation	Sample Volume	Holding Time
TSS/VSS	Pre-cleaned glass or cubitainer	4º C, dark	400 mL	7 days
TDS	Pre-cleaned glass or cubitainer	4º C, dark	250 mL	7 days
Chloride	Pre-cleaned glass or cubitainer	4º C, dark	100 mL	28 days
Sulfate	Pre-cleaned glass or cubitainer	4º C, dark	100 mL	28 days
Total Phosphorus	Pre-cleaned glass or cubitainer	4º C, dark, pH<2 with H_2SO_4	150 mL	28 days
Total Kjeldahl Nitrogen	Pre-cleaned glass or cubitainer	4º C, dark, pH<2 with H_2SO_4	200 mL	28 days
Nitrite/Nitrate Nitrogen	Pre-cleaned glass or cubitainer	4º C, dark	150 mL	48 hrs
Ammonia-Nitrogen	Pre-cleaned glass or cubitainer	4º C, dark, pH<2 with H_2SO_4	150 mL	28 days
ortho-Phosphorus	Pre-cleaned glass or cubitainer	4º C, dark	150 mL	28 days
TOC	Pre-combusted borosilicate glass bottle	4º C, dark, pH<2 with H_2SO_4	100 mL	28 days
Chlorophyll *a*	Cubitainer	4º C, dark	1000 mL	lab filter < 48 hrs; filter may be stored 30 days
Pheophytin *a*	Cubitainer	4º C, dark	1000 mL	lab filter < 48 hrs; filter may be stored 30 days
$CBOD_5$	Plastic or glass	4º C	4000 ml	48 hours

Analytical Methods

Analytical methods were selected to comply with TCEQ rules for analysis methodologies pursuant to the TSWQS (§307.1 - §307.10) in that the data generally were generated for comparison to these standards and/or criteria. The Standards state that "Procedures for laboratory analysis will be in accordance with the most recently published edition of *Standard Methods for the Examination of Water and Wastewater*, the latest version of the *TCEQ Surface Water Quality Monitoring Procedures Manual*, 40 CFR 136, or other reliable procedures acceptable to the Agency." [30 TAC §307.9(a)] Analytical methods and associated parameters are listed in Table 12.

Table 12.—Analytical methods, units, and reporting limits for water quality parameters collected during the study.

Parameters	Units	Method Type	Method	Method Description	STORET	AWRL
Field Parameters						
24-hr. # obs. DO	number		SWQMP	Multiprobe	89858	NA
24-hr. avg. DO	mg/l		SWQMP	Multiprobe	89857	NA
24-hr. min. DO	mg/l		SWQMP	Multiprobe	89855	NA
24-hr. max. DO	mg/l		SWQMP	Multiprobe	89856	NA
24-hr. min. pH	pH units		SWQMP	Multiprobe	00216	NA
24-hr. max. pH	pH units		SWQMP	Multiprobe	00215	NA
24-hr # obs. pH	number		SWQMP	Multiprobe	00223	NA
24-hr.avg. salinity	ppt		SWQMP	Multiprobe	00218	NA
24-hr. min. salinity	ppt		SWQMP	Multiprobe	00219	NA
24-hr. max. salinity	ppt		SWQMP	Multiprobe	00217	NA
24-hr. avg. conductivity	umhos/cm		SWQMP	Multiprobe	00212	NA
24-hr. min. conductivity	umhos/cm		SWQMP	Multiprobe	00214	NA
24-hr. max. conductivity	umhos/cm		SWQMP	Multiprobe	00213	NA
24-hr. avg. water temperature	°C		SWQMP	Multiprobe	00209	NA
24-hr. min. water temperature	°C		SWQMP	Multiprobe	00211	NA

Parameters	Units	Method Type	Method	Method Description	STORET	AWRL
24-hr. max. water temperature	°C		SWQMP	Multiprobe	00210	NA
Water depth of measurement	m		SWQMP	Multiprobe	13850	NA
pH	pH units		SWQMP		00400	NA
DO	mg/L		SWQMP		00300	NA
Conductivity	umhos/cm		SWQMP		00094	NA
Temperature	°C		SWQMP		00010	NA
Secchi Depth	meters		SWQMP		00078	NA
Days since last significant rainfall	days		SWQMP		72053	NA
Flow	cfs	recording meter	Acoustic Doppler	Sontek XR ADCP or equivalent	00061	NA
Flow Severity	1-no flow, 2-low, 3-normal, 4-flood, 5-high, 6-dry		SWQMP		01351	NA
Laboratory Parameters						
Ammonia-N	mg/L	colorimetric	EPA 350.1 w/ distillation		00610	0.05
CBOD$_5$	mg/L	potentiometric	Std. Methods 5210 B	total	00314	NA
Chloride	mg/L	ion chromatography	EPA 300.0		00940	10

Parameters	Units	Method Type	Method	Method Description	STORET	AWRL
Chlorophyll *a*	ug/L	colorimetric	Std. Methods 10200-H		32211	5.0
Nitrate-N	mg/L	ion chromatography	EPA 300.0	total	00620	0.05
Nitrite-N	mg/L	ion chromatography	EPA 300.0	total	00615	0.05
o-phosphorus	mg/L	ion chromatography	EPA 300.0	dissolved	70507	0.06
Pheophytin *a*	ug/L	colorimetric	Std. Methods 10200-H		32218	5.0
Sulfate	mg/L	ion chromatography	EPA 300.0		00945	10
TDS	mg/L	residue gravimetric	EPA 160.1		70300	10.0
TKN	mg/L	colorimetric, automated phenate	PAI-DK03	total	00625	0.2
TOC	mg/L	oxidation	EPA 415.2		00680	2.0
Total Phosphorus	mg/L	colorimetric, automated, block digestor	365.1	total	00665	0.06
TSS	mg/L	gravimetric	EPA 160.2		00530	4.0
VSS	mg/L		EPA 160.4		00535	4.0

Quality Control

Sampling done as part of this study followed quality control (QC) requirements are outlined in the *TCEQ Surface Water Quality Monitoring Procedures Manual.* See the QAPP (TPWD 2003a) for details of field and laboratory quality assurance and quality control procedures.

For the water chemistry samples, for the first three trips field duplicates were collected. Beginning with the fourth trip in August 2003, field splits were collected. One QC sample was obtained for every ten water chemistry samples or portion thereof. Precision of duplicate and split results was analyzed. If precision for a parameter was outside of the acceptable range then results for that parameter were flagged for further investigation. Individual sample results were examined for discrepancies to determine if the data should be discarded. No results were discarded based on comparison of duplicates and splits.

Equipment blanks were collected once per trip for each type of equipment (bucket, Niskin bottle, etc.) that was used to collect a water sample. No equipment contamination was observed during the study.

Data were generally reliable. Sample results for 2003 sampling trips were accompanied by comments from the laboratory. Where such comments indicated a potential problem, individual results were examined. Following discussion with TCEQ staff, most results were deemed acceptable. For both the upper and mid-coast, only about 55 of about 484 sample results taken in 2003 were discarded. In 2004, the laboratory changed their procedures and simply did not report data that they believed to be unreliable, so no additional analysis was required. In both 2003 and 2004, samples were discarded that arrived at the laboratory in leaking containers, outside of the acceptable temperature range, or for which holding times were exceeded. Additional computerized data checks were done to ensure data quality prior to submitting data to TCEQ.

Prior to deployment, multiparameter datasondes were calibrated according to manufacturers' instructions. Diurnal water quality measurements were logged electronically and later downloaded to computers. Instruments were post-calibrated and post-calibration records were checked for each deployment to verify that instruments did not exceed the criteria required by TCEQ (page 9-11 of the *TCEQ Surface Water Quality Monitoring Procedures*). Data for a given parameter were discarded when post-calibration did not meet acceptable limits for that parameter. Other QA/QC activities included verifying that data were reported in the correct units.

The goal of each deployment was to collect a complete 24-hour set of measurements, which were averaged to determine means, maxima and minima for the various parameters. In some cases the datasondes were deployed for less time than 24 hours. In those cases, mean values and other statistics were calculated from several measurements, evenly spaced throughout the deployment period (e.g. every three hours) and intervening measurements were discarded and not included in the analysis.

Original field data sheets are maintained in the TPWD Austin office under the supervision of the Project Manager. Copies of the data sheets were provided to the Data Manager, QA Officer and data entry personnel. Laboratory data were provided electronically to the Data Manager and in hard copy to the QA Officer. A Microsoft Access database was created to manage the data. Field data were entered manually and laboratory and datasonde data were uploaded. Electronic files are stored on the TPWD network. All data is backed up on network drives and on compact disk.

Quality checks were made on all data that was keyed into electronic format. Internal checks were run to ensure consistency between TCEQ laboratory data labeling and TPWD sample identification and to verify that data could be retrieved and that units were appropriate.

Hard copies of all field data, QA/QC checklists and quarterly reports are kept on file at the TPWD office (Coastal Fisheries Division) at 3000 South IH-35, Suite 320, Austin, Texas 78704. All documents will be kept for 5 years or as stipulated by the TCEQ.

Biological Sampling

Benthic and Aquatic Invertebrates

Benthic infauna were sampled with an Ekman dredge. Benthic organisms were collected from one side of the stream and mid-channel, placed in a 500-micron mesh bag, and preserved in 10% buffered formalin with Rose Bengal.

Five samples from one side and five samples in the middle of the channel were taken for a total of ten per station. From trip to trip, benthic samples were not routinely collected on the same side, although there was no systematic random sampling pattern. Side samples were considered to represent both sides. Samples were processed and analyzed individually, not combined. On trips when benthic data were collected, sediment samples were also collected and analyzed for grain size, percent clay, percent silt, percent sand, percent gravel, total organic carbon, and percent solids.

Figure 8.—Adam Whisenant bagging invertebrate sample in Lost River, 4 Nov 2003. Staff often encountered large rafts of floating water hyacinth (*Eichhornia crassipes*) while sampling near shore.

TPWD staff also sampled aquatic invertebrates at each station by conducting a five-minute shoreline sweep with a 500-micron mesh D-frame net on each side of the stream. Samples were preserved in the field using the technique described above.

Figure 9.—Greg Conley sweeping the shoreline of Lost River with a D-frame net, 4 Nov 2003.

Benthic samples were delivered to the Center for Coastal Studies at Texas A&M University – Corpus Christi for identification and enumeration.

Nekton

Sampling access and stream characteristics dictated sampling methods used at each site. Nekton sampling included the use of seines, gill nets, trawls and electrofishing. It was not possible to trawl the most upstream station on Cow Bayou due to the presence of numerous dead trees in the substrate.

Nekton sampling was conducted in close vicinity to each sample site location where water quality and benthic data were also collected.

For each nekton sampling effort organisms were identified to species, measured to the nearest millimeter, and recorded on field data sheets. When a sample reached 19 individuals of one species the remainder would be counted for that specific species and sample, but not measured. Nekton samples were either returned to the water or retained for preservation. Retained specimens were placed in plastic bags, labeled, and placed on ice. Specimens were later placed in 10% formalin for voucher specimens or laboratory identification. When fish were too large for voucher specimen containers, digital photographs were taken in the field.

Seines

A straight seine was used for sampling shallow shoreline areas of Lost River and Cow Bayou. The seine was ten feet in length and six feet in height with ¼-inch delta weave mesh. A seine sampling effort consisted of at least six seine hauls for each station covering a minimum distance of 125 feet. At each station, both shorelines were sampled by conducting three seine hauls for each shoreline, typically for 20 to 30 foot linear distances. Changing shorelines enabled staff to sample all available habitat types at each station. This procedure varied at the upstream station of Cow Bayou, where dense forested vegetation, cypress knees and sheer bank shorelines prevented seine hauls of linear distances greater than ten feet. At CB 1, multiple seine hauls were conducted until at least 60 feet of each shoreline had been sampled. It was often difficult to avoid hanging up the net at this station due to the cypress knees.

Figure 10.—Adam Whisenant and Cindy Contreras lifting seine in Cow Bayou.

The station locations included both cut banks and sloping vegetated shorelines. The water level at the upstream stations fluctuated significantly due to the narrow stream width and steep shoreline slope for both streams depending on environmental conditions. During flood events or high tides streams were above the bank full stage and seine samples were collected in the riparian zone. Samples collected in May and June 2004 were considered to represent flood events. During north wind low tide events, as water levels dropped, seine samples were collected below the vegetation line. The lower stations were less affected by flood and high tide conditions due to the wide stream width and minimal slope along the shorelines. These stations also contained fewer snags, improving the efficiency and consistency of sampling between seasons. The nearshore sediments contained a higher degree of organic detrital material that was caught in the net with the fish and invertebrates. Throughout the study period a significant increase in growth of giant salvinia (*Salvinia molesta*) at CB 2A was observed. Giant salvinia grows outward from the shoreline, and at times limited the amount of available shoreline where seining could occur.

Gill nets

Gill nets were set at all stations for the study with one net set per station. The nets were set as close to perpendicular to the shoreline as the stream width would allow. The 100-foot gill nets consisted of four 25-foot monofilament panels with the bar mesh size range from one to four inches. The one-inch panel was anchored at the edge of the shoreline with the four-inch panel anchored towards the middle of the channel. The nets were marked with fluorescent orange polyballs and bullet floats to prevent boats from running over the nets. Danforth anchors were used at each end of the net to keep the nets stretched to minimize effects from the currents. The nets were set at sunset and picked up after sunrise the next day for an approximate 12-hour period. The heavy anchors used on the deep end of the net helped maintain the straight-line stretched deployment shape of the nets and minimized the capture of unwanted reptiles.

Gill nets are designed as a passive method of collecting fish. They maintain consistency in catch efficiency during moderate environmental conditions. Gill nets and other passive gears are inconsistent in efficiency during adverse environmental conditions. The gill net catch efficiency is affected by rainfall flood events and low tide events associated with strong north winds. Flood events on Lost River carried water hyacinth mats into the nets, limiting the space available to catch fish in the monofilament and distorting the configuration of the nets, resulting in low catch rates. During a low tide event associated with a cold front on the first sampling trip (March 2003), a significant length of the net was out of the water lying on the shoreline by sunrise the following day.

Figure 11.—Steven Mitchell, Jason Leifester and Marty Kelly retrieving gill nets in Lost River, 23 Mar 2004.

Trawls

Ten-foot otter trawls were used at the three stations of Lost River and the three lower stations of Cow Bayou. The upper station of Cow Bayou was not sampled by trawl due to the extent of woody debris present along the bottom of the channel. The lower station of Cow Bayou was not sampled for the first fall season due to an increase in snags and woody debris that followed landfall of a tropical storm. The trawl chosen for the study contained a 10-mm mesh liner in the cod end of the net that collected a wide size range of animals from post-larval to adults. The trawl was towed with a 60-foot trawl bridle attached to two 2.5-foot trawl doors. The trawl was towed at a motor speed of between 700 to 800 rpm (or approximately 3 mph) for a period of five minutes. A sampling effort consisted of three five-minute trawls which spanned the area up and downstream from the station location. When large debris was caught in the net during sampling the sample replicate was discarded and a new replicate conducted. An onboard depth finder was used to canvas the bottom substrate before deploying the trawl to help avoid large debris.

The ten-foot otter trawl was used to collect demersal finfish and invertebrates that inhabit the thalweg portion of the stream. The trawl was also effective at sampling juvenile and sub-adult forms. The thalweg habitat type is independent of depth or proximity to shoreline and biota are collected from the bottom portion of the water column, an area that is most likely to contain the lowest dissolved oxygen concentrations. Other gears used in the study collected finfish from the surface and along the shorelines of the stream where dissolved oxygen concentrations are less likely to vary.

The catch efficiency of the trawl is affected by environmental conditions and the type of trawl selected for the stream. Trawls are designed to work the bottom sediment and require a relatively smooth substrate. Snags and debris caught in the net along the bottom affect the configuration of the net as well as the velocity of the water flowing through the net. The 10-foot trawl used was relatively light and was affected by stream currents along the bottom of the channel and wind speeds at the surface. Increased water velocity through the net would pick the net up off the bottom where only the trawl doors would be in place working the sediment reducing the catch rate of the gear. When wind or currents were present, trawling was conducted down-current in one direction for each of the three five-minute trawls to maintain consistency and minimize adverse velocities through the net. This method results in varying distances sampled between stations and between replicates for the same five-minute time period.

Figure 12.—Cindy Contreras retrieving trawl in Cow Bayou, 24 Mar 2004.

During the two-year study period the environmental conditions varied greatly on Cow Bayou and Lost River. These changes in environmental conditions affected the catch rate. The upper most station of Lost River was problematic during rainfall runoff events due to woody debris from the forested riparian zone that lined the banks. The downstream station of Cow Bayou substrate changed dramatically with the presence of trees and woody debris following a tropical storm. The onboard depth finder was used to canvas an area prior to deploying the trawl and this increased effectiveness with the gear.

Electrofishing

A boat-mounted electrofishing unit was used at each sampling station when salinities were low enough to permit effective sampling. The sampling effort was a minimum of 900 seconds at each station. Additional time was recorded if new species were collected near the end of the 900 seconds. Electrofishing was used primarily along the shoreline to sample each available fish habitat, such as macrophyte beds, woody debris, tree roots, or overhanging branches. Each shoreline was sampled. The electrofisher was either used continually when sampling long stretches of consistent fish habitat or used intermittently when sampling overhanging trees, tree roots, or floating debris. Two netters were on to the boat bow to collect stunned fish with long-handled dip nets. Dip net contents were emptied into the on-board fish holding tank and kept until the sampling effort was complete.

In 2003, electrofishing was conducted with the TPWD Jasper Inland Fisheries District 3D office boat mounted electrofisher. The unit was a Smith Root 5.0 GPP Electrofishing System, which had the capability to shock in conductivities ranging from 10-5,500 microSiemens/cm, and was powered by a 6,000 watt gasoline generator. In 2004, the electrofishing boats from the TCEQ Beaumont and Houston offices were used, depending on logistical needs for each trip. The electrofishing units were Smith Root 7.5 GPP Electrofishing Systems and had the capability to shock in conductivities ranging from 10-11,000 microSiemens/cm. The units were powered by a 7,500 watt gasoline generator. Each electrofisher was rigged with a safety foot switch that depressed to enable electricity to pass through the shocker arrays deployed in front of the boat. The sampling time was recorded by a timer on the electrofishing unit and only recorded when the safety foot switch was depressed.

Data Analysis

In addition to conducting use attainability analyses for three tidal streams, a goal of this study to advance the understanding of biological assessment methods that can be applied to tidally influenced streams. Assessment methods which have been utilized for inland surface waters, as well as estuarine and coastal marine waters, have historically been based on establishing biological criteria which measure the ecological health and diversity of the biological communities' characteristic of these water bodies. These biological criteria can serve as guidelines or benchmarks adopted by regulatory agencies to evaluate the biological integrity of surface waters. The concept of biological criteria can serve as a practical approach to establishing management goals designed to protect or restore biological integrity (Gibson et al. 2000). The criteria themselves are defined as "narrative expressions or numerical values that describe the biological integrity of aquatic communities inhabiting waters of a given designated aquatic life use" (EPA 1990). Coupled with the traditional physical and chemical criteria used by the EPA and TCEQ to establish the beneficial use classifications of surface waters, the integration of the biological assessment provides for a more holistic approach to the protection and management of aquatic ecosystems. Currently, no established methodology exists for assessing the biological integrity of tidally influenced streams in Texas.

Bioassessment, coupled with habitat assessment, helps to identify probable causes of impairment that may not be detected by the more traditional physical and chemical water quality analyses alone. The detection of water resource impairment, accomplished by comparing biological assessment results to the biological criteria, leads to a more definitive chemical testing and focused investigations which should reveal the cause of the degradation (Gibson et al. 2000). This in turn should lead to an evaluation of the source of the impacts (either point source or non-point source) and a determination of the effectiveness of any control measures recommended for these sources (i.e., the application of the TMDL process).

A central principle of a biological assessment is the comparison of a water body to a biological criterion, based in part, on a reference condition (Gibson et al. 2000). Impairment of the water body under investigation can then be judged by its departure from the biocriteria. In this conceptual framework, comparative assessment is predicated on the ability to define, measure, and compare biological integrity between similar systems. Because absolutely pristine tidal river segments probably do not exist along the coast of Texas, comparisons must be made with the understanding that reference segments exist with some minimal level of acceptable impacts.

In their technical guidance document that establishes the protocols for establishing biocriteria, Gibson et al. (2000) recognize that reference conditions need to be established in a variety of ways. They should include information derived from:

> **Historical Data** are usually available that describes biological conditions in the region over some period of time in the past. Careful review and evaluation of these data provide insight about the communities that once existed and/or that may be reestablished. Review of the literature and existing data is an important initial phase in the biocriteria development process. However, if data have not been collected for this specific purpose, they need to be carefully reviewed before being applied;
> **Reference Sites** are minimally impaired locations in the same or similar water bodies and habitat types at which data are collected for comparison with test sites. Reference sites could include sites that are away from point source or concentrated nonpoint loadings; sites occurring along impact gradients

(nearfield/farfield); and regional reference sites that may be applied to a variety of test sites in a given area;

Expert Opinion/Consensus A consensus of qualified experts is always needed for establishing the reference condition; and helping develop the biocriteria. This is especially the case in impaired locales where no candidate reference sites are acceptable and models are deemed unreliable. In these cases, expert consensus is a workable alternative used to establish reference "expectations." Under such circumstances, the reference condition may be defined using a consensus of expert opinion based on sound biological principles acceptable to the region of interest. The procedures for these determinations and decisions should be well documented for the record.

The determination of the reference condition should also be developed from a population of sites, and not from a single site. A review of Contreras (2003a, 2003b, and 2003c) reveals the relative paucity of historical biological data that exists for these tidally influenced water bodies. To that end, even less historical data was available for most of the potential reference water bodies initially investigated. TPWD staff has therefore relied heavily the "Expert Opinion/Consensus" procedures outlined in Gibson et al. (2000) in making determinations of reference conditions.

Because each tidal stream station under investigation was characterized with respect to its potential for saltwater intrusion (e.g., upper, middle, and lower stations), site-specific reference conditions were also chosen to represent the upper, middle, and lower reaches, and these were paired with the corresponding test sites for all comparative purposes.

Owing to a general lack of available historical data, coupled with the absence of any established protocol for determining biological integrity in tidally influenced coastal segments, the initial task before the project team is to determine whether any significant differences can be found between the reference streams and the study streams. Analysis includes a review of the data by conventional means and analysis using multivariate statistics, which is described in detail below.

Separate comparisons of the mid-coast and upper-coast study and reference streams may involve either parametric or non-parametric tests. The null hypothesis in all tests is whether water quality or any other attainment indicator (e.g., biocriteria) at the study sites is significantly different from the conditions at the reference sites.

Parametric Statistics

Parametric statistics, such as Analysis of Variance (ANOVA; F-statistic) and the t-test (t-statistic) are suitable for datasets that exhibit a normal distribution. In order to conclude that there is no significant difference between the water quality conditions (or any other attainment criteria) at the study sites and the reference sites, both the F-statistic and the t-statistic should exhibit probabilities exceeding the 0.05 probability cutoff for the 95 percent confidence interval. In case where multiple study sites are compared to the control site, parametric procedures such as Dunnett's test for comparisons with a control, Fisher's Least Significant Difference (LSD) test, or Duncan's Multiple Range test can be used to test for differences among the means.

Because water quality, biological, and sediment samples are often characterized by small sample sizes (in the case of water quality and sediment collections) or highly skewed, non-normal distributions (in the case of the nekton, benthic infauna, and aquatic insect collections), it is likely that non-parametric tests may be more appropriate for these datasets. Parametric statistics may be more useful for comparisons of the instream and riparian corridor habitat data, flow, and the short-term and long-term physicochemical measurements.

Principal components is another parametric-based statistical test that is used to reduce the sheer numbers of variables (water quality parameters, habitat variables, physicochemical parameters, etc.) down to a manageable subset that explains the greatest amount of total variation. These reduced principal component scores are then used as dependent variables either in logistical or multiple regressions; or similarly as the dependent variables for a multivariate analysis of variance (MANOVA). In each case, this reduced set of variables still tests for differences between the study and reference streams. A limitation posed by the sampling design is the large number of variables relative to the limited number of "replicates" or observations. Ideally, a five-to-one dependent variable-to-independent variable ratio (i.e., dependent variables to observations) is optimal to satisfy the assumptions of many multivariate parametric procedures (Johnson and Wichern 1992).

Non-parametric Statistics

Historically, many of the derived parameters (metrics) used in developing specific biocriteria can be classified as non-parametric community measures or indexes, drawn from dynamic assessments of the fish, invertebrate, macrophyte, and planktonic assemblages that make up a biological community (Karr et al. 1986; Engle et al. 1994; Deegan et al. 1997; Allen and Smith 2000). These dimensionless indexes are used to summarize a series of diverse community measures into one or more quantitative variables. Indexes are used to reveal much of the underlying information inherent in the vast amount of raw data a biological assessment generates. It is in this realm of data reduction, indices are much akin to the principal components and canonical correlations tests. Indexes are most often used to describe measures of community composition such as species abundance, diversity, evenness, richness, and dominance or conditions such as incidence of disease, malformation, and parasite load, or distribution of year classes and age structure (Table 13).

Table 13.—Potential metrics for biological communities that could be considered for tidally influenced streams. Reprinted from Gibson et al. (2000); Table 11-1, and modified for this study.

	Richness	Composition	Tolerance	Trophic/Habitat
Macrophytes	➢ Not applicable	➢ Not applicable	➢ TSS ➢ Light attenuation ➢ Chlorophyll a ➢ DIN ➢ DIP	➢ % Cover ➢ Density of new shoots ➢ Biomass ➢ Stem Counts
Benthic Macroinvertebrates	➢ Dominant taxa ➢ Taxa Richness ➢ Shannon-Wiener Diversity Index ➢ Mean # of species ➢ Pielou's Evenness Index ➢ Average taxonomic diversity	➢ # amphipods per event ➢ Amphipod biomass ➢ Mean abundance of bivalves/site ➢ # of gastropods per event	➢ % Polychaetes ➢ Polychaete biomass ➢ % Oligochaetes ➢ Oligochaete biomass	➢ % or biomass epibenthic ➢ % or biomass deposit feeders ➢ % or biomass suspension feeders
Fish	➢ Dominant taxa ➢ Taxa richness ➢ Average taxonomic diversity ➢ # of estuarine spawners ➢ # anadromous spawners ➢ Total fish exclusive of *Brevoortia* sp.	➢ Total # of species ➢ # species in bottom trawl ➢ # species comprising 90% of individuals ➢ # of marine species ➢ # of freshwater species	➢ #, %, or biomass of *Brevoortia* sp. ➢ #, %, or biomass of *Anchoa* sp. ➢ #, %, or biomass of Poeciliidae ➢ % Incidence of disease, tumors, or anomalies	➢ Proportion of planktivores ➢ Proportion of benthic feeders ➢ Proportion of piscivores ➢ Sciaenidae composition

Increasing levels of environmental stress have historically been considered to decrease overall diversity, decrease species richness, and decrease evenness (or conversely increase the dominance of a few species) (Clarke and Warwick 2001). This oversimplified interpretation of the effects of "stress" may, however, not be observed. Recent theories on the influence of disturbance or stress on diversity have suggested that in situations where disturbance is minimal, species diversity can be reduced due to competitive exclusion (Paine 1966; Connell 1978; Huston 1979; Dial and Roughgarden 1998; Payton et al. 2002). These works show that at slightly increased levels or frequency of disturbance, competition is relaxed and an overall increase in diversity results. At even higher or more frequent levels of disturbance, species start to become eliminated by stress, so that overall diversity falls off. Thus it is at some intermediate level of disturbance that diversity is highest.

Depending on the starting point of the community under investigation, in relation to any existing stress levels, increasing levels of stress (e.g., induced by pollution), may either result in an increase or a decrease in diversity (Clarke and Warwick 2001). It is therefore difficult, if not impossible, to determine where a particular tidal stream community under investigation may fall along this continuum, or what value of diversity (or any other metric utilized to describe a specific biocriterion) would be expected if the community were not subjected to any anthropogenic stresses. Therefore, changes in diversity can only be assessed by comparisons between stations along a spatial contamination gradient or with historical data (Clarke and Warwick 2001). This conceptual framework was central to the site selection criteria outlined in this document. With a general lack of historic data on which to base any meaningful comparisons, it first must be established that significant differences can be detected within each study stream, and secondarily, these differences deviate significantly from the expectations of the reference condition.

The PRIMER v5.0 (Plymouth Routines in Multivariate Ecological Research) software program may be used for community-based analysis. Multidimensional scaling (MDS), or non-metric ordination of the samples, is a technique that constructs a "map" or a configuration of the samples in a specified number of dimensions that graphically represents the underlying sample patterns. The basis of the MDS is the similarity matrix among all the samples. These can include the biological data, the physicochemical data, or any of the datasets collected for this study. Separate ordinations of the stations can then be related by the rank correlations of the different similarity matrices. MDS is computationally more efficient than parametric-based techniques, and there is no need to limit the "dependent variable" side of the equation to the most abundant species (as is the case of an ANOVA or MANOVA of the biological data).

Similarities between each pair of samples are calculated using the Bray-Curtis similarity measure (for biological data) or Euclidean Distance (for the environmental and physicochemical data). The Bray-Curtis measure is defined as:

Equation 2.

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

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

Different transformations of the raw data can place additional weight on the rarer species, allowing for a more complete picture of the biological community to emerge. Agreement between the configurations of the different datasets can be measured by weighted Spearman's rank correlation. This allows for the species configuration (the biological picture) to be confirmed or rejected by the configurations of the "other data" (the physical and chemical pictures) that was collected concurrently. Stated another way, this technique reveals if the patterns in the biology agree with the physical and chemical patterns seen in the "impaired" water bodies.

Second stage MDS (Clarke and Warwick 2001) is a time-series technique incorporating the Spearman Rank correlations between the underlying similarity matrices calculated for each sample date-station two-way layout. Second stage MDS concentrates only on whether the community pattern among the stations is similar temporally across sample dates. Second stage MDS can be used to explore variability over seasons and as well as across years.

Analysis of Similarity (ANOSIM) is analogous to the parametric-based ANOVA in that it requires the same *a priori* designations of impacted or reference streams, but it is not nearly as limited as an ANOVA because there are no parametric assumptions placed on the data. The multivariate form of the similarity matrix, which is the same foundation of the MDS procedure, is the basis for this test. This test is built on a simple non-parametric permutation procedure, applied to the (rank) similarity matrix underlying the ordination of the samples. The procedure constructs a test statistic (R) based on the ranks of the similarities within and between stations. This value is then tested for significant differences against a null distribution constructed from random sampling of all possible permutations of the sample labels (Clarke and Warwick 2001). Values of the R-statistic close to unity show that the community compositions of the samples are very different, whereas those close to zero demonstrate that there are very similar.

The SIMPER (SIMilarity PERcentages – PRIMER v5.0) routine may be used to examine the contribution of individual species (i) to the community structure seen at each station (Equation 2.). Values of $S_{jk}(i)$ are averaged over all pairs of samples (*j,k*) between stations to give the average contribution. The ratio of Savg(*i*) to its standard deviation indicates how consistently a species discriminates among the assemblages. If a species is found at consistent levels (i.e., densities) across all samples at a station, then the standard deviation of its contribution is low, and the ratio is high (Clarke and Warwick 2001). Such a species will contribute more to the intra-group similarity, and can be thought of as typifying that group. Candidate species for "indicator taxa" (either tolerant or intolerant taxa with respect to pollution/water quality degradation/low dissolved oxygen, nutrient loadings, etc.) can be identified with this test.

Average taxonomic diversity and distinctness tests address some of the shortcomings identified with species richness and many of the other diversity indices (Warwick and Clarke 1995). They are based not only on the species abundances (denoted by x_i, the number of individuals of species i in the sample), but also on the taxonomic distances (ω_{ij}) through a classification tree between every pair of individuals (Figure 13). Average taxonomic diversity of a sample is then defined as:

Equation 3.

$$\Delta = [\ \sum\sum_{i<j} \omega_{ij}\, x_i x_j\ ] \,/\, [N(N-1)/2]$$

Where the double summation is over all pairs of species i and j ($i,j = 1,2,\ldots,S$: $i<j$), and $N = \sum_i x_i$, the total number of individuals in the sample. Δ has a simple interpretation; it is the average 'taxonomic distance apart' of every pair of individuals in the sample, or stated another way, the expected path length between any two individuals drawn at random. In the hypothetical sample shown in Figure 13, the distance between individuals in species 1 and 2 (drawn in bold lines) is $\omega_{12}= 50$; between species 3 and 4 is $\omega_{34}=100$; and between two individuals of species 5 is $\omega_{55}=0$ (Clarke and Warwick 2001).

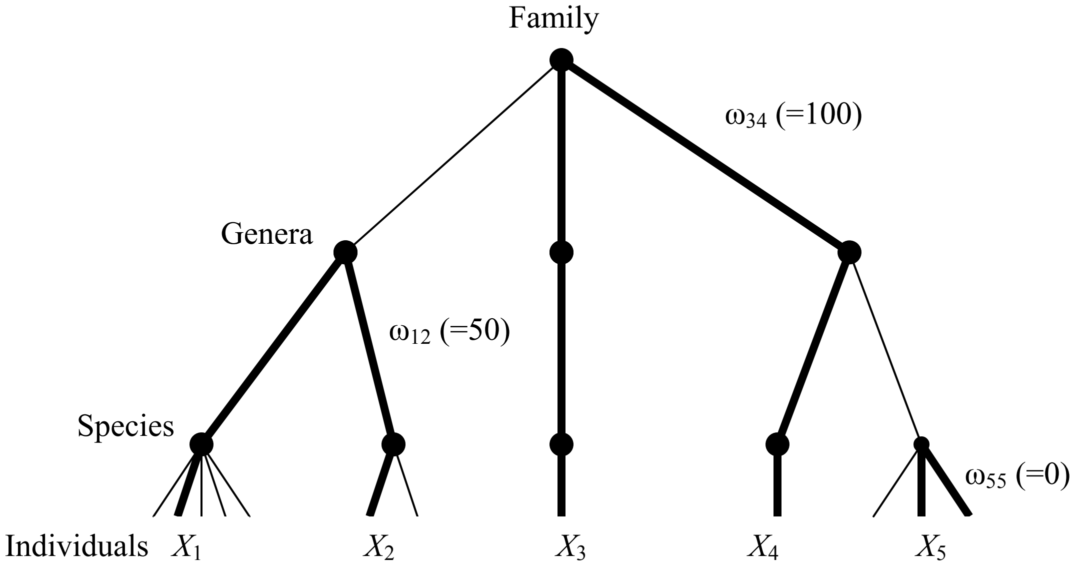


Figure 13.—Hypothetical taxonomic tree for a sample consisting of 5 species, scaled such that the largest number of steps in the tree (the two species at the greatest taxonomic distance apart) is set to ω = 100. Redrawn from Clarke and Warwick (2001).

When the taxonomic tree reduces to a single level hierarchy (all the species belong to a common genus), then Δ becomes:

Equation 4.

$$\Delta^o = [2 \sum\sum_{i<j} p_i p_j] / (1 - N^{-1}), \quad \text{where } p_i = x_i / N$$
$$= (1 - \sum_i p_i^2) / (1 - N^{-1})$$

Equation 4. is a form of the Simpson diversity index. Δ can therefore be seen as a natural extension of Simpson, from the case where path length between individuals is either 0 (same species) or 100 (different species) or a more refined scale that captures the intervening relatedness values (0=same species, 20 different species in the same genera, 40=different genera but the same family, etc.; Clarke and Warwick 2001). In order to eliminate the dominating effect of the species abundance distribution $\{x_i\}$, leaving a distinctness measure that is more reflective of the overall taxonomic hierarchy, Warwick and Clarke (1995) recommend dividing Δ by the Simpson index Δ^o, to give average taxonomic distinctness:

Equation 5.

$$\Delta^* = [\ \sum\sum_{i<j} \omega_{ij}\, x_i x_j] \ / \ [\ \sum\sum_{i<j} x_i x_j]$$

One of the qualities of the taxonomic diversity (Δ) and average taxonomic distinctness (Δ^*) is that they are sample-size independent, inheriting this property from the Simpson index from which they are generalized. This fact can be exploited when comparing current data to historical datasets (albeit in their limited availabilities as noted in Contreras (2003a, 2003b, and 2003c) or for comparing different studies for which the sampling effort is unequal, uncontrolled, or unknown. The taxonomic diversity and distinctness measures can be primarily used for the biological data (nekton, benthic infauna, and aquatic insects). If successful, these measurements could ultimately be used as the building blocks for an IBI-type measure that could be applied coast-wide to tidally influenced water bodies.

Statistical Methods

Statistical methods for assessing ecosystem health and assigning site-specific uses and criteria within tidally influenced portions of river basin and coastal basin waters rely heavily on the non-parametric ordination techniques outlined in the previous section. Schematically, this methodology is shown beginning in Figure 14. In Part A (Figure 14), MDS procedures are used to identify the configurations of the different datasets (e.g., biological, physicochemical, habitat. etc.). Here, the goal of the MDS is to assess any agreement between the biological "picture" and the more traditional physical and chemical "picture." Spearman's rank correlation is used to quantify the degree of agreement between the independent datasets (in Figure 14, designation of 1, 2, and 3 in the hypothetical MDS plots represent the upper, middle, and lower station designations used for this study). The natural separation of the "biological" and the "physical and chemical" measurements are also evaluated with the same rank correlation method. The distinction among the stations on a common stream (in terms of its biological communities, and physical and chemical properties), as well as the differences between them in relation to the reference condition, must first be established.

The biological communities are further assessed with the Average Taxonomic Distinctness measure. Any significant differences between the reference condition and the study streams are identified with the ANOSIM procedure (Figure 15). The ANOSIM procedure is valid for not only the biological communities, but also for the physical and chemical constituents as well. The variables most responsible for the separations seen in the ANOSIM are identified with the SIMPER procedure. From this, a suite of indicator taxa can be identified, and their sensitivity to variability in the physical and chemical datasets assessed (Figure 16). Core metrics that include information about the taxonomic breath of the study locations can then be developed. The threshold (biocriteria) for discriminating between impaired and unimpaired conditions provides the basis for the assessment.

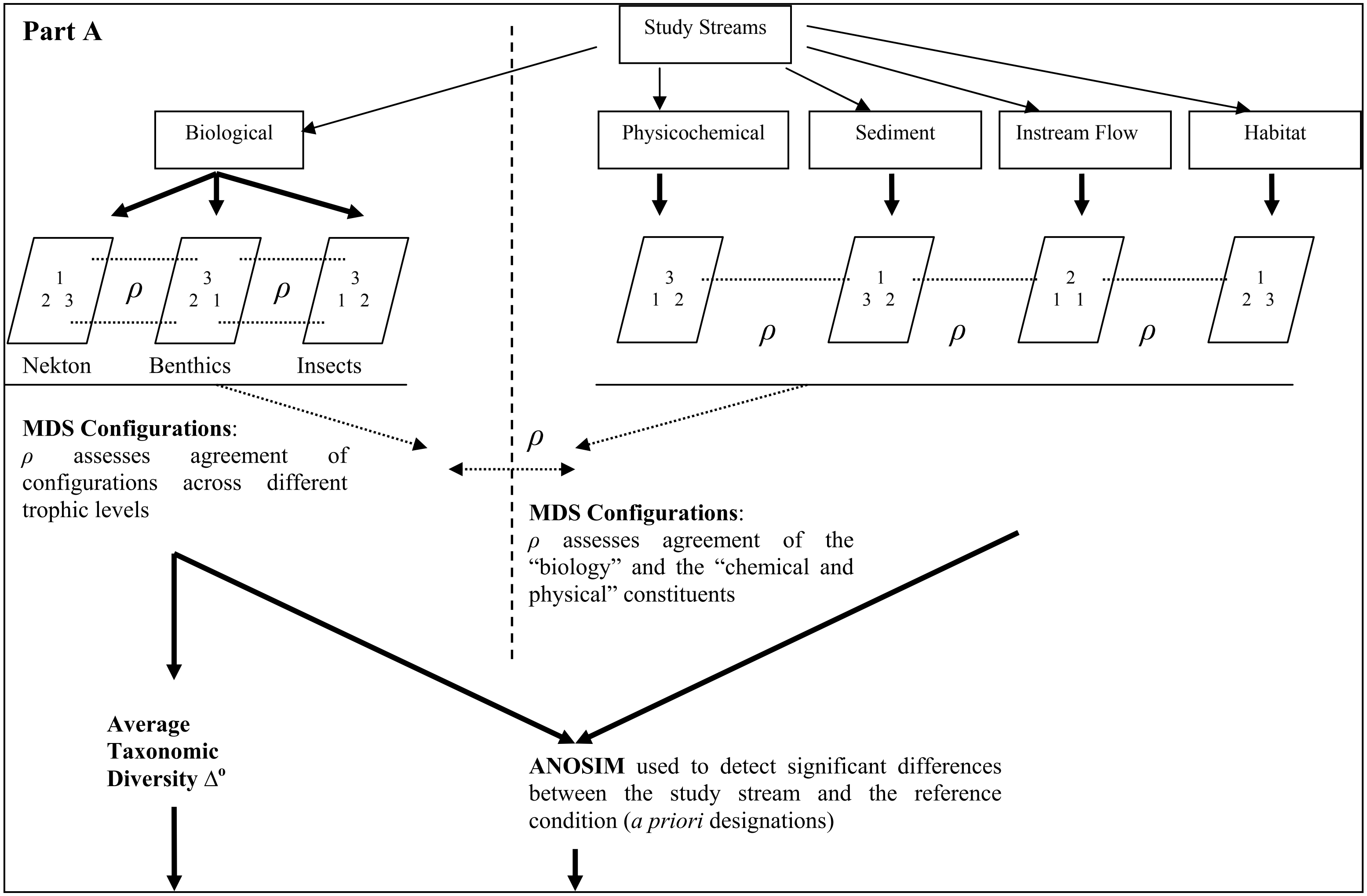
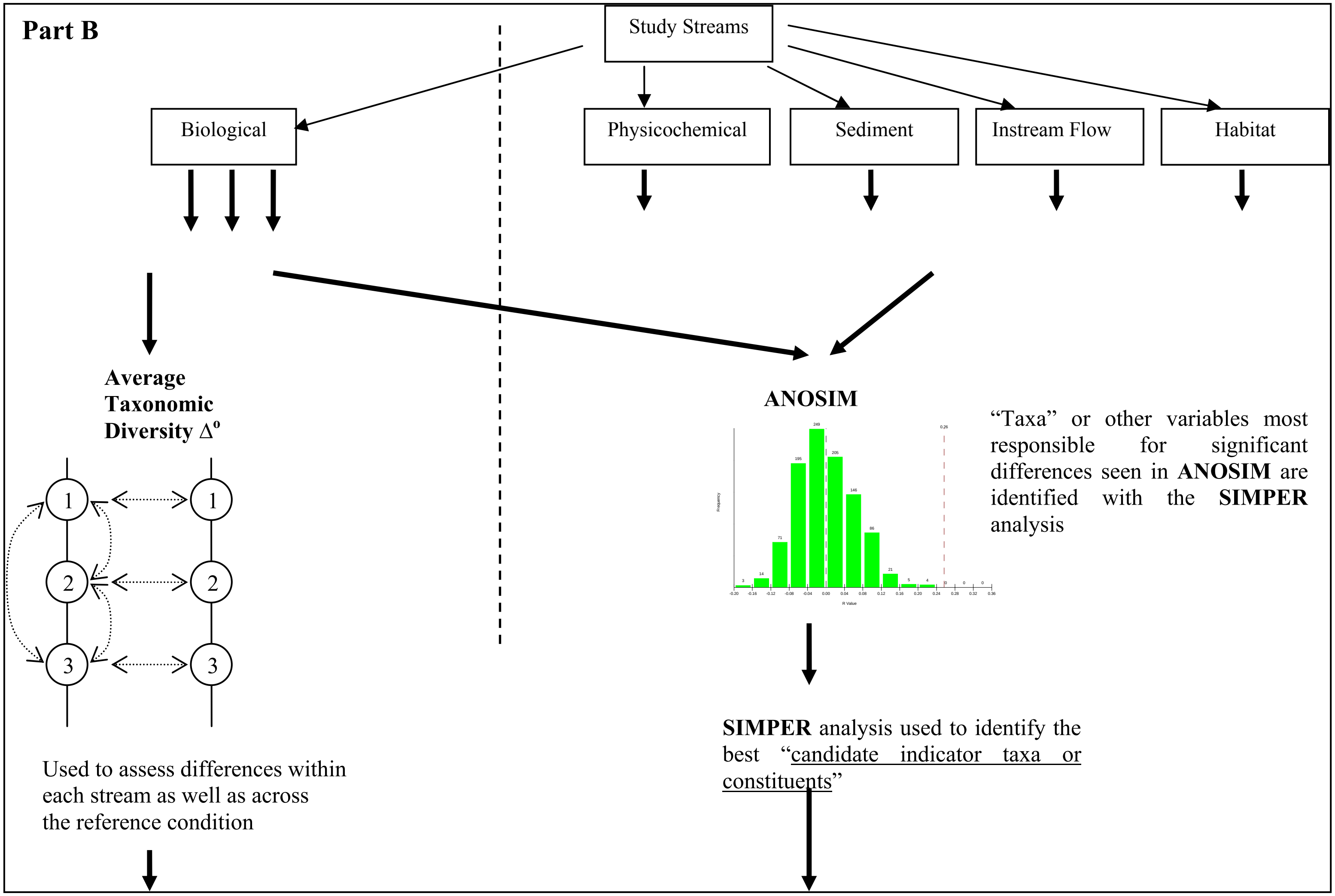


Figure 14.—The process for assessing ecosystem health and determining biocriteria in tidally influenced streams.



Used to assess differences within each stream as well as across the reference condition

"Taxa" or other variables most responsible for significant differences seen in **ANOSIM** are identified with the **SIMPER** analysis

SIMPER analysis used to identify the best "candidate indicator taxa or constituents"

Figure 15.—The process for assessing ecosystem health and determining biocriteria in tidal streams (continued).

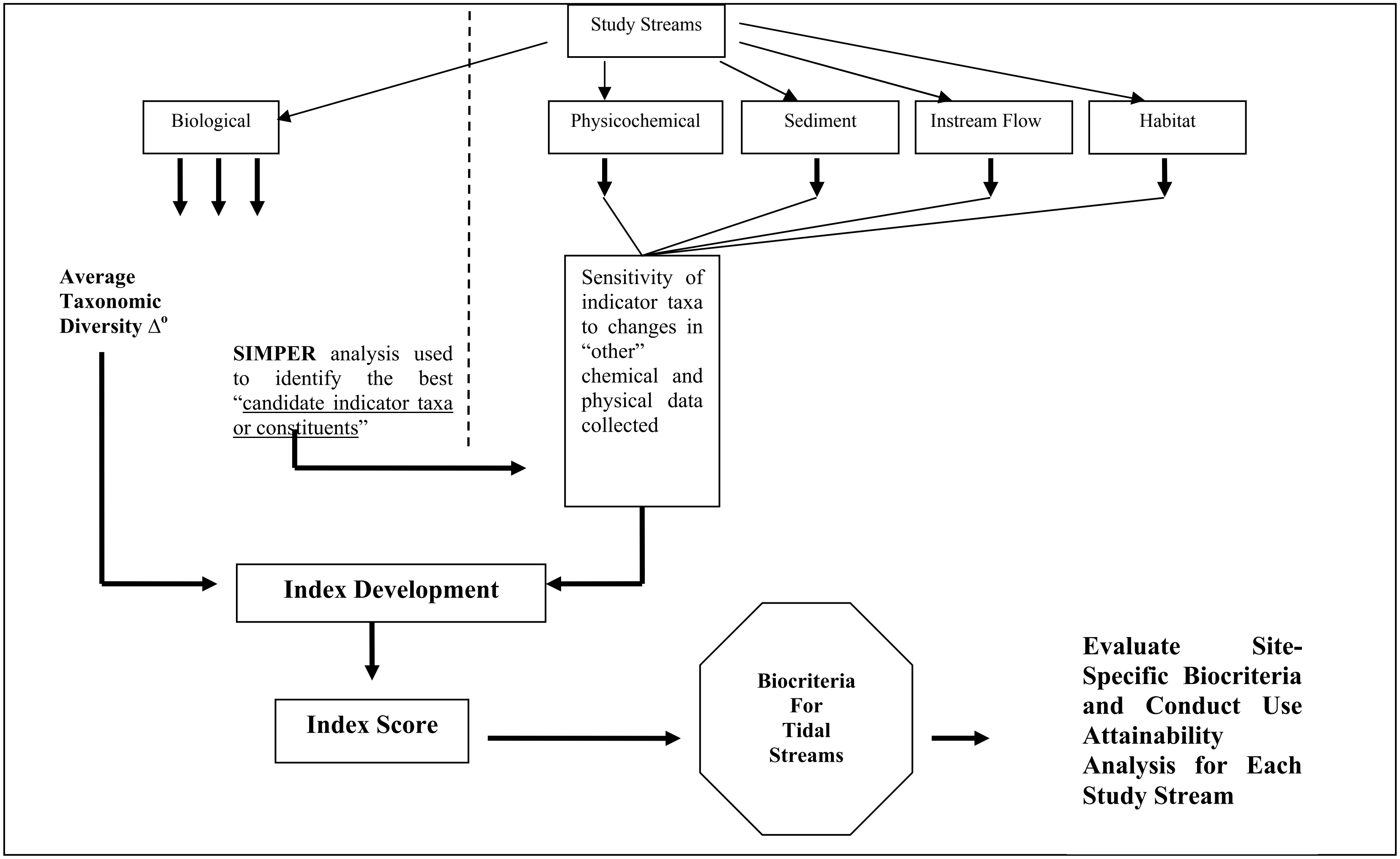


Figure 16.—The process for assessing ecosystem health and determining biocriteria in tidal streams (continued).

Results

Supporting Information

Rainfall data were obtained from Texas A&M's Texas Weather Connection website (http://webgis.tamu.edu/default.aspx.) This is not measured rainfall data, but rather estimated rainfall from NEXRAD radar patterns. Hence data are available at high spatial resolution. For purposes of depicting the general precipitation patterns that occurred during this study, Anahuac was selected as the station nearest Lost River and Bridge City to represent Cow Bayou (Figure 17).

Hydrographs from the nearest gages available are depicted in Figure 18 through Figure 21. A USGS gage on Cow Bayou near Mauriceville is approximately 14 miles upstream of the Cow Bayou study area, and the gage on the Sabine River near Ruliff is approximately 25 miles northeast of the Cow Bayou study area. The gage at the Trinity River at Wallisville is approximately 5 miles south of the Lost River study area and the gage at the Trinity River at Liberty is approximately 21 miles north of the Lost River study area.

Precipitation data was reviewed from information provided on the Texas Water Development Board web site (TWDB 2006). Data sources include precipitation data obtained from the National Climatic Data Center (NCDC). These data are available as monthly precipitation totals for areas of Texas bounded by one-degree quadrangles. For the quadrangle that encompasses most of Orange County, the mean precipitation over a 65-year period ending in 2004 was 56.3 inches. In 2003, the total annual precipitation was 50.9 inches. This total was well above the 10th percentile of the data set (36.3 inches). In 2004, the total annual precipitation was 75.5 inches. This exceeded the 90th percentile of the data set (70.8 inches). For the quadrangle that encompasses most of Chambers County and a portion of lower Liberty County, the mean precipitation over a 65-year period ending in 2004 was 48.2 inches. In 2003, the total annual precipitation was 53.8 inches (well above the mean). In 2004, the total annual precipitation was 61.5 inches, right at the 90th percentile of the data set. It can be seen that 2004 was a wetter year at both streams than 2003. It can also be seen that 2003 was a wet year for Lost River, but a relatively average year for Cow Bayou.

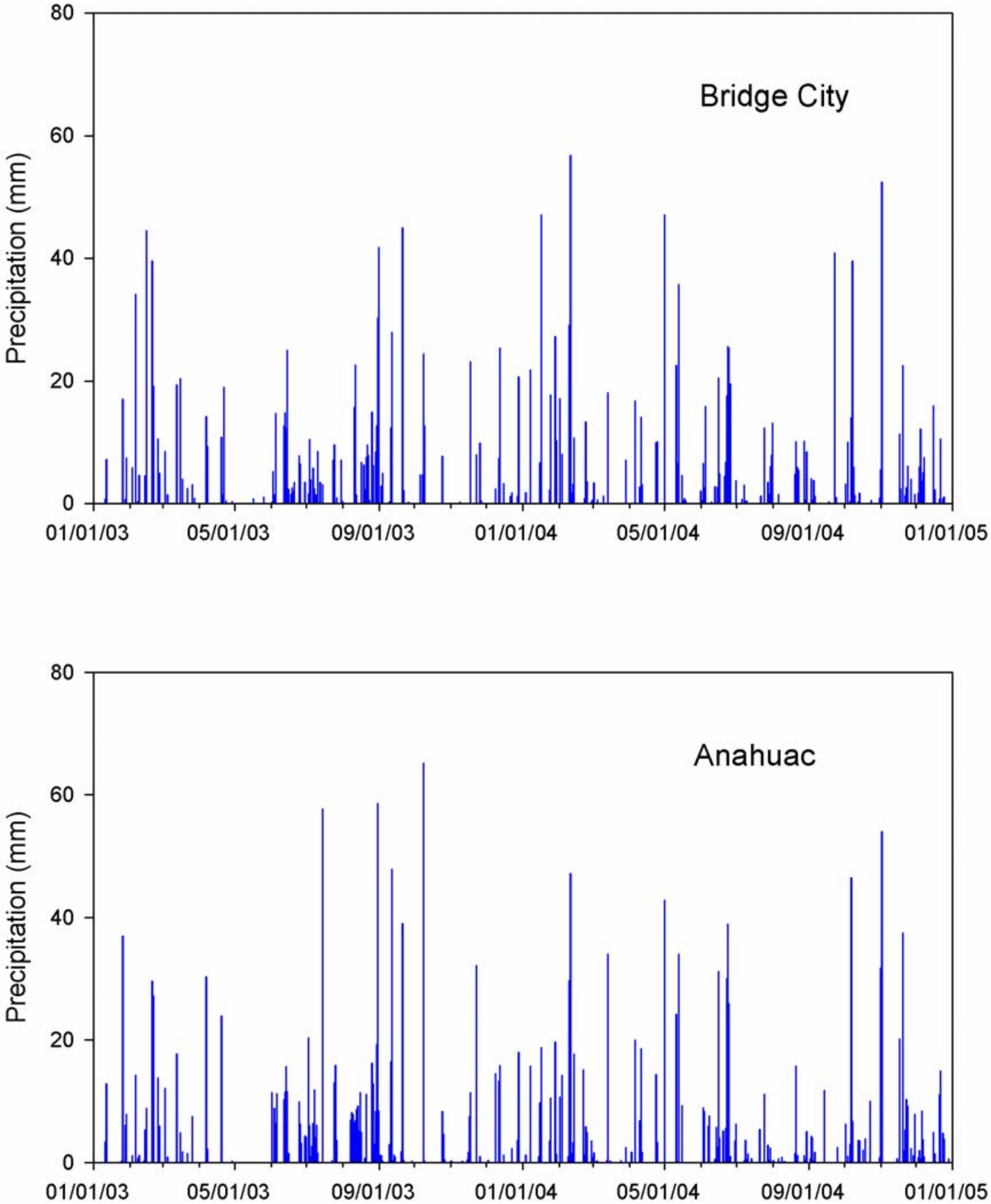


Figure 17.—Rainfall estimated from ground-based radar (NEXRAD) for Bridge City, Texas, and Anahuac, Texas, 2003-2004.

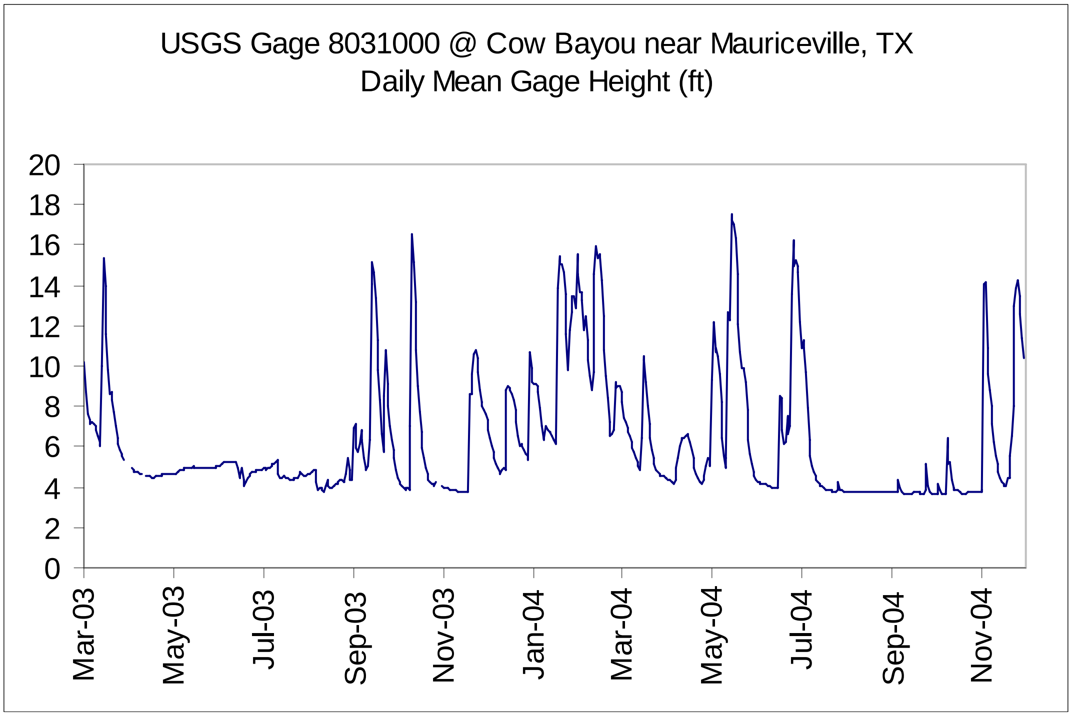


Figure 18.—Hydrograph obtained from USGS Gage 8031000 (Cow Bayou near Mauriceville, Texas.)

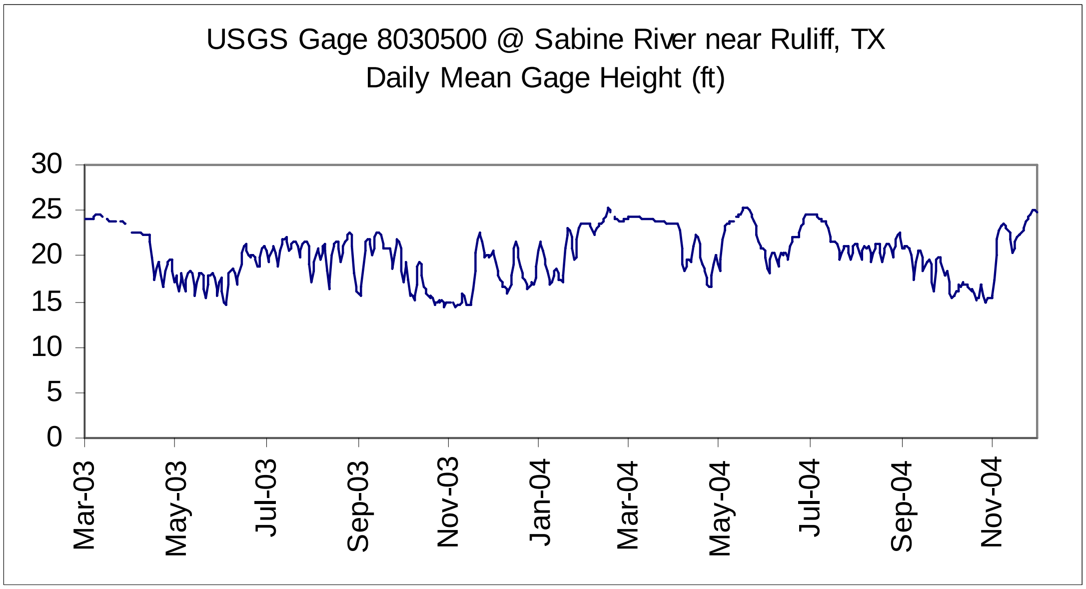


Figure 19.—Hydrograph obtained from USGS Gage 8030500 (Sabine River near Ruliff, Texas.)

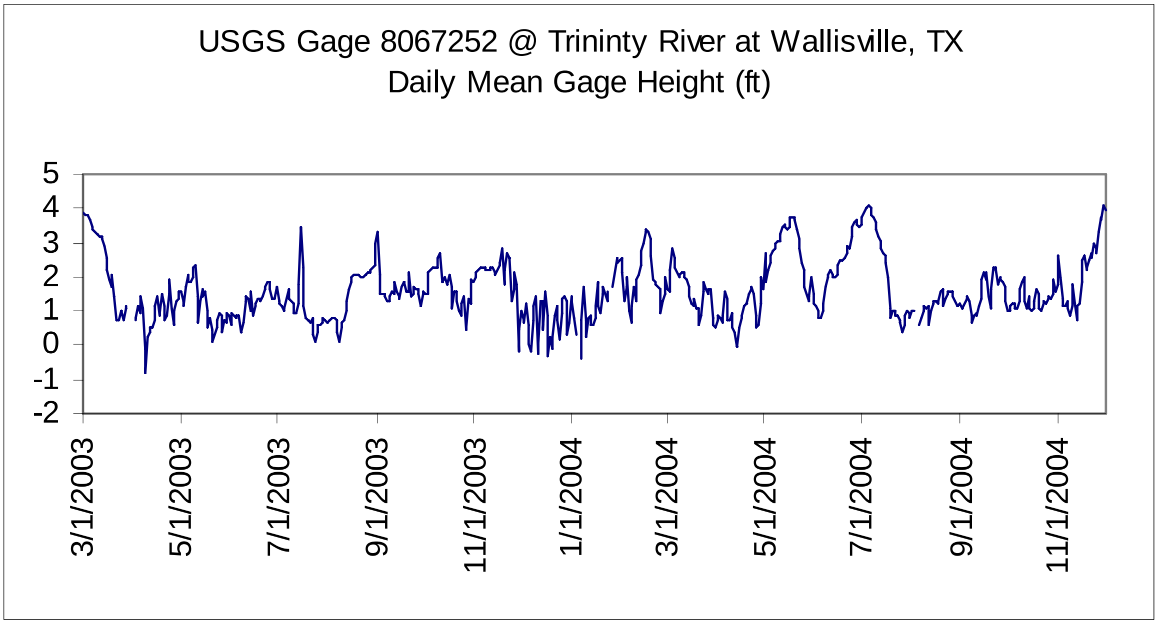


Figure 20.—Hydrograph obtained from USGS Gage 8067252 (Trinity River near Wallisville, Texas.)

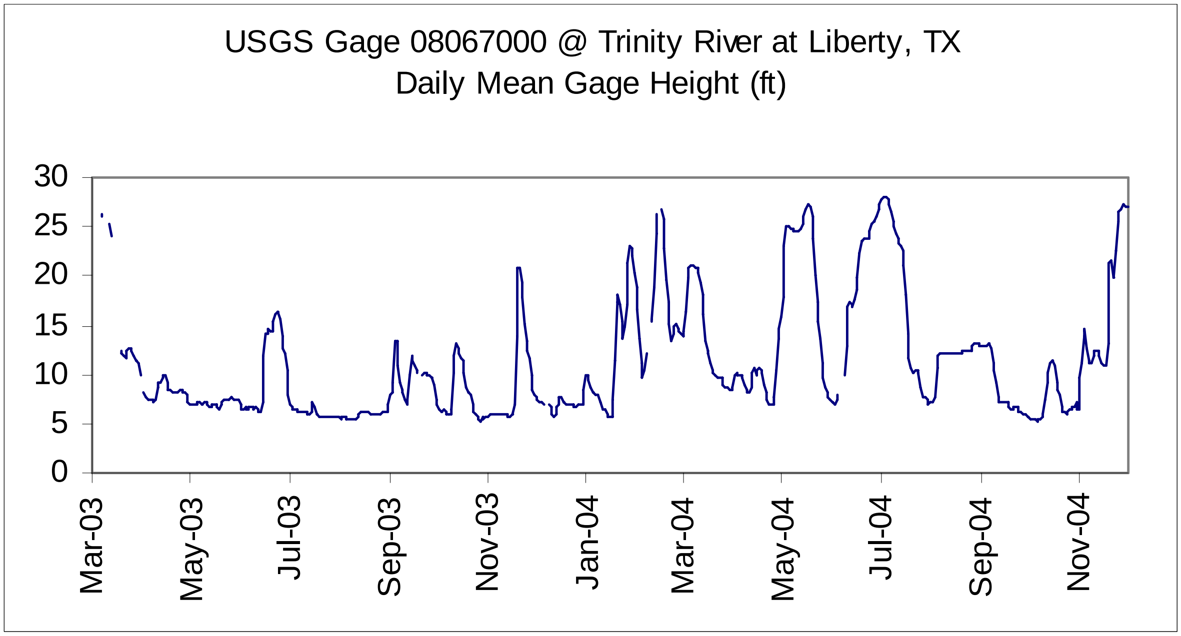


Figure 21.—Hydrograph obtained from USGS Gage 08067000 (Trinity River at Liberty, Texas.)

Hydrology

Flow data (discharge and velocity) were recorded in two tidal streams on the upper Texas coast, Cow Bayou and Lost River. The coastal streams studied are small, with limited channel inputs between stations.

Study sites differed in cross-sectional area with downstream sites having much larger channels. Lost River and Cow Bayou had a large difference in cross-sectional area between the upstream and downstream stations (as directly recorded by the SonTek ADCP; Table 14; Figure 22). Table 14 does not include area estimates for the surface and bottom blanking distances nor for the shallow edges along the bank. Therefore, estimates of cross-sectional area should not be used to calculate channel discharge from the ADV data.

Table 14.—Mean cross-sectional area (ft^2) ± SD of all stations on Cow Bayou and Lost River. Mean area was determined based on measurements recorded by the SonTek ADCP. Estimates do not include areas associated with the surface and bottom blanking distances or shallow edges. Figure 22 provides a graphical representation of this information. NA denotes not applicable.

Stream Station	Lost River	Cow Bayou
1	383 ± 121	548 ± 186
2A	NA	464 ± 156
2	577 ± 238	1,793 ± 281
3	2,539 ± 412	2,486 ± 385

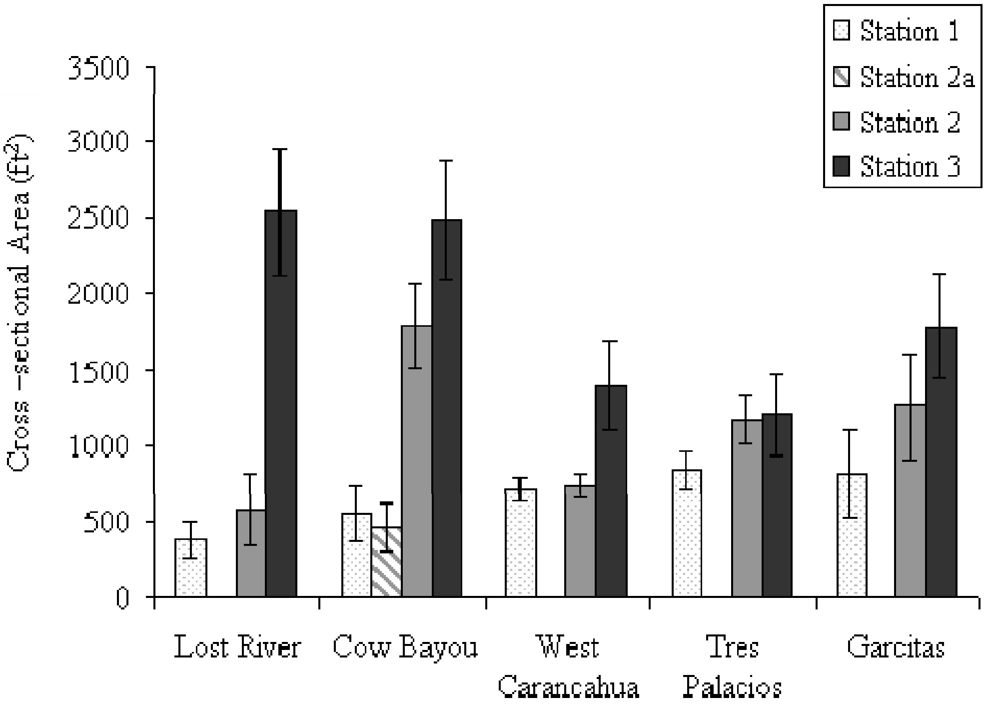


Figure 22.—Mean cross-sectional area of stations on all study streams. Mean area was determined based on measurements recorded by the SonTek ADCP. Estimates do not include areas associated with the surface and bottom blanking distances or shallow edges.

Instantaneous discharge measurements (ADCP data) were collected at all study sites, when possible, during twelve sampling events between April 2003 and November 2004. Generally, replicate measures of flow were not sufficiently consistent (within the USGS recommended 5% agreement) to calculate mean discharge with confidence according to USGS procedures. However, recognizing the dynamic nature of tidal streams and the difficulty associated with obtaining accurate measures of flow, mean discharge was calculated based on all reasonable recorded estimates of stream discharge (AbsQ) to provide a general estimate of mean discharge (cfs) at each site during each event (Table 10) and over time (Table 15).

Table 15.—Mean discharge (cfs) at study sites on Lost River and Cow Bayou. Means were calculated from estimates of volume transport given by replicate transects obtained using an ADCP during each sampling event between April 2003 and November 2004. Estimated discharge includes the surface and bottom blanking distances and shallow edges. Mean discharge in each month was determined using all replicate transects with reasonable estimates of discharge. NA denotes missing data.

Study Stream	Site Name	2003						2004					
		April*	May	June	Aug	Sept	Nov	March	May	June	Aug	Sept	Nov
Lost River	LR 1	126	29	65	24	49	72	28	709	337	5	9	NA
	LR 2	NA	9	255	153	9	114	136	2,781	2,303	91	352	NA
	LR 3	179	1,472	1,432	393	280	2,418	4,181	8,100	3,388	173	5,128	2,170
Cow Bayou	CB 1	66	298	162	58	561	11	297	1,292	NA	161	122	294
	CB 2A	305	67	70	82	177	79	121	406	NA	63	35	80
	CB 2	416	1,355	814	80	942	656	1,158	2,731	NA	114	1,142	557
	CB 3	1,019	3,712	1,597	135	1,645	1,901	3,464	5,444	NA	1,118	2,451	691

* Replicate measures of mean discharge during most events was not sufficiently consistent (within USGS recommended 5% agreement) to calculate mean discharge with confidence. Values are reported here to provide a general estimate of stream discharge at these sites.

This study is among the first to use Doppler technology to quantify flow within the shallow tidal streams along the Texas Gulf coast. Presently, there is no accepted methodology for analyzing and reporting flow data under such conditions, except to take upwards of eight transects per site per event or to report only the values obtained for one transect (Norris 2001). Following the USGS standard protocol of conducting four transects, this study documents variation in stream discharge and velocities over relatively short periods of time in tidal streams. In addition to stream discharge, time-series of current velocity measurements (ADV data) were collected from the middle station in each study stream between June 2003 and November 2004. Although results of analyses for each site are discussed below, a few general patterns regarding stream discharge at these sites are worth noting here. At all stations, discharge was highly variable as indicated by the standard deviation of the means. Peak flows were recorded in May 2004 on the upper coast (Table 15).

When the two years are considered separately, peak flows occurred in different months. For example in 2003, maximum discharge at upper coast stations occurred in April, May, June, or November; whereas, peak flows at all stations occurred during the month of May in 2004. Peak flows did not occur in August at any site in either year.

Detecting Bi-directional Flows

Stream discharge measurements were recorded at a total of 16 tidally influenced stations in five coastal streams. Out of all events recorded at these sites between June 2003 and November 2004, none exhibited bi-directional flows. For purposes of this study, bi-directional flow was defined as a change of 120˚ or more in the direction of flow between recorded bins. In this data set, the maximum difference in directional flow between adjacent bins was 63˚.

Flow data was recorded in two tidal streams on the upper Texas coast, Lost River and Cow Bayou. Lost River is connected via a diffuse network of waterways to the Trinity River and Trinity Bay. Cow Bayou is a small tributary of the Sabine River which flows into Sabine Lake. Mean discharge over time at the downstream site, calculated for all sampling periods from June 2003 to November 2004, was higher in Lost River (2,519 cfs ± 2,293) as compared to Cow Bayou (2,118 cfs ± 1,530). However, flow in both rivers is highly variable, as indicated by the standard deviation. See Table 15 to compare mean discharge at each station during each sampling event and Table 16 for mean discharge at a station for the period April 2003 to November 2004.

Table 16.—Mean discharge (cfs) ± SD over time (from April 2003 to November 2004) for Cow Bayou and Lost River. Mean discharge was determined using all replicate transects with reasonable estimates of discharge. NA denotes not applicable.

Stream Station	Lost River	Cow Bayou
1	149 ± 35	306 ± 57
2A	NA	144 ± 20
2	704 ± 174	916 ± 106
3	2,519 ± 331	2,118 ± 233

Cow Bayou

Flow Characteristics

Mean discharge along Cow Bayou ranged from 300 cfs at the upstream station to 2,100 cfs at the downstream station during the study period. However, station CB 2A had the lowest mean discharge over time, and often had lower discharge than the upstream station (Table 15). The two uppermost Cow Bayou sites (CB 1 and CB 2A) had consistently low flows, except in May 2004 (Table 15). The middle and downstream stations frequently had much higher flows (Figure 23, Figure 24). The first sampling of current velocities at Cow Bayou occurred in June 2003 and resulted in only 24 hours of continuous data collection (Figure 25A). This data set was too short to apply the filtering process; however, the raw data indicate cyclical upstream-downstream shifts in the current. If this pattern of flow was not caused by tidal cycles, then it may have been due to wind or overflow from the Sabine River. Again in August 2003, stream velocity was measured for a 24 hour period. Flow in Cow Bayou was weak, possibly suggesting upstream-downstream cycles in direction of water flow (Figure 25B). Data collected in September 2003 was insufficient for elucidating patterns of flow (Figure 25C). In November 2003, stream discharge was strongly downstream, possibly due to strong effects of tidal currents during flood tide. This is suggested by the substantial decrease in stream discharge at regular intervals of tidal frequency (Figure 25D). The March 2004 data included measures of velocity for a 24 hour period. Strong upstream and downstream currents were recorded (Figure 26A). Data collected in May 2004 covered a 12 day period, including many tidal cycles. Currents measured before May 19 (Julian day 139) were strongly downstream (Figure 27A), after which tidal currents were stronger than residual currents (Figure 27B, Figure 27C). See the section "Tidal Influence on Stream Discharge in Lost River" for further discussion. Measurements collected in August 2004 were erratic, suggesting mechanical error (Figure 26C). September 2004 flow data were influenced by spring tides resulting in stronger than normal currents and flows with upstream movements, which dominated through most of the sampling period (Figure 26D).

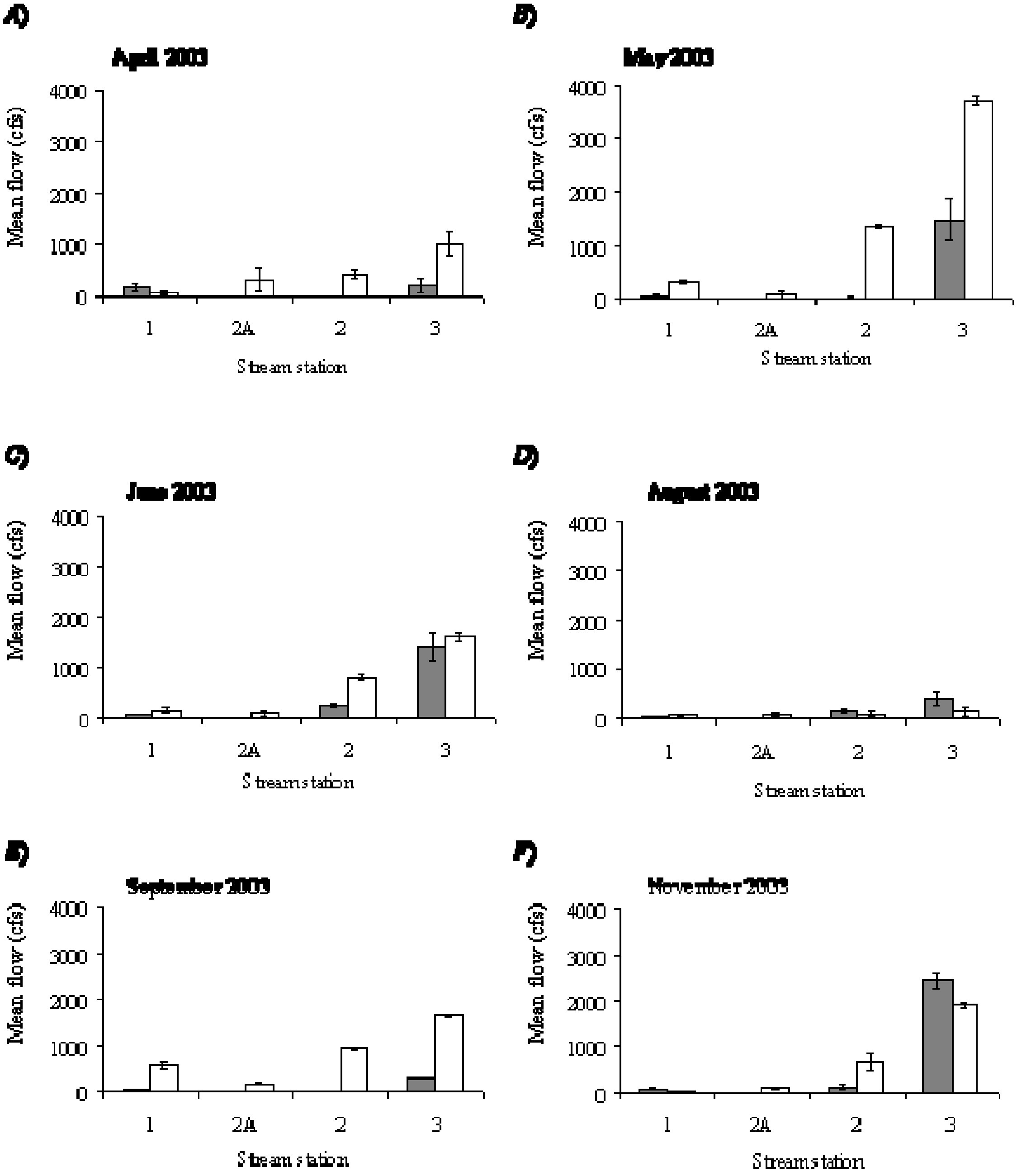


Figure 23.—Mean flow (cfs) ± 1 SD at Lost River (the reference site, grey) and Cow Bayou (white), for the months of A) April, B) May, C) June, D) August, E) September, and F) November 2003. Stream stations are: (1) upstream, (2A) upper-middle, (2) middle, and (3) downstream.

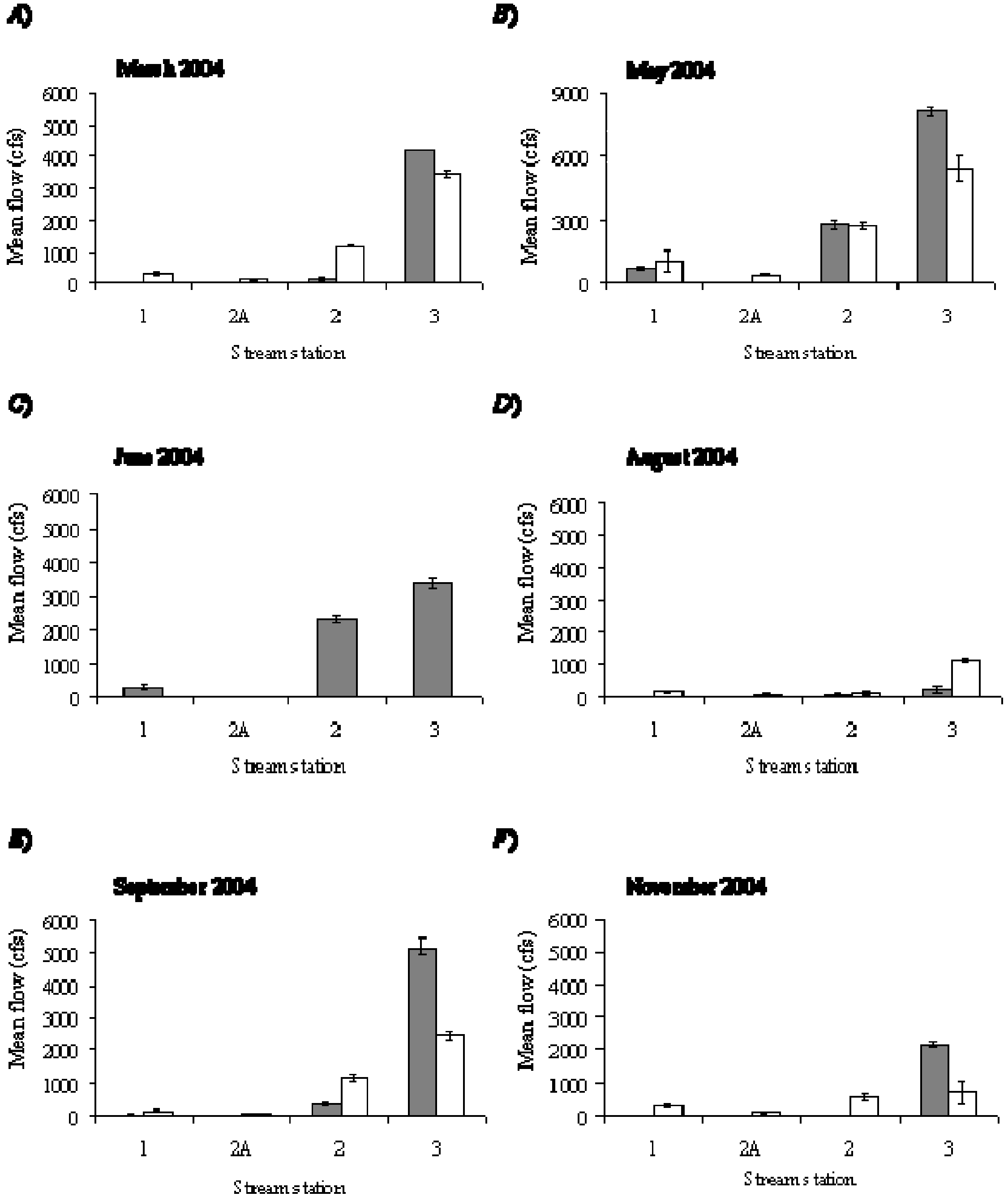


Figure 24.—Mean flow (cfs) ± 1 SD at Lost River (the reference site, grey) and Cow Bayou (white), for the months of A) March, B) May, C) June, D) August, E) September, and F) November 2004. Stream stations are: (1) upstream, (2A) upper-middle, (2) middle, and (3) downstream.

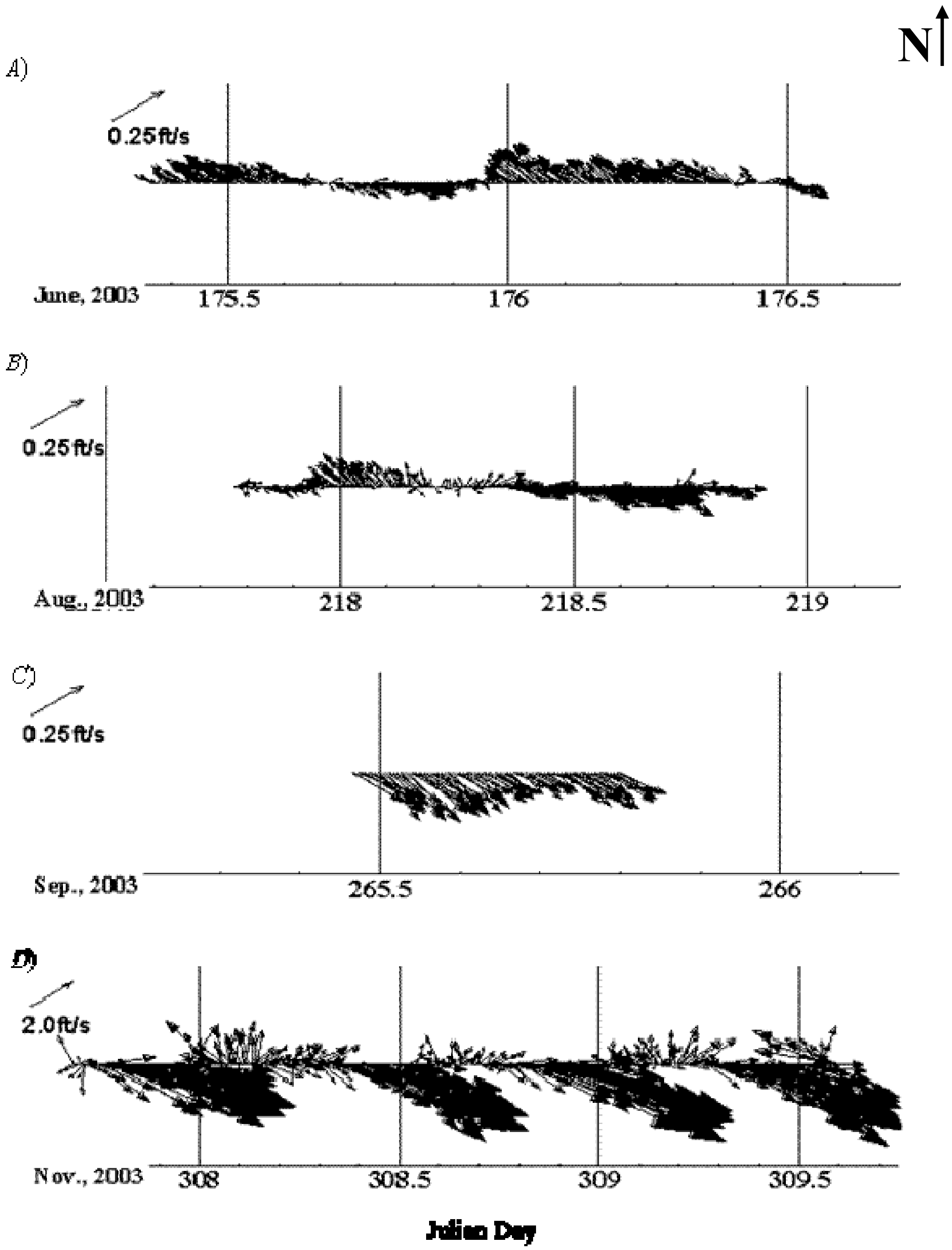


Figure 25.—Total current velocities measured in Cow Bayou in 2003. (A) 24-25 June, (B) 5-6 August, (C) 22 September, and (D) 3-5 November. x-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

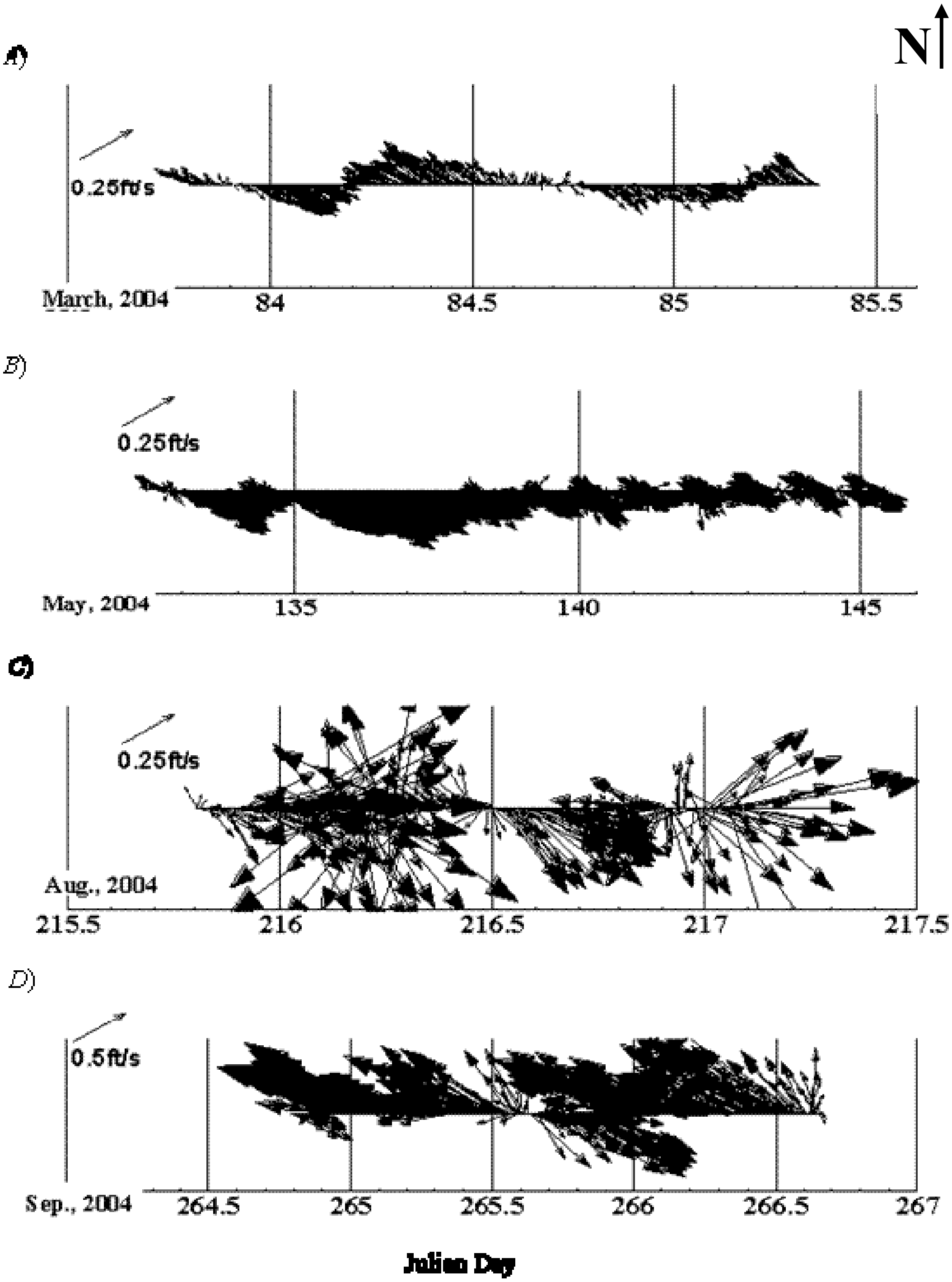


Figure 26.—Total current velocities measured at Cow Bayou in 2004. (A) 25-26 March, (B) 13-26 May, (C) 3-5 August, and (D) 21-23 September. x-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

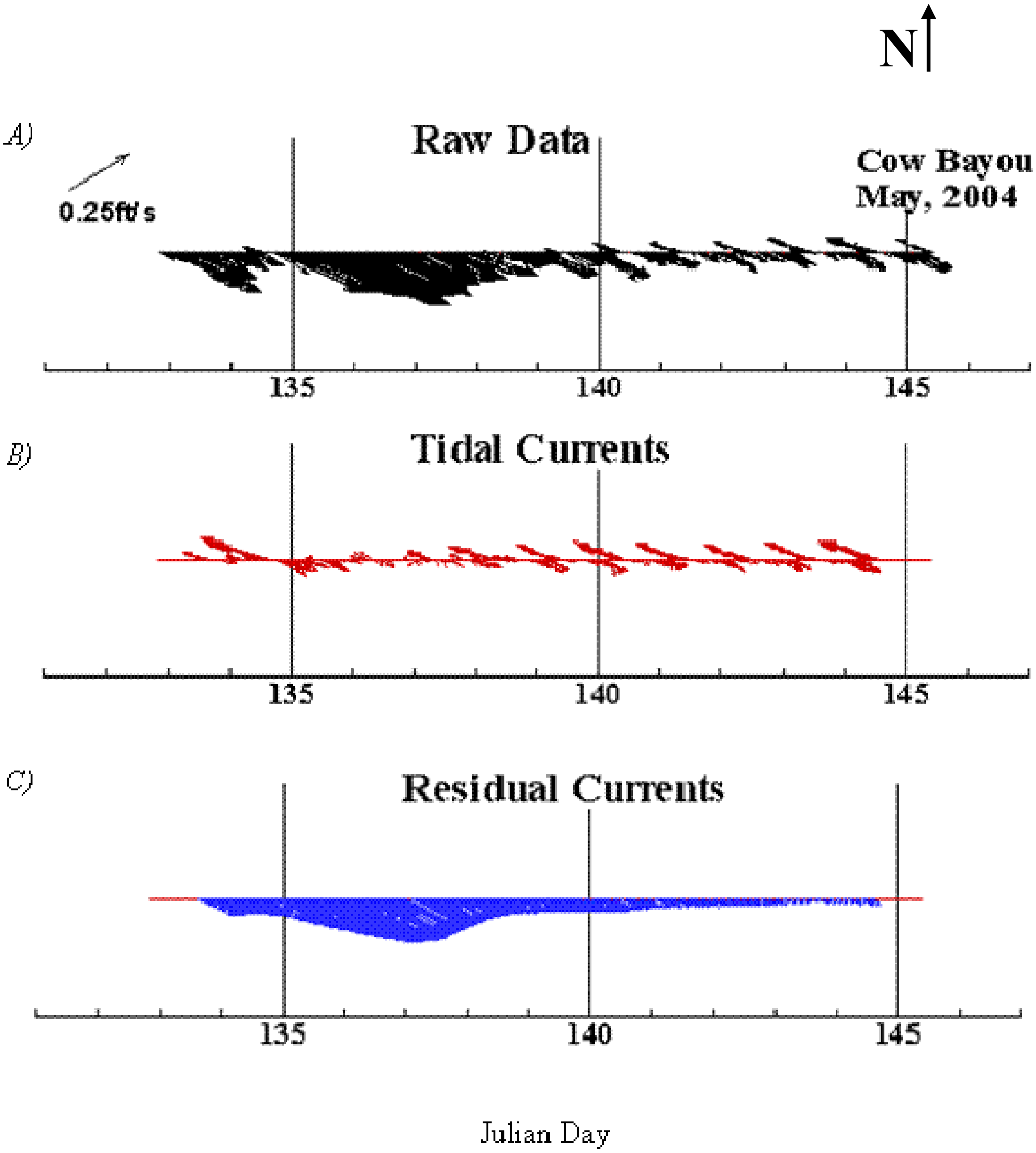


Figure 27.—Flow composition at Cow Bayou, 13-26 May 2004. (A) Raw flow data with (B) tidal and (C) residual currents extracted. x-axis is Julian day with five-day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

Tidal Influence on Stream Discharge

In total, eight sampling events recorded time-series of velocity data from Cow Bayou. Of these, data from two sampling events (May 2004 and September 2004) were processed to separate tidal and residual flows. Time-series data from the other events were not long enough to apply the filtering process. Figure 27 and Figure 28 show results from the filtering process and indicate that currents in Cow Bayou may be dominated by either strong downstream or strong upstream flows (for example, Figure 27A, Figure 28A). In May 2004, downstream discharge was strong for six days prior to May 19 (Julian Day 139, Figure 27C) and ameliorated tidal currents moving upstream (Figure 27B). After May 19, downstream currents weakened and downstream-upstream oscillations followed the tidal cycle (Figure 27A, B). The short data collection period in September 2004 limited ability to apply the filtering technique (Figure 28). However, results indicate that residual currents were directed upstream (Figure 28C) while tidal currents were directed downstream (Figure 28B).

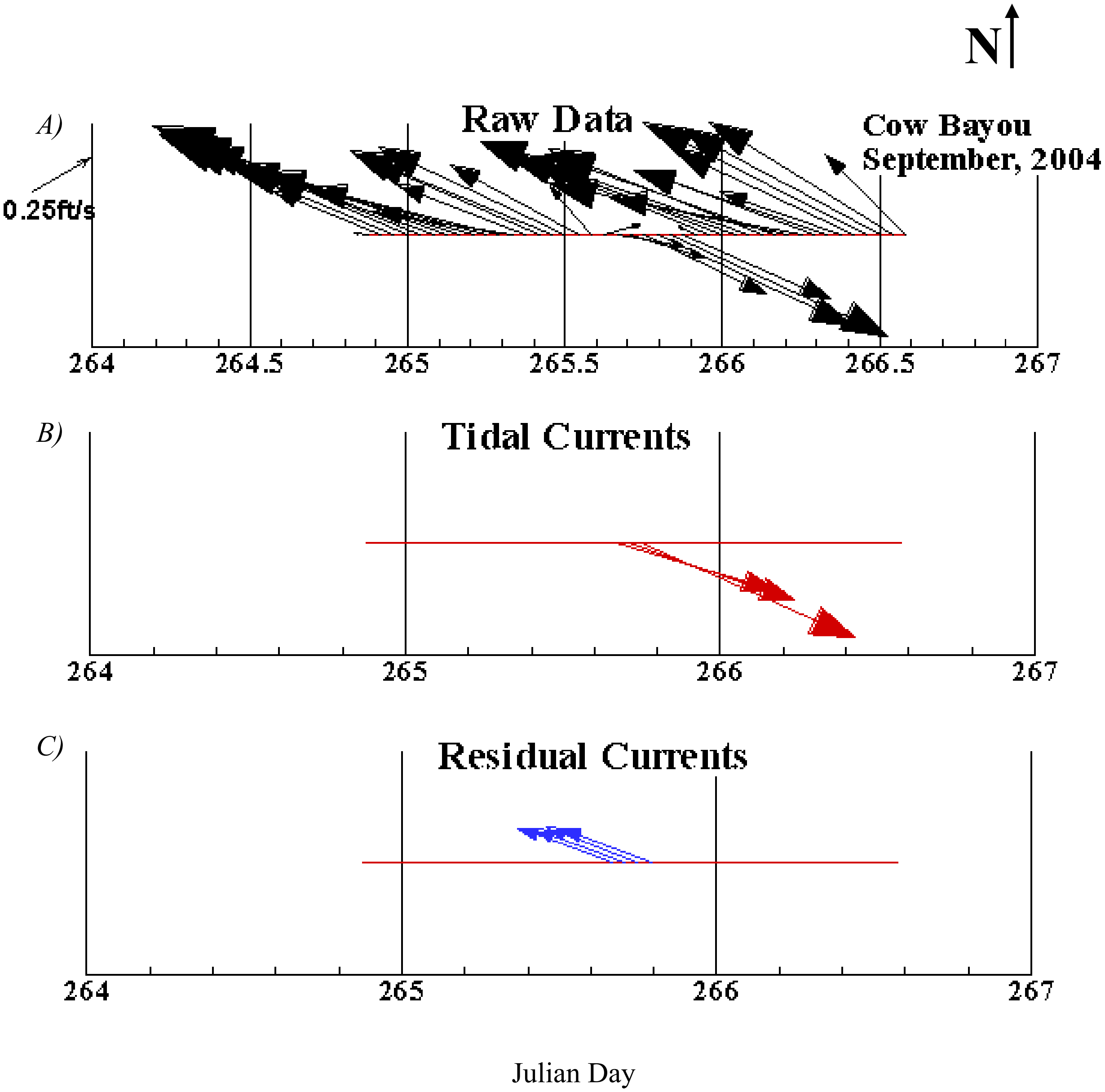


Figure 28.—Flow composition at Cow Bayou, 21-23 September 2004. (A) Raw flow data with (B) tidal and (C) residual currents extracted. x-axis is Julian day with day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

Lost River

Flow Characteristics

Mean discharge over time was substantially lower at the upstream and middle stations in Lost River in comparison to the downstream station (Table 15 and Table 16; Figure 23 and Figure 24). In June 2003, measured currents at Lost River were consistently downstream during the three day sampling period (Figure 29A). The velocity of residual (downstream) currents (Figure 29C), those associated solely with freshwater discharges, was influenced by the tidal cycle, but not enough to change the direction of flow from downstream to upstream (Figure 29A, B). More discussion is included below. In August 2003, however, directional currents were primarily upstream throughout the sampling period (Figure 30B). River velocity was measured only for a 24-hour period during September 2003 (Figure 30C), which makes data interpretation difficult. However, it appears that river discharge shifted from moving downstream to moving upstream, possibly in conjunction with tidal phases. In November 2003, Lost River showed classic oscillations in river velocity as tidal phases changed (Figure 30D). Although there was weak upstream movement of the current at flood tide, overall discharge was downstream.

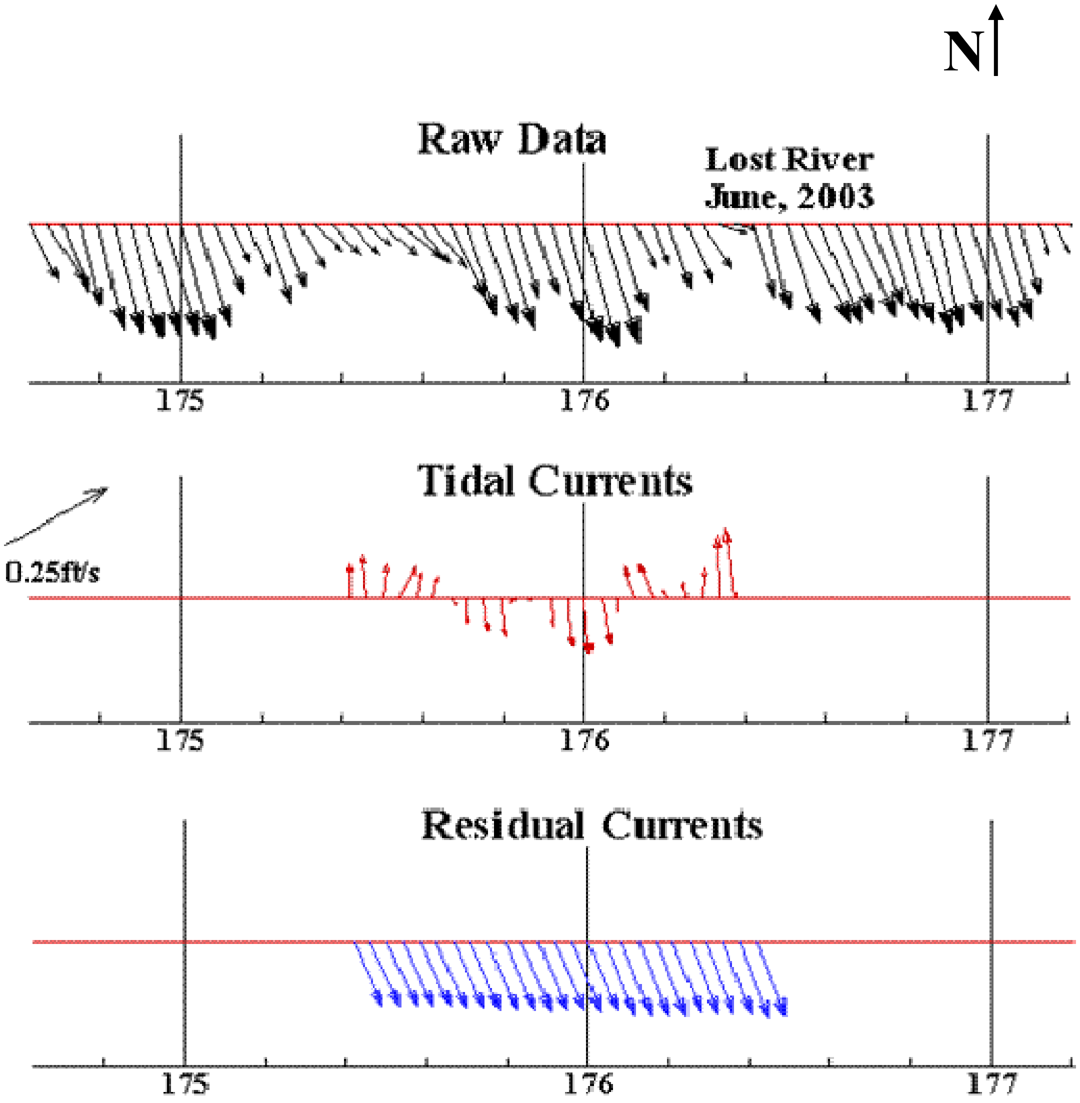


Figure 29.—Flow composition at Lost River, 24-26 June 2003. (A) Raw flow data with (B) tidal and (C) residual currents extracted. x-axis is Julian day with day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

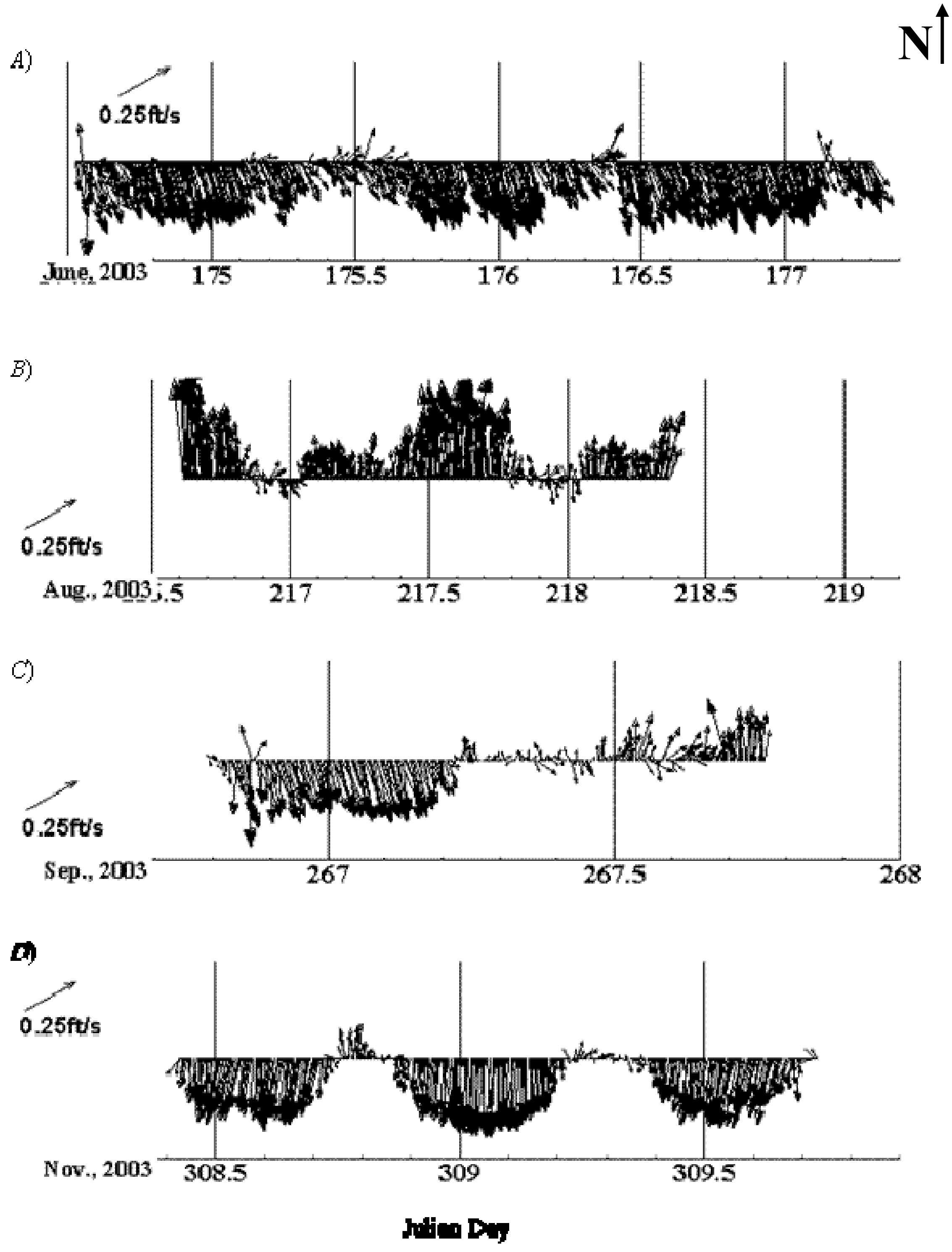


Figure 30.—Total current velocities measured at Lost River in 2003. (*A*) 23-26 June, (*B*) 5-6 August, (*C*) 23-24 September, and (*D*) 4-5 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

Data collected during March 2004 was analyzed using a filtering process to separate tidal flow from stream discharge. Tidal currents were similar in magnitude throughout the sampling period, but residual current velocities varied (Figure 31B). Overall, residual currents moved downstream, except for a short period in which tidal currents contributed to a directional shift in flow (Figure 31C). See the section "Tidal Influence on Stream Discharge in Lost River" for further discussion. In August 2004, current velocities had upstream and downstream movements, suggesting directional shifts in water movement with changing tidal cycles (Figure 32B). Measurements collected over a two-day period during September 2004 occurred during spring tide. Hence, current velocities were strong in both upstream and downstream directions (Figure 32C).

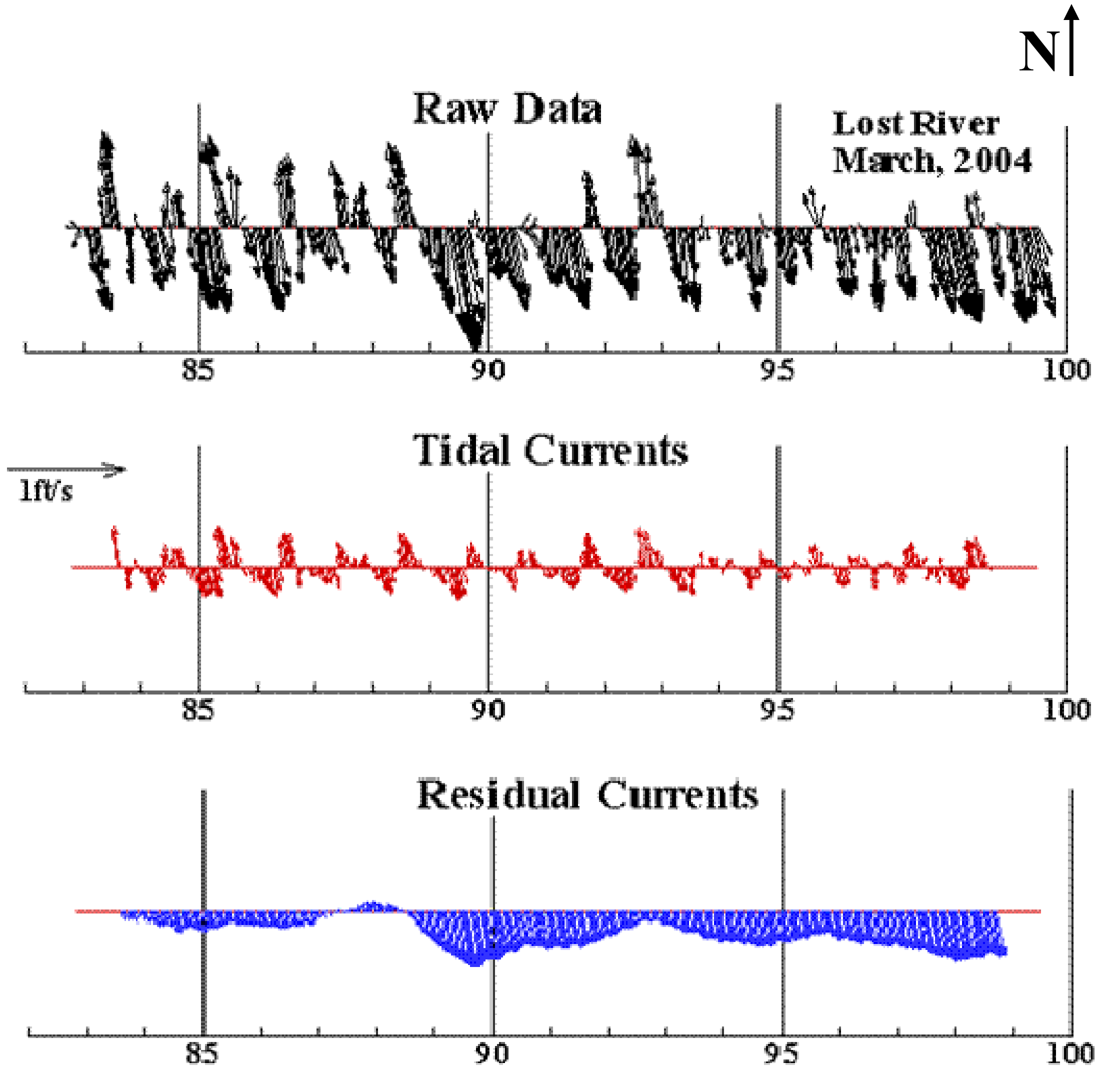


Figure 31.—Flow composition at Lost River, March 25 to April 10, 2004. (A) Raw flow data with (B) tidal and (C) residual currents extracted. x-axis is Julian day with five-day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

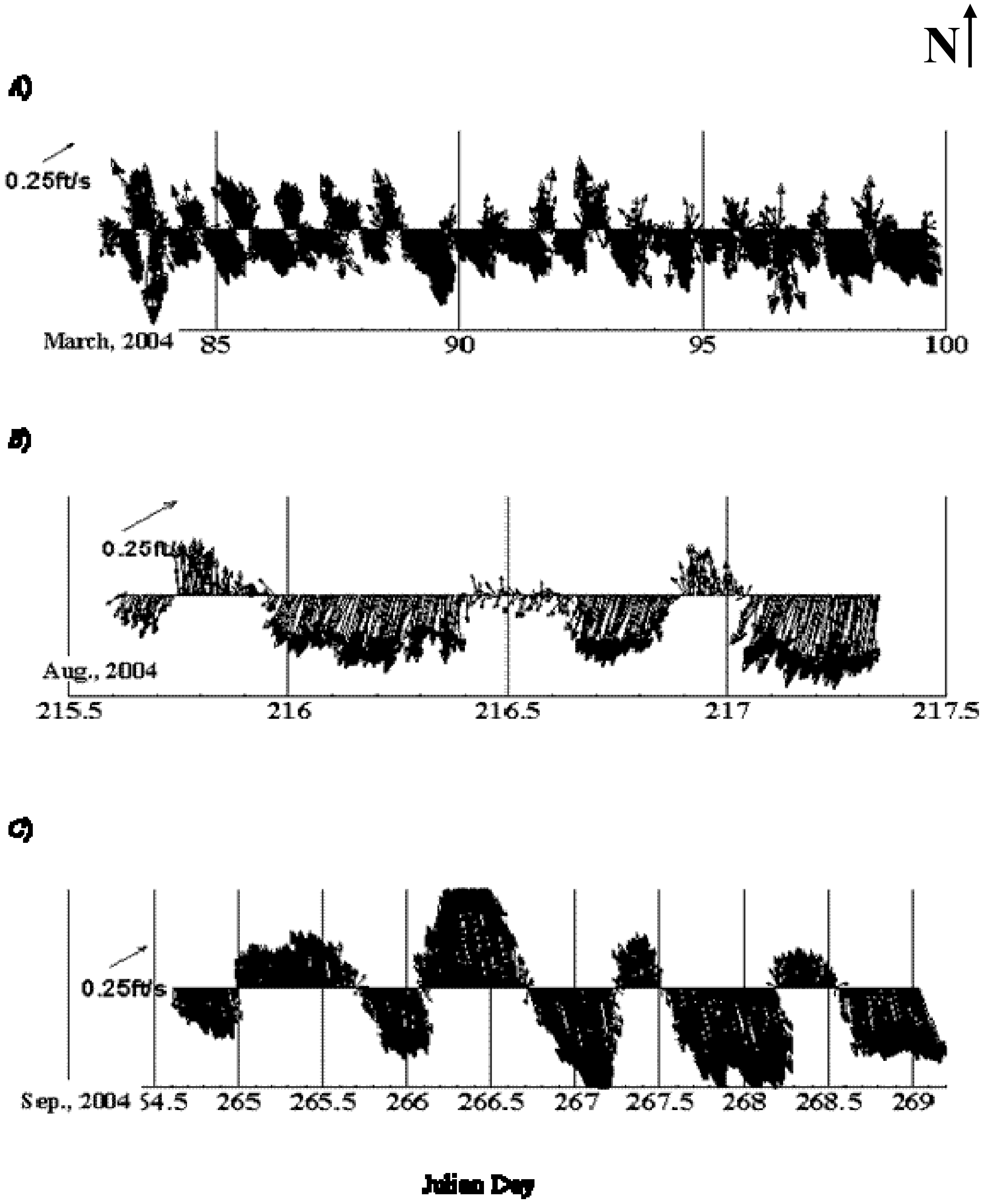


Figure 32.—Total current velocities measured at Lost River in 2004. (A) 25 March to 10 April, (B) 3-5 August, and (C) 22-24 September. x-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

Tidal Influence on Stream Discharge

In total, seven sampling events recorded stream flow data from Lost River. Of these, tidal filtering was applied to three data sets; June 2003, March 2004, and September 2004, encompassing a total of 19 tidal cycles. Currents in Lost River oscillate between downstream freshwater flows and upstream flows influenced by tidal cycles (Figure 29C, Figure 31C, Figure 33C). In June 2003, the upstream movement of water during flood tide was not enough to counter downstream flows, though it weakened the velocity of downstream discharge. Stream discharge fluctuated with the tidal cycles in all three sampling events, but the direction of residual currents did not correspond with changes in the tidal cycle. Exceptions to this occurred twice, once during March 2004 and once during September 2004. Additionally when river discharge is weak, wind or other forces may influence direction of river flow.

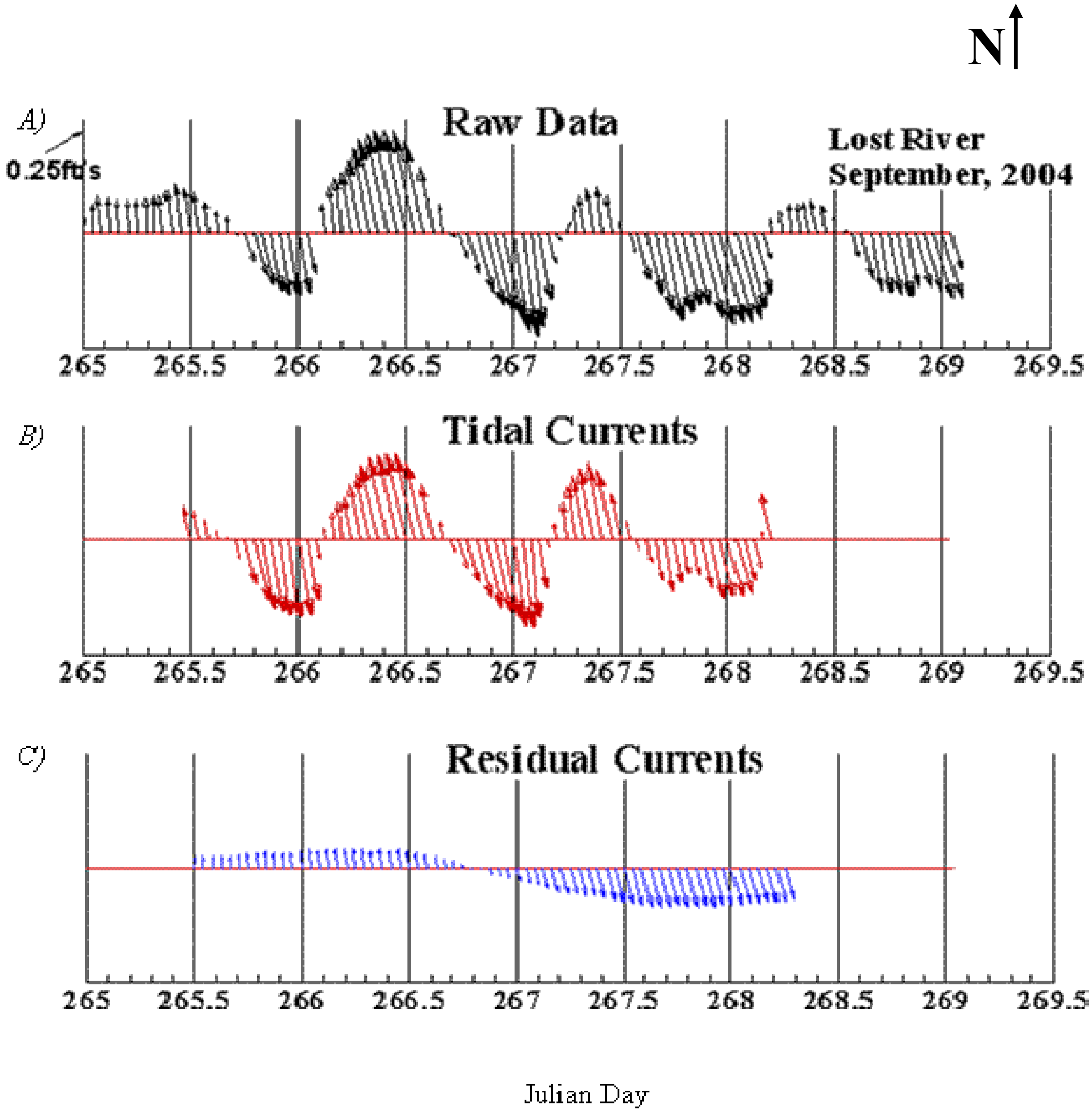


Figure 33.—Flow composition at Lost River, 22-24 September 2004. (*A*) Raw flow data with (*B*) tidal and (*C*) residual currents extracted. *x*-axis is Julian day with half-day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

Instream and Riparian Habitat

Average thalweg (maximum channel depth) measurements were quite different between the upper coast tidal streams (Table 17). Cow Bayou generally was much deeper than Lost River, with average thalweg measurements ranging from 4.6 to 5.0 m in the main channel reaches. However, this was not the case for the original stream channel site (CB 2A) in Cow Bayou (depth = 2.3 m), which was similar in depth to the reach measurements found for Lost River, which ranged between 2.7 and 1.8 m.

Systematic measurements of shoreline depths for each stream reach revealed that both streams showed similar patterns along their shoreline edges (Table 17). Depths along the sides of channels in both streams were greatest at the uppermost sampling reaches (CB 1 = 1.4 ± 0.9 m; LR 1 = 1.1 ± 0.4 m) and these channel-side depths progressively decreased to their respective lower sampling reaches nearest the bay (CB 3 = 0.5 ± 0.2 m; LR 3 = 0.5 ± 0.2 m). In-channel habitat for both streams was characterized either as pools or glides, and the number of side channels per 100 m generally decreased from the upper to lower sites in both streams. Similarly, the number of snags (which is a measure of fish cover complexity) along the bottom also decreased from the upper to lower reach of each stream.

Table 17.—Channel characteristics by stream reach for Cow Bayou and Lost River. Data are means (n=11). Standard deviations are presented in parentheses. Overall stream means and standard deviations are also included below each stream's reach statistics (n=33). Overall stream means for Cow Bayou do not include values for CB 2A.

Stream	Reach	Thalweg (m)	Shoreline Depth (m)	Wetted Width (m)		Bankfull Width (m)		Bankfull Height (m)	Incised Height (m)	Bank Angle (degrees)		Side Channels (No./100m)	Snags (No./ 100m)	Large Woody Debris (No./100m)
Cow Bayou	1	4.6 (1.1)	1.4 (0.9)	31.3	(7.2)	33.5	(8.6)	0.2 (0.1)	0.2 (0.1)	2.5	(0.0)	1.2	2.3	0.5
Cow Bayou	2	4.6 (0.5)	0.9 (1.0)	81.9	(20.6)	82.6	(21.1)	0.2 (0.1)	1.0 (1.2)	31.6	(35.6)	0.7	0.3	0.0
Cow Bayou	2A	2.3 (0.3)	0.5 (0.1)	54.1	(6.9)	55.0	(6.9)	0.2 (0.0)	0.2 (0.0)	3.9	(4.5)	0.2	0.3	3.6
Cow Bayou	3	5.0 (0.4)	0.5 (0.2)	109.0	(15.2)	110.7	(15.4)	0.2 (0.1)	0.3 (0.3)	11.6	(20.2)	0.3	0.2	0.5
MEAN		4.7 (0.8)	0.9 (0.8)	74.1	(35.9)	75.6	(35.9)	0.2 (0.1)	0.5 (0.8)	15.2	(26.0)	0.7	0.9	0.3
Lost River	1	2.3 (0.3)	1.1 (0.4)	33.7	(11.8)	35.2	(12.2)	0.4 (0.1)	1.1 (0.6)	32.0	(20.1)	0.7	0.7	0.0
Lost River	2	1.8 (0.4)	0.6 (0.3)	64.6	(21.6)	65.7	(21.7)	0.3 (0.2)	0.3 (0.3)	8.0	(7.6)	0.9	0.2	0.0
Lost River	3	2.7 (1.0)	0.5 (0.2)	226.7	(151.8)	227.5	(151.8)	0.2 (0.1)	0.3 (0.1)	5.2	(6.1)	0.3	0.0	0.0
MEAN		2.3 (0.7)	0.7 (0.4)	108.4	(121.6)	109.5	(121.4)	0.3 (0.1)	0.6 (0.5)	15.1	(17.5)	0.6	0.3	0.0

Dominant bottom substrate types measured during thalweg sampling were generally similar for the two streams (Table 18). The vast majority of substrates measured were generally in the “fines” category which include silt and/or clay materials (<0.6 mm, not gritty). For Cow Bayou, between 96 and 100% of all bottom substrate measurements for its four sampling reaches were in the fines category. Lost River had similar substrates with fines accounting for between 67% and 100% of all measurements of bottom substrate at its three sampling reaches. Sand (0.6 to 2 mm, gritty) was only measured in Lost River, but gravel sized (2 to 64 mm) materials were occasionally found along both stream bottoms.

The dominant shoreline and shallow nearshore substrate type was generally similar to the one found in the depths of these streams (Table 18). Most sampling sites of both streams were dominated by fine materials along their banks and shallow edges with some sand or woody material as secondary components.

Table 18.—Dominant channel and shoreline substrate composition by stream reach for Cow Bayou and Lost River. Data are means (n=11). Overall stream means are also included below each stream's reach statistics (n=33). Overall stream means for Cow Bayou do not include values for Cow Bayou reach 2A. The gravel category is presented only for channel bottom statistics, and the wood category is only presented for the shallow nearshore and shoreline statistics.

Stream	Reach	THALWEG			SHALLOW NEARSHORE			SHORELINE		
		Gravel (%)	Sand (%)	Fines (%)	Sand (%)	Fines(%)	Wood (%)	Sand (%)	Fines (%)	Wood (%)
Cow Bayou	1	0	0	100	18	64	18	18	55	27
Cow Bayou	2	4	0	96	9	91	0	9	91	0
Cow Bayou	2A	0	0	100	0	64	36	9	91	0
Cow Bayou	3	1	0	99	18	82	0	18	82	0
MEAN		2	0	98	15	79	6	15	76	9
Lost River	1	0	0	100	18	82	0	9	91	0
Lost River	2	0	33	67	18	82	0	18	82	0
Lost River	3	14	0	86	0	100	0	0	100	0
MEAN		5	11	84	12	88	0	9	91	0

Very little large woody debris was found in either stream, usually far less than 1 piece per 100 m (Table 17). However, CB 2A was an exception to this pattern, having on average 3.6 pieces per 100 m.

Wetted and bankfull channel width measurements showed similar patterns for both streams with both growing wider from the upstream to downstream reaches (Table 17). Cow Bayou wetted width ranged from 31.3 ± 7.2 m at CB 1 to 109.0 ± 15.2 m at CB 3. Likewise, wetted widths for Lost River ranged from 33.7 ± 11.8 m at LR 1 to 226.7 ± 151.8 m at LR 3. Bankfull widths were nearly the same as wetted widths in these two streams. Bankfull height by reach for both streams ranged from 0.2 to 0.4 m above the water line. Channel incised height was generally the same as measurements of bankfull height in Cow Bayou except at CB 2 where incised height (1.0 m) was greater than that for bankfull height (0.2 m). Bankfull and incised heights were also generally similar for Lost River except that incised height at LR 1 (1.1 m) was higher than its respective bankfull height (0.4 m). These last two observations were also reflected in the measurements of bank angles along the stream reaches. Overall for both streams, bank angles at the majority of sites within each reach were characterized as either flat (<5º) or gradual (between 5 and 30º). However, some sampling sites for CB 2 and LR 1 had bank angles characterized as either steep (between 30 and 75º) or vertical (>75º).

Canopy densities of the riparian habitat along sides of these streams, as measured using a densiometer, showed similar patterns for both streams (Table 19). Canopy density decreased from upper to lower stream reaches. Canopy densities at CB 1 were 99% and declined to 34% at CB 3. Likewise, canopy densities in Lost River declined from LR 1 (70%) to LR 3 (19%).

Table 19.—Canopy density and percent vegetative cover by stream reach for riparian habitats along Cow Bayou and Lost River. Data are means with standard deviations in parentheses (n=11). Overall stream means and standard deviations are also included below each stream's reach statistics (n=33). Overall stream means for Cow Bayou do not include values for Cow Bayou reach 2A.

Stream	Reach	Canopy Density (%)	CANOPY		UNDERSTORY		GROUND COVER			TOTAL COVER
			Big Trees	Small Trees	Woody Shrubs	Herbs, Grass, Forbs	Woody Shrubs	Herbs, Grass, Forbs	Bare/ Duff	
Cow Bayou	1	99 (2)	25 (7)	43 (17)	20 (5)	19 (8)	5 (0)	21 (5)	29 (8)	133
Cow Bayou	2	40 (39)	14 (13)	15 (11)	8 (6)	28 (21)	3 (2)	39 (13)	11 (9)	107
Cow Bayou	2A	35 (42)	11 (8)	14 (15)	15 (8)	39 (15)	3 (2)	26 (15)	8 (7)	107
Cow Bayou	3	34 (36)	5 (13)	10 (10)	2 (2)	45 (21)	2 (2)	22 (13)	9 (8)	87
MEAN		58 (42)	15 (14)	22 (19)	10 (9)	31 (20)	3 (2)	28 (13)	16 (12)	109
Lost River	1	70 (33)	19 (18)	26 (10)	16 (11)	19 (9)	6 (3)	59 (8)	6 (3)	145
Lost River	2	37 (44)	5 (6)	19 (23)	6 (3)	37 (18)	3 (2)	42 (15)	4 (1)	112
Lost River	3	19 (33)	0 (1)	8 (11)	3 (2)	57 (19)	2 (2)	31 (23)	5 (4)	101
MEAN		42 (42)	8 (13)	18 (17)	8 (9)	38 (22)	3 (3)	44 (20)	5 (3)	119

Visual estimates of riparian vegetative cover reflected similar results. Overall plant cover decreased from upper to lower reaches of both streams (Table 19). For Cow Bayou, total vegetative cover at CB 1 was 133% (coverage from canopy, understory and ground cover layers are summed together to a maximum of 300%), but declined to 87% at CB 3. In similar fashion, Lost River had total vegetative cover of 145% at LR 1 and this declined to 101% at LR 3. Large and small trees were most prevalent in the uppermost reaches of both streams and decreased in percent cover in downstream sites. This same pattern was also generally seen for woody understory and ground cover along these two streams. Conversely, herbaceous cover in the understory increased in downstream reaches, but herbaceous cover at ground level either decreased (Lost River) or followed no clear pattern (Cow Bayou) from upstream to downstream reaches. Overall though, upstream sites were more forested while downstream sites were more open and dominated by herbaceous species such as grasses.

Both streams showed similar patterns in the relative amount of fish cover found in the shallow areas of their upper, mid, and lower reaches, but were quite different in terms of the actual values for these measures (Table 20). Total fish cover in Cow Bayou was highest at CB 1 with a total cover of 98%, a decline to 50% at CB 2 (54% for CB 2A), and a slight increase at CB 3 to 61%. Lost River had a total fish cover of 41% at LR 1, 18% for LR 2, and 22% for LR 3. Almost all of this fish cover was composed of natural materials for both streams. Interestingly, they both showed a similar pattern in terms of the change in the types of natural fish cover. Fish cover in both streams was composed mostly of woody materials in their upper reaches (small woody debris, live trees in stream, and overhanging woody material less than 1 m from water surface) and transitioned to more herbaceous materials at their lower reaches (filamentous algae and/or emergent macrophytes).

Table 20.—Percent fish cover by stream reach for Cow Bayou and Lost River. Data are means with standard deviations in parentheses (n=11). Overall stream means and standard deviations are also included below each stream's reach statistics (n=33). Overall stream means for Cow Bayou do not include values for Cow Bayou reach 2A.

Stream	Reach	Filamentous Algae	Macrophytes	Large Woody Debris	Small Woody Debris	Live Trees in Stream	Overhanging Vegetation	Undercut Banks	Boulders/ Ledges	Artificial Structures	TOTAL COVER
Cow Bayou	1	2 (3)	9 (8)	0 (2)	16 (10)	57 (20)	12 (10)	1 (2)	0 (0)	0 (0)	98
Cow Bayou	2	2 (3)	16 (22)	0 (0)	15 (26)	4 (7)	7 (9)	3 (3)	0 (0)	3 (3)	50
Cow Bayou	2A	3 (3)	24 (19)	3 (3)	14 (10)	4 (2)	4 (2)	2 (3)	0 (0)	0 (0)	54
Cow Bayou	3	30 (27)	23 (20)	0 (2)	3 (3)	0 (0)	3 (8)	1 (2)	0 (0)	1 (2)	61
MEAN		11 (20)	16 (18)	0 (1)	11 (17)	20 (29)	8 (9)	2 (2)	0 (0)	1 (2)	70
Lost River	1	0 (0)	4 (2)	0 (0)	7 (6)	7 (9)	19 (16)	4 (2)	0 (0)	0 (0)	41
Lost River	2	0 (0)	7 (6)	0 (0)	5 (0)	0 (2)	4 (7)	1 (2)	0 (0)	0 (0)	18
Lost River	3	0 (0)	10 (10)	0 (0)	4 (2)	1 (2)	3 (3)	4 (2)	0 (0)	0 (2)	22
MEAN		0 (0)	7 (7)	0 (0)	5 (4)	3 (6)	9 (12)	3 (2)	0 (0)	0 (1)	27

The degree of human influence observed in Cow Bayou was greater than in Lost River (Table 21). Walls, dikes, revetments, rip-rap or dams were observed at 27% of sampling sites along the three reaches of Cow Bayou as compared to only 3 % of sites on Lost River (all values presented for Cow Bayou exclude data from CB 2A for comparability purposes since Lost River only had 3 stream reaches). Similarly, buildings were observed from 39% of sites along Cow Bayou versus 3% of Lost River sites. Roads and/or railroads were observed from 33% of Cow Bayou sampling sites and 11% of Lost River sites. Parks or lawns were observed from 29% of Cow Bayou sites, but none were observed along Lost River. Power lines were also seen more often along Cow Bayou (47% of sites) than Lost River (6%). Overall, signs of human influence for both streams appear to be chiefly associated with direct human habitation. Using a weighted averaging method outlined in Kaufmann et al. (1999) which accounts not only for the presence of these human disturbances but also their distance from the sampling area, Cow Bayou appeared to be much more impacted by human influences. This index showed that Cow Bayou's overall average degree of human influence was 1.02 (excluding CB 2A values) and Lost River's was 0.11. This index should be viewed merely as a comparative value with no broader context.

Table 21.—Percent frequency of occurrence of human influences by stream reach for Cow Bayou and Lost River. Data are means (n=11). Overall stream means are also included below each stream's reach statistics (n=33). Overall stream means for Cow Bayou do not include values for Cow Bayou reach 2A.

Stream	Reach	Wall/Dike/ Revetment/ Riprap/Dam	Buildings	Pavement/ Cleared Lot	Road/ Railroad	Pipes	Landfill/ Trash	Park/ Lawn	Row Crops	Pasture/ Range/ Hay	Logging	Mining	Power Lines	Weighted Average – All Human Influence*
Cow Bayou	1	0	0	0	0	0	0	0	0	5	0	0	0	0.02
Cow Bayou	2	45	68	14	68	0	9	59	0	0	0	5	68	1.63
Cow Bayou	2A	5	9	0	0	0	0	9	0	0	0	9	14	0.23
Cow Bayou	3	36	50	27	32	9	45	27	0	5	0	5	73	1.40
MEAN		27	39	14	33	3	18	29	0	3	0	3	47	1.02
Lost River	1	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Lost River	2	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Lost River	3	9	9	0	32	14	0	0	0	0	0	0	18	0.33
MEAN		3	3	0	11	5	0	0	0	0	0	0	6	0.11

* For a detailed description of the procedure used for weighting human influences see Kaufmann et al. 1999.

Land cover

Watershed delineation near the coast presents challenges due to the low gradient; hydrology often consists of sheet flow and there are numerous anthropomorphic features that affect flow. The eight-digit HUCs were used as an outer boundary and watershed delineation was done by hand. Results of the land cover analysis are presented in Table 22 and land cover maps are in Appendix C.

The land cover category "Pine Forest" represents mainly cultivated loblolly pine. "Grassland" is about 90% cultivated coastal Bermuda grass. "Upland Cold-Deciduous Shrubland" includes elm, willow and *Baccharis*. "Evergreen Shrubland" is typically eastern red cedar and huisache in the upper coast. "Exposed Land" is usually agricultural (<10% of total). "Salt Prairie" is *Spartina spartinae*-dominated, and usually adjacent to riparian or estuarine zone. "Grass Farm" is typically St. Augustine grass and a potential source of nutrients in the watershed. "Swamp" represents mostly bald cypress with some water tupelo. "Marsh" includes all types from tidal to fresh, mostly adjacent to streams or the estuarine zone. "Bottomland Forest" is dominated by oaks, mainly overcup oaks, with some *Nyssa* (black gum or water tupelo) and *Liquidambar* (sweetgum).

Comparing Cow Bayou to Lost River, there is less grass land cover in the latter. Lost River has more bottomland and upland forest than Cow Bayou. There is more pine forest in the upper watershed of Cow Bayou.

Table 22.—Area and percent cover of land cover classes, and total area, for the watersheds of Cow Bayou and Lost River. Percentages in parentheses represent a negative number (values are greater at Cow Bayou than at Lost River.)

	Lost River Basin		**Cow Bayou Basin**		**% Cover**
Class names	**Hectares**	**% Cover**	**Hectares**	**% Cover**	**Lost-Cow**
Pine Forest	915.3	6.5	7,991.6	25.4	(18.9)
Grassland	2,227.4	15.8	9,407.5	29.9	(14.1)
Upland Cold-Deciduous Forest	1,953.1	13.9	6,178.3	19.7	(5.8)
Evergreen Shrubland	579.0	4.1	1,596.8	5.1	(1.0)
Exposed Land	69.9	0.5	100.0	0.3	0.2
Salt Prairie	39.4	0.3	0.0	0.0	0.3
Urban / Roads	754.2	5.4	1,249.4	4.0	1.4
Grass Farm	308.6	2.2	0.0	0.0	2.2
Swamp	500.8	3.6	350.3	1.1	2.5
Marsh	824.7	5.9	1,051.0	3.3	2.5
Agriculture	774.3	5.5	785.6	2.5	3.0
Open Water	1,112.0	7.9	852.8	2.7	5.2
Bottomland Forest	4,018.4	28.6	1,859.2	5.9	22.6
Total	14,077.0		31,422.5		

There was a concern that some land cover categories had a disproportionate influence on the overall interpretation when the entire watershed was considered. For example, Lost River had 754.2 hectares categorized as “Urban/Roads” when there are very few residences or roads near the stream. An analysis of nonpoint source runoff might wrongly conclude that runoff from cities and roads could be a significant concern for Lost River. To focus more on potential nonpoint sources that are closer to the streams and more likely to influence water quality, a second land cover analysis was done on a 200-meter buffer zone surrounding each stream. Land cover for just that area is summarized in Table 23.

Table 23.—Area and percent cover of land cover classes, and total area, for a 200-meter buffer zone surrounding Cow Bayou and Lost River.

	Lost River Buffer		Cow Bayou Buffer		% Cover
Class Name	**Hectares**	**% Cover**	**Hectares**	**% Cover**	**Lost-Cow**
Upland Cold Deciduous Forest	141.2	6.2	1,231.2	24.7	(18.5)
Grassland	138.3	6.1	1,151.5	23.1	(17.0)
Pine Forest	182.7	8.1	886.3	17.8	(9.7)
Evergreen Shrubland	78.6	3.5	295.8	5.9	(2.5)
Urban / Roads	32.7	1.4	129.3	2.6	(1.2)
Exposed Land	19.2	0.9	53.3	1.1	(0.2)
Agriculture	11.0	0.5	12.8	0.3	0.2
Salt Prairie	7.7	0.3	0.0	0.0	0.3
Grass Farm	26.0	1.2	0.0	0.0	1.2
Swamp	95.9	4.2	82.6	1.7	2.6
Marsh	225.7	9.9	286.4	5.8	4.2
Open Water	378.9	16.7	316.8	6.4	10.3
Bottomland Forest	932.3	41.1	535.9	10.8	30.3
Total	2,270.2		4,981.9		

Water and Sediment Quality

24-hour field measurements

Results of 24-hour datasonde deployments for Cow Bayou are summarized in Table 24.

Table 24.—Summary of 24-hour field measurements with datasondes in Cow Bayou.

Station	Date Deployed	Depth m	Avg Temp ˚C	Min Temp ˚C	Max Temp ˚C	Avg DO mg/l	Min DO mg/l	Max DO mg/l	Avg Spec Cond us/cm	Min Spec Cond us/cm	Max Spec Cond us/cm	Min pH	Max pH
CB 1	8-Apr-2003	0.3	19.73	18.80	20.90	1.70	1.50	2.00	252	241	263	6.3	6.3
CB 1	5-May-2003	1.0	25.75	25.20	26.40	1.58	1.20	2.20	407	391	441		
CB 1	24-Jun-2003	1.0	29.62	29.20	30.16	3.88	3.36	4.93	2,107	1,410	2,897	6.8	6.9
CB 1	5-Aug-2003	0.9	30.45	30.23	31.19	3.72	3.09	5.29	1,352	1,177	1,539	6.9	7.07
CB 1	22-Sep-2003	0.8	23.46	23.16	23.89	4.45	4.20	4.85	47	45	50	5.96	6.1
CB 1	5-Nov-2003	0.3	21.18	20.97	21.58	0.86	0.63	1.16	326	127	871	6.01	6.14
CB 1	23-Mar-2004	0.8	20.21	19.63	20.83	2.50	2.25	2.91	90	87	91	5.98	6.11
CB 1	11-May-2004	0.9	22.00	21.14	23.39	5.26	3.08	6.50	66	52	116	5.94	6.62
CB 1	21-Jun-2004	0.8	27.46	26.95	28.38	2.64	2.12	3.11	71	67	74	5.83	5.93
CB 1	2-Aug-2004	0.8	29.55	28.95	30.89	2.74	2.48	3.94	248	235	275	6.37	6.47
CB 1	20-Sep-2004	1.0	28.22	27.56	28.68	3.81	3.31	4.82	4,841	2,095	6,516	6.34	6.56
CB 1	8-Nov-2004	0.8	16.00	15.45	16.25	6.78	6.52	7.00	58	56	60	5.53	5.83
CB 2	7-Apr-2003	0.5	20.81	19.64	22.39	5.89	5.51	6.22	261	254	274	6.65	6.8
CB 2	6-May-2003	1.0	26.71	26.38	28.12	6.06	5.41	7.28	3,061	2,142	3,862	6.78	6.96
CB 2	24-Jun-2003	1.0	32.01	31.54	32.98	5.55	4.71	7.42	5,005	4,634	5,332	6.91	7.28
CB 2	5-Aug-2003	0.9	31.93	31.36	33.16	6.05	5.07	8.30	3,289	3,169	3,386	6.97	7.75
CB 2	22-Sep-2003	0.8	24.37	23.95	24.85	3.57	3.26	3.84	98	83	119	6.08	6.19
CB 2	5-Nov-2003	0.3	23.95	23.28	24.68	6.25	5.58	7.25	5,556	4,171	6,678	6.64	6.89
CB 2	23-Mar-2004	1.0	20.09	19.79	20.48	5.07	4.50	6.09	193	166	211	6.48	6.76
CB 2	11-May-2004	0.9	23.73	22.24	25.29							6.27	6.5
CB 2	21-Jun-2004	0.8	29.43	28.85	30.22	2.66	2.29	3.17	185	151	232	5.93	6.57
CB 2	2-Aug-2004	0.8	32.25	31.22	34.19	7.13	6.57	8.41	1,560	1,073	1,878	6.52	6.96
CB 2	20-Sep-2004	0.8	29.01	28.47	29.62	6.67	5.41	8.29	9,762	8,755	10,315	6.78	7.15

Station	Date Deployed	Depth	Avg Temp	Min Temp	Max Temp	Avg DO	Min DO	Max DO	Avg Spec Cond	Min Spec Cond	Max Spec Cond	Min pH	Max pH
		m	˚C	˚C	˚C	mg/l	mg/l	mg/l	us/cm	us/cm	us/cm		
CB 2	8-Nov-2004	0.8	18.46	17.67	19.63	9.38	9.26	9.54	196	173	253	6.11	6.46
CB 2A	6-May-2003	1.0	26.39	25.88	27.07	4.19	3.17	5.37	1,830	1,683	2,049	6.5	6.72
CB 2A	5-Aug-2003	0.9	31.92	31.28	33.76	5.84	4.22	8.61	3,328	3,307	3,354	6.82	7.64
CB 2A	22-Sep-2003	0.8	24.48	23.71	25.49	2.89	2.15	3.69	141	105	194	6.05	6.23
CB 2A	5-Nov-2003	0.3	22.96	22.33	23.97	8.26	7.58	9.08	3,630	3,309	3,991	6.36	6.57
CB 2A	23-Mar-2004	0.9	20.77	20.02	22.02	4.61	3.76	5.53	172	161	179	6.12	6.42
CB 2A	11-May-2004	0.9	23.23	21.79	25.42				133	104	159	6.31	6.51
CB 2A	21-Jun-2004	0.8	29.68	28.95	30.58	3.07	1.67	4.14	165	160	171	6.35	6.45
CB 2A	2-Aug-2004	0.7	31.84	30.93	33.05				695	660	732	6.33	6.55
CB 2A	20-Sep-2004	0.8	28.80	28.47	29.52	6.03	5.13	7.84	8,383	7,362	9,353	6.45	6.99
CB 2A	8-Nov-2004	1.0	17.52	17.32	17.89	4.10	3.38	4.61	278	256	373	5.15	5.64
CB 3	7-Apr-2003	0.5	19.88	18.65	21.17	6.62	6.03	7.90	326	244	415	6.59	6.87
CB 3	7-May-2003	1.0	26.04	25.69	27.08	6.11	5.10	7.26	5,852	4,941	7,166	6.75	7.19
CB 3	24-Jun-2003	1.0	30.45	29.57	31.46	6.21	5.54	7.30	2,697	1,708	3,438	6.94	7.26
CB 3	5-Aug-2003	0.9	31.55	30.69	32.84	6.58	5.79	7.87	3,160	1,987	4,035	7.09	7.88
CB 3	22-Sep-2003	0.8	25.20	24.68	25.85	3.58	2.96	5.21	628	224	1,907	6.25	6.75
CB 3	5-Nov-2003	0.3	23.88	23.10	24.73	6.80	6.35	7.56	10,852	9,103	13,052	6.94	7.28
CB 3	23-Mar-2004	0.8	18.58	17.65	19.28	8.02	7.29	8.51	514	240	1,024	6.76	6.96
CB 3	11-May-2004	0.9	23.47	23.10	24.14				155	139	183	6.54	6.89
CB 3	21-Jun-2004	0.8	29.43	28.40	30.21	5.28	3.74	6.61	278	181	372	6.44	6.94
CB 3	2-Aug-2004	0.7	31.35	30.52	32.60	5.46	3.79	6.53	3,746	3,140	4,392	6.43	7.03
CB 3	20-Sep-2004	0.8	28.82	28.03	29.34				12,286	7,982	16,208	6.85	7.53
CB 3	8-Nov-2004	0.8	19.38	18.55	21.02	6.02	4.90	7.18	749	496	1,158	6.4	6.76

In Cow Bayou, dissolved oxygen tended to be lowest at CB 1 and highest at CB 3, with intermediate values at CB 2 and CB 2A (Figure 34). Mean dissolved oxygen ranged from 0.9 to 6.8 mg/l at CB 1, 2.7 to 9.4 mg/l at CB 2, 2.9 to 8.3 mg/l at CB 2A, and 3.6 to 8.0 mg/l at CB 3. The lowest dissolved oxygen measurements recorded at each station were 0.6 at CB 1, 2.3 at CB 2, 1.7 at CB 2A, and 3.0 mg/l at CB 3.

As previously mentioned, the dissolved oxygen criterion for Cow Bayou is mean of 4.0 mg/l and minimum of 3.0 mg/l. Out of 41 means, 14 (34%) did not meet the criterion of 4.0 mg/l.

Direct comparison with the DO standards was approximated by examining only the data meeting the requirements for assessing surface water as spelled out in the 2004 agency guidance (TCEQ 2003b). Thus data collected during November 2003 and 2004 were excluded from the analysis since this was after the end of the index period. Also data from the first sampling trip of each year (April 2003 and March 2004) were arbitrarily excluded so the data set would attain the correct proportion of measurements from the critical period. The 24-hour mean and 24-hour minimum DO values were evaluated for each station separately and for each stream as a whole (Table 25). According to the standards, Lost River is fully supporting the aquatic life use when the data from all three stations are combined. When each station is considered separately, there are not enough measurements to establish use support. However there was only one exceedance of the minimum DO at LR 2 out of eight sets of 24-hour data, which might put the reach into a Tier 1 concern category. Considering that none of the mean DO measurements were below the criterion, it does not seem likely that there is a real concern for DO in Lost River. When considering data from all four stations, Cow Bayou is not supporting the aquatic life use (11 exceedances out of 26 measurements for mean DO). When each Cow Bayou station is considered individually, all four stations would be classified as Tier 1 concerns because more than 10% of the time the 24-hour average or minimum concentrations are less than the criteria.

Table 25.—Number of exceedances of the DO mean and the DO minimum for 24-hour datasonde data collected in Cow Bayou and Lost River. Only data collected during the index period were evaluated to allow direct comparison with the standards.

Stream/Station	Number of Exceedances of DO Mean	Number of Exceedances of DO minimum	Number of Observations
CB 1	6	3	8
CB 2	2	1	7
CB 2A	2	2	5
CB 3	1	1	6
All Cow Bayou	11	7	26
LR 1	0	0	8
LR 2	0	1	8
LR 3	0	0	8
All Lost River	0	1	24

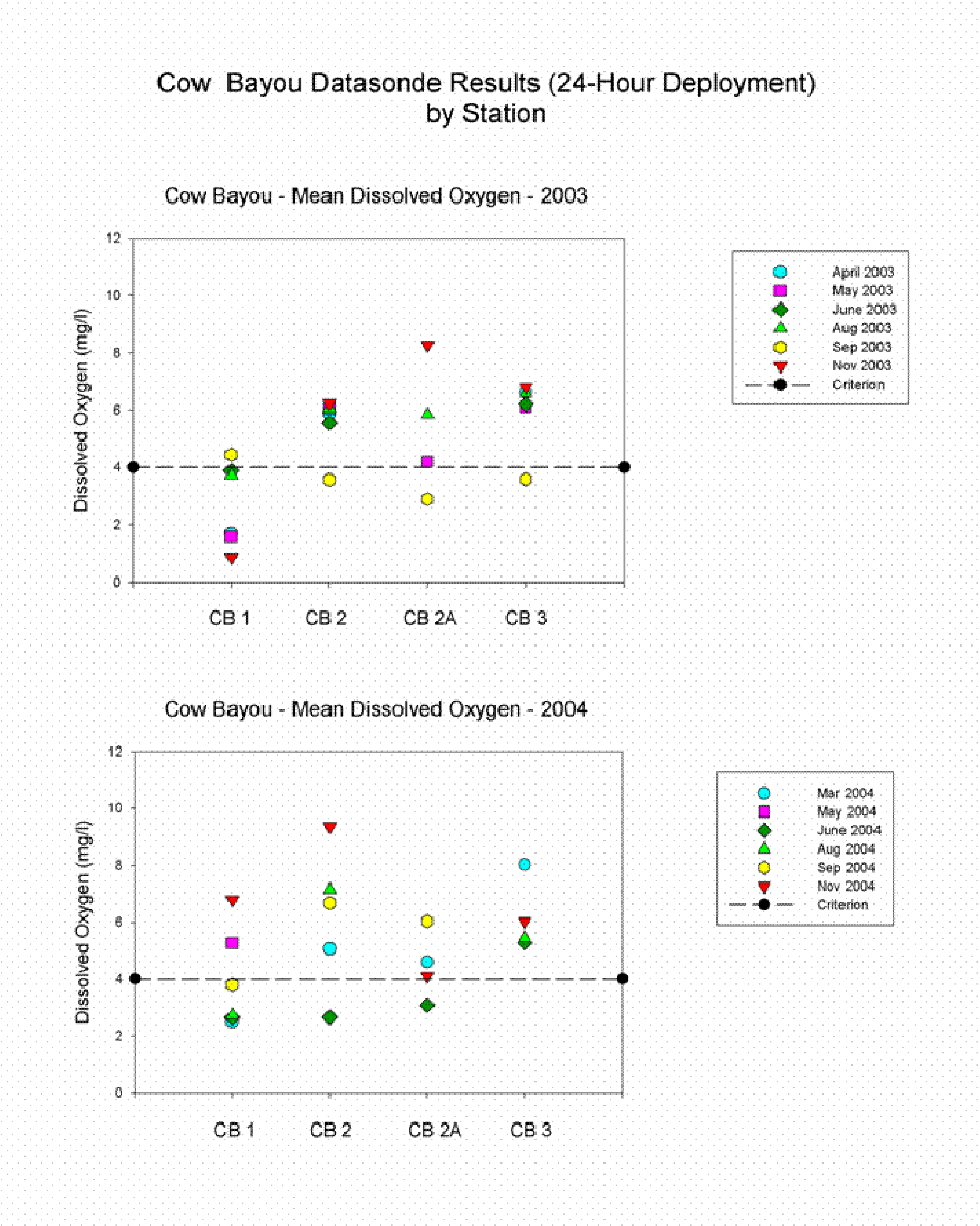


Figure 34.—Mean dissolved oxygen by station measured in Cow Bayou (24-hour datasonde deployment). Sampling locations are described in the text. Figure reprinted from Radloff (2005).

Specific conductance tended to be lowest at CB 1 and highest at CB 3 with intermediate values at CB 2 and CB 2A. Mean specific conductance ranged from 47 to 4,840 umhos/cm at CB 1, 98 to 9,760 umhos/cm at CB 2, 133 to 8,380 umhos/cm at CB 2A, and 155 to 12,300 umhos/cm at CB 3. Mean specific conductance was variable, generally peaking in mid to late summer at all four stations. A peak also occurred in November 2003 that was more distinct at stations CB 2, CB 2A and CB 3 than at CB 1.

Water temperature followed a predictable seasonal pattern in both 2003 and 2004 (Figure 35). The highest mean water temperatures were recorded in the months of August, closely followed by June and September. The lowest mean water temperatures were recorded in April 2003, March 2004, and November 2004. Mean water temperature ranged from 16.0 to 30.4 degrees C at CB 1, 18.5 to 32.2 degrees C at CB 2, 17.5 and 31.9 degrees C at CB 2A, and 18.6 and 31.6 degrees C at CB 3.

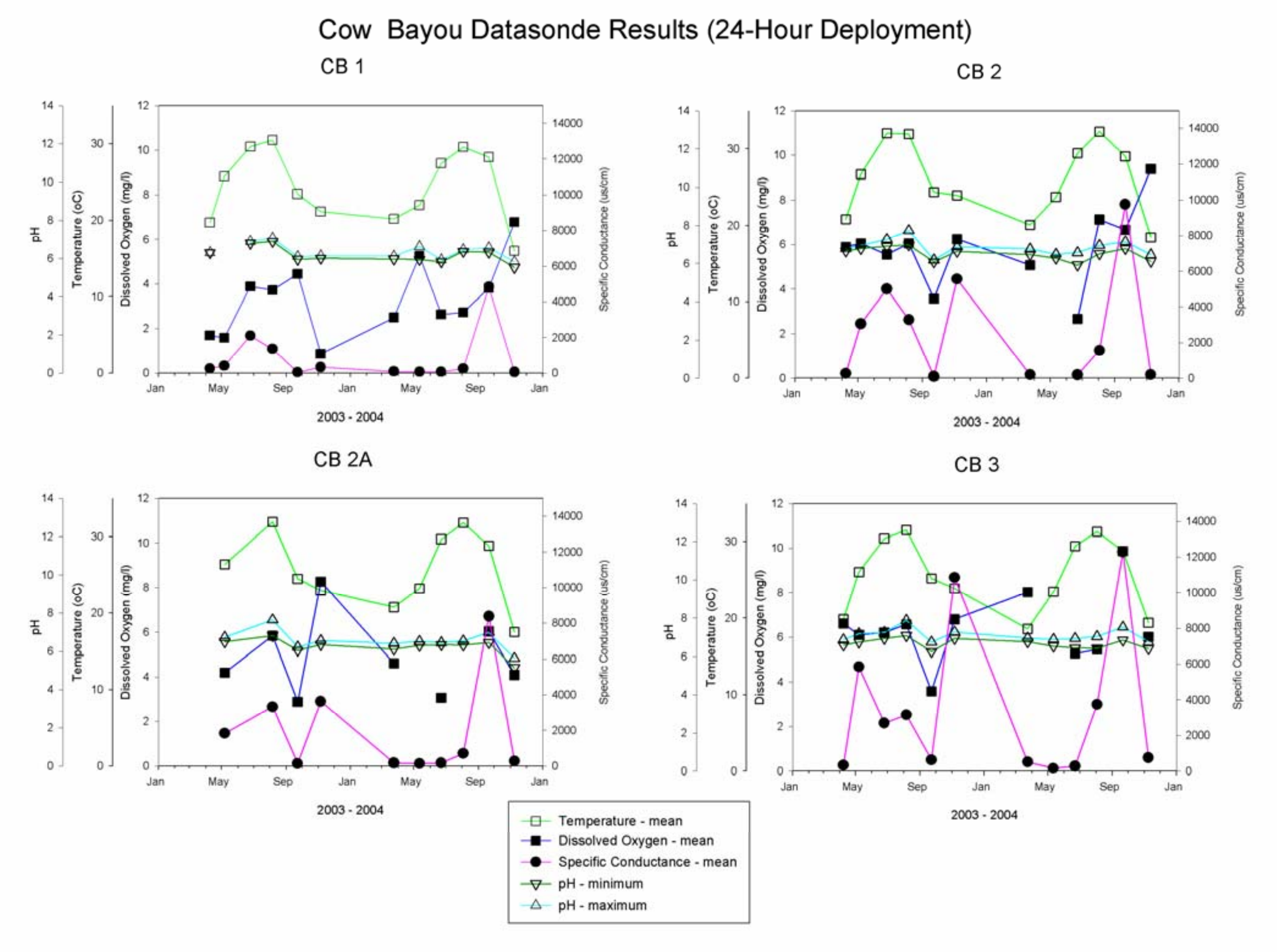


Figure 35.—Temperature, dissolved oxygen, pH, and specific conductance measured in Cow Bayou (24-hour datasonde deployment). Sampling locations are described in the text. Connecting lines do not represent continuous data collection and are drawn to aid visualization. Figure reprinted from Radloff (2005).

24-hour measurements revealed little variability in pH during the study. Minimum pH ranged from 5.5 to 6.9 standard units at CB 1, 5.9 and 7.0 standard units at CB 2, 5.2 and 6.8 standard units at CB 2A, and 6.2 and 7.1 standard units at CB 3. Maximum pH ranged from 5.8 to 7.1 standard units at CB 1, 6.2 and 7.8 standard units at CB 2, 5.6 and 7.6 standard units at CB 2A, and 6.8 and 7.9 standard units at CB 3.

In Lost River, mean dissolved oxygen was somewhat variable, but consistently above the criterion of 4.0 mg/l at all three stations on Lost River (Figure 40). Mean dissolved oxygen ranged from 5.4 to 11.4 mg/l at LR 1, 4.4 to 10.8 mg/l at LR 2, and 5.8 to 10.0 mg/l at LR 3 (Table 26). The lowest dissolved oxygen measurement recorded at each station was 4.0 mg/l at LR 1, 2.9 mg/l at LR 2, and 4.1 mg/l at LR 3.

Lost River frequently exhibited higher DO levels than Cow Bayou. For example, in June 2003 datasondes were deployed first at Lost River and a couple of days later at Cow Bayou. Almost all of the measurements from Cow Bayou were lower than those from Lost River (Figure 36). DO at CB 1 was notably lower than at the other stations.

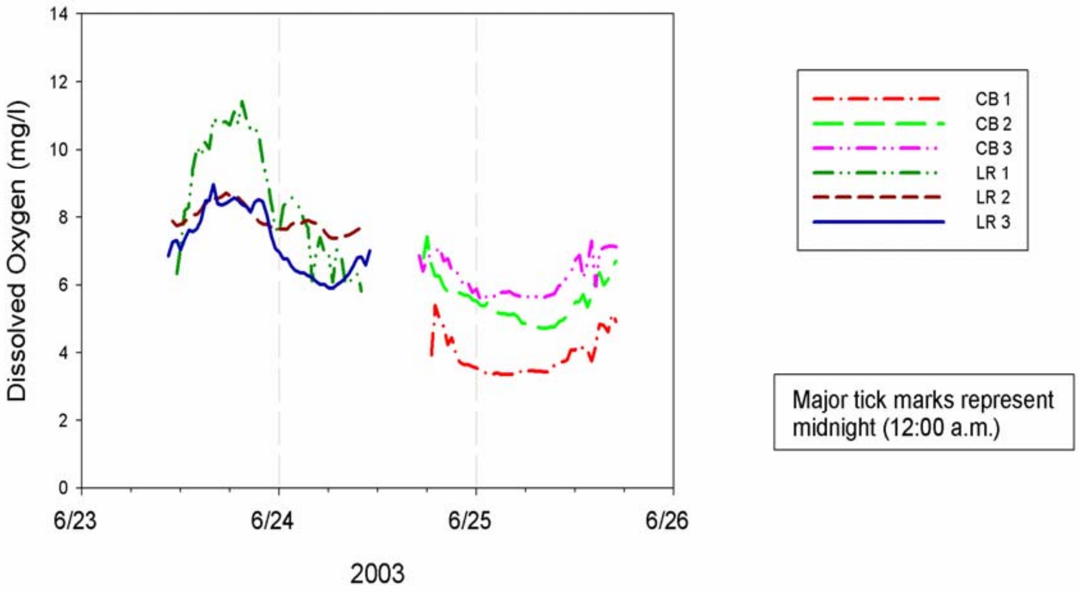


Figure 36.—Diurnal DO measurements from Cow Bayou and Lost River, Jun 2003. Figure reprinted from Radloff (2005).

In late summer, DO levels were lower at both streams (Figure 37). During this sampling period, DO even peaked a little higher at the lower three stations of Cow Bayou than at Lost River. However CB 1 continued to have much lower DO than the other stations.

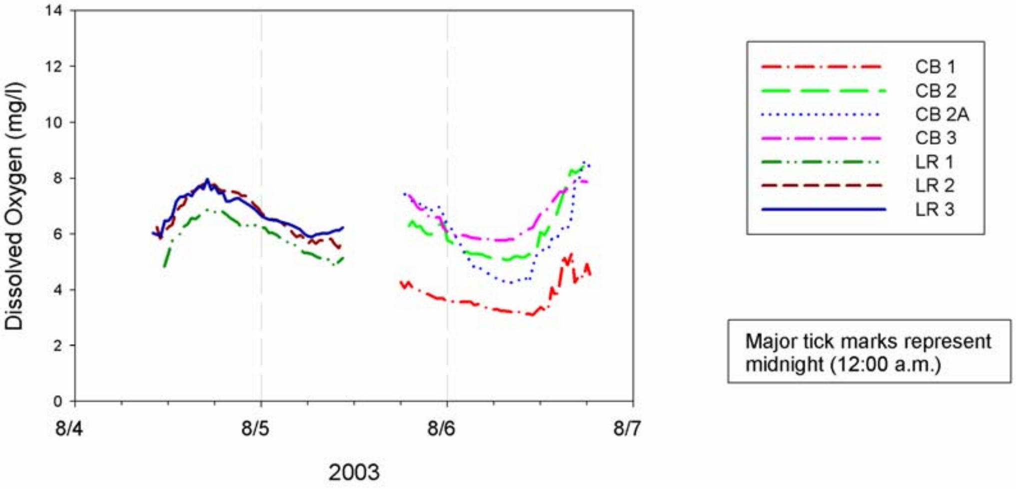


Figure 37.—Diurnal DO measurements from Cow Bayou and Lost River, Aug 2003. Figure reprinted from Radloff (2005).

The next year additional datasondes were available to use on the project so that diurnal measurements could be taken simultaneously at all seven stations. In June 2004 almost all of the DO measurements at Cow Bayou were below those at Lost River, and below the DO criterion (Figure 38).

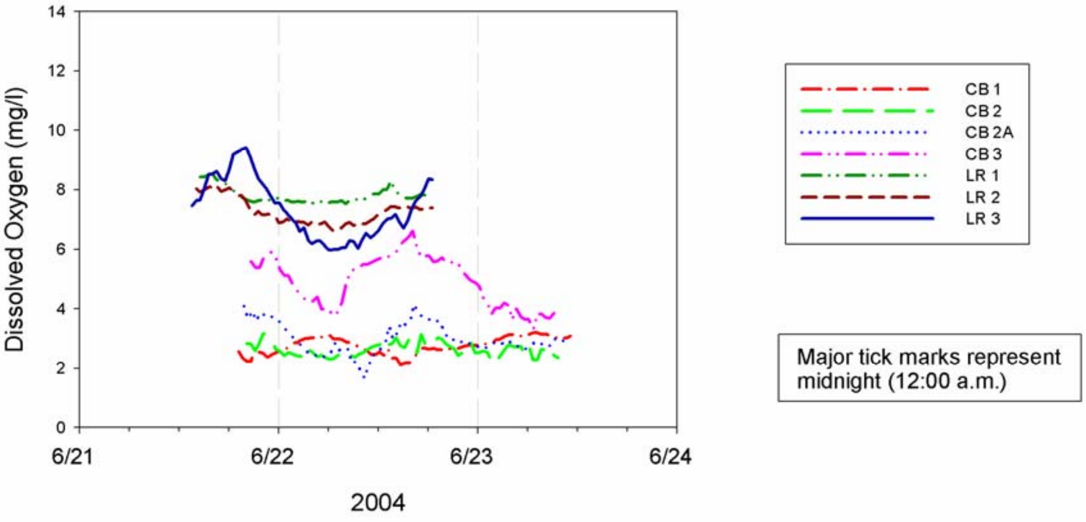


Figure 38.—Diurnal DO measurements from Cow Bayou and Lost River, Jun 2004. Figure reprinted from Radloff (2005).

In August 2004 Cow Bayou and Lost River had similar DO patterns, with the exception of CB 2 which had elevated DO, and CB 1 which had typically low DO (Figure 39).

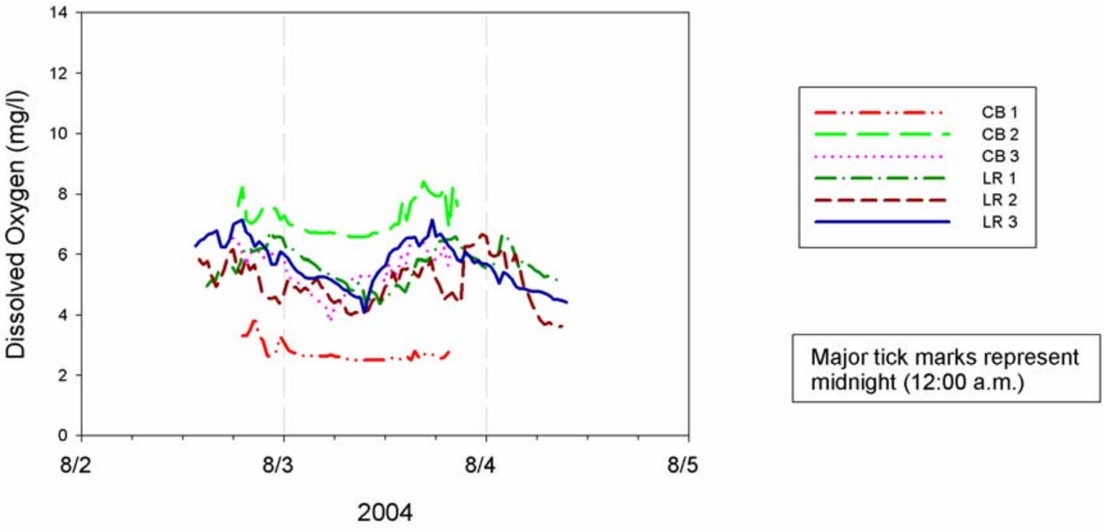


Figure 39.—Diurnal DO measurements from Cow Bayou and Lost River, Aug 2004. Figure reprinted from Radloff (2005).

Relatively low mean specific conductance values measured during this study reflected the fact that 2003 and 2004 were relatively wet years in southeastern Texas. Mean specific conductance measurements varied little over the course of the study (Figure 41). Values were higher in mid to late summer in 2003 and 2004, with this effect less pronounced at increasing distance upstream. Mean specific conductance ranged from 344 to 553 umhos/cm at LR 1, 324 to 619 umhos/cm at LR 2, and 326 to 3,120 umhos/cm at LR 3.

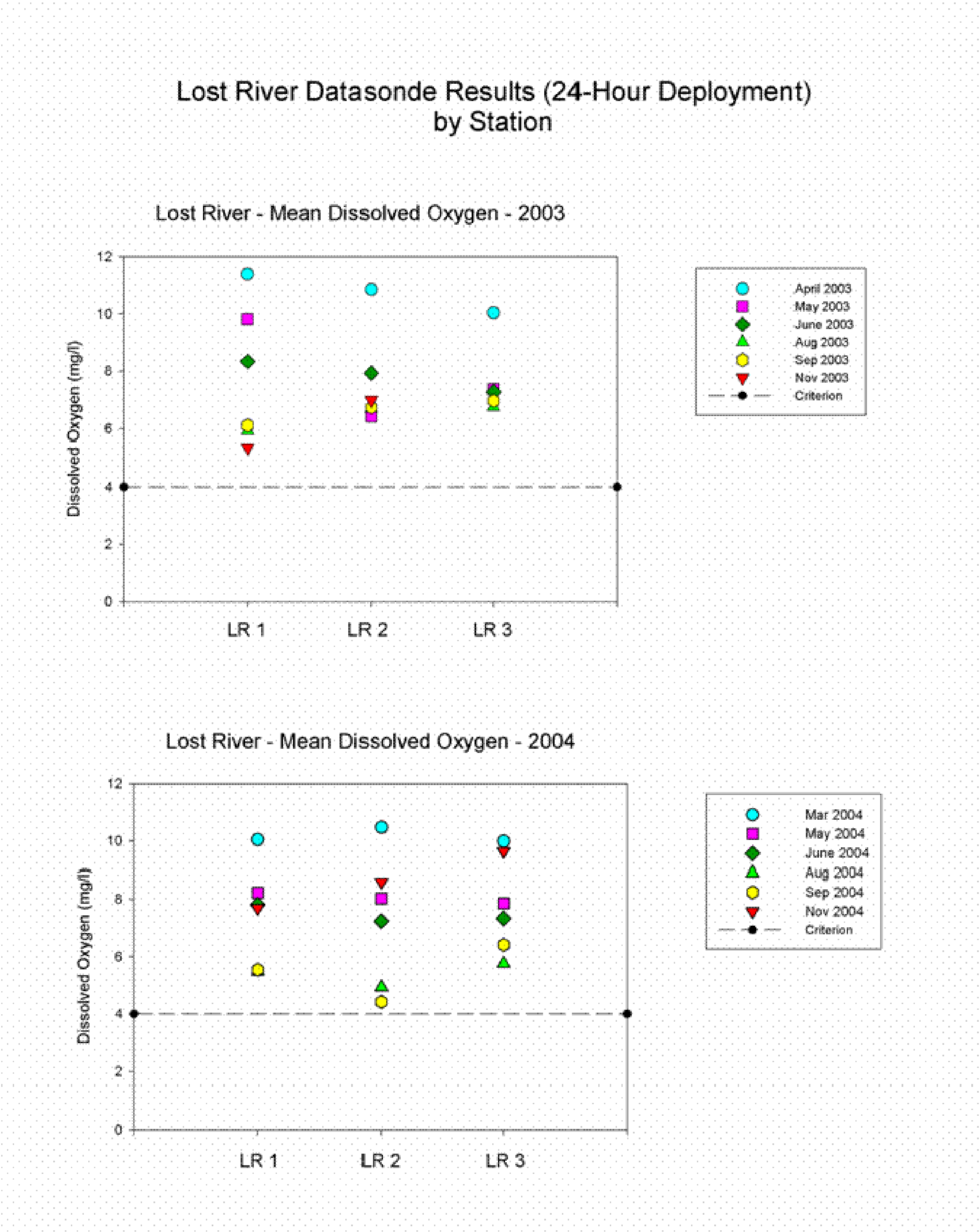


Figure 40.—Mean dissolved oxygen by station measured in Lost River (24-hour datasonde deployment). Sampling locations are described in the text. Figure reprinted from Radloff (2005).

Table 26.—Summary of field physicochemical measurements taken by datasondes in Lost River, 2003-2004.

Station	Date Deployed	Depth	Avg Temp	Min Temp	Max Temp	Avg DO	Min DO	Max DO	Avg Spec Cond	Min Spec Cond	Max Spec Cond	Min pH	Max pH
		m	˚C	˚C	˚C	mg/l	mg/l	mg/l	us/cm	us/cm	us/cm		
LR 1	8-Apr-2003	0.3	19.48	18.54	20.32	11.39	10.26	12.31	447	417	549	8.05	8.39
LR 1	5-May-2003	1.0	27.18	26.69	27.49	9.82	8.48	11.20	345	339	350	8.09	8.54
LR 1	23-Jun-2003	0.8	31.08	30.00	32.27	8.35	5.81	10.91	352	349	356	7.6	8.5
LR 1	4-Aug-2003	1.0	33.07	32.12	34.00	5.93	4.81	6.87	553	544	560	7.78	8.1
LR 1	23-Sep-2003	0.3	26.45	25.75	27.79	6.12	4.03	8.38	403	376	429	6.84	7.64
LR 1	4-Nov-2003	0.7	23.67	23.15	24.44	5.37	4.51	6.27	360	357	363	7.23	7.37
LR 1	22-Mar-2004	0.7	20.88	19.99	21.92	10.04	8.40	11.48	466	423	498	7.45	8.01
LR 1	10-May-2004	0.8	22.83	22.63	23.40	8.24	7.40	9.78	362	360	363	7.51	7.97
LR 1	21-Jun-2004	0.8	28.60	28.23	29.56	7.81	7.53	8.53	344	340	359	7.82	8.06
LR 1	2-Aug-2004	0.8	31.52	30.95	32.26	5.48	4.21	6.76	377	361	396	7.11	7.4
LR 1	20-Sep-2004	1.0	28.61	27.84	29.59	5.55	4.48	6.64	370	369	372	6.95	7.32
LR 1	1-Nov-2004	0.8	19.63	19.01	20.52	7.70	6.73	9.26	432	417	453	7.15	7.54
LR 2	8-Apr-2003	0.3	20.30	18.66	22.50	10.85	8.98	12.83	370	345	394	7.54	8.53
LR 2	5-May-2003	1.0	26.62	25.95	27.29	6.42	4.34	7.61	498	419	578	7.21	7.82
LR 2	23-Jun-2003	0.8	29.58	29.09	30.51	7.94	7.37	8.71	332	326	335	7.95	8.32
LR 2	4-Aug-2003	1.0	32.46	31.36	33.61	6.69	5.49	7.80	962	809	1,166	7.75	8.1
LR 2	23-Sep-2003	1.0	26.79	26.13	28.52	6.74	5.91	8.09	337	327	342	7.09	8.07
LR 2	4-Nov-2003	0.9	22.95	22.36	23.89	6.99	5.86	7.69	363	354	383	7.42	7.65
LR 2	22-Mar-2004	0.7	20.13	18.85	22.30	10.47	8.75	12.74	384	374	398	7.7	8.49
LR 2	10-May-2004	0.8	23.10	22.83	23.55	8.03	7.44	8.91	357	354	359	7.53	7.76
LR 2	21-Jun-2004	0.8	28.77	28.26	29.61	7.25	6.63	8.14	324	323	325	7.54	7.85
LR 2	2-Aug-2004	0.7	32.15	31.06	33.48	4.94	4.02	6.16				6.86	7.04
LR 2	20-Sep-2004	1.0	28.75	27.94	29.87	4.43	2.86	6.64	619	390	2,270	6.83	7.55

Station	Date Deployed	Depth	Avg Temp	Min Temp	Max Temp	Avg DO	Min DO	Max DO	Avg Spec Cond	Min Spec Cond	Max Spec Cond	Min pH	Max pH
		m	˚C	˚C	˚C	mg/l	mg/l	mg/l	us/cm	us/cm	us/cm		
LR 2	1-Nov-2004	0.8	20.43	19.76	21.69	8.61	7.88	9.79	339	335	343	7.46	7.85
LR 3	10-Apr-2003	0.5	18.53	14.90	20.60	10.04	9.10	11.60	380	345	837	8	8.7
LR 3	5-May-2003	1.0	26.52	25.74	27.15	7.36	6.62	8.30	1,397	572	2,906	7.62	8.05
LR 3	23-Jun-2003	0.8	32.16	30.79	34.01	7.29	5.90	8.97	405	351	429	8.11	8.61
LR 3	4-Aug-2003	1.0	31.47	30.10	33.30	6.75	5.89	7.98				7	8.32
LR 3	23-Sep-2003	0.8	27.07	26.22	28.90	6.97	6.31	7.97	425	398	448	7.42	8
LR 3	4-Nov-2003	0.9	24.82	24.15	25.76							7.68	7.95
LR 3	22-Mar-2004	0.8	20.08	18.62	21.51	9.99	8.64	11.13	388	364	400	7.88	8.17
LR 3	10-May-2004	0.9	24.00	23.15	24.94	7.87	6.99	8.89	370	365	414	7.44	7.76
LR 3	21-Jun-2004	0.8	29.30	28.02	30.96	7.34	5.97	9.41	326	323	328	7.49	8.22
LR 3	2-Aug-2004	0.8	33.02	31.49	34.59	5.77	4.09	7.14	453	377	564	7.45	7.9
LR 3	20-Sep-2004	1.0	29.07	27.86	30.85	6.42	5.93	7.16	3,119	950	8,802	7.43	7.7
LR 3	8-Nov-2004	0.8	21.29	20.10	23.10	9.65	9.04	11.07	636	534	665	7.75	8.23

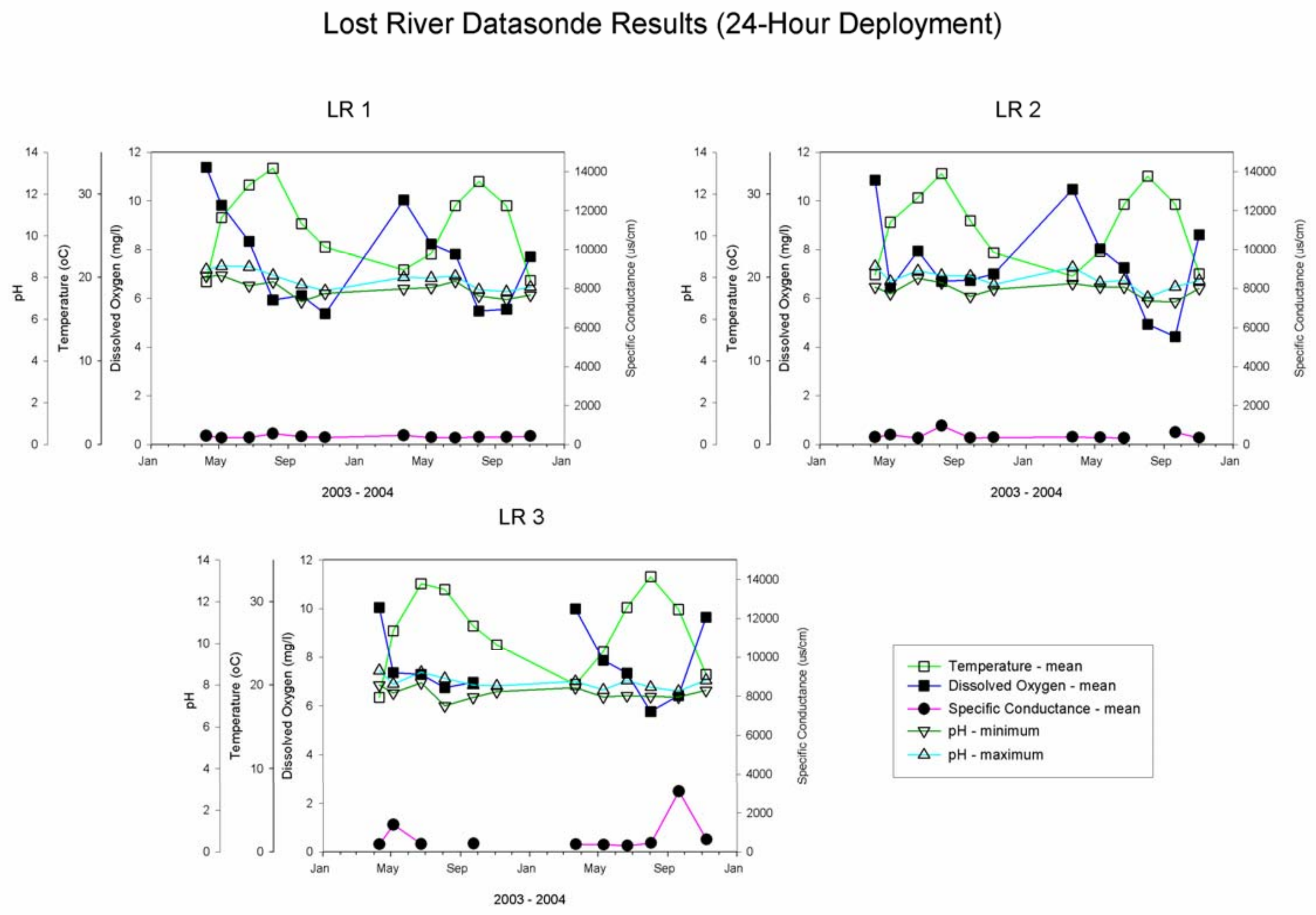


Figure 41.—Temperature, dissolved oxygen, pH, and specific conductance measured in Lost River (24-hour datasonde deployment). Sampling locations are described in the text. Connecting lines do not represent continuous data collection and are drawn to aid visualization. Figure reprinted from Radloff (2005).

Water temperature followed a predictable seasonal pattern in both 2003 and 2004 (Figure 41). The highest mean water temperatures were recorded in the months of August, closely followed by June and September. The lowest mean water temperatures were recorded in April 2003, March 2004, and November 2004. Mean water temperature ranged from 19.5 to 33.1 degrees C at LR 1, 20.1 to 32.5 degrees C at LR 2, and 18.5 and 33.0 degrees C at LR 3.

24-hour measurements revealed little variability in pH during the study. Minimum pH ranged from 6.8 to 8.1 standard units at LR 1, 6.8 to 8.0 standard units at LR 2, and 7.4 to 8.1 standard units at LR 3. Maximum pH ranged from 7.3 to 8.5 standard units at LR 1, 7.0 to 8.5 standard units at LR 2, and 7.7 to 8.7 standard units at LR 3.

MDS configuration of the samples are displayed in Figure 42. Cow Bayou and Lost River values appear clearly segregated. ANOSIM showed no differences among Cow Bayou stations, nor among Lost River stations.

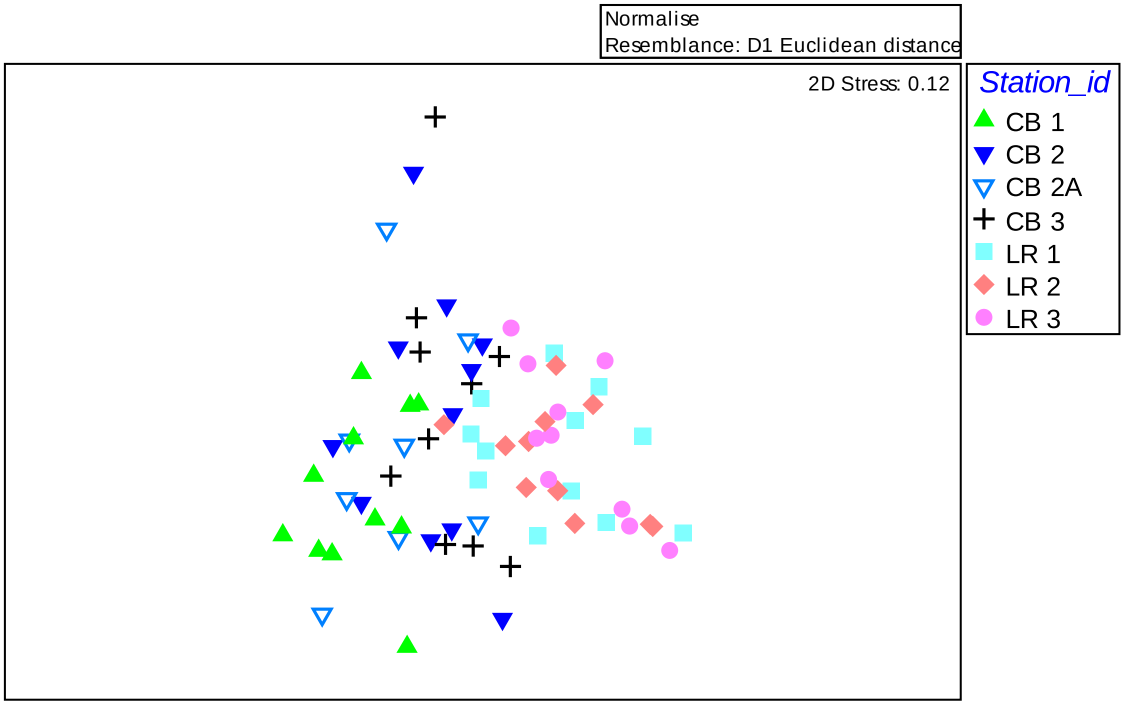


Figure 42.—MDS ordination of the 24-hour mean measurements from the datasonde deployments for Cow Bayou and Lost River (water temperature, DO, pH, and specific conductance).

The PCA plot of the datasonde data is presented in Figure 43. Cow Bayou samples exhibit more spread than the Lost River samples, and are located on the left-hand side of the chart. Lost River samples are a little more tightly clustered and are located on the right half of the chart.

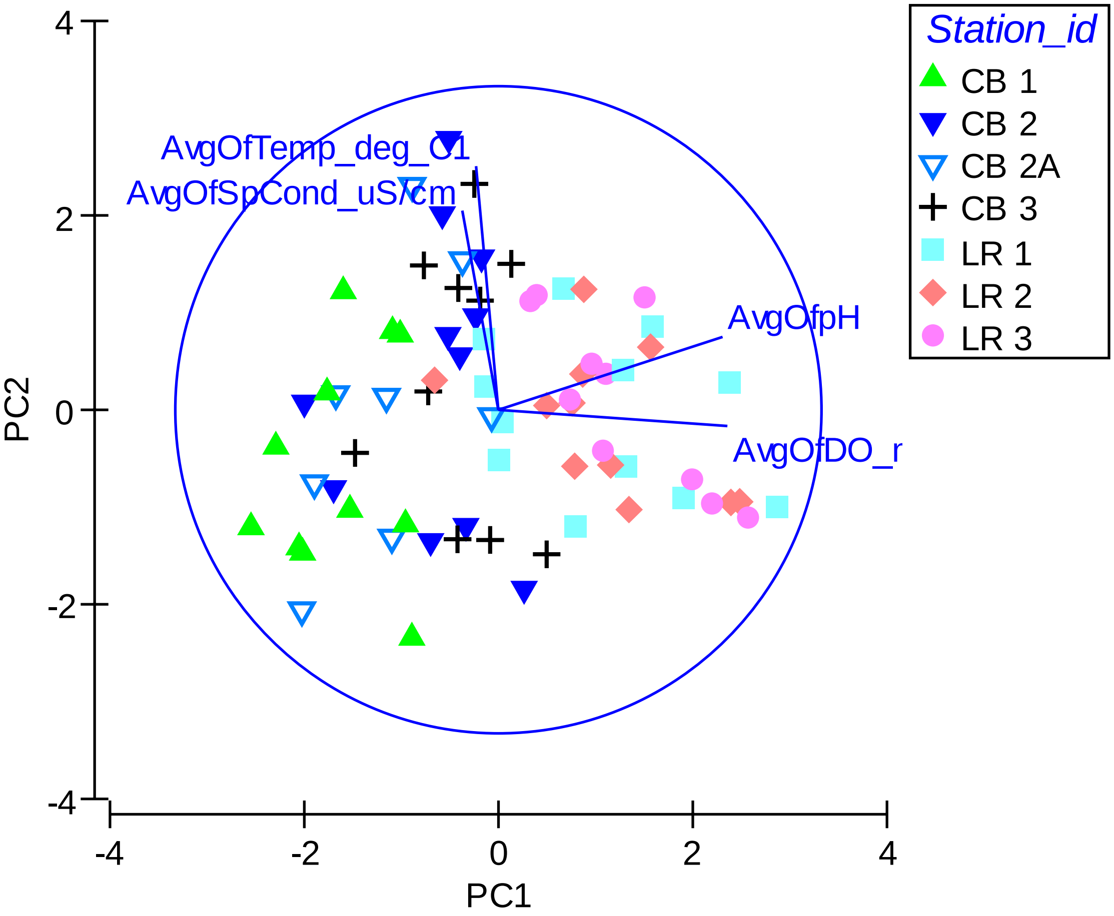


Figure 43.—PCA plot of datasonde data from Cow Bayou and Lost River (24-hour mean DO (mg/l), 24-hour mean of pH measurements (standard units), 24-hour mean water temperatures (degrees Celsius), and 24-hour mean specific conductance (umhos/cm).

The first two principal components explain 75.9% of the variation in the data (Table 27). The first principal component was associated negatively with DO and pH. The second principal component reflected higher temperature and specific conductance. Cow Bayou samples tend to be more negatively associated with DO and pH. They also exhibit a greater range of water temperature and specific conductance. Lost River samples are associated with higher DO and pH.

Table 27.—Correlations of the surface measurements from the 24-hour datasonde deployments for temperature (degrees Celsius), pH (standard units), DO (mg/l), specific conductance (umhos/cm), and Secchi depth (meters), with the first three principal components, cumulative percent variation for each principal component, and eigenvalues, for Cow Bayou and Lost River.

Variable	PC 1	PC 2	PC 3
Cumulative Percent	43.7	75.9	96.8
Eigenvalue	1.750	1.290	0.835
Mean temperature	-0.069	0.753	0.540
Mean pH	0.693	0.226	0.218
Mean DO	0.708	-0.050	-0.281
Mean sp. Cond.	-0.112	0.616	-0.763

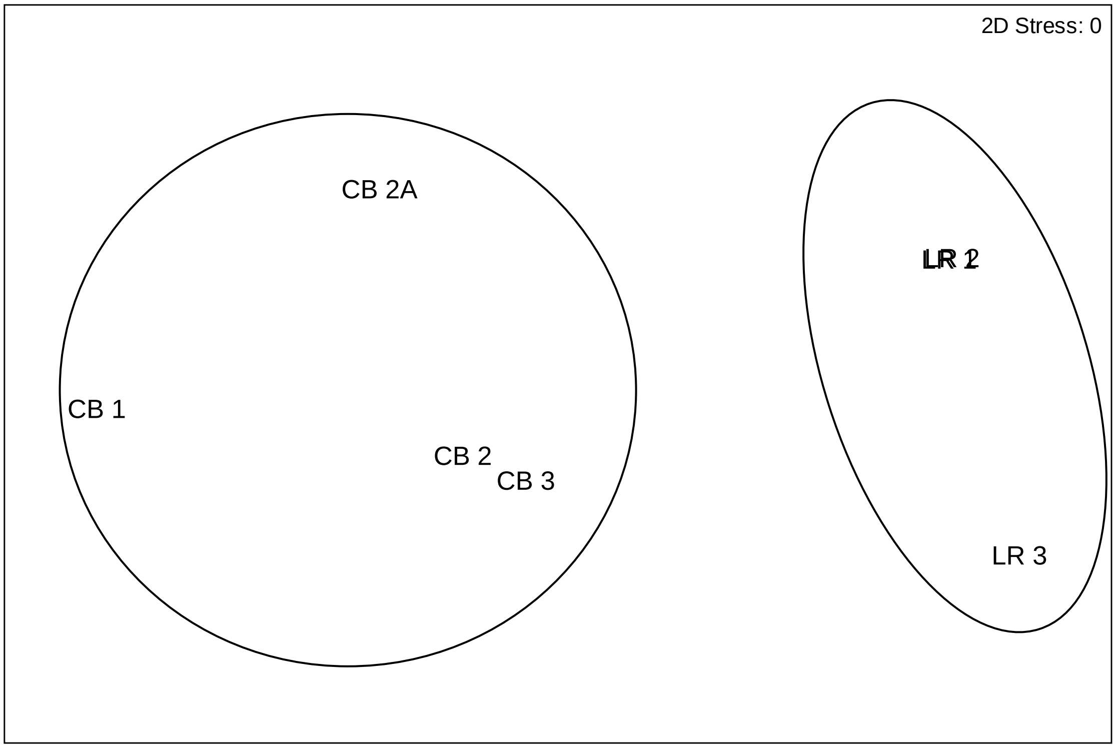


Figure 44.—Means plot MDS configuration of 24-hour datasonde measurements from Cow Bayou and Lost River. Stations within an ellipse are not significantly different based on ANOSIM comparisons among the streams (*p* > 0.05).

ANOSIM shows that there are significant differences between stations from the two streams (Global R = 0.285, $p < 0.001$; Figure 44).

Physicochemical Profiles

At all four stations in Cow Bayou, about half of the instantaneous profiles showed depressed dissolved oxygen near the bottom. Notable examples of this phenomenon occurred at CB 1 in June 2003 (Figure 45), CB 2 in August 2003 (Figure 46), CB 2A in August 2004 (Figure 47), and CB 3 in September 2004 (Figure 48). Several times during the study, stratification by temperature occurred, following the definition of one-half degree temperature change (TCEQ 2003a). Examples of this are seen in the profiles measured on CB 2A and CB 3 in Aug 2004 (Figure 47, Figure 48). Less often stratification by specific conductance was observed, as defined by a 6000 uS/cm difference in specific conductance (TCEQ 2003a). An example can be seen in CB 2 and CB 2A in Nov 2003 (Figure 49).

Data from the profiles in Cow Bayou are presented in Table 28 through Table 31.

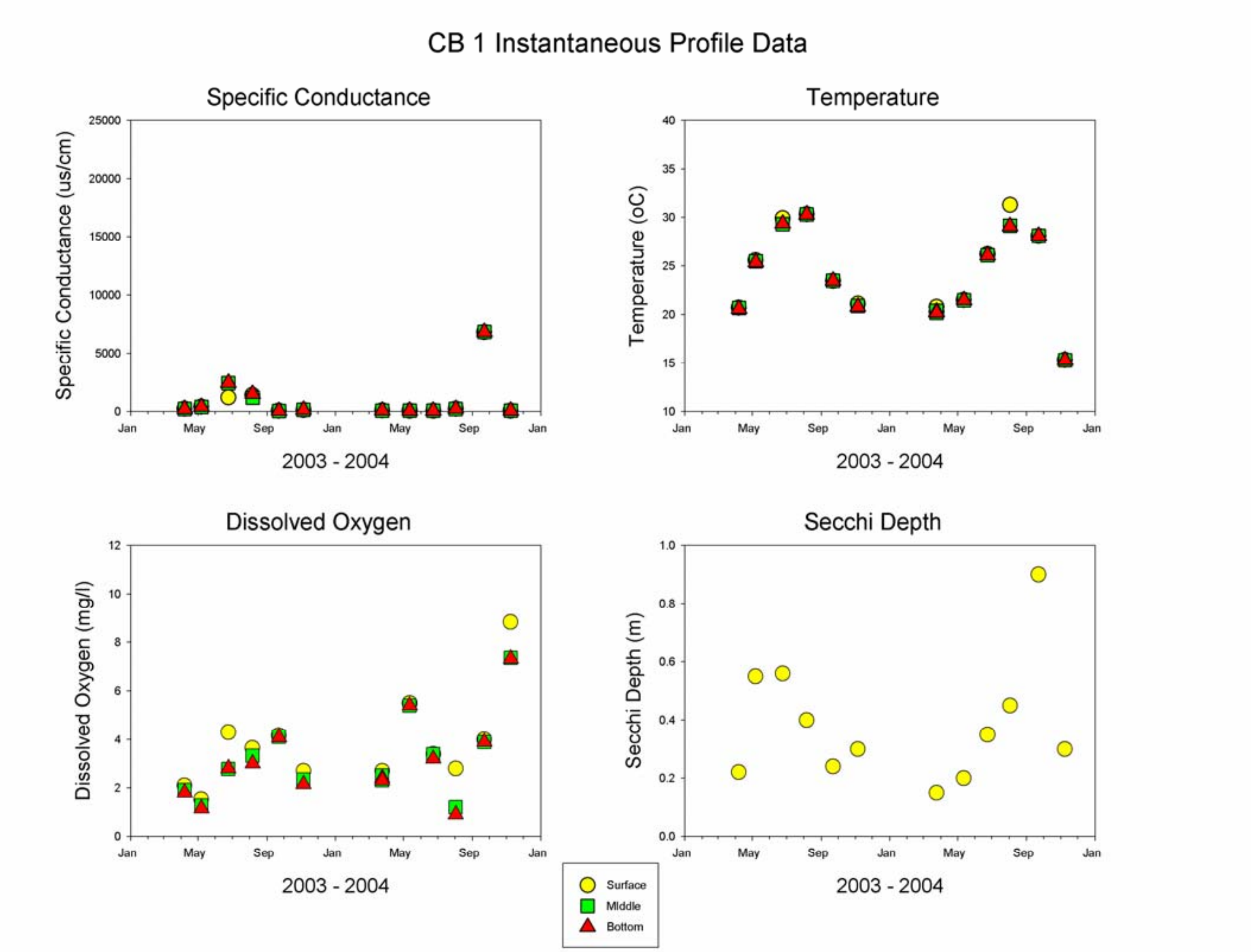


Figure 45.—Water column profile physicochemical parameter data at three depths and Secchi depth in Cow Bayou at station CB 1, 50 yds (45.7 m) downstream of Cole Creek confluence. Figure reprinted from Radloff (2005).

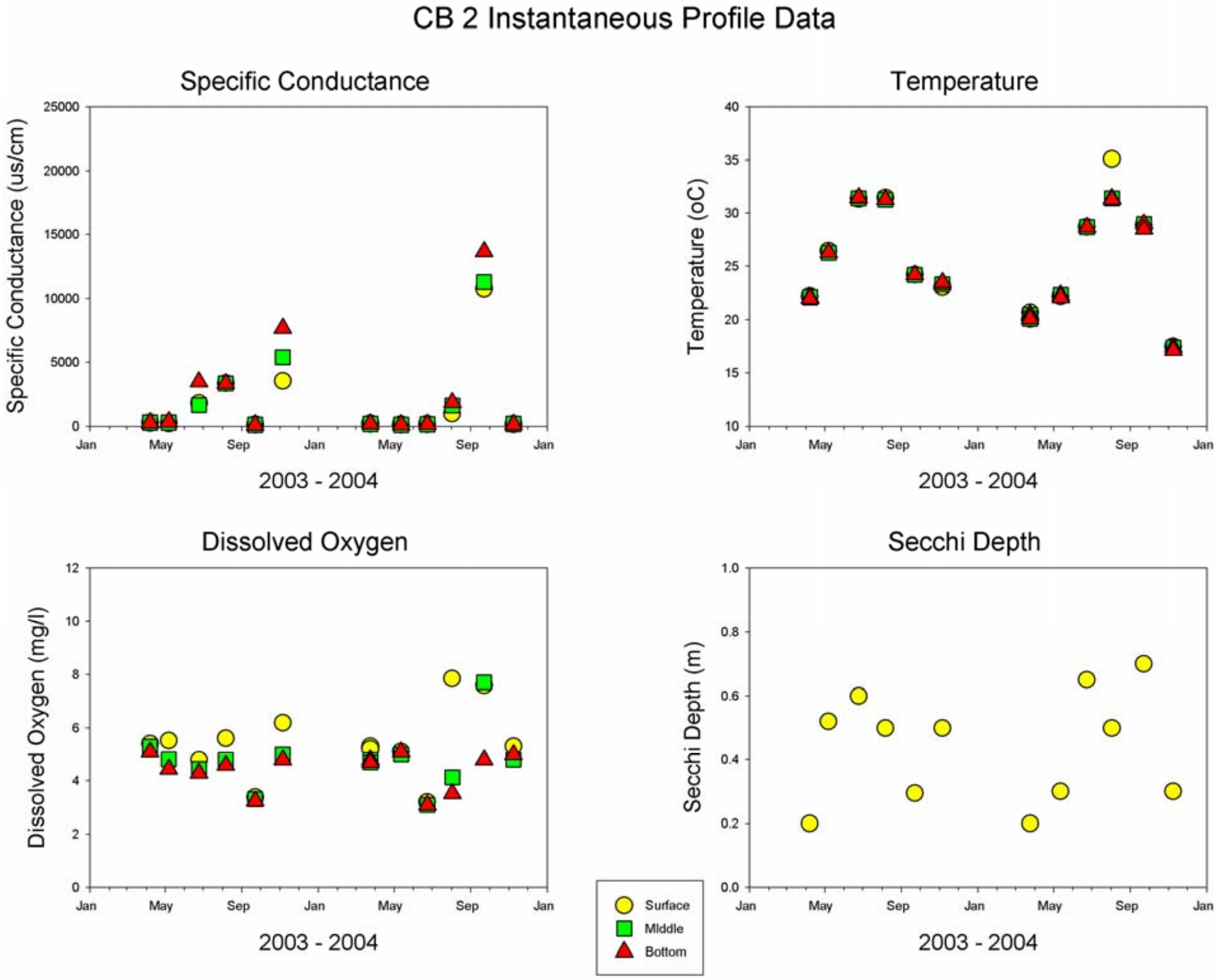


Figure 46.—Water column profile physicochemical parameter data at three depths and Secchi depth in Cow Bayou at station CB 2, at SH 87. Figure reprinted from Radloff (2005).

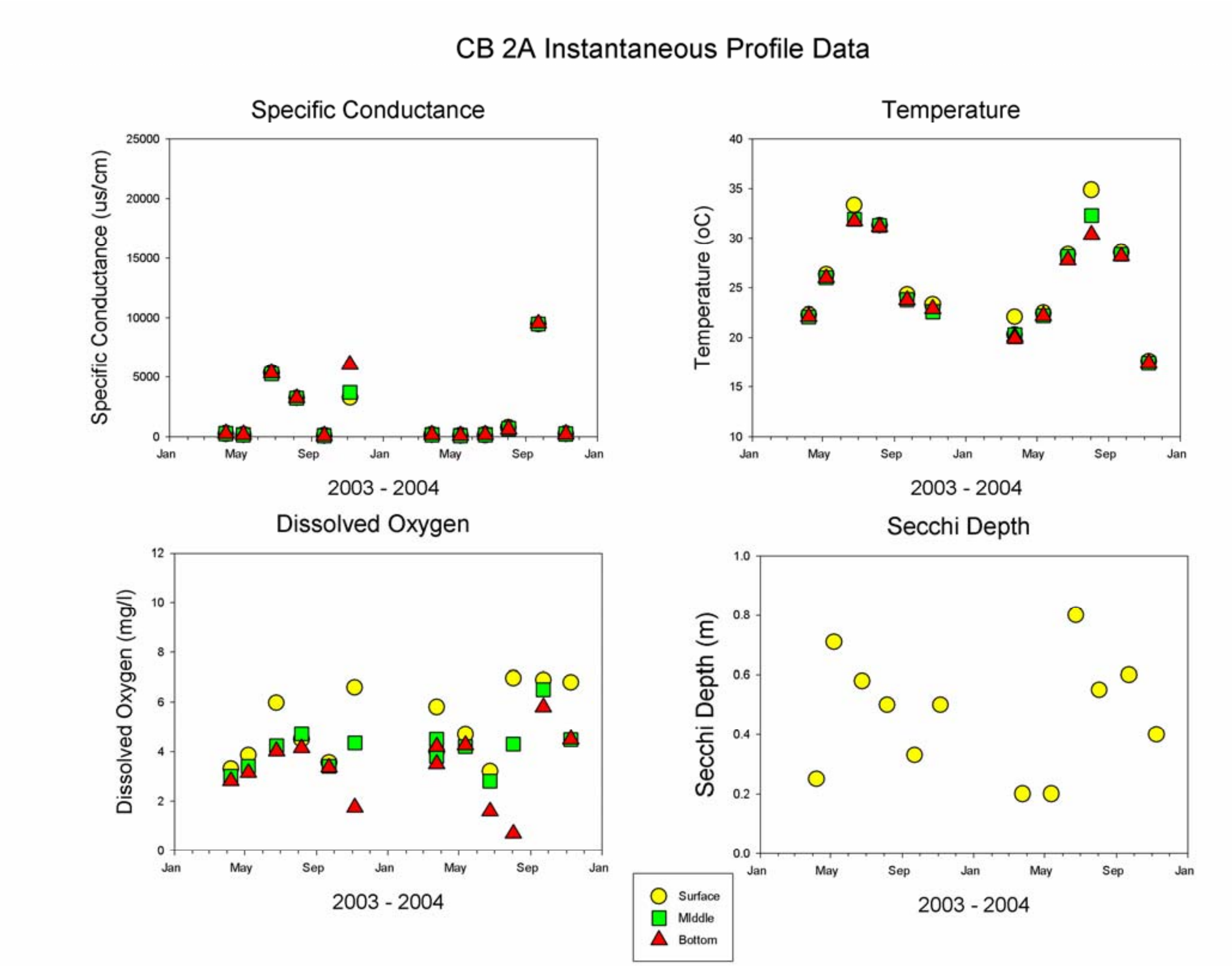


Figure 47.—Water column profile physicochemical parameter data at three depths and Secchi depth in Cow Bayou at station CB 2A, approximately 2.2 km upstream of SH 87 in original stream channel northeast of Bridge City. Figure reprinted from Radloff (2005).

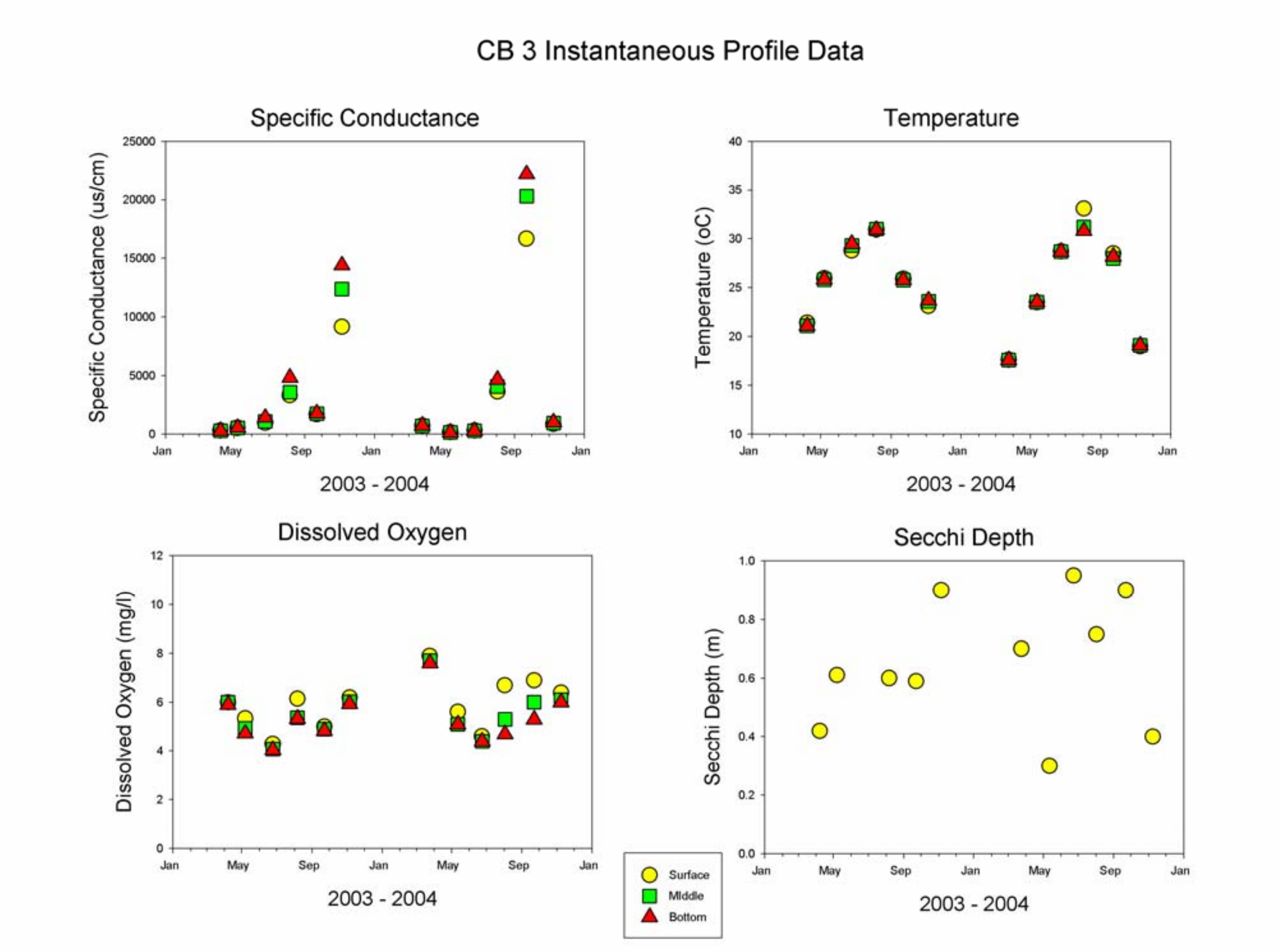


Figure 48.—Water column profile physicochemical parameter data at three depths and Secchi depth in Cow Bayou at station CB 3, 2400 ft (732 m) upstream of Sabine River confluence. Figure reprinted from Radloff (2005).

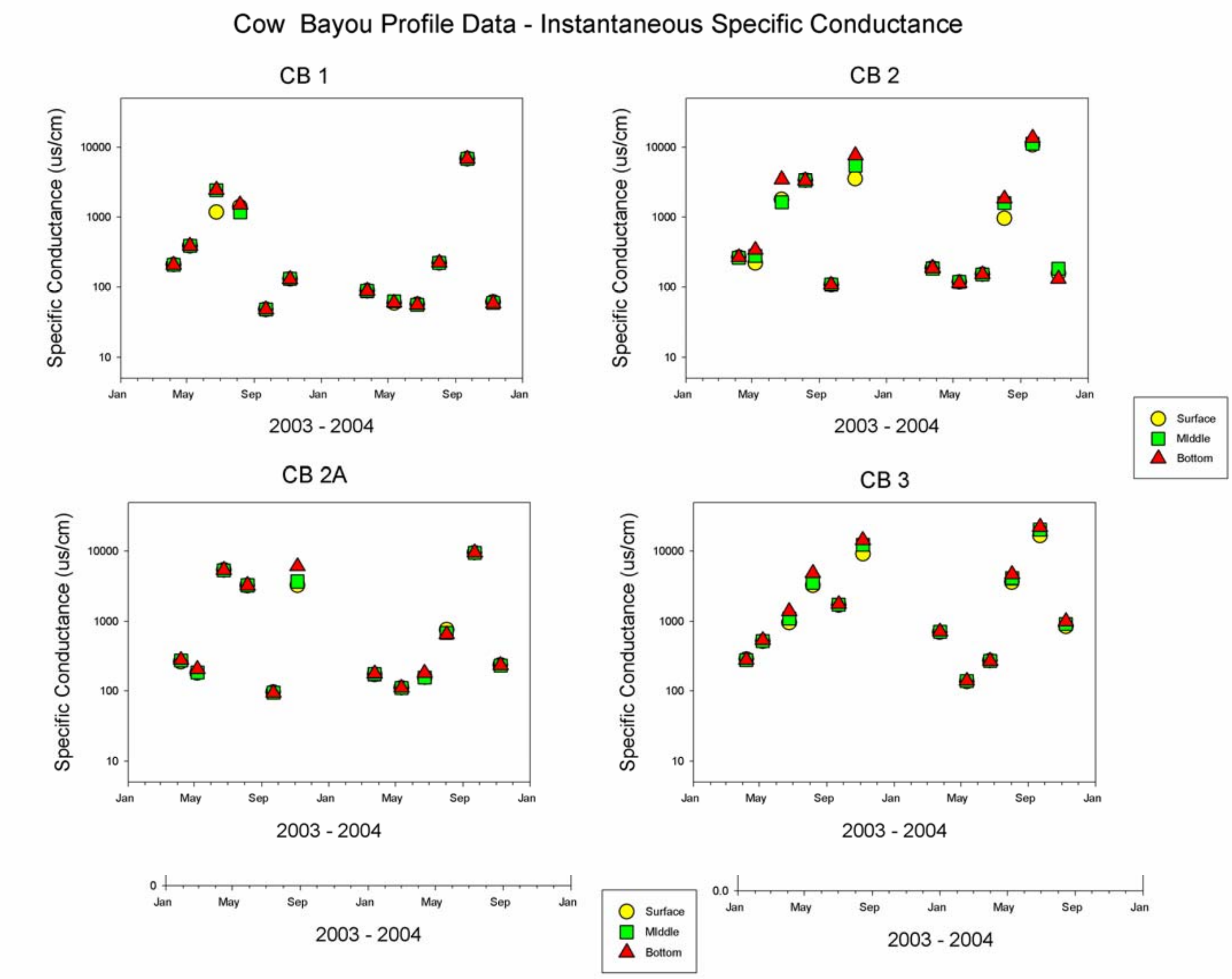


Figure 49.—Water column profile specific conductance data at three depths in Cow Bayou. Sampling locations are described in the text. Figure reprinted from Radloff (2005).

Table 28.—Water column profile physicochemical parameter data from datasonde measurements taken in Cow Bayou at station CB 1.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 1	4/7/2003	10:50 AM	0.3	0.22	20.7	2.1	22.8	210	6.4
CB 1	4/7/2003	10:50 AM	2.0		20.70	1.9	21.3	210	6.40
CB 1	4/7/2003	10:50 AM	3.7		20.60	1.8	20	210	6.40
CB 1	5/7/2003	11:00 AM	0.3	0.55	25.58	1.52	15.9	391	6.19
CB 1	5/7/2003	11:00 AM	3.0		25.50	1.27	15.2	393	6.16
CB 1	5/7/2003	11:00 AM	5.7		25.40	1.15	14.1	392	6.15
CB 1	6/24/2003	11:30 AM	0.3	0.56	29.92	4.3	53.1	1180	6.82
CB 1	6/24/2003	11:30 AM	3.0		29.34	2.77	37.2	2440	6.70
CB 1	6/24/2003	11:30 AM	5.0		29.38	2.8	36.8	2460	6.70
CB 1	8/6/2003	10:08 AM	0.3	0.40	30.35	3.65	48.2	1410	6.91
CB 1	8/6/2003	10:08 AM	2.5		30.32	3.32	41	1170	6.88
CB 1	8/6/2003	10:08 AM	5.0		30.31	3.01	39.2	1510	6.87
CB 1	9/22/2003	9:44 AM	0.3	0.24	23.47	4.16	48.9	48	5.79
CB 1	9/22/2003	9:44 AM	3.0		23.46	4.11	48.3	48	5.77
CB 1	9/22/2003	9:44 AM	5.0		23.47	4.09	48	48	5.78
CB 1	11/5/2003	11:45 AM	0.3	0.30	21.1	2.7	30.5	131	6.24
CB 1	11/5/2003	11:45 AM	2.0		20.90	2.34	26.4	132	6.19
CB 1	11/5/2003	11:45 AM	4.0		20.80	2.14	24	130	6.16
CB 1	3/24/2004	11:00 AM	0.3	0.15	20.3	2.7	28.7	88	6
CB 1	3/24/2004	11:00 AM	0.3	0.15	20.8	2.7	30.7	89	5.8
CB 1	3/24/2004	11:00 AM	2.4		20.20	2.3	25.4	88	6.00
CB 1	3/24/2004	11:00 AM	2.4		20.40	2.5	28.2	89	5.90
CB 1	3/24/2004	11:00 AM	4.6		20.30	2.4	26.8	89	5.90

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 1	3/24/2004	11:00 AM	4.8		20.20	2.3	26.2	88	6.00
CB 1	5/12/2004	10:15 AM	0.3	0.20	21.5	5.5	62.3	59	6
CB 1	5/12/2004	10:15 AM	2.0		21.50	5.4	61.3	62.5	6.00
CB 1	5/12/2004	10:15 AM	4.2		21.50	5.4	61.2	60	6.00
CB 1	6/23/2004	12:00 PM	0.3	0.35	26.2	3.4	40.5	57	6
CB 1	6/23/2004	12:00 PM	2.0		26.10	3.4	41.5	56	6.10
CB 1	6/23/2004	12:00 PM	4.0		26.10	3.2	39.7	56	6.10
CB 1	8/2/2004	6:22 PM	0.3	0.45	31.3	2.8	35	221	7
CB 1	8/2/2004	6:22 PM	2.4		29.18	1.2	15.5	225	6.89
CB 1	8/2/2004	6:22 PM	3.9		29.10	0.9	12.9	225	6.80
CB 1	9/22/2004	9:40 AM	0.3	0.90	28.1	4	54	6843	6.5
CB 1	9/22/2004	9:40 AM	2.0		28.10	3.9	52	6850	6.50
CB 1	9/22/2004	9:40 AM	4.0		28.10	3.9	52.1	6841	6.50
CB 1	11/8/2004	7:30 AM	0.3	0.30	15.3	8.83	88.2	62	4.7
CB 1	11/8/2004	7:30 AM	2.2		15.30	7.37	73.6	60	4.44
CB 1	11/8/2004	7:30 AM	4.1		15.30	7.33	73.1	59	4.43

Table 29.—Water column profile physicochemical parameter data from datasonde measurements taken in Cow Bayou at station CB 2.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 2	4/7/2003	9:55 AM	0.3	0.20	22.2	5.4	61.9	270	6.7
CB 2	4/7/2003	9:55 AM	3.0		22.10	5.3	61	265	6.70
CB 2	4/7/2003	9:55 AM	4.9		22.00	5.1	58.2	269	6.70
CB 2	5/7/2003	9:49 AM	0.3	0.52	26.45	5.52	68.6	222	6.67
CB 2	5/7/2003	9:49 AM	2.5		26.29	4.81	60.6	280	6.61
CB 2	5/7/2003	9:49 AM	4.0		26.30	4.45	55.4	343	6.57
CB 2	6/24/2003	8:24 AM	0.3	0.60	31.37	4.79	65.3	1780	6.97
CB 2	6/24/2003	8:24 AM	1.0		31.43	4.45	60.6	1630	6.95
CB 2	6/24/2003	8:24 AM	3.7		31.49	4.3	58.4	3470	6.93
CB 2	8/6/2003	9:17 AM	0.3	0.50	31.47	5.6	74.2	3340	7.19
CB 2	8/6/2003	9:17 AM	2.3		31.30	4.8	63.6	3330	7.14
CB 2	8/6/2003	9:17 AM	3.8		31.30	4.59	65	3330	7.13
CB 2	9/22/2003	9:05 AM	0.3	0.30	24.2	3.38	40.3	109	6.1
CB 2	9/22/2003	9:05 AM	2.5		24.20	3.32	39.6	109	6.10
CB 2	9/22/2003	9:05 AM	4.1		24.20	3.25	38.8	108	6.10
CB 2	11/5/2003	9:45 AM	0.3	0.50	23.1	6.2	73.8	3520	6.7
CB 2	11/5/2003	9:45 AM	1.5		23.30	5	58.9	5400	6.70
CB 2	11/5/2003	9:45 AM	2.5		23.50	4.8	58.4	7680	6.70
CB 2	3/24/2004	9:32 AM	0.3	0.20	20.1	5.3	56.8	187	6.4
CB 2	3/24/2004	9:32 AM	0.3	0.20	20.7	5.2	57.8	187	6.3
CB 2	3/24/2004	9:32 AM	1.8		20.50	4.8	55	187	6.30
CB 2	3/24/2004	9:32 AM	2.0		20.10	4.7	51.5	184	6.50
CB 2	3/24/2004	9:32 AM	3.1		20.40	4.8	53.3	190	6.40
CB 2	3/24/2004	9:32 AM	4.0		20.10	4.7	52.4	187	6.40

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 2	5/12/2004	9:24 AM	0.3	0.30	22.2	5.1	59.4	118	6.3
CB 2	5/12/2004	9:24 AM	2.0		22.30	5	57.1	119	6.30
CB 2	5/12/2004	9:24 AM	4.0		22.10	5.1	58.7	115	6.30
CB 2	6/23/2004	9:55 AM	0.3	0.65	28.7	3.2	41.1	154	6.4
CB 2	6/23/2004	9:55 AM	1.8		28.70	3.1	40.6	153	6.40
CB 2	6/23/2004	9:55 AM	3.6		28.70	3.1	40.3	153	6.40
CB 2	8/2/2004	5:42 PM	0.3	0.50	35.1	7.85	113.6	951	7.52
CB 2	8/2/2004	5:42 PM	1.9		31.40	4.14	50	1594	6.96
CB 2	8/2/2004	5:42 PM	2.9		31.30	3.53	48.6	1840	6.90
CB 2	9/22/2004	3:23 PM	0.3	0.70	28.9	7.6	105.3	10750	7.2
CB 2	9/22/2004	3:23 PM	2.1		29.00	7.7	106.5	11260	7.30
CB 2	9/22/2004	3:23 PM	4.2		28.50	4.8	66.6	13670	7.10
CB 2	11/8/2004	8:36 AM	0.3	0.30	17.5	5.3	55.6	157.1	6.6
CB 2	11/8/2004	8:36 AM	1.5		17.40	4.8	50.1	183.8	6.30
CB 2	11/8/2004	8:36 AM	3.0		17.10	5	50.8	132.3	6.40

Table 30.—Water column profile physicochemical parameter data from datasonde measurements taken in Cow Bayou at station CB 2A.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 2A	4/7/2003	10:20 AM	0.3	0.25	22.3	3.3	38	264	6.5
CB 2A	4/7/2003	10:20 AM	1.0		22.10	3	34.5	275	6.50
CB 2A	4/7/2003	10:20 AM	2.0		22.10	2.8	32.1	279	6.40
CB 2A	5/7/2003	10:22 AM	0.3	0.71	26.38	3.86	47	181	6.34
CB 2A	5/7/2003	10:22 AM	1.0		26.02	3.4	42.4	185	6.31
CB 2A	5/7/2003	10:22 AM	2.3		25.99	3.14	39.4	208	6.32
CB 2A	6/24/2003	12:11 PM	0.3	0.58	33.37	5.97	84.4	5360	7.07
CB 2A	6/24/2003	12:11 PM	1.0		31.93	4.23	57.8	5280	6.97
CB 2A	6/24/2003	12:11 PM	2.0		31.76	4.02	52.6	5350	6.91
CB 2A	8/6/2003	9:42 AM	0.3	0.50	31.34	4.5	59.8	3250	7.02
CB 2A	8/6/2003	9:42 AM	1.0		31.33	4.72	63.4	3240	6.98
CB 2A	8/6/2003	9:42 AM	2.0		31.19	4.14	56.1	3240	6.92
CB 2A	9/22/2003	9:14 AM	0.3	0.33	24.3	3.56	42.4	97	6.24
CB 2A	9/22/2003	9:14 AM	1.5		23.80	3.4	40.2	95	6.10
CB 2A	9/22/2003	9:14 AM	2.1		23.77	3.36	39.8	94	5.93
CB 2A	11/5/2003	11:00 AM	0.3	0.50	23.3	6.6	74.2	3296	6.6
CB 2A	11/5/2003	11:00 AM	1.2		22.60	4.36	51.3	3720	6.50
CB 2A	11/5/2003	11:00 AM	2.1		22.90	1.76	20.9	6053	6.30
CB 2A	3/24/2004	10:12 AM	0.3	0.20	20.3	4	44.3	173	6.3
CB 2A	3/24/2004	10:12 AM	0.3	0.20	22.1	5.8	65.5	174	6.3
CB 2A	3/24/2004	10:12 AM	1.3		20.10	3.8	41.6	174	6.30
CB 2A	3/24/2004	10:12 AM	1.4		20.30	4.5	50.9	177	6.30
CB 2A	3/24/2004	10:12 AM	2.4		20.10	4.2	46.2	178	6.30
CB 2A	3/24/2004	10:12 AM	2.5		19.90	3.5	39.1	179	6.30

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 2A	5/12/2004	10:46 AM	0.3	0.20	22.5	4.7	52.9	112	6.2
CB 2A	5/12/2004	10:46 AM	1.2		22.20	4.2	49.8	111	6.10
CB 2A	5/12/2004	10:46 AM	2.3		22.20	4.27	49	111	6.10
CB 2A	6/23/2004	10:56 AM	0.3	0.80	28.4	3.2	42	158	6.3
CB 2A	6/23/2004	10:56 AM	1.0		28.20	2.8	36.4	157	6.30
CB 2A	6/23/2004	10:56 AM	2.0		27.80	1.6	19.8	182	6.20
CB 2A	8/2/2004	6:00 PM	0.3	0.55	34.9	6.97	94.9	755	7.26
CB 2A	8/2/2004	6:00 PM	1.0		32.30	4.3	49.8	685	6.90
CB 2A	8/2/2004	6:00 PM	1.9		30.40	0.7	9.1	651	6.70
CB 2A	9/22/2004	11:36 AM	0.3	0.60	28.6	6.9	93.5	9468	7
CB 2A	9/22/2004	11:36 AM	1.1		28.40	6.5	87.1	9488	6.90
CB 2A	9/22/2004	11:36 AM	2.0		28.20	5.8	77.7	9530	6.90
CB 2A	11/8/2004	8:30 AM	0.3	0.40	17.6	6.8	64.3	236	5.6
CB 2A	11/8/2004	8:30 AM	1.2		17.40	4.49	47.6	234	5.60
CB 2A	11/8/2004	8:30 AM	2.0		17.40	4.5	48	235	5.50

Table 31.—Water column profile physicochemical parameter data from datasonde measurements taken in Cow Bayou at station CB 3.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 3	4/7/2003	8:56 AM	0.3	0.42	21.4	6	68	287	6.8
CB 3	4/7/2003	8:56 AM	3.0		21.10	6	67.5	277	6.80
CB 3	4/7/2003	8:56 AM	4.7		21.10	5.9	66.8	280	6.80
CB 3	5/7/2003	8:45 AM	0.3	0.61	25.97	5.33	67	517	6.6
CB 3	5/7/2003	8:45 AM	3.0		25.81	4.93	63.5	525	6.61
CB 3	5/7/2003	8:45 AM	5.0		25.86	4.72	59	539	6.57
CB 3	6/24/2003	7:34 AM	0.3		28.79	4.29	55.2	959	6.88
CB 3	6/24/2003	7:34 AM	2.0		29.34	4.09	51.7	1093	6.85
CB 3	6/24/2003	7:34 AM	3.3		29.48	4.05	45.7	1400	6.85
CB 3	8/6/2003	8:41 AM	0.3	0.60	30.93	6.14	81.4	3300	7.29
CB 3	8/6/2003	8:41 AM	2.0		30.98	5.36	72.7	3590	7.24
CB 3	8/6/2003	8:41 AM	4.0		30.91	5.33	73.3	4840	7.24
CB 3	9/22/2003	8:40 AM	0.3	0.59	25.9	5	62.4	1700	6.58
CB 3	9/22/2003	8:40 AM	3.0		25.78	4.9	60.4	1740	6.63
CB 3	9/22/2003	8:40 AM	6.0		25.78	4.83	59.6	1770	6.67
CB 3	11/5/2003	9:00 AM	0.3	0.90	23.1	6.2	73.4	9150	6.8
CB 3	11/5/2003	9:00 AM	2.5		23.60	6.02	74	12370	6.90
CB 3	11/5/2003	9:00 AM	4.7		23.70	5.93	73.5	14400	7.08
CB 3	3/24/2004	8:24 AM	0.3	0.70	17.6	7.9	83.3	695	6.6
CB 3	3/24/2004	8:24 AM	2.5		17.60	7.7	81.6	707	6.70
CB 3	3/24/2004	8:24 AM	5.0		17.60	7.6	80.9	714	6.70
CB 3	5/12/2004	8:45 AM	0.3	0.30	23.5	5.6	65	136	6.3
CB 3	5/12/2004	8:45 AM	2.5		23.50	5.1	61.1	140	7.00
CB 3	5/12/2004	8:45 AM	5.5		23.50	5.1	60.8	140	6.40

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
CB 3	6/23/2004	8:49 AM	0.3	0.95	28.7	4.6	58.4	272	6.3
CB 3	6/23/2004	8:49 AM	2.0		28.70	4.4	56.5	272	6.30
CB 3	6/23/2004	8:49 AM	3.6		28.70	4.4	55.3	272	6.50
CB 3	8/2/2004	5:18 PM	0.3	0.75	33.1	6.7	94.6	3630	7.3
CB 3	8/2/2004	5:18 PM	2.2		31.20	5.3	73	4080	7.20
CB 3	8/2/2004	5:18 PM	4.0		30.80	4.7	63.8	4650	7.20
CB 3	9/22/2004	1:40 PM	0.3	0.90	28.5	6.9	95.4	16670	7.4
CB 3	9/22/2004	1:40 PM	2.7		28.00	6	84.4	20300	7.60
CB 3	9/22/2004	1:40 PM	5.2		28.20	5.3	75.2	22200	7.60
CB 3	11/8/2004	7:30 AM	0.3	0.40	19	6.4	68.2	842.2	6.8
CB 3	11/8/2004	7:30 AM	2.2		19.10	6.1	65.3	918.8	6.80
CB 3	11/8/2004	7:30 AM	4.5		19.10	6	64.3	1006	6.80

At all three stations in Lost River, about half of the instantaneous profiles showed stratification with respect to dissolved oxygen. Examples of this phenomenon occurred at LR 1 in June 2003 (Figure 50), LR 2 in August 2003 (Figure 51), and LR 3 in September 2004 (Figure 52). Stratification by temperature occurred occasionally, for example at all three stations in September 2003. Rarely stratification by specific conductance was observed, for example at LR 3 in September 2004.

Data from the profiles in Lost River is presented in Table 32 through Table 34.

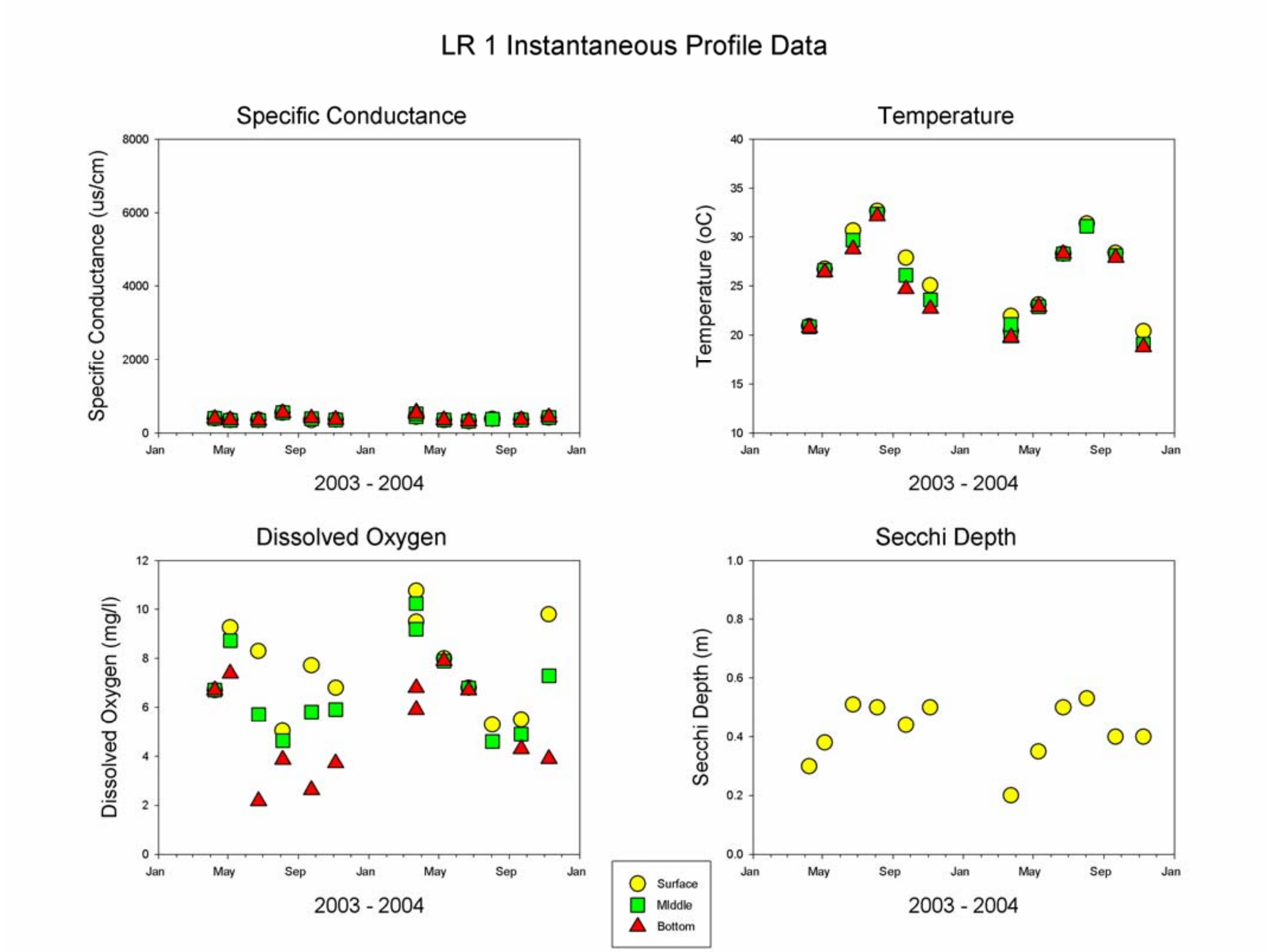


Figure 50.—Water column profile physicochemical parameter data at three depths and Secchi depth in Lost River at station LR 1, at the Chambers County line and 5.4 km upstream of John Wiggins Bayou.

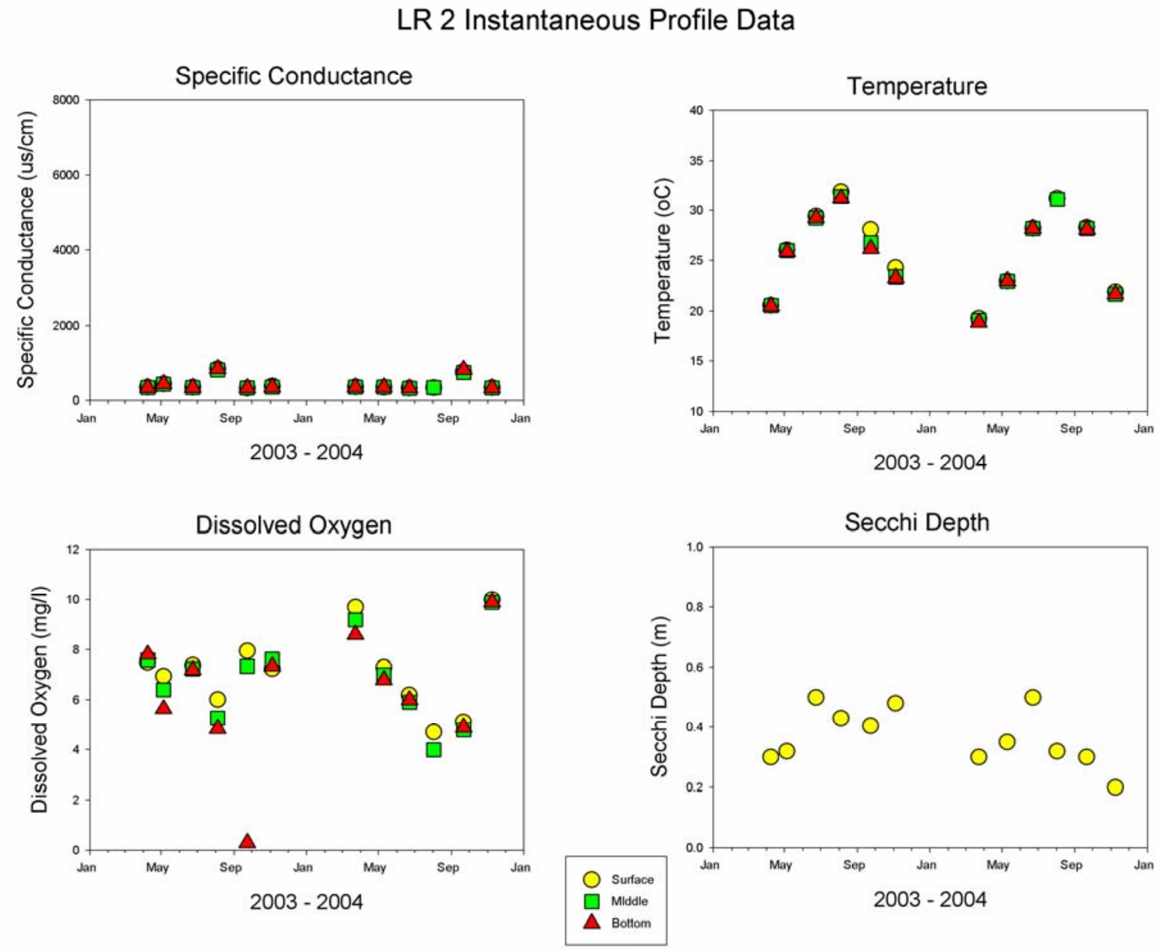


Figure 51.—Water column profile physicochemical parameter data at three depths and Secchi depth in Lost River at station LR 2, approximately 2.6 km upstream of the confluence with John Wiggins Bayou and northeast of Lost Lake oil field.

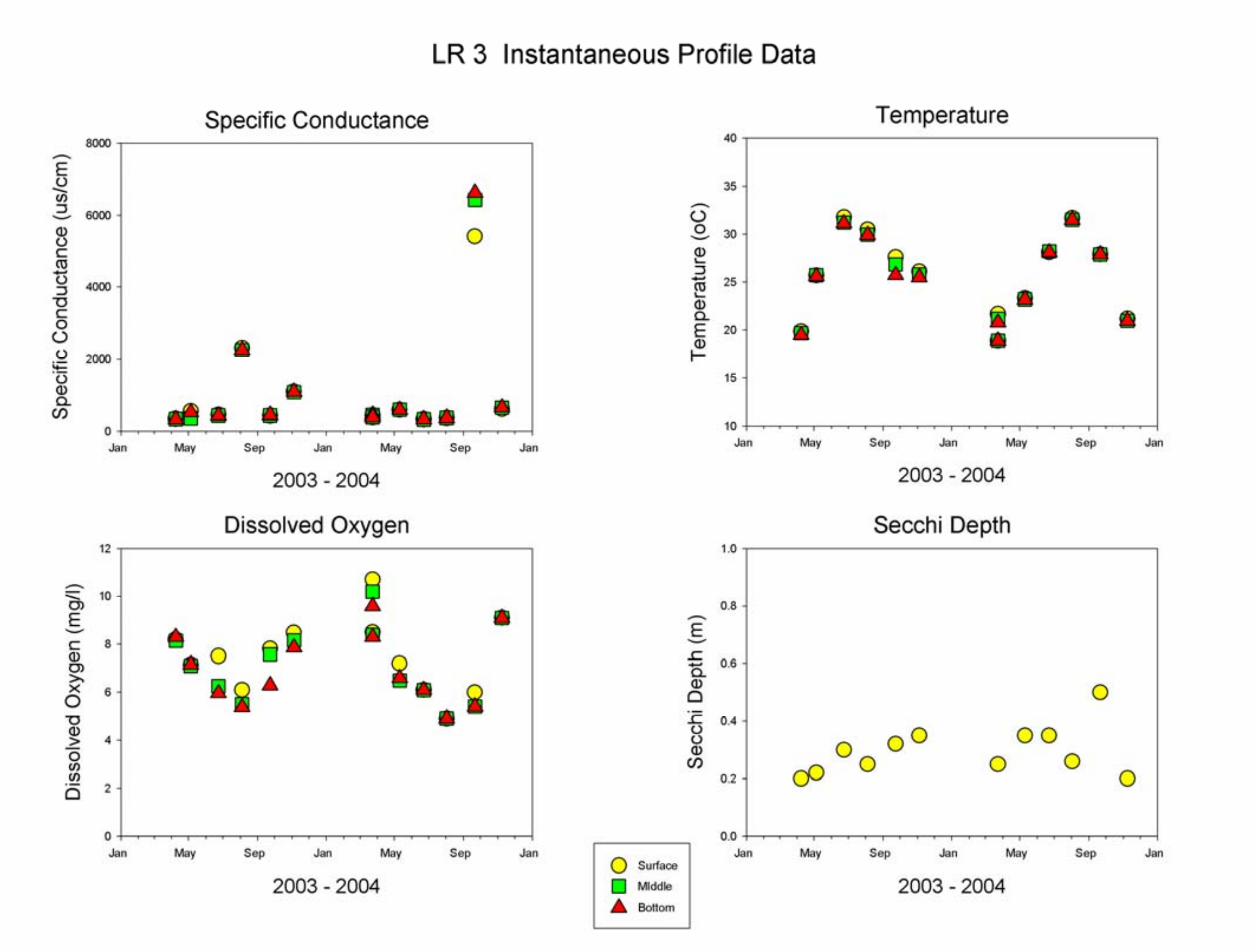


Figure 52.—Water column profile physicochemical parameter data at three depths and Secchi depth in Lost River at station LR 3, at confluence with Old River Lake approx. 1.3 km upstream of IH-10.

Table 32.—Water column profile physicochemical parameter data from datasonde measurements taken in Lost River at station LR 1.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
LR 1	4/8/2003	11:15 AM	0.3	0.30	20.91	6.7	75.5	396	7.36
LR 1	4/8/2003	11:15 AM	0.7		20.86	6.71	74.4	398	7.35
LR 1	4/8/2003	11:15 AM	1.6		20.77	6.71	74.2	396	7.35
LR 1	5/5/2003	11:09 AM	0.3	0.38	26.73	9.27	115.6	348	7.88
LR 1	5/5/2003	11:09 AM	1.0		26.64	8.73	110.8	348	7.89
LR 1	5/5/2003	11:09 AM	1.6		26.42	7.39	92	352	7.75
LR 1	6/23/2003	10:59 AM	0.3	0.51	30.66	8.3	111.6	354	7.85
LR 1	6/23/2003	10:59 AM	1.0		29.70	5.7	72.6	347	7.47
LR 1	6/23/2003	10:59 AM	2.0		28.77	2.18	26.2	343	7.09
LR 1	8/4/2003	11:15 AM	0.3	0.50	32.7	5.04	70.2	554	7.83
LR 1	8/4/2003	11:15 AM	0.9		32.39	4.64	63.7	556	7.76
LR 1	8/4/2003	11:15 AM	1.4		32.17	3.87	53	550	7.63
LR 1	9/23/2003	6:05 PM	0.3	0.44	27.9	7.72	98.8	350	7.2
LR 1	9/23/2003	6:05 PM	1.2		26.10	5.8	75.5	392	7.00
LR 1	9/23/2003	6:05 PM	2.3		24.70	2.63	31.8	407	6.82
LR 1	11/4/2003	3:45 PM	0.3	0.50	25.1	6.8	82.4	362	7.23
LR 1	11/4/2003	3:45 PM	1.4		23.60	5.9	69.8	363	7.24
LR 1	11/4/2003	3:45 PM	2.8		22.70	3.73	40.4	364	7.06
LR 1	3/23/2004	11:16 AM	0.3	0.20	20.4	9.5	107.5	437	7.6
LR 1	3/23/2004	11:16 AM	0.3	0.20	21.95	10.77	124.6	464	7.48
LR 1	3/23/2004	11:16 AM	1.2		20.30	9.2	102.6	449	7.60
LR 1	3/23/2004	11:16 AM	1.2		21.10	10.25	116	524	7.32
LR 1	3/23/2004	11:16 AM	2.2		19.70	5.9	69	570	7.00

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
LR 1	3/23/2004	11:16 AM	2.4		19.80	6.8	76.5	533	7.40
LR 1	5/10/2004	1:05 PM	0.3	0.35	23.1	8		351	7.8
LR 1	5/10/2004	1:05 PM	1.0		22.90	7.9		351	7.80
LR 1	5/10/2004	1:05 PM	2.5		22.90	7.9		351	7.80
LR 1	6/22/2004	10:25 AM	0.3	0.50	28.3	6.8	89.3	322	7.7
LR 1	6/22/2004	10:25 AM	0.7		28.30	6.8	89.1	322	7.70
LR 1	6/22/2004	10:25 AM	1.2		28.30	6.7	87.8	322	7.70
LR 1	8/2/2004	1:43 PM	0.3	0.53	31.4	5.3	71.2	382	7.7
LR 1	8/2/2004	1:43 PM	1.0		31.10	4.6	62.8	377	7.70
LR 1	8/2/2004	1:43 PM							
LR 1	9/21/2004	11:35 AM	0.3	0.40	28.4	5.5	71.6	361	7.6
LR 1	9/21/2004	11:35 AM	1.0		28.10	4.9	63.4	361	7.50
LR 1	9/21/2004	11:35 AM	2.1		27.90	4.3	55.6	362	7.50
LR 1	11/8/2004	3:00 PM	0.3	0.40	20.4	9.8	109.5	413.9	8.1
LR 1	11/8/2004	3:00 PM	1.0		19.10	7.3	80.9	419.2	7.70
LR 1	11/8/2004	3:00 PM	1.5		18.80	3.9	52	437	7.70

Table 33.—Water column profile physicochemical parameter data from datasonde measurements taken in Lost River at station LR 2.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
LR 2	4/8/2003	11:49 AM	0.3	0.30	20.57	7.5	82.5	344	7.35
LR 2	4/8/2003	11:49 AM	0.6		20.56	7.58	83.5	342	7.35
LR 2	4/8/2003	11:49 AM	1.4		20.51	7.81	87.1	342	7.43
LR 2	5/5/2003	10:10 AM	0.3	0.32	26.06	6.94	86.7	440	6.9
LR 2	5/5/2003	10:10 AM	1.0		26.01	6.41	79.2	437	7.03
LR 2	5/5/2003	10:10 AM	2.0		25.88	5.64	70	444	7.07
LR 2	6/23/2003	10:34 AM	0.3	0.50	29.43	7.37	96.7	353	7.72
LR 2	6/23/2003	10:34 AM	1.0		29.25	7.24	94.6	347	7.74
LR 2	6/23/2003	10:34 AM	1.6		29.25	7.19	94	342	7.72
LR 2	8/4/2003	11:57 AM	0.3	0.43	31.87	6.01	81.8	837	7.91
LR 2	8/4/2003	11:57 AM	1.0		31.40	5.27	71.6	814	7.78
LR 2	8/4/2003	11:57 AM	1.3		31.25	4.85	65.7	839	7.70
LR 2	9/23/2003	6:40 PM	0.3	0.41	28.1	7.94	101.6	327	8.02
LR 2	9/23/2003	6:40 PM	1.2		26.80	7.33	91.7	328	7.88
LR 2	9/23/2003	6:40 PM	2.3		26.20	0.31	5.3	329	7.26
LR 2	11/4/2003	4:25 PM	0.3	0.48	24.3	7.25	86.7	377	7.37
LR 2	11/4/2003	4:25 PM	1.0		23.40	7.62	89.6	357	7.40
LR 2	11/4/2003	4:25 PM	1.6		23.30	7.34	84.7	357	7.12
LR 2	3/23/2004	9:58 AM	0.3	0.30	19.3	9.7	104.5	356	7.6
LR 2	3/23/2004	9:58 AM	1.0		19.10	9.2	99.5	356	7.70
LR 2	3/23/2004	9:58 AM	1.9		18.90	8.6	91.5	356	7.60
LR 2	5/10/2004	2:02 PM	0.3	0.35	23	7.3		352	7.6
LR 2	5/10/2004	2:02 PM	1.0		23.00	7		352	7.60
LR 2	5/10/2004	2:02 PM	2.0		23.00	6.8		352	7.50

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
LR 2	6/22/2004	9:45 AM	0.3	0.50	28.2	6.2	79.4	325	7.4
LR 2	6/22/2004	9:45 AM	1.0		28.20	5.9	77.1	325	7.40
LR 2	6/22/2004	9:45 AM	2.0		28.20	6	78.3	326	7.50
LR 2	8/2/2004	1:15 PM	0.3	0.32	31.2	4.7	65	340	7.7
LR 2	8/2/2004	1:15 PM	1.5		31.10	4	54.1	341	7.60
LR 2	8/2/2004	1:15 PM							
LR 2	9/21/2004	9:56 AM	0.3	0.30	28.3	5.1	65.9	763	7.5
LR 2	9/21/2004	9:56 AM	0.9		28.20	4.8	62	746	7.40
LR 2	9/21/2004	9:56 AM	1.7		28.10	4.9	63.8	820	7.50
LR 2	11/8/2004	3:17 PM	0.3	0.20	21.9	10	112.9	330.8	8.3
LR 2	11/8/2004	3:17 PM	0.6		21.70	9.9	111.2	331.2	8.30
LR 2	11/8/2004	3:17 PM	1.0		21.70	9.9	112.1	330.3	8.30

Table 34.—Water column profile physicochemical parameter data from datasonde measurements taken in Lost River at station LR 3.

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
LR 3	4/8/2003	12:20 PM	0.3	0.20	19.88	8.2	89.3	334	7.7
LR 3	4/8/2003	12:20 PM	1.2		19.72	8.15	88.4	332	7.69
LR 3	4/8/2003	12:20 PM	3.4		19.51	8.3	90	328	7.75
LR 3	5/5/2003	9:15 AM	0.3	0.22	25.7	7.14	87.3	545	7.36
LR 3	5/5/2003	9:15 AM	1.0		25.70	7.1	87.1	353	7.56
LR 3	5/5/2003	9:15 AM	2.5		25.60	7.16	87.8	516	7.64
LR 3	6/23/2003	9:53 AM	0.3	0.30	31.77	7.51	102.8	448	7.96
LR 3	6/23/2003	9:53 AM	2.0		31.24	6.27	84.8	436	7.90
LR 3	6/23/2003	9:53 AM	3.6		31.15	5.96	80.5	430	7.86
LR 3	8/4/2003	12:26 PM	0.3	0.25	30.5	6.1	82	2309	7.8
LR 3	8/4/2003	12:26 PM	2.0		29.96	5.5	73.2	2250	7.89
LR 3	8/4/2003	12:26 PM	2.7		29.91	5.38	71.6	2250	7.86
LR 3	9/23/2003	7:25 PM	0.3	0.32	27.62	7.82	99.3	434	7.8
LR 3	9/23/2003	7:25 PM	2.0		26.83	7.58	95	437	7.80
LR 3	9/23/2003	7:25 PM	3.5		25.72	6.29	77.2	447	7.50
LR 3	11/4/2003	4:55 PM	0.3	0.35	26.1	8.48	104.9	1093	7.92
LR 3	11/4/2003	4:55 PM	2.0		25.80	8.16	100.6	1083	7.86
LR 3	11/4/2003	4:55 PM	3.7		25.50	7.87	97	1087	7.90
LR 3	3/23/2004	8:25 AM	0.3	0.25	18.9	8.5	92.4	387	8.4
LR 3	3/23/2004	8:25 AM	0.3	0.25	21.7	10.7	122	443	8.6
LR 3	3/23/2004	8:25 AM	1.5		21.20	10.2	115	444	8.50
LR 3	3/23/2004	8:25 AM	1.8		18.90	8.4	91.1	387	8.40
LR 3	3/23/2004	8:25 AM	2.7		20.80	9.6	108	443	8.50
LR 3	3/23/2004	8:25 AM	3.7		18.90	8.3	91	387	8.40

Station	Date	Arrival Time	Depth from Surface (m)	Secchi Depth (m)	Temp (deg C)	DO (mg/l)	DO (% sat.)	Spec Cond (uS/cm)	pH
LR 3	5/10/2004	2:30 PM	0.3	0.35	23.3	7.2		584	7.3
LR 3	5/10/2004	2:30 PM	2.0		23.20	6.5		594	7.40
LR 3	5/10/2004	2:30 PM	4.0		23.20	6.6		583	7.30
LR 3	6/22/2004	9:00 AM	0.3	0.35	28.1	6.1	80.8	324	7.5
LR 3	6/22/2004	9:00 AM	2.0		28.20	6.1	79.3	324	7.50
LR 3	6/22/2004	9:00 AM	3.3		28.10	6.1	79.9	324	7.60
LR 3	8/2/2004	12:46 PM	0.3	0.26	31.7	4.9	66.7	367	7.8
LR 3	8/2/2004	12:46 PM	1.3		31.50	4.9	66.2	365	7.90
LR 3	8/2/2004	12:46 PM	2.6		31.50	4.9	66.8	365	7.90
LR 3	9/21/2004	8:50 AM	0.3	0.50	27.9	6	76.6	5410	7.6
LR 3	9/21/2004	8:50 AM	1.7		27.90	5.4	72.2	6440	7.50
LR 3	9/21/2004	8:50 AM	3.4		27.90	5.4	71.4	6630	7.50
LR 3	11/8/2004	12:30 PM	0.3	0.20	21.2	9.1	102.6	610.4	7.8
LR 3	11/8/2004	12:30 PM	1.6		21.00	9.1	100.3	642.9	8.00
LR 3	11/8/2004	12:30 PM	3.2		21.00	9.1	100.2	649.5	7.90

MDS ordination of the surface measurements from physicochemical profiles is displayed in Figure 53. Data from Cow Bayou and Lost River stations appear near each other on the chart, but apparently in two distinct groups with minimal overlap. Surface measurements from profiles taken in Cow Bayou are more variable than those of Lost River, which cluster together fairly tightly.

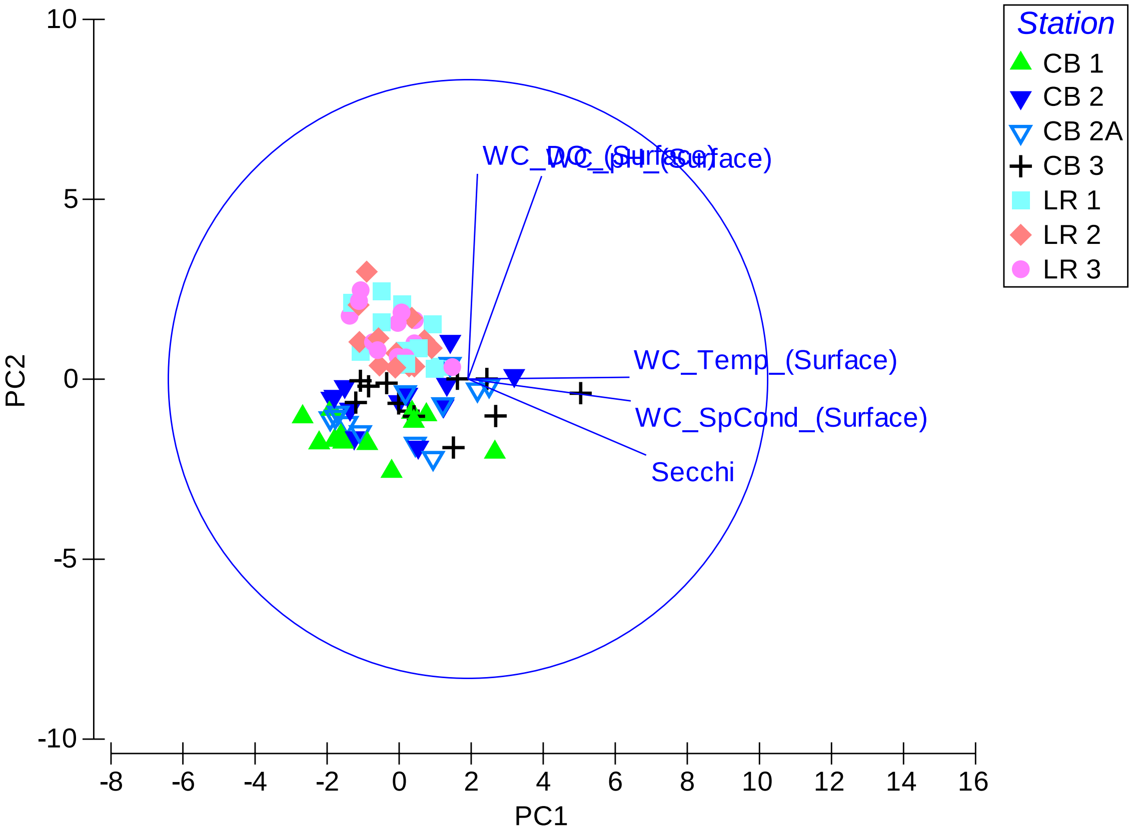


Figure 53.—PCA plot of the surface measurements from the physicochemical profiles taken in Cow Bayou and Lost River.

PCA analysis reveals that the first two principal components explain about 70% of the variability in the data (Table 35). The dimensionless x and y axes of the MDS configuration in Figure 53 represent the first and second principal components, respectively. The first component is positively correlated with temperature, specific conductance, and Secchi depth, so it represents hotter, saltier, and clearer water conditions. See Figure 54, which displays increasing specific conductance moving across the chart from left to right. The second component is positively correlated with pH and DO, so it represents higher pH and DO conditions. It can be seen that the samples from CB 1 hug the bottom left corner of the chart, representing fresher conditions, lower water clarity, and most importantly, lower DO. Lost River samples are generally higher on the y axis than Cow Bayou samples, representing higher DO and pH.

Table 35.—Correlations of the surface measurements from the physicochemical profiles temperature (degrees Celsius), pH (standard units), DO (mg/l), specific conductance (umhos/cm), and Secchi depth (meters), with the first three principal components, cumulative percent variation for each principal component, and eigenvalues, for Cow Bayou and Lost River.

Variable	**PC 1**	**PC 2**	**PC 3**
Cumulative percent	37.8	69.9	88.5
Eigenvalue	1.89	1.6	0.932
Temperature	0.539	0.006	0.656
pH	0.245	0.678	0.274
DO	0.031	0.686	-0.404
Sp. Cond.	0.543	-0.073	-0.544
Secchi	0.594	-0.254	-0.189

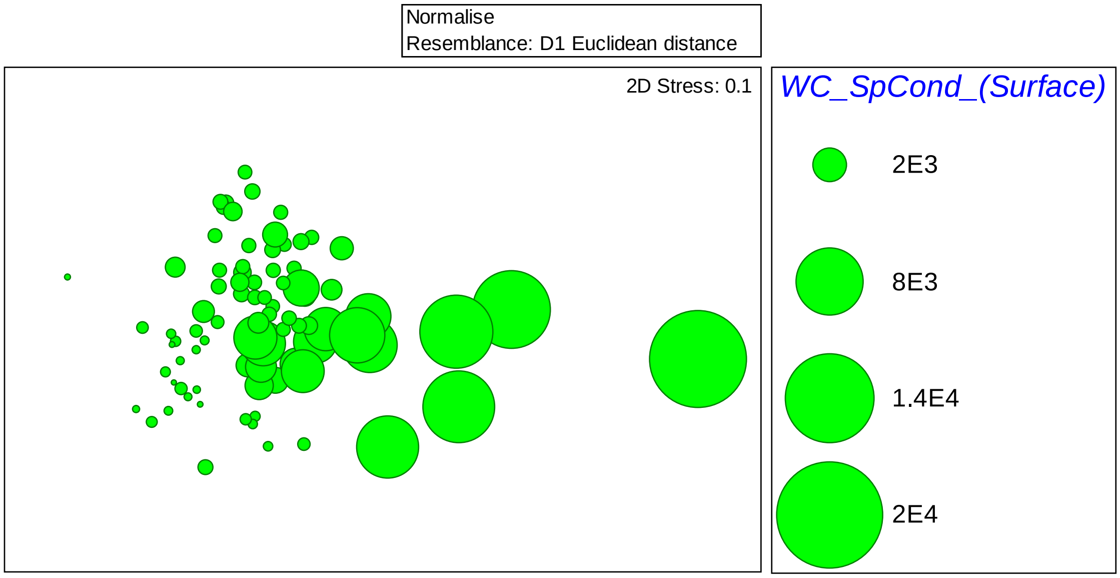


Figure 54.— MDS ordination of the surface measurements from the physicochemical profiles taken in Cow Bayou and Lost River as in Figure 53, but overlaid onto each sample is specific conductance. Size of the bubble is represented by the scale (specific conductivity in uhos/cm).

ANOSIM tests showed that surface measurements from all four Cow Bayou stations were similar to each other (Global R = 0.035, $p < 0.278$; Figure 55). The same was true for Lost River (Global R = -0.076, $p < 0.86$). Since surface physicochemical measurements were not distinct within streams, the measurements for each stream were combined and

ANOSIM analysis run for a comparison of Cow Bayou with Lost River measurements. The difference was statistically significant (Global R = 0.25, $p < 0.001$).

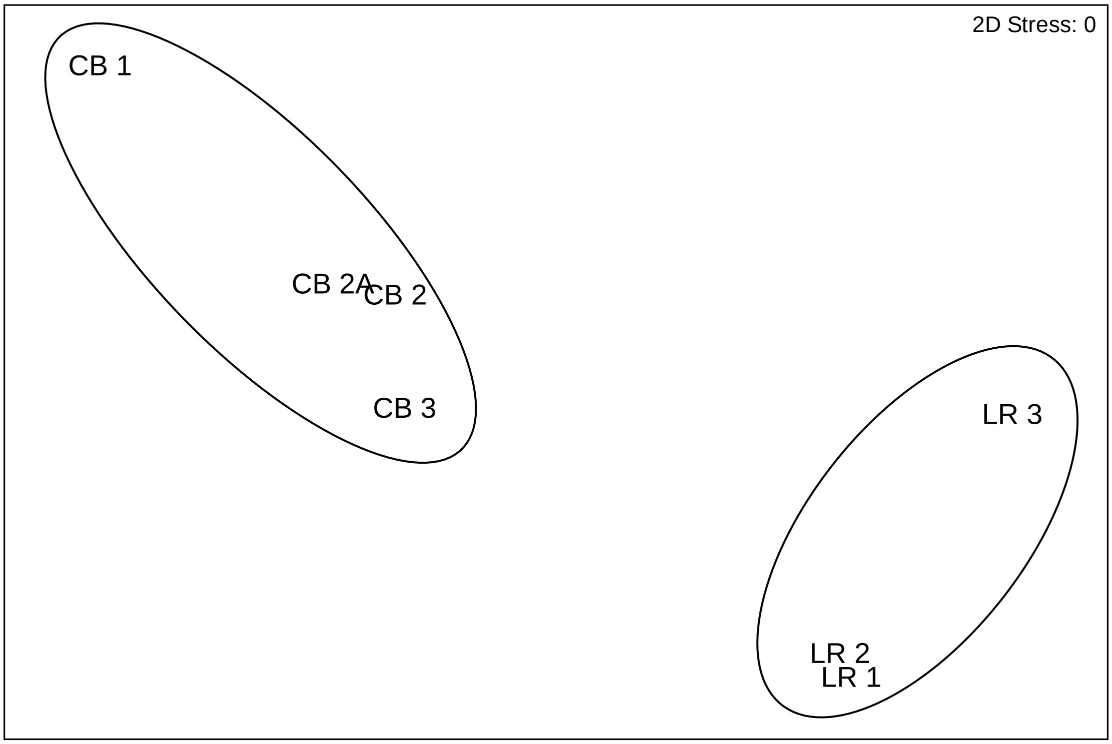
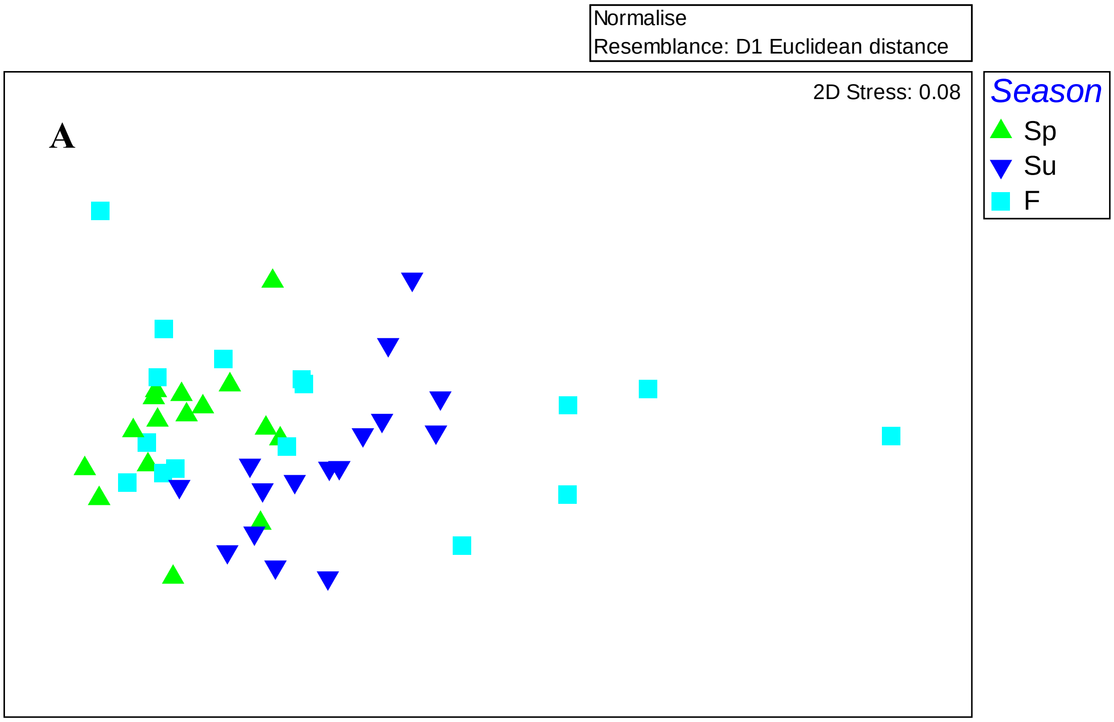


Figure 55.—Means plot MDS ordination of the stations based on surface measurements from the physicochemical profiles taken in Cow Bayou and Lost River. Stations within an ellipse are not significantly different based on ANOSIM comparisons among the stations ($p > 0.05$).

Both Cow Bayou and Lost River data showed seasonality, as revealed by ANOSIM (Figure 56). Cow Bayou samples were different among seasons (Global R = 0.234, $p < 0.001$), this driven primarily by the difference between spring and summer samples (R = 0.563, $p < 0.001$). Summer samples are much hotter and saltier, as evinced by the summer samples being positioned to the right of the spring samples on Figure 56A. Lost River samples were also different among seasons (Global R = 0.303, $p < 0.001$), again driven by differences between spring and summer measurements (R = 0.705, $p < 0.001$).

Middle and bottom measurements from the physicochemical profiles showed some stratification in the water column, as was seen in Figure 45 through Figure 52. Rank correlations between the surface and middle measurements was $\rho = 0.862$ ($p < 0.001$) for Cow Bayou and $\rho = 0.817$ ($p < 0.001$) between the surface and bottom measurements. For Lost River, $\rho = 0.872$ ($p < 0.001$) for the surface and middle measurements and 0.566 ($p < 0.001$) for the surface and bottom measurements. More vertical stratification was evident in Lost River.



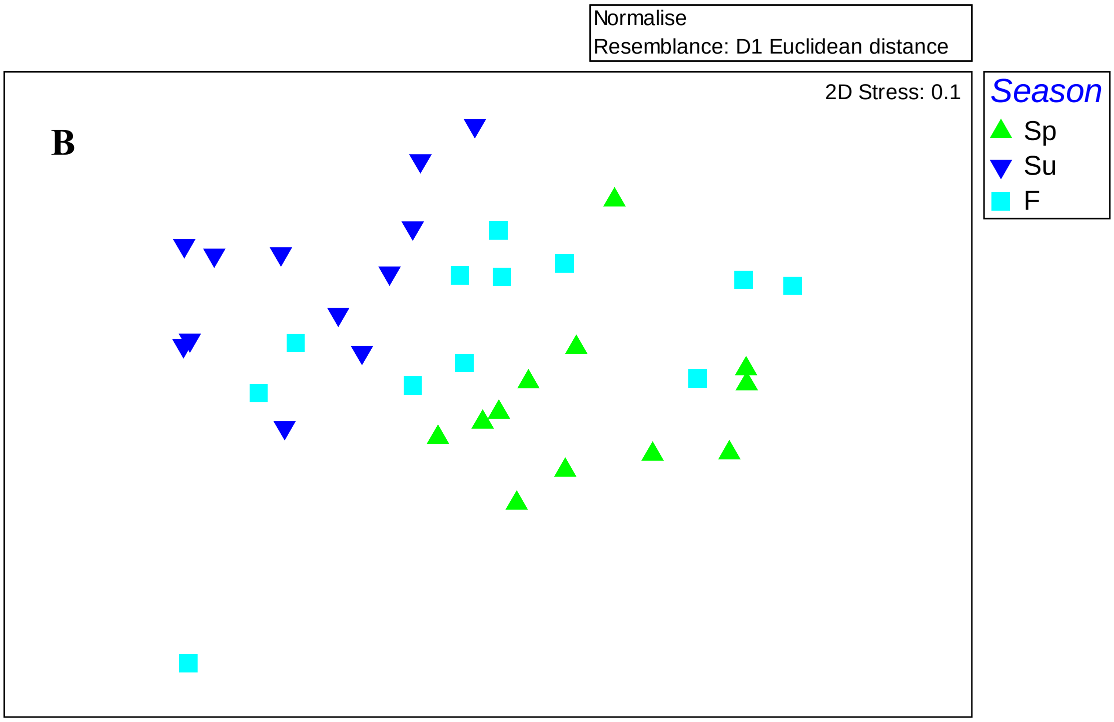


Figure 56.—MDS ordination of the surface measurement from the physicochemical profiles overlaid by season, for Cow Bayou (A) and Lost River (B).

Water Chemistry

Results of lab analysis on water samples for CB 1 are presented in Table 36. Nutrient concentrations were frequently at or below the laboratory reporting limit. For example, ortho-phosphorus concentrations were reported at the ambient water reporting limit (AWRL) of 0.06 mg/l for every sample except three. Those samples were reported as <0.18 mg/l; for these three samples the laboratory was unable to achieve the AWRL. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a). Total phosphorus ranged from 0.05 to 0.15 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). Ammonia ranged from 0.05 (the AWRL) to 0.16. The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

Chlorophyll *a* can be viewed as a nutrient response parameter. The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at CB 1 ranged from 1 (the AWRL) to 26.7 ug/L, with two samples exceeding the screening level, one collected on 2 Aug 2004 and one on 22 Sep 2004.

TDS, chloride and sulfate concentrations in a tidally-influenced water body would be expected to track with specific conductance or salinity measurements. TDS ranged from 100 to 3,920 mg/L at CB 1. A cursory comparison of these parameters with 24-hour means for specific conductance confirmed this expectation. On the sampling trip where TDS was 100 mg/L, the mean specific conductance was 58 uS/cm. On the sampling trip where TDS was 3,920 mg/L, mean specific conductance was 4,841 uS/cm. Chloride and sulfate concentrations followed the same general pattern. These results will not be discussed further in the station by station results.

Some parameters did not vary much over the course of the study, or from station to station. All $CBOD_5$ measurements ranged from 3 to 4 mg/L. Most nitrite concentrations were measured at the laboratory's detection limit. Most nitrate measurements were at the laboratory's detection limit. The highest nitrate measured was 0.55 mg/L at LR 1 on 10 May 2004. The screening level for nitrate + nitrite in tidal streams is 1.83 mg/L, so none of these measurements even came close to the screening level. These will not be discussed further in the station by station results.

Table 36.—Water chemistry data from grab samples collected from Cow Bayou at station CB 1, 50 yds (45.7 m) downstream of Cole Creek confluence.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	CBOD$_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
CB 1	4/7/2003	0.3	242	29	20	18	8	3	1.07	8.65	<3	0.16	0.14	<0.05	1.58	0.12	<0.06
CB 1	5/7/2003	0.3	266	69	34	14	3	<1	<1	<1	<3	0.14	0.08	<0.05	1.08	0.11	<0.06
CB 1	6/24/2003	0.3	1,080	476	95	10	15	5	1.07	55.4	4	<0.05	<0.05	<0.05	0.72	<0.05	<0.06
CB 1	8/6/2003	0.3	844	357	67	10	11	2	6.94	33	<3	0.08	<0.05	<0.05	0.7	0.06	<0.06
CB 1	8/6/2003	0.3	804	357	67	10	14	2	8.01	35	<3	<0.05	<0.05	<0.05	0.68	0.06	<0.06
CB 1	9/22/2003	0.3	110	3	4	19	35	6	3.4	<1	<3	0.06	<0.05	<0.05	1.43	0.09	<0.06
CB 1	11/5/2003	0.3	141	19	9	16	5	2	3.63	<1	<3	0.08	<0.05	<0.05	0.86	0.1	<0.06
CB 1	3/24/2004	0.3	199	13	6	19	28	5	<1	1.01	<3	0.14	0.05	<0.05	1.7	0.05	<0.06
CB 1	5/12/2004	0.3	105	6	5	12	58	9	1.02	<1	<3	<0.05	0.05	<0.05	0.98	0.11	<0.06
CB 1	6/23/2004	0.3	115	6	6	12	20	4	1.07	1.92	<3	<0.05	0.07	<0.05	0.96	0.1	<0.06
CB 1	8/2/2004	0.3	188	27	28	16	11	4	23	<1	4	<0.05	0.07	<0.05	1	0.13	<0.06
CB 1	9/22/2004	0.3	3,860	2,020	279	8	10	2	26.7	6.47	<3	<0.05	<0.15	<0.15	0.82	<0.05	<0.18
CB 1	11/8/2004	0.3	101	4	8	18	22	5	1.7	<1	<3	<0.05	<0.05	<0.05	0.79	0.09	<0.06
CB 1	5/7/2003	5.6	284	69	34	14	3	<1			<3	0.14	0.08	<0.05	1.05	0.1	<0.06
CB 1	6/24/2003	5.2	1,410	656	116	10	26	4			<3	0.05	<0.05	<0.05	0.66	0.05	<0.06
CB 1	8/6/2003	5.5	840	364	67	10	25	5			<3	<0.05	<0.05	<0.05	0.82	0.07	<0.06
CB 1	9/22/2003	5	105	4	4	19	56	8			<3	0.07	<0.05	<0.05	1.17	0.11	<0.06
CB 1	11/5/2003	4	139	19	9	16	7	2			<3	0.07	<0.05	<0.05	0.99	0.15	<0.06
CB 1	3/24/2004	4.6	197	13	6	19	34	7			<3	0.16	0.05	<0.05	1.77	<0.05	<0.06
CB 1	3/24/2004	4.6	199	13	6	19	36	8			<3	0.14	0.05	<0.05	1.7	0.12	<0.06
CB 1	5/12/2004	4.4	107	7	6	12	57	8			<3	<0.05	0.06	<0.05	1.05	0.12	<0.06
CB 1	6/23/2004	4	122	7	6	12	36	6			<3	0.05	0.07	<0.05	0.93	0.1	<0.06
CB 1	8/2/2004	3.9	185	27	29	16	7	2			<3	0.08	0.08	<0.05	0.88	0.11	<0.06
CB 1	9/22/2004	4.2	3,920	2,030	281	8	17	2			<3	<0.05	<0.15	<0.15	0.74	<0.05	<0.18
CB 1	9/22/2004	4.2	3,870	2,030	280	8	19	2			<3	<0.05	<0.15	<0.15	0.73	<0.05	<0.18
CB 1	11/8/2004	15	103	4	8	18	27	4			<3	0.05	<0.05	<0.05	0.83	0.1	<0.06
CB 1	11/8/2004	15	100	4	8	18	18	2			<3	0.08	<0.05	<0.05	0.82	0.09	<0.06
	MEANS:		727.26	320	55	14	23	4	6.1	11.3	3.1	0.078	0.087	0.06	1.02	0.1	0.07

Results of lab analysis on water samples for CB 2 are presented in Table 37. Nutrient concentrations were frequently at or below the laboratory reporting limit. All but one of the ortho-phosphorus concentrations were reported below the laboratory reporting limit, although several times the AWRL of 0.06 mg/l was not achieved. The "highest" ortho-phosphorus measurement was reported at <0.36 mg/L. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a). Total phosphorus ranged from 0.05 to 0.37 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). Ammonia ranged from 0.05 (the AWRL) to 0.25. The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at CB 2 ranged from 1 (the AWRL) to 34.2 ug/L, with three samples exceeding the screening level, all collected in late summer or fall.

Table 37.—Water chemistry data from grab samples collected from Cow Bayou at station CB 2, at SH 87.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	CBOD$_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
CB 2	4/7/2003	0.3	238	48	13	15	11	4	<1	16.8	<3	0.25	0.12	<0.05	1.52	0.18	<0.06
CB 2	5/7/2003	0.3	1,230	654	104	10	10	2	4.27	45.8	<3	0.06	<0.05	<0.05	0.91	0.11	<0.06
CB 2	6/24/2003	0.3	2,590	1,400	213	7	11	4	<1	29.4	<3	<0.05	<0.05	<0.05	0.73	0.09	<0.06
CB 2	6/24/2003	0.3	2,720	1,410	213	6	12	4	<1	16.3	<3	<0.05	<0.05	<0.05	0.82	0.1	<0.06
CB 2	8/6/2003	0.3		963	140	8	16	5	15	22.4	<3	0.06	<0.05	<0.05	0.77	0.12	<0.06
CB 2	9/22/2003	0.3	110	18	5	16	21	5	4.35	<1	<3	0.07	0.07	<0.05	1.43	0.12	<0.06
CB 2	11/5/2003	0.3	1,850	952	134	12	10	4	34.2	<1	<3	<0.05	<0.10	<0.10	0.82	0.09	<0.12
CB 2	3/24/2004	0.3	203	36	10	13	26	5	1.56	<1	<3	0.16	0.08	<0.05	1.28	0.14	<0.06
CB 2	5/12/2004	0.3	129	22	6	11	57	8	1.42	<1	<3	<0.05	0.05	<0.05	0.95	0.37	<0.06
CB 2	6/23/2004	0.3	129	27	8	9	15	4	2.14	<1	<3	0.09	<0.05	<0.05	0.86	0.13	<0.06
CB 2	8/2/2004	0.3	556	236	38	14	11	6	21.9	<1	4	<0.05	<0.05	<0.05	0.92	0.11	<0.06
CB 2	8/2/2004	0.3	522	234	38	14	11	6	20.8	4.59	4	<0.05	<0.05	<0.05	0.98	0.11	<0.06
CB 2	9/22/2004	0.3	6,200	3,290	462	5	9	3	25.4	3.6	<3	<0.05	<0.25	<0.25	0.68	<0.05	<0.30
CB 2	11/8/2004	0.3	152	31	9	17	10	2	2.67	<1	<3	0.06	<0.05	<0.05	0.77	0.08	<0.06
CB 2	5/7/2003	4.4	1,660	786	124	9	13				<3	0.14	<0.05	<0.05	0.59	0.12	0.11
CB 2	6/24/2003	4.3	2,760	1,450	219	7	17	5			<3	0.05	<0.05	<0.05	0.75	0.11	<0.06
CB 2	8/6/2003	4.6	1,900	953	141	8	40	8			<3	0.07	<0.05	<0.05	0.95	0.15	<0.06
CB 2	9/22/2003	4.1	115	18	5	16	24	5			<3	0.1	0.07	<0.05	1.04	0.12	<0.06
CB 2	11/5/2003	2.5	4,090	2,240	313	8	15	3			<3	0.07	<0.20	<0.20	0.67	0.08	<0.24
CB 2	11/5/2003	2.5	4,060	2,230	311	8	17	3			<3	0.07	<0.20	<0.20	0.84	0.08	<0.24
CB 2	3/24/2004	3.8	202	36	10	13	34	6			<3	0.13	0.08	<0.05	1.34	0.13	<0.06
CB 2	5/12/2004	4.2	123	22	6	11	52	9			<3	0.06	0.05	<0.05	1.11	0.15	<0.06
CB 2	6/23/2004	3.6	131	28	8	9	16	4			<3	0.08	<0.05	<0.05	0.78	0.13	<0.06
CB 2	6/23/2004	3.6	129	27	8	9	13	3			<3	0.09	<0.05	<0.05	0.85	0.15	<0.06
CB 2	8/2/2004	2.9	832	424	68	12	10	2			<3	0.06	<0.05	<0.05	0.81	0.1	<0.06
CB 2	9/22/2004	4.5	7,260	3,870	541	4	45	6			<3	<0.05	<0.30	<0.30	0.7	0.1	<0.36
CB 2	11/8/2004	13	149	31	9	16	20	3			<3	0.09	<0.05	<0.05	0.83	0.12	<0.06
	MEANS:		1,540	794	117	10.6	20.2	4.6	9.76	10.42	3.1	0.08	0.09	0.08	0.91	0.12	0.10

Results of lab analysis on water samples for CB 2A are presented in Table 38. Nutrient concentrations were frequently at or below the laboratory reporting limit. All of the ortho-phosphorus concentrations were reported below the laboratory reporting limit, although several times the AWRL of 0.06 mg/l was not achieved. The “highest” ortho-phosphorus measurement was reported at <0.6 mg/L. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a). Total phosphorus ranged from 0.05 to 0.27 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). Ammonia ranged from 0.05 (the AWRL) to 0.17. The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at CB 2A ranged from 1 (the AWRL) to 43.3 ug/L, with three samples exceeding the screening level, all collected in late summer or fall.

Table 38.—Water chemistry data from grab samples collected from Cow Bayou at station CB 2A, approximately 2.2 km upstream of SH 87 in original stream channel northeast of Bridge City.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	$CBOD_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
CB 2A	4/7/2003	0.3	247	51	11	17	11	4	2.14	20.3	<3	0.17	0.1	<0.05	3.4	0.18	<0.06
CB 2A	5/7/2003	0.3	1,030	474	74	12	7	3	<1	<1	<3	0.09	<0.05	<0.05	0.87	0.07	<0.06
CB 2A	6/24/2003	0.3	3,030	1,580	232	8	11	3	<1	14	<3	<0.05	<0.05	<0.05	0.83	0.07	<0.06
CB 2A	8/6/2003	0.3	1,780	929	126	10	12	5	22.4	2.99	<3	<0.05	<0.05	<0.05	0.95	0.12	<0.06
CB 2A	9/22/2003	0.3	113	16	4	16	22	5	9.61	2.35	<3	<0.05	<0.05	<0.05	0.97	0.09	<0.06
CB 2A	11/5/2003	0.3	1,780	923	131	12	11	4	43.3	<1	4	<0.05	<0.05	<0.05	0.98	0.08	<0.06
CB 2A	3/24/2004	0.3	190	34	8	14	22	4	2.14	<1	<3	0.1	<0.05	<0.05	1.28	0.14	<0.06
CB 2A	5/12/2004	0.3	118	20	8	10	42	7	1.87	<1	<3	<0.05	<0.05	<0.05	0.9	0.14	<0.06
CB 2A	5/12/2004	0.3	123	20	8	10	45	8	2.5	<1	3	<0.05	<0.05	<0.05	0.92	0.15	0.07
CB 2A	6/23/2004	0.3	125	30	8	9	12	3	5.34	1.76	<3	<0.05	<0.05	<0.05	0.82	0.1	<0.06
CB 2A	8/2/2004	0.3	452	190	34	14	9	4	18.2	7.26	3	<0.05	<0.05	<0.05	0.91	0.11	<0.06
CB 2A	9/22/2004	0.3	5,290	2,880	399	6	10	2	34.7	2.67	<3	<0.05	<0.25	<0.25	0.8	0.06	<0.30
CB 2A	11/8/2004	0.3	193	53	11	16	11	2	2.85	<1	<3	0.06	<0.05	<0.05	0.76	0.08	<0.06
CB 2A	5/7/2003	2.3	296	491	77	11	18	3			<3	0.07	<0.05	<0.05	0.98	0.09	<0.06
CB 2A	6/24/2003	2.1	3,000	1,570	231	8	15	2			<3	0.05	<0.05	<0.05	0.89	0.1	<0.06
CB 2A	8/6/2003	2.1	1780	939	127	10	16	5			<3	<0.05	<0.05	<0.05	0.97	0.12	<0.06
CB 2A	9/22/2003	2.1	107	16	4	16	24	6			<3	0.05	<0.05	<0.05	0.99	<0.05	<0.06
CB 2A	11/5/2003	2.1	2,660	1,360	190	11	16	4			<3	0.11	<0.15	<0.15	0.97	0.07	<0.18
CB 2A	3/24/2004	2.3	190	34	8	14	30	7			<3	0.11	<0.05	<0.05	1.35	0.14	<0.06
CB 2A	5/12/2004	2.5	109	19	8	10	42	7			3	<0.05	<0.05	<0.05	0.93	0.27	<0.06
CB 2A	6/23/2004	2	129	30	8	9	12	3			<3	<0.05	<0.05	<0.05	0.78	0.12	<0.06
CB 2A	8/2/2004	1.9	382	161	31	15	11	3			<3	0.06	<0.05	<0.05	0.92	0.12	<0.06
CB 2A	9/22/2004	2.3	5,540	2,910	404	6	23	4			<3	<0.05	<0.25	<0.25	0.82	0.08	<0.30
CB 2A	11/8/2004	7	177	52	11	16	12	4			<3	<0.05	<0.05	<0.05	0.84	0.07	<0.06
	MEANS:		1,202	616	89.7	11.7	18.5	4.2	11.31	4.41	3.0	0.07	0.07	0.07	1.04	0.11	0.09

Results of lab analysis on water samples for CB 3 are presented in Table 39. Nutrient concentrations were frequently at or below the laboratory reporting limit. All of the ortho-phosphorus concentrations were reported below the laboratory reporting limit, although several times the AWRL of 0.06 mg/l was not achieved. The "highest" ortho-phosphorus measurement was reported at <0.60 mg/L. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a), so it is possible that this measurement reflected elevated ortho-phosphorus. Total phosphorus ranged from 0.05 to 0.27 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). Ammonia ranged from 0.05 (the AWRL) to 0.17. The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at CB 3 ranged from 1 (the AWRL) to 18.5 ug/L. CB 3 is the only station in Cow Bayou that did not have at least one chlorophyll *a* measurement above the screening level.

Table 39.—Water chemistry data from grab samples collected from Cow Bayou at station CB 3, 2400 ft (732 m) upstream of Sabine River confluence.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	$CBOD_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
CB 3	4/7/2003	0.3	189	50	20	9	8	3	<1	15.5	<3	0.1	0.07	<0.05	0.89	0.09	<0.06
CB 3	5/7/2003	0.3	2,730	1,450	218	6	9	3	6.94	<1	<3	0.08	<0.05	<0.05	0.58	0.08	<0.06
CB 3	5/7/2003	0.3	2,680	1,460	218	6	9	3	3.08	<1	<3	0.07	<0.05	<0.05	0.77	0.05	<0.06
CB 3	6/24/2003	0.3	1,480	737	128	7	11	4	<1	15.9	<3	<0.05	0.09	<0.05	0.58	0.09	<0.06
CB 3	8/6/2003	0.3	1,820	951	152	6	14	4	12.8	7.37	<3	<0.05	<0.05	<0.05	0.65	0.1	<0.06
CB 3	9/22/2003	0.3	904	446	73	8	10	2	4.79	<1	<3	<0.05	<0.05	<0.05	0.55	0.07	<0.06
CB 3	9/22/2003	0.3	852	447	74	8	13	2	1.6	1.6	<3	<0.05	<0.05	<0.05	0.54	0.07	<0.06
CB 3	11/5/2003	0.3	4,780	2,770	387	6	6	3	13.5	<1	<3	<0.05	<0.25	<0.25	0.7	0.08	<0.30
CB 3	3/24/2004	0.3	348	146	35	6	13	2	2.67	<1	<3	<0.05	<0.05	<0.05	0.5	<0.05	<0.06
CB 3	5/12/2004	0.3	133	27	8	11	34	7	3.17	<1	<3	<0.05	<0.05	<0.05	0.91	0.12	<0.06
CB 3	6/23/2004	0.3	176	53	17	9	8	3	<1	3.36	<3	0.08	<0.05	<0.05	0.74	0.12	<0.06
CB 3	8/2/2004	0.3	1,950	1,040	162	6	7	2	7.12	3.35	<3	<0.05	<0.10	<0.10	0.54	<0.05	<0.12
CB 3	9/22/2004	0.3	9,890	5,180	718	3	7	<1	18.5	<1	<3	<0.05	<0.40	<0.40	0.57	0.05	<0.48
CB 3	11/8/2004	0.3	526	209	38	10	10	2	3.34	1.33	<3	0.07	0.06	<0.05	0.54	0.08	<0.06
CB 3	5/7/2003	5.3	5,850	1,540	229	6	20	3			<3	0.11	<0.05	<0.05	0.73	0.07	<0.06
CB 3	5/7/2003	5.3	3,140	1,540	231	6	16	2			<3	0.1	<0.05	<0.05	0.65	0.08	<0.06
CB 3	6/24/2003	5.2	1,860	928	154	6	8	<1			<3	0.06	0.1	<0.05	0.58	0.08	<0.06
CB 3	8/6/2003	3.9	2,230	1,140	180	6	13	3			<3	0.06	<0.05	<0.05	0.67	0.1	<0.06
CB 3	9/22/2003	6	960	480	78	8	26	4			<3	0.06	<0.05	<0.05	0.69	<0.05	<0.06
CB 3	11/5/2003	4.7	8,970	4,480	624	3	22	4			<3	0.05	<0.35	<0.35	0.64	0.1	<0.42
CB 3	3/24/2004	4.7	414	183	40	6	27	4			<3	<0.05	<0.05	<0.05	0.48	0.06	<0.06
CB 3	5/12/2004	5.7	131	26	7	11	47	8			<3	0.05	<0.05	<0.05	1.01	0.28	<0.06
CB 3	6/23/2004	3.6	182	54	17	9	13	4			<3	0.09	<0.05	<0.05	0.73	<0.05	<0.06
CB 3	8/2/2004	4	2,220	1,190	182	6	11	2			<3	<0.05	<0.10	<0.10	0.46	0.07	<0.12
CB 3	9/22/2004	5.5	13,000	6,980	968	2	33	7			<3	<0.05	<0.50	<0.50	0.54	0.08	<0.60
CB 3	11/8/2004	18	600	269	46	10	30	7			<3	0.07	0.06	<0.05	0.67	0.1	<0.06
	MEANS:		2,616	1,300	192	6.9	16.3	3.5	5.75	3.96	3	0.06	0.11	0.10	0.65	0.08	0.125

Results of lab analysis on water samples for LR 1 are presented in Table 40. Nutrient concentrations were frequently at or below the laboratory reporting limit. About half of the ortho-phosphorus concentrations were reported below the AWRL. Ortho-phosphorus ranged from 0.06 to 0.16. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a). Total phosphorus ranged from 0.07 to 0.28 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). Ammonia ranged from 0.05 (the AWRL) to 0.08. The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at LR 1 ranged from 1 (the AWRL) to 48.7 ug/L. Two samples exceeded the screening level, one taken on 23 Mar 2004 and one collected on 8 Nov 2004.

Table 40.—Water chemistry data from grab samples collected from Lost River at station LR 1, at the Chambers County line and 5.4 km upstream of John Wiggins Bayou.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	CBOD$_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
LR 1	4/8/2003	0.3	254	43	30	6	37	4	<1	76.6	3	0.08	0.24	<0.05	0.81	0.11	<0.06
LR 1	5/5/2003	0.3	212	30	28	6	18	6	<1	101	4	<0.05	<0.05	<0.05	0.79	0.09	<0.06
LR 1	6/23/2003	0.3	204	25	32	6	17	4	<1	45.5	<3	<0.05	<0.05	<0.05	0.65	0.09	<0.06
LR 1	8/4/2003	0.3	322	77	37	6	16	3	10.3	<1	<3	<0.05	<0.05	<0.05	0.74	0.12	<0.06
LR 1	9/23/2003	0.3	222	38	30	7	16	4	12.3	10.9	<3	<0.05	<0.05	<0.05	0.47	0.16	0.09
LR 1	11/4/2003	0.3	228	32	28	6	30	6			<3	0.07	<0.05	<0.05	0.73	0.16	<0.06
LR 1	3/23/2004	0.3	266	53	37	7	39	6	31.2	16.2	3	<0.05	0.16	<0.05	0.94	0.08	<0.06
LR 1	5/10/2004	0.3	218	29	43	6	53	6	13.4	2.35	<3	<0.05	0.54	<0.05	0.79	0.11	0.07
LR 1	6/22/2004	0.3	205	23	34	6	50	7	9.61	<1	<3	<0.05	0.3	<0.05	0.66	0.15	0.09
LR 1	6/22/2004	0.3	202	23	34	6	52	7	9.61	3.1	<3	<0.05	0.3	<0.05	0.64	0.13	0.08
LR 1	8/2/2004	0.3	244	36	27	7	17	4	12.3	4.17	<3	<0.05	<0.05	<0.05	0.73	0.15	<0.06
LR 1	9/21/2004	0.3	228	26	28	6	20	6	18	8.61	<3	<0.05	<0.05	<0.05	0.61	0.07	<0.06
LR 1	11/8/2004	0.3	282	54	43	7	22	8	48.7	3.6	4	<0.05	0.05	<0.05	0.99	0.18	<0.06
LR 1	5/5/2003	1.8	210	31	29	6	24	7			<3	<0.05	<0.05	<0.05	<0.05	0.1	<0.06
LR 1	6/23/2003	1.8	196	25	32	6	16	2			<3	0.05	<0.05	<0.05	0.75	0.11	<0.06
LR 1	8/4/2003	1.5	308	77	37	6	28	5			<3	<0.05	<0.05	<0.05	0.6	0.1	<0.06
LR 1	9/23/2003	2.3	262	61	30	9	32	7			<3	<0.05	<0.05	<0.05	0.74	0.28	0.16
LR 1	11/4/2003	2.8	218	33	28	6	16	4	3.74	26.9	<3	<0.05	<0.05	<0.05	0.64	0.18	<0.06
LR 1	3/23/2004	2.1	290	70	40	7	78	11			3	0.07	0.06	<0.05	1.05	0.12	<0.06
LR 1	5/10/2004	2.7	220	29	43	6	61	10			<3	<0.05	0.55	<0.05	0.71	0.15	0.06
LR 1	6/22/2004	1.2	206	23	34	6	63	7			<3	<0.05	0.3	<0.05	0.66	0.13	0.06
LR 1	8/2/2004	1	240	34	26	7	19	4			<3	<0.05	<0.05	<0.05	0.73	0.16	<0.06
LR 1	9/21/2004	2.3	228	26	28	6	66	10			<3	<0.05	<0.05	<0.05	0.74	0.13	<0.06
LR 1	9/21/2004	2.3	228	26	28	6	84	12			<3	<0.05	<0.05	<0.05	0.76	0.12	<0.06
LR 1	11/8/2004	1.7	300	58	45	6	45	9			<3	0.05	0.12	<0.05	0.75	0.17	<0.06
	MEANS:		239.7	39.3	33.2	6.4	36.8	6.4	13.24	23.15	3.1	0.053	0.135	0.05	0.709	0.134	0.068

Results of lab analysis on water samples for LR 2 are presented in Table 41. Nutrient concentrations were frequently at or below the laboratory reporting limit. About half of the ortho-phosphorus concentrations were reported below the AWRL. Ortho-phosphorus ranged from 0.06 to 0.10 mg/L. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a). Total phosphorus ranged from 0.10 to 0.40 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). Ammonia ranged from 0.05 (the AWRL) to 0.06 mg/L. The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at LR 2 ranged from 1 (the AWRL) to 34.7 ug/L. Two samples exceeded the screening level, one taken on 23 Jun 2003 and one collected on 8 Nov 2004.

Table 41.—Water chemistry data from grab samples collected from Lost River at station LR 2, approximately 2.6 km upstream of the confluence with John Wiggins Bayou and northeast of Lost Lake oil field.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	CBOD$_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
LR 2	4/8/2003	0.3	222	29	26	6	34	9	3.2	61.1	<3	0.06	0.36	<0.05	0.76	0.12	<0.06
LR 2	4/8/2003	0.3	218	29	26	6	36	12	3.2	49.9	<3	0.09	0.36	<0.05	0.65	0.13	<0.06
LR 2	5/5/2003	0.3	240	52	34	7	34	10	3.2	70.8	4	<0.05	<0.05	<0.05	0.93	0.14	<0.06
LR 2	5/5/2003	0.3	254	51	34	7	30	6	1.07	76.7	4	<0.05	<0.05	<0.05	0.91	0.15	<0.06
LR 2	6/23/2003	0.3	213	22	36	5	46	6	19.5	16.2	<3	<0.05	0.42	<0.05	0.53	0.26	<0.06
LR 2	8/4/2003	0.3	502	163	46	7	22	5	<1	22.4	<3	<0.05	<0.05	<0.05	0.8	0.14	<0.06
LR 2	9/23/2003	0.3	206	27	31	6	21	4	12.8	5.13	<3	<0.05	<0.05	<0.05	0.68	0.14	0.08
LR 2	11/4/2003	0.3	202	30	28	6	14	4	<1	16.2	<3	<0.05	<0.05	<0.05	0.51	0.11	<0.06
LR 2	3/23/2004	0.3	204	32	35	6	32	6	13.4	12.8	<3	<0.05	0.44	<0.05	0.87	0.12	<0.06
LR 2	3/23/2004	0.3	204	32	35	6	32	6	32	15.3	<3	<0.05	0.44	<0.05	0.84	0.1	<0.06
LR 2	5/10/2004	0.3	210	29	43	6	51	6	10.7	4.27	<3	<0.05	0.51	<0.05	0.67	0.12	<0.06
LR 2	6/22/2004	0.3	202	24	34	6	70	9	12.3	4.54	<3	<0.05	0.27	<0.05	0.75	0.12	0.06
LR 2	8/2/2004	0.3	216	24	24	6	34	6	9.61	2.72	<3	<0.05	<0.05	<0.05	0.68	0.16	0.08
LR 2	9/21/2004	0.3	406	119	50	7	28	5	13.4	4.87	<3	<0.05	<0.05	<0.05	0.7	0.1	<0.06
LR 2	11/8/2004	0.3	232	24	32	6	34	7	34.7	5.01	<3	<0.05	0.11	<0.05	0.68	0.18	<0.06
LR 2	11/8/2004	0.3	234	24	32	6	38	9	38.9	6.48	<3	<0.05	0.1	<0.05	0.68	0.17	0.06
LR 2	5/5/2003	2.1	248	52	34	7	34	7			4	<0.05	<0.05	<0.05	0.93	0.15	<0.06
LR 2	5/5/2003	2.1	262	51	35	7	31	7			3	<0.05	<0.05	<0.05	0.93	0.16	<0.06
LR 2	6/23/2003	1.5	209	22	36	5	74	9			<3	<0.05	0.42	<0.05	0.66	0.15	<0.06
LR 2	8/4/2003	1.5	488	158	46	7	32	7			<3	<0.05	<0.05	<0.05	0.58	0.15	<0.06
LR 2	9/23/2003	2.3	214	28	31	6	32	6			<3	<0.05	<0.05	<0.05	0.54	0.17	0.08
LR 2	11/4/2003	1.6	236	31	28	6	178	24			<3	<0.05	<0.05	<0.05	0.96	0.34	<0.06
LR 2	11/4/2003	1.6	222	31	28	6	230	27			<3	<0.05	<0.05	<0.05	1.05	0.4	<0.06
LR 2	3/23/2004	1.6	210	32	35	6	40	6			3	<0.05	0.44	<0.05	0.83	0.12	<0.06
LR 2	5/10/2004	2.5	222	29	43	6	57	7			<3	<0.05	0.51	<0.05	0.7	0.12	0.06
LR 2	6/22/2004	2	203	24	34	6	62	8			<3	<0.05	0.27	<0.05	0.7	0.14	0.07
LR 2	8/2/2004	1.5	222	24	24	6	41	8			<3	<0.05	<0.05	<0.05	0.75	0.17	0.07
LR 2	9/21/2004	1.9	522	178	56	7	56	8			<3	<0.05	<0.05	<0.05	0.88	0.16	0.1
LR 2	11/8/2004	1.3	224	23	32	6	109	16			<3	<0.05	0.1	<0.05	0.83	0.22	0.06
	MEANS:		257	48.1	34.8	6.2	52.8	8.6	13.12	23.4	3.1	0.052	0.19	0.05	0.76	0.162	0.064

Results of lab analysis on water samples for LR 3 are presented in Table 42. Nutrient concentrations were frequently at or below the laboratory reporting limit. For three samples the laboratory reporting limit was greater than the AWRL. About half of the ortho-phosphorus concentrations were reported below the AWRL. The highest concentration measured was 0.06, although one sample was reported at <0.18 mg/L. The screening level for ortho-phosphorus in tidal streams is 0.55 mg/L (TNRCC 2000a). Total phosphorus ranged from 0.09 to 0.23 mg/L. The screening level for total phosphorus in tidal streams is 0.71 mg/L (TNRCC 2000a). All the ammonia measurements were at or below 0.05 (the AWRL.) The screening level for ammonia in tidal streams is 0.58 mg/L (TNRCC 2000a).

The screening level for chlorophyll *a* in tidal streams is 19.2 ug/L (TNRCC 2000a). Chlorophyll *a* at LR 3 ranged from 1 (the AWRL) to 28.2 ug/L. Two samples exceeded the screening level, one taken on 23 Mar 2004 and one collected on 8 Nov 2004.

Table 42.—Water chemistry data from grab samples collected from Lost River at station LR 3, at confluence with Old River Lake approx. 1.3 km upstream of IH-10.

Station	Date Sampled	Depth	TDS	Chloride	Sulfate	TOC	TSS	VSS	Chlorophyll *a*	Pheophytin *a*	$CBOD_5$	Ammonia-N	Nitrate-N	Nitrite-N	TKN	TP	ortho-P
		meters	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
LR 3	4/8/2003	0.3	254	32	28	6	88	14	5.34	127	<3	<0.05	<0.05	<0.05	1.23	0.19	<0.06
LR 3	5/5/2003	0.3	328	81	38	7	58	11	2.14	53.2	<3	<0.05	<0.05	<0.05	0.91	0.15	<0.06
LR 3	6/23/2003	0.3	262	52	37	6	41	7	<1	24.6	<3	<0.05	<0.05	<0.05	0.82	0.13	<0.06
LR 3	6/23/2003	0.3	274	52	37	6	41	8	<1	29	<3	<0.05	<0.05	<0.05	0.84	0.13	<0.06
LR 3	8/4/2003	0.3	1,480	667	113	7	33	6	<1	38.1	<3	<0.05	<0.05	<0.05	0.85	0.16	<0.06
LR 3	8/4/2003	0.3	1,490	672	114	7	33	5	<1	<1	<3	<0.05	<0.05	<0.05	0.78	<0.05	<0.06
LR 3	9/23/2003	0.3	260	61	30	7	35	6	7.48	18.3	<3	<0.05	<0.05	<0.05	0.83	0.14	<0.06
LR 3	11/4/2003	0.3	592	236	54	7	20	4	3.74	18.7	<3	<0.05	<0.10	<0.10	0.63	0.12	<0.12
LR 3	3/23/2004	0.3	222	41	36	7	45	6	22.2	10.2	<3	<0.05	<0.05	<0.05	0.91	0.09	<0.06
LR 3	5/10/2004	0.3	216	29	42	6	42	7	8.01	5.07	<3	<0.05	0.4	<0.05	0.66	0.13	<0.06
LR 3	5/10/2004	0.3	214	29	42	6	39	6	5.87	2.35	<3	<0.05	0.4	<0.05	0.69	0.12	<0.06
LR 3	6/22/2004	0.3	203	24	33	7	52	8	10.7	3.9	<3	<0.05	0.15	<0.05	0.73	0.13	<0.06
LR 3	8/2/2004	0.3	236	33	31	7	44	7	7.12	<1	<3	<0.05	<0.05	<0.05	0.79	0.19	0.06
LR 3	8/2/2004	0.3	246	33	30	7	42	6	5.34	3.38	<3	<0.05	<0.05	<0.05	0.8	0.17	<0.06
LR 3	9/21/2004	0.3	3,150	1,610	243	6	22	4	18	8.14	<3	<0.05	<0.15	<0.15	0.79	0.1	<0.18
LR 3	11/8/2004	0.3	392	111	40	6	47	9	28.2	3.81	<3	<0.05	<0.05	<0.05	0.72	0.19	<0.06
LR 3	5/5/2003	3.4	310	76	37	6	65	11			<3	<0.05	<0.05	<0.05	0.94	0.18	<0.06
LR 3	6/23/2003	3.6	280	52	37	6	56	10			<3	<0.05	<0.05	<0.05	0.81	0.14	<0.06
LR 3	8/4/2003	3	1,360	589	103	7	40	6			<3	<0.05	<0.05	<0.05	0.9	0.15	<0.06
LR 3	9/23/2003	3.5	276	66	31	7	41	8			<3	<0.05	<0.05	<0.05	0.68	0.16	<0.06
LR 3	11/4/2003	3.7	604	244	55	7	23	4			<3	<0.05	<0.05	<0.05	0.73	0.13	<0.06
LR 3	3/23/2004	3.4	228	41	36	7	70	12			3	<0.05	<0.05	<0.05	0.96	0.11	<0.06
LR 3	5/10/2004	4.5	208	29	42	6	50	7			<3	<0.05	0.4	<0.05	0.74	0.13	<0.06
LR 3	6/22/2004	3.3	207	24	33	7	54	9			<3	<0.05	0.15	<0.05	0.87	0.13	0.06
LR 3	8/2/2004	2.6	236	33	30	7	61	9			<3	<0.05	<0.05	<0.05	0.81	0.2	0.06
LR 3	9/21/2004	3.6	3,970	2,020	300	6	104	14			<3	<0.05	<0.15	<0.15	1.05	0.21	<0.18
LR 3	11/8/2004	4	396	119	41	6	116	19			<3	<0.05	<0.05	<0.05	0.93	0.23	<0.06
	MEANS:		663	261.3	62.7	6.6	50.4	8.3	8.01	21.73	3	0.05	0.106	0.06	0.83	0.147	0.071

Surface and bottom water samples were selected for routine water chemistry analysis on each trip and at each station. Three variables were highly correlated and determined to be redundant when examined via a draftsman's plot. VSS was highly correlated with TSS and was dropped from further analysis. Chloride and sulfate were both highly correlated with TDS and with each other. Sulfate and TDS were therefore also dropped from the analysis.

Surface water chemistry data from Cow Bayou and Lost River are displayed in Figure 57.

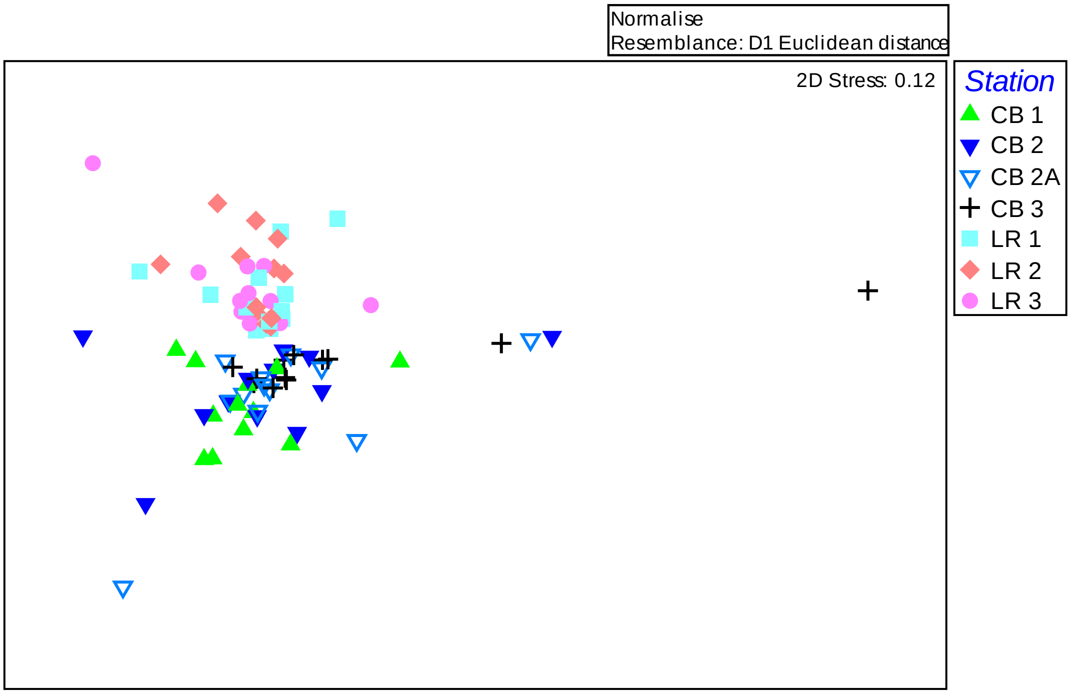


Figure 57.— MDS configuration of the surface water chemistry samples in Cow Bayou and Lost River, by station.

Based on PCA the first three principal components explained about 63% of the variation in the data (Table 43). The first principal component represented elevated chloride, fluoride, ortho-phosphorus and nitrite, and decreased levels of TOC. The second principal component reflected elevated chloride, nitrite and ortho-phosphorus, and decreased levels of alkalinity, total phosphorus and TSS. Cow Bayou and Lost River water chemistry measurements appear to fall into distinct groupings (Figure 58).

Table 43.—Correlations of the surface water chemistry measurements with the first three principal components, cumulative percent variation for each principal component, and eigenvalues, for Cow Bayou and Lost River.

Variable	PC1	PC2	PC3
Cumulative Percent	30.2	52.3	63.4
Eigenvalue	4.22	3.1	1.56
$CBOD_5$	-0.026	-0.019	0.424
ALK (alkalinity)	0.267	-0.388	-0.065
TSS	0.052	-0.413	-0.255
Ammonia	-0.257	0.153	-0.459
Nitrite	0.348	0.334	-0.188
Nitrate	0.265	-0.051	-0.384
Total N (K)	-0.269	0.099	-0.427
Phosphorus(total phosphorus)	-0.078	-0.317	-0.285
TOC	-0.385	0.236	-0.063
Chloride	0.330	0.367	-0.056
Fluoride	0.399	-0.225	-0.096
Chl_a (chlorophyll-a)	0.218	0.056	0.219
Pheo-a (pheophytin-a)	0.031	-0.270	-0.008
Ortho_P (ortho-phosphorus)	0.353	0.337	-0.172

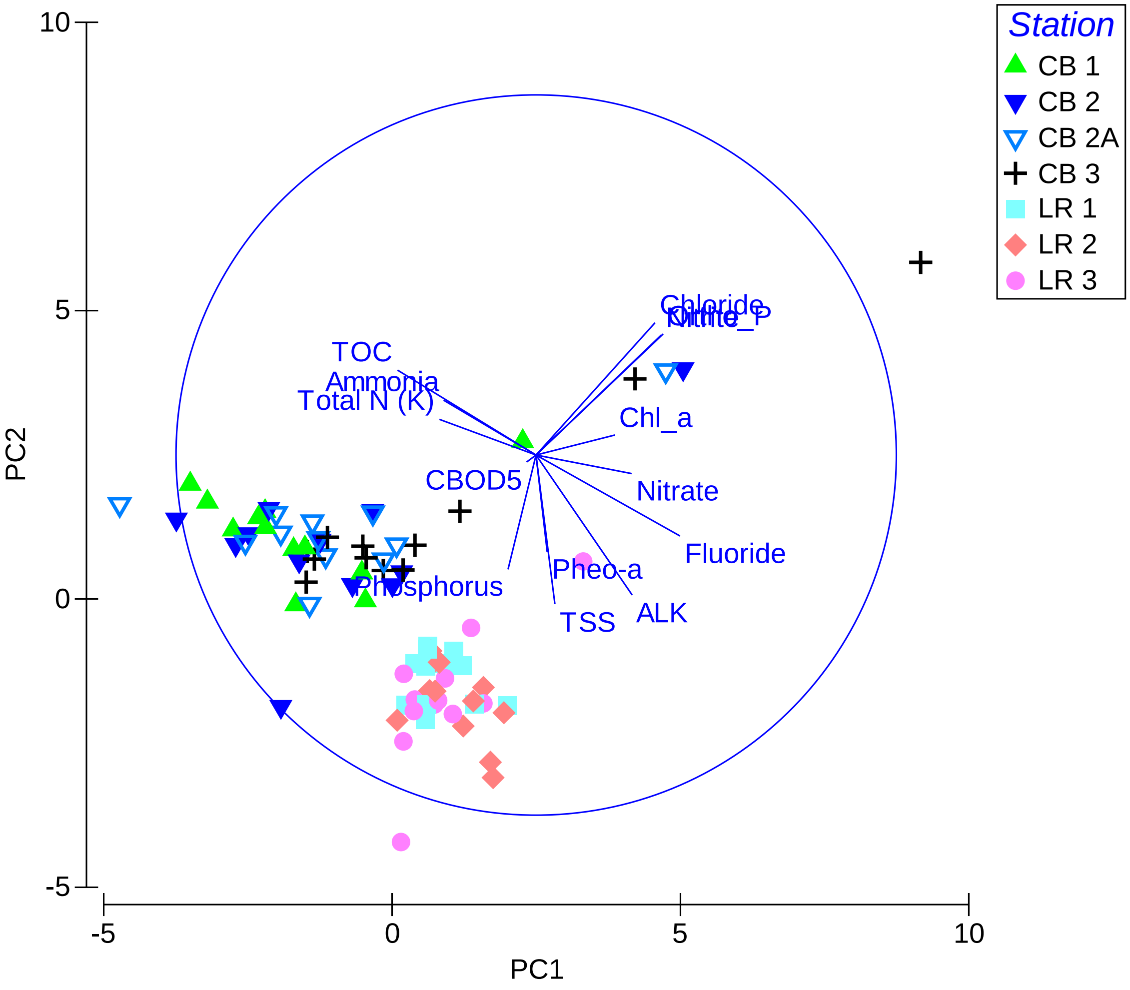


Figure 58.—Ordination of the samples based on PCA of surface water chemistry from Cow Bayou and Lost River.

Cow Bayou samples tend to have higher TOC, ammonia, and TKN. Lost River samples tend to have higher total phosphorus, TSS, fluoride, alkalinity, and nitrate.

Means plot MDS ordination of the stations shows how the stations within a stream had similar water chemistry, and that the samples are distinct from between streams (Figure 59).

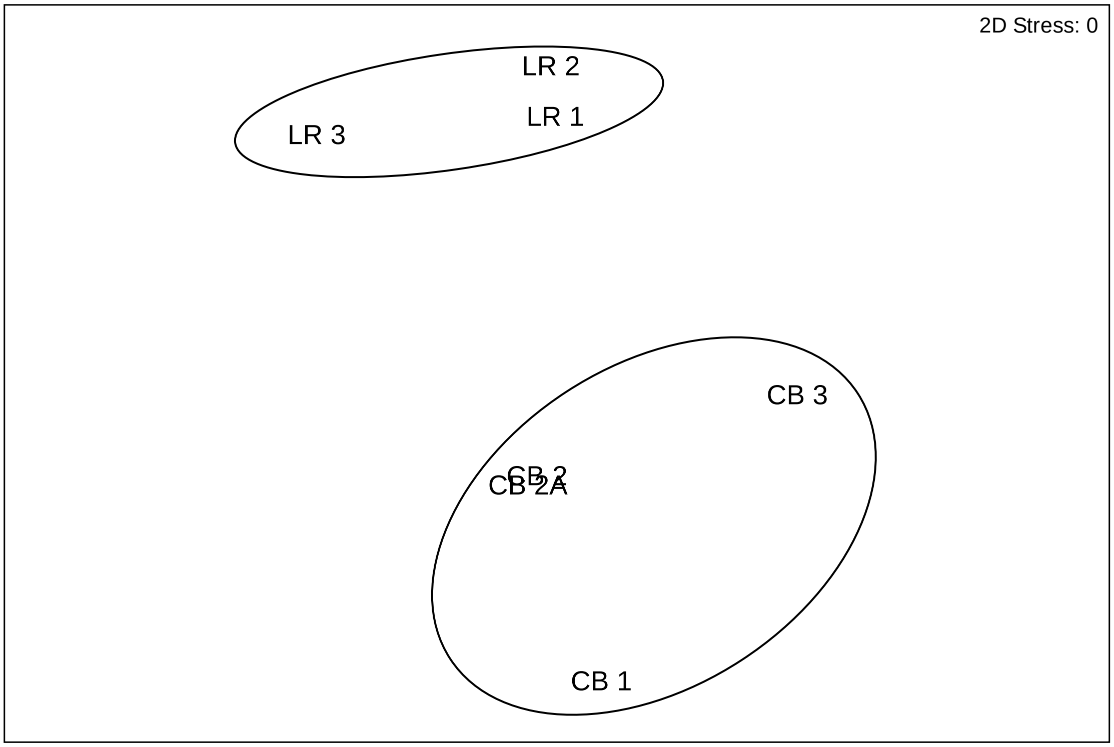


Figure 59.—Means plot MDS ordination of the stations based on surface water chemistry measurements from Cow Bayou and Lost River. Stations within an ellipse are not significantly different based on ANOSIM comparisons among the stations (*p* > 0.05).

Rank correlations between the surface and bottom water chemistry was $\rho = 0.697$ ($p < 0.001$) for Cow Bayou and $\rho = 0.563$ ($p < 0.001$) for Lost River. This showed that the surface and bottom water chemistry was closely related in both streams. Compare the configuration of the bottom water chemistry MDS (Figure 60) with Figure 57.

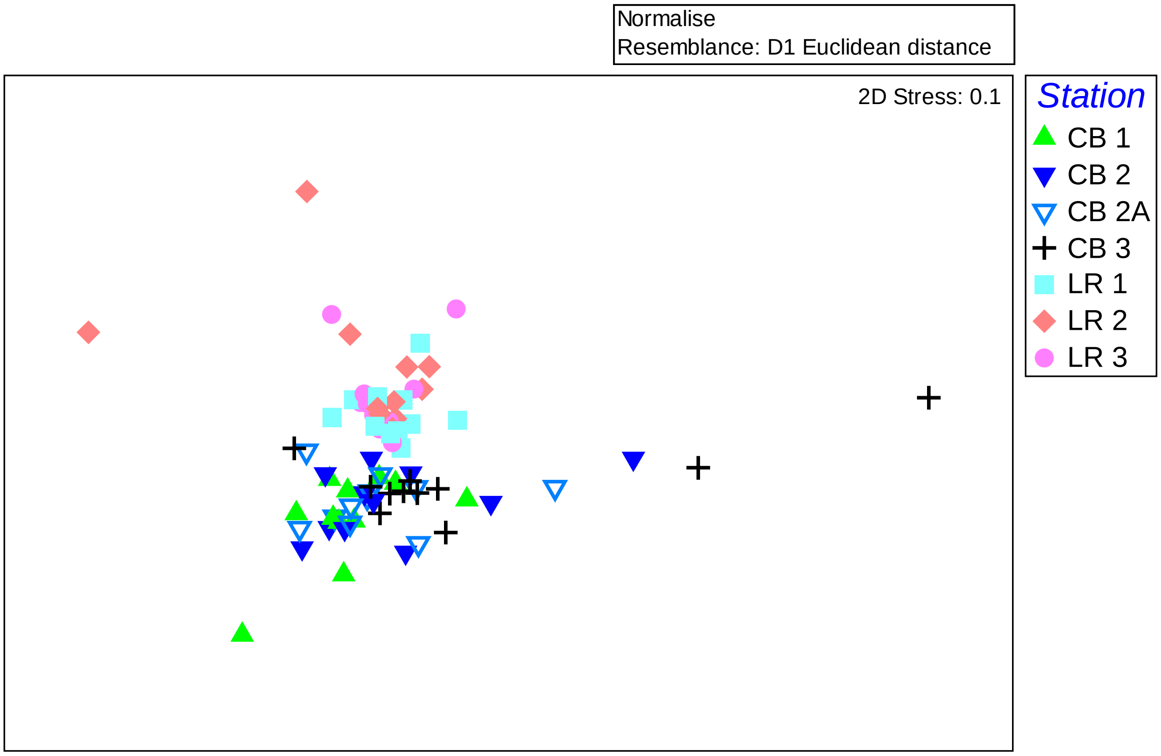


Figure 60.—MDS configuration of bottom water chemistry samples from Cow Bayou and Lost River, by station.

Sediment

Sediment results are presented in Table 44. TOC is a measure of the organic material in sediments. High levels can be deleterious to organisms living in or on the sediments. EPA's National Coastal Assessment Program uses a range of 20,000-50,000 mg/kg to indicate fair sediment quality, and over 50,000 mg/kg to indicate poor sediment quality. Extremely low levels (below about 500 mg/kg) are also associated with impaired benthic communities.

None of the samples showed extremely low TOC (<500 mg/kg). Three samples in Cow Bayou exceeded 50,000 mg/kg (two exceedances at CB 2 and one at CB 2A). All of the three samples were taken from the side of the channel.

The mean TOC concentration for all the Cow Bayou samples was 31,667 mg/kg, while the mean for Lost River was only 11,616 mg/kg.

Table 44. —Sediment analysis from Cow Bayou and Lost River. N/A indicated missing data.

Station	Date	Sample location	Depth (m)	TOC (mg/kg,dry)	Percent solids	Percent gravel	Percent silt	Percent clay	Percent sand
CB 1	5/7/2003	Middle	5.2	<4,000	69.3	0	30.0	21.0	49.0
CB 1	5/7/2003	Side	0.5	45,100	29.1	0	42.0	32.0	26.0
CB 1	8/6/2003	Middle	4.3	5,740	65.8	<0.01	24.3	23.2	52.6
CB 1	8/6/2003	Side	0.5	27,400	38.8	<0.01	41.3	40.1	18.6
CB 1	11/5/2003	Middle	5.5	28,000	43.8	<0.01	24.0	22.0	54.0
CB 1	11/5/2003	Side	0.6	32,000	32.3	<0.01	34.0	36.0	30.0
CB 1	5/12/2004	Side	2.4	19,000	43.0	<0.01	34.6	38.7	26.7
CB 1	6/23/2004	Middle	4.9	13,600	65.2	<0.01	16.0	18.4	65.6
CB 1	6/23/2004	Side	0.8	20,800	36.5	<0.01	39.9	34.6	25.5
CB 1	9/22/2004	Middle	4.2	N/A	58.6	<0.01	30.5	22.4	47.1
CB 1	9/22/2004	Side	2.7	N/A	43.1	<0.01	38.5	30.8	30.7
CB 2	5/7/2003	Middle	5.5	22,400	43.8	0	14.0	23.0	63.0
CB 2	5/7/2003	Side	0.6	36,400	35.7	0	35.0	23.0	42.0
CB 2	8/6/2003	Middle	3.9	40,100	26.8	<0.01	31.6	64.4	4.0
CB 2	8/6/2003	Side	0.5	78,900	28.0	<0.01	31.7	44.5	23.8
CB 2	11/5/2003	Middle	4.9	36,000	32.6	<0.01	36.0	34.0	30.0
CB 2	11/5/2003	Side	2.1	22,000	42.9	<0.01	16.0	30.0	54.0
CB 2	5/12/2004	Middle	4.5	32,000	32.3	<0.01	27.7	51.4	21.0
CB 2	5/12/2004	Middle	4.2	41,000	29.6	<0.01	31.6	59.3	9.1
CB 2	6/23/2004	Middle	3.7	41,900	29.3	<0.01	25.7	53.3	21.1

Station	Date	Sample location	Depth (m)	TOC (mg/kg,dry)	Percent solids	Percent gravel	Percent silt	Percent clay	Percent sand
CB 2	6/23/2004	Side	0.6	74,800	24.9	<0.01	22.1	32.1	45.8
CB 2	9/22/2004	Middle	4.5	N/A	31.1	<0.01	37.4	47.9	14.7
CB 2	9/22/2004	Side	0.6	N/A	61.9	<0.01	15.9	11.9	72.2
CB 2A	5/7/2003	Middle	2.7	32,600	24.4	0	30.0	68.0	2.0
CB 2A	5/7/2003	Side	0.6	11,300	56.5	0	4.0	7.0	88.0
CB 2A	8/6/2003	Middle	2.1	42,500	24.3	<0.01	33.6	66.4	0.0
CB 2A	8/6/2003	Side	0.9	62,500	25.1	<0.01	33.7	44.6	21.7
CB 2A	11/5/2003	Middle	2.4	45,000	20.2	<0.01	2.0	44.0	54.0
CB 2A	11/5/2003	Side	0.9	43,000	27.3	<0.01	22.0	34.0	44.0
CB 2A	5/12/2004	Middle	2.5	40,000	27.6	<0.01	28.9	59.7	11.4
CB 2A	5/12/2004	Side	1	22,000	45.7	<0.01	4.0	28.2	67.8
CB 2A	6/23/2004	Middle	2.1	40,100	24.7	<0.01	31.7	60.6	7.8
CB 2A	6/23/2004	Side	0.6	13,800	54.5	<0.01	3.6	14.4	82.0
CB 2A	9/22/2004	Middle	2.3	N/A	24.9	<0.01	41.4	55.2	3.4
CB 2A	9/22/2004	Side	0.95	N/A	56.4	<0.01	13.9	9.9	76.2
CB 3	5/7/2003	Middle	5.5	14,300	47.8	0	12.0	19.0	69.0
CB 3	5/7/2003	Side	0.6	44,300	30.1	0	26.0	25.0	49.0
CB 3	8/6/2003	Middle	4.6	16,800	43.9	<0.01	19.5	30.3	50.2
CB 3	8/6/2003	Side	0.5	26,600	36.4	<0.01	31.6	48.4	20.1
CB 3	11/5/2003	Middle	3.9	12,000	44.1	<0.01	11.6	26.0	62.4
CB 3	11/5/2003	Side	0.6	27,000	36.7	<0.01	20.0	26.0	54.0
CB 3	5/12/2004	Middle	5.5	19,000	46.3	<0.01	17.7	33.4	48.9
CB 3	5/12/2004	Side	0.5	34,000	38.6	<0.01	28.0	24.0	48.0
CB 3	6/23/2004	Middle	5.2	11,300	57.5	<0.01	10.0	20.0	70.0

Station	Date	Sample location	Depth (m)	TOC (mg/kg,dry)	Percent solids	Percent gravel	Percent silt	Percent clay	Percent sand
CB 3	6/23/2004	Side	0.5	28,100	36.7	<0.01	25.7	33.6	40.7
CB 3	9/22/2004	Middle	5.5	N/A	52.2	<0.01	16.1	20.2	63.7
CB 3	9/22/2004	Side	0.9	N/A	45.4	<0.01	15.8	11.9	72.3
LR 1	5/5/2003	Middle	2.4	12,500	42.8	0	31.0	41.0	28.0
LR 1	5/5/2003	Side	0.3	4,540	67.6	0	20.0	14.0	66.0
LR 1	8/4/2003	Middle	1.8	10,200	44.8	<0.01	32.0	41.5	26.5
LR 1	8/4/2003	Side	0.5	10,200	22.8	<0.01	24.0	59.5	16.6
LR 1	11/4/2003	Middle	2.1	14,000	38.1	<0.01	40.0	49.3	10.7
LR 1	11/4/2003	Side	0.5	16,000	33.1	<0.01	18.0	81.0	1.0
LR 1	6/22/2004	Middle	2.7	7,320	60.5	<0.01	40.7	34.6	24.7
LR 1	6/22/2004	Side	0.7	5,000	70.2	<0.01	31.5	21.7	46.8
LR 1	9/21/2004	Middle	2.4	N/A	62.0	<0.01	34.7	28.9	36.4
LR 1	9/21/2004	Side	0.6	N/A	63.1	<0.01	33.5	17.8	48.7
LR 2	5/5/2003	Middle	2.1	8,240	55.7	0	10.0	24.0	66.0
LR 2	5/5/2003	Side	0.3	8,530	56.4	0	34.0	28.0	38.0
LR 2	8/4/2003	Middle	1.8	12,300	33.8	<0.01	31.9	45.5	22.6
LR 2	8/4/2003	Side	0.5	5,650	65.4	<0.01	12.0	17.6	70.5
LR 2	11/4/2003	Middle	1.8	22,000	25.8	<0.01	34.1	65.4	0.5
LR 2	11/4/2003	Side	0.6	7,000	66.0	<0.01	26.0	17.2	56.9
LR 2	6/22/2004	Side	0.8	7,200	63.6	<0.01	38.4	24.2	37.4
LR 2	9/21/2004	Middle	2.4	N/A	53.4	<0.01	23.6	38.6	37.8
LR 2	9/21/2004	Side	1.2	N/A	66.8	<0.01	28.8	30.0	41.2
LR 3	5/5/2003	Middle	3	8,460	54.1	3	24.0	53.0	20.0
LR 3	5/5/2003	Side	0.5	16,000	38.7	0	35.0	53.0	12.0

Station	Date	Sample location	Depth (m)	TOC (mg/kg,dry)	Percent solids	Percent gravel	Percent silt	Percent clay	Percent sand
LR 3	8/4/2003	Middle	3.6	13,700	43.1	2.40	33.9	51.5	12.2
LR 3	8/4/2003	Side	0.5	17,000	39.1	2.90	18.0	31.6	47.5
LR 3	11/4/2003	Middle	3.6	18,000	32.6	<0.01	36.0	55.1	8.9
LR 3	11/4/2003	Side	0.5	17,000	41.5	<0.01	34.0	30.0	36.0
LR 3	6/22/2004	Middle	3.7	14,300	39.2	3.12	37.3	41.5	18.1
LR 3	6/22/2004	Side	0.8	12,900	54.3	<0.01	30.2	28.2	41.6
LR 3	9/21/2004	Middle	4.0	N/A	42.2	<0.01	23.3	38.0	38.8
LR 3	9/21/2004	Side	0.6	N/A	56.9	<0.01	14.3	19.6	66.1

Sediment samples were collected only once per season, and sediment samples from the middle of the channel and near the side of the channel were analyzed separately.

PCA of the mid-channel sediment data reveals that the first two components alone explain about 82% of the variation in the data. The first component is positively loaded by percent sand and percent solids, and negatively loaded by percent clay. The second component reflects high TOC, and lower values for percent gravel and percent silt.

Table 45.—Correlations of the mid-channel sediment measurements with the first three principal components, cumulative percent variation for each principal component, and eigenvalues, for Cow Bayou and Lost River.

Variable	PC1	PC2	PC3
Cumulative Percent	57.6	81.5	94.8
Eigenvalue	3.45	1.44	.799
TOC Sed	-0.388	0.497	-0.204
% Solids	0.465	-0.327	0.200
% Gravel	-0.051	-0.590	-0.776
% Silt	-0.337	-0.478	0.536
% Clay	-0.513	-0.044	-0.085
% Sand	0.503	0.260	-0.149

A PCA plot of the mid-channel sediment data for both Cow Bayou and Lost River shows how the sediment data separates the Cow Bayou stations (Figure 61). CB 1 and CB3 samples are at the far right of the graph due to a high percentage of sand (as high as 72.3%) – these stations had higher average percentage of sand than any of the other stations studied. CB 2 and CB 2A were at the upper left quadrant of the graph due to higher levels of TOC than the other stations. These two stations each had about twice as much TOC than the other stations, on the average. Perhaps this could be explained by the proximity of these stations to the Orangefield oil field. ANOSIM confirms differences exist between the Cow Bayou stations (Global R = 0.545, $p < 0.04$). ANOSIM interpretation indicates that CB 2 and CB 2A are the only Cow Bayou stations that are alike in their mid-channel characteristics. Data for the Lost River stations are more variable; in fact ANOSIM reveals no significant difference among the stations (Global R = 0.103, $p < 0.373$). Neither Cow Bayou nor Lost River showed seasonality in the mid-channel sediment data.

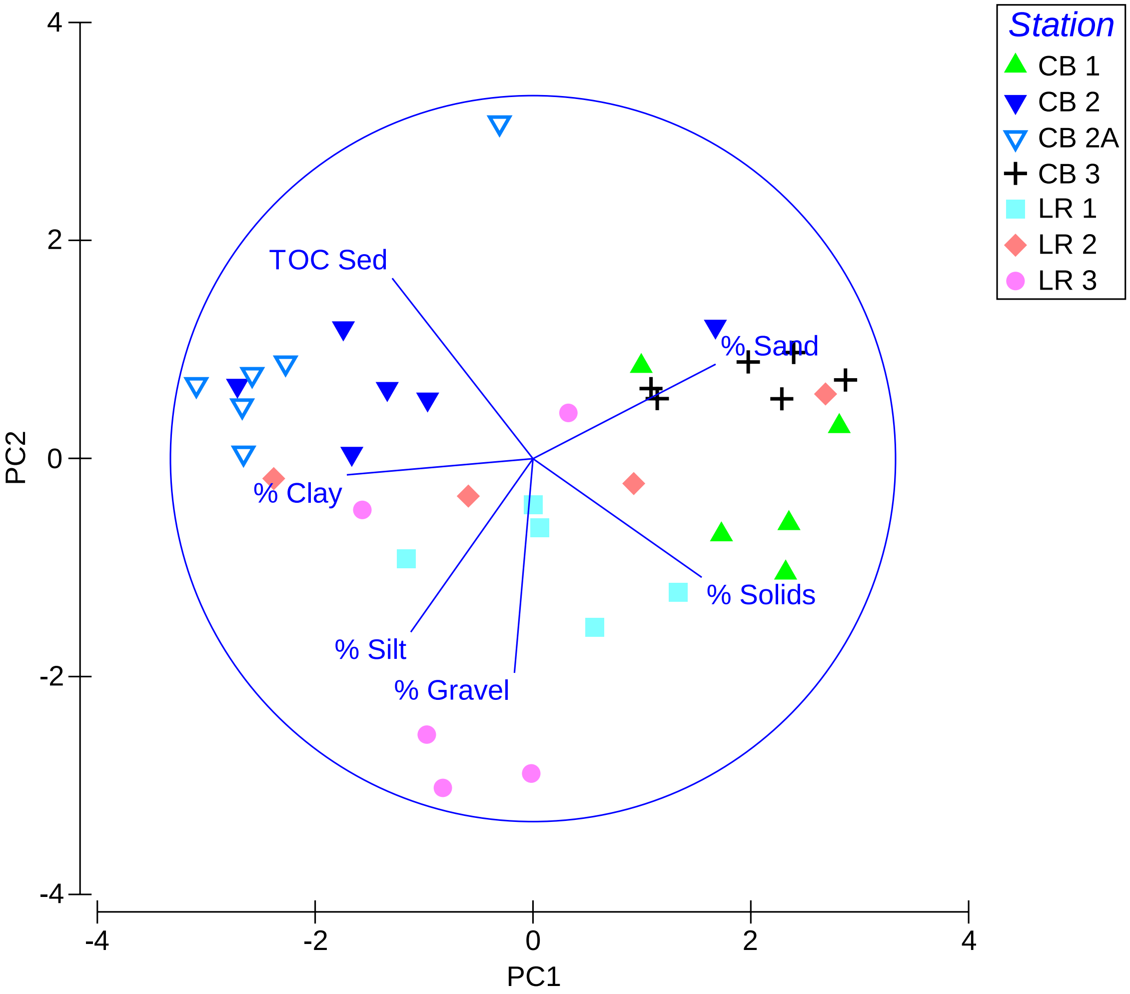


Figure 61.—PCA ordination of mid-channel sediment samples from Cow Bayou and Lost River.

PCA of the channel-side sediment data indicated that 70% of the variation in the data was explained by the first two principal components (Table 46). The first principal component reflected higher percent clay and lower percent sand and percent solids. The second principal component reflected higher TOC and lower percent silt.

Table 46.—Correlations of the channel-side sediment measurements with the first three principal components, cumulative percent variation for each principal component, and eigenvalues, for Cow Bayou and Lost River.

Variable	PC1	PC2	PC3
Cumulative Percent	50.7	70.1	87.1
Eigenvalue	3.04	1.16	1.02
TOC Sed	0.356	0.515	0.428
% Solids	-0.470	-0.444	-0.114
% Gravel	-0.018	0.423	-0.845
% Silt	0.371	-0.513	-0.024
% Clay	0.484	-0.072	-0.229
% Sand	-0.529	0.302	0.192

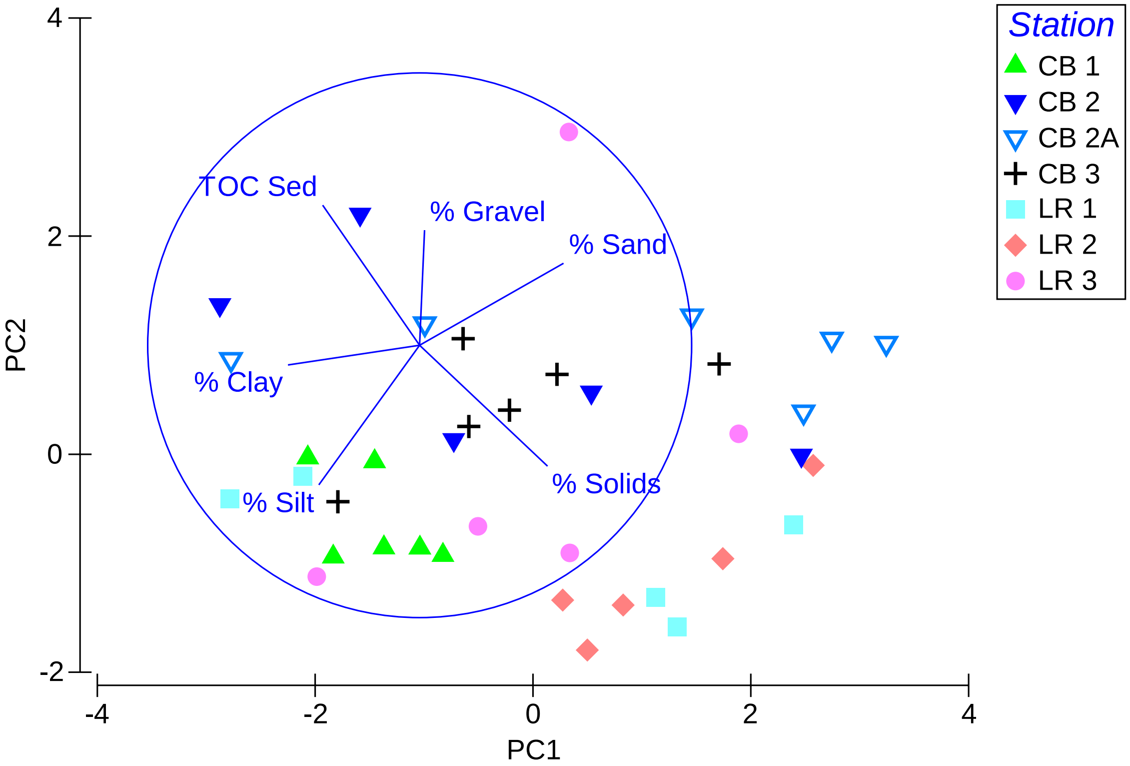


Figure 62.—PCA ordination of channel-side sediment samples from Cow Bayou and Lost River (vectors have been shifted from the graph origin to aid in visualization).

The PCA ordination plot (Figure 62) does not reveal such neat distinctions between the Cow Bayou stations as the similar plot of the mid-channel sediment data. However CB 1 samples cluster together closely again, mainly because of higher percent silt measurements. As before, Lost River stations exhibited greater variability. The one outlier near the top of the graph is a sample from LR 3 where a small amount of gravel (about 3%) was measured. Gravel was negligibly small in all other samples so this single measurement had a large effect on the analysis.

ANOSIM tests revealed significant differences between stations in Cow Bayou, primarily due to the uniqueness of CB 1 (Global R = 0.349, $p < 0.02$). There were no significant differences between stations in Lost River (Global R = -0.139, $p < 0.867$). Means plot MDS is shown in Figure 63.

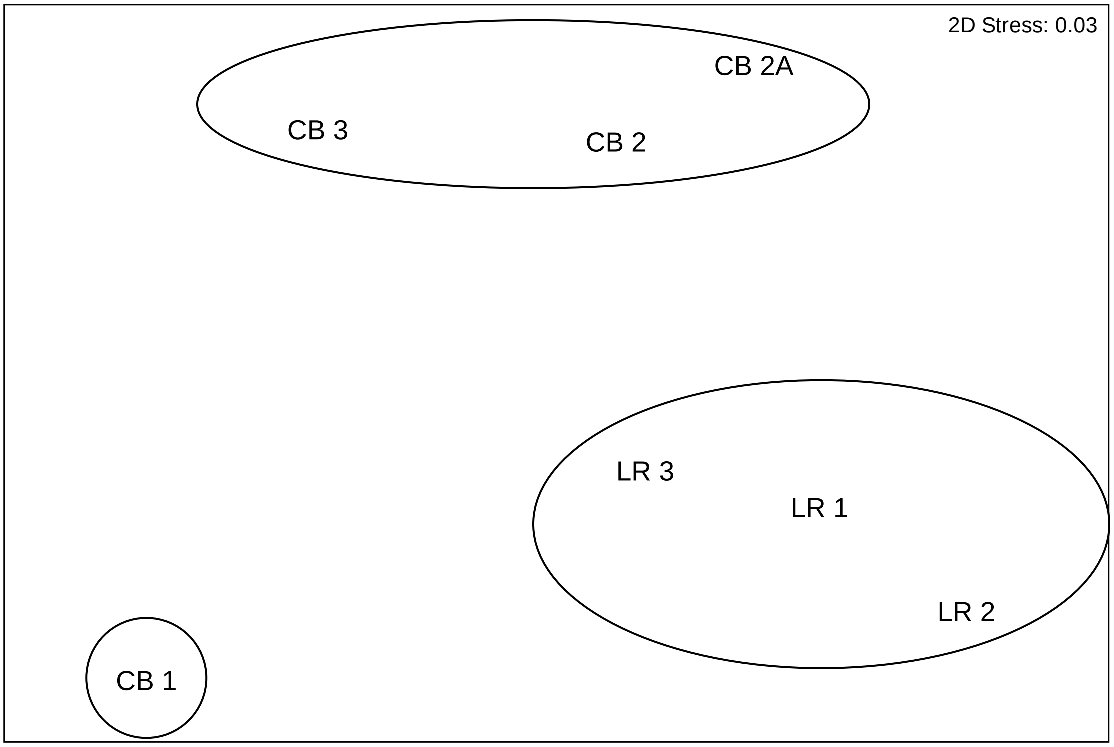


Figure 63.—Means plot MDS ordination of the stations based on channel-side sediment measurements from Cow Bayou and Lost River. Stations within an ellipse are not significantly different based on ANOSIM comparisons among the stations (*p* > 0.05).

Biological Evaluation

Invertebrates

Benthic Infauna

Samples collected during the first year were identified to the lowest possible taxonomic classification. Due to the high level of diversity in the aquatic invertebrate collections, samples from the second year of the study were identified only to family level.

For purposes of simplicity the organisms collected by the Ekman dredge will be referred to as "benthic infauna." In practice, no attempt was made during the taxonomic identification and enumeration to separate epifaunal organisms from infaunal organisms, so all are considered here as benthic infauna.

A total of 6,030 individual organisms were identified and enumerated from the samples collected by Ekman dredge at mid-channel (Table 47). Individual tables of results by station and by trip are in Appendix A.

Table 47.—Number of organisms and totals by taxon (higher-level taxonomy, usually family level) for each station collected at mid-channel by Ekman dredge in Cow Bayou and Lost River, 2003-2004.

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Acarina							1	1
Acrididae	1			3				4
Ampharetidae	11	32	3	9	8	8	47	118
Anisoptera				2				2
Araneae	12		10	40	30		11	103
Assimineidae	5	3						8
Baetidae		2	57	1	2		11	73
Belostomatidae				2				2
Bivalvia		2			2			4
Bopyridae	2				2			4
Branchiobdellidae		1		1				2
Caenidae				20	70		3	93
Capitellidae		1	1	2	5		1	10
Carabidae			1					1
Ceratopogonidae	23	12	3	2	6	1		47
Chaoboridae		4						4
Chironomidae	494	71	234	118	164	55	151	1,287
Coenagrionidae	3		3					6
Collembola				7				7
Corixidae	18	1	7	5	6		26	63
Corophiidae	7	42	2	5	20			76
Curculionidae	1		3					4
Diptera	1							1
Dreissenidae	73	1		2	1	1		78
Dysticidae				2	1		3	6
Dytiscidae				1				1
Ephemeroptera	5		1	9				15
Eunicidae	3							3
Gammaridae	56	3		10	166		11	246
Gerridae	58		18	15			21	112
Gyrinidae				1				1
Haliplidae				5	1			6
Hebridae				1				1
Helicopsychidae	1							1
Heptageniidae	1							1
Homoptera	6		19	74	105		15	219
Hyalellidae					2		1	3

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Hydrobiidae	247	13	38	13	62	3	1	377
Hydrophilidae	1		1	4	4		2	12
Idoteidae	2	5	32		5			44
Janiridae		7			8			15
Lepidoptera	1		3	3			2	9
Macroveliidae							1	1
Mactridae	1	4	12	2	1	5	4	29
Melitidae			1					1
Mysidacea	160	1	1	352	89		518	1,121
Nemata	1	4						5
Nematomorpha				3				3
Nemertea	3	17	6			8		34
Nepidae	1			25			1	27
Nereididae	20	36	8	5	2			71
Noteridae	3							3
Odonata	7							7
Oedicerotidae	1	3						4
Oligochaeta	310	167	184	176	273	22	41	1,173
Orthoptera							1	1
Panopeidae					1			1
Physidae				1				1
Pilargidae	1	1	3					5
Pisidiidae		17		2				19
Planorbidae							1	1
Portunidae	14	1	2	31	27		5	80
Pyralidae			1					1
Pyramidellidae		2	2	1	27	8		40
Rhynchobdellida				1				1
Saldidae	1				1			2
Scirtidae							1	1
Sphaeromatidae	2			15	2			19
Spionidae	59	31	9	4	84		15	202
Taltridae	3		52	1			1	57
Tellinidae	2				1			3
Tipulidae				1				1
Tricorythidae	7							7
Tridactylidae	6							6
Tunicata					2			2
Xanthidae	12				1			13
Zygoptera				5	9		4	18
Grand Total	1,646	484	717	982	1,190	111	900	6,030

MDS configuration of the Ekman dredge samples from the middle of the stream are shown in Figure 64. Although samples were processed separately (five replicates) they were combined for statistical analysis.

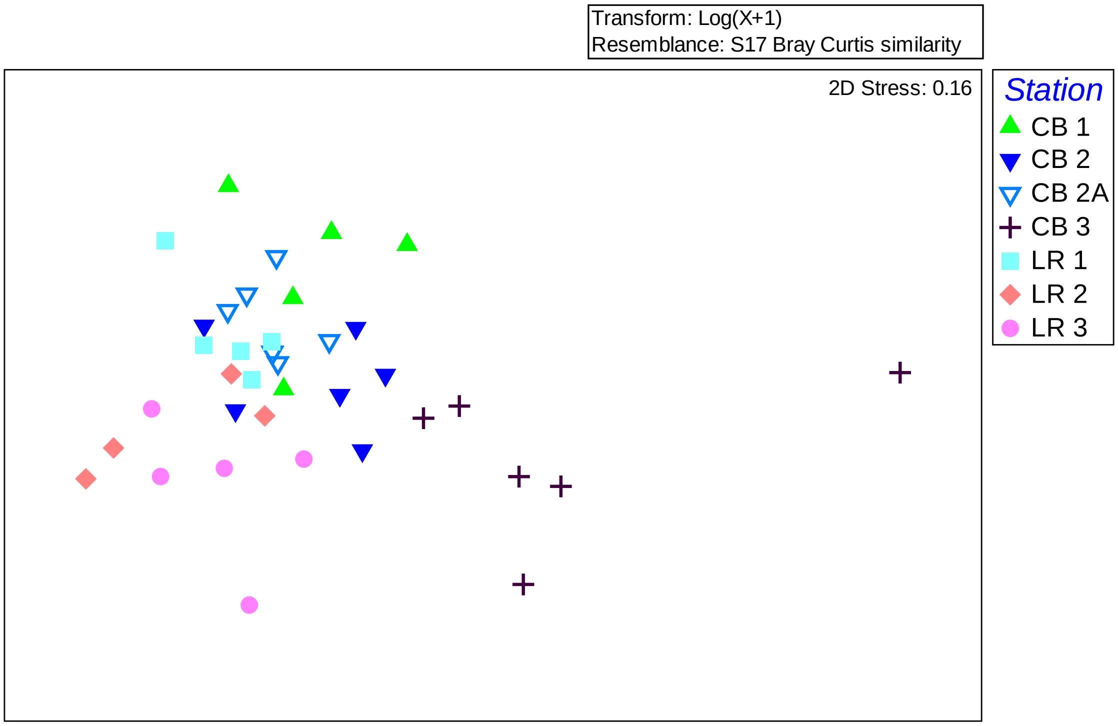


Figure 64.— MDS configuration of the Ekman dredge samples from the middle of the channel in Cow Bayou and Lost River. Graph has been oriented so that downstream stations in each stream (stations CB 3 and LR 3) are more or less near the bottom of the graph and upstream stations are nearer the top of the graph. This orientation is followed in successive graphs of the same data.

ANOSIM confirmed differences among stations for Cow Bayou (Global R = 0.407, $p < 0.001$) but not for Lost River (Global R = 0.3, $p < 0.067$). CB 1, CB 2, and CB 2A were all alike, and each distinct from CB 3. For example, average dissimilarity between CB 2 and CB 3 was 65.1. Differences between the two stations were reflected by greater abundances of oligochaetes and chironomids at CB 2, and greater abundances of *Rangia* clams, hydrobiid snails, and the polychaete *Parandalia* at CB 3.

Table 48.—The contributions of selected individual taxa to the total average dissimilarity between benthic infauna assemblages as measured by Ekman dredge grabs taken from the middle of the channel in stations CB 2 and CB 3. Average abundances of species, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Taxon	CB 2 Av.Abund	CB 3 Av.Abund	Diss/SD	Cum.%
Rangia	1.01	4.74	1.50	12.78
Oligochaeta	4.64	2.20	1.14	24.74
Hydrobiidae	1.04	3.54	1.32	34.68
Chironomidae	3.53	2.44	0.97	42.56
Parandalia	0.00	2.36	1.88	50.16
Amphicteis floridus	2.97	2.39	0.98	56.52
Streblospio benedicti	1.43	1.11	0.92	62.65
Ceratopogonidae	0.89	0.42	0.69	66.45
Nemertea	0.00	1.18	0.95	70.13
Mytilopsis leucophaeata	0.00	0.84	0.69	72.44
Edotia montosa	0.26	0.26	0.54	74.60
Mysidacea	0.18	0.26	0.52	76.63
Gammarus mucronatus	0.44	0.26	0.74	78.61
Texadina barretti	0.00	0.47	0.44	80.30
Chaoboridae	0.47	0.00	0.41	81.99
Bezzia	0.47	0.00	0.42	83.62
Rangia cuneata	0.26	0.26	0.58	85.08
Cambaridae	0.00	0.36	0.44	86.39
Capitella capitata	0.00	0.42	0.44	87.68
Nemata	0.36	0.00	0.42	88.96
Gammarus palustris	0.00	0.36	0.44	89.99
Hyalella	0.00	0.36	0.44	91.03

Samples from the three uppermost Cow Bayou stations were not significantly different from those collected from LR 1 (Figure 65).

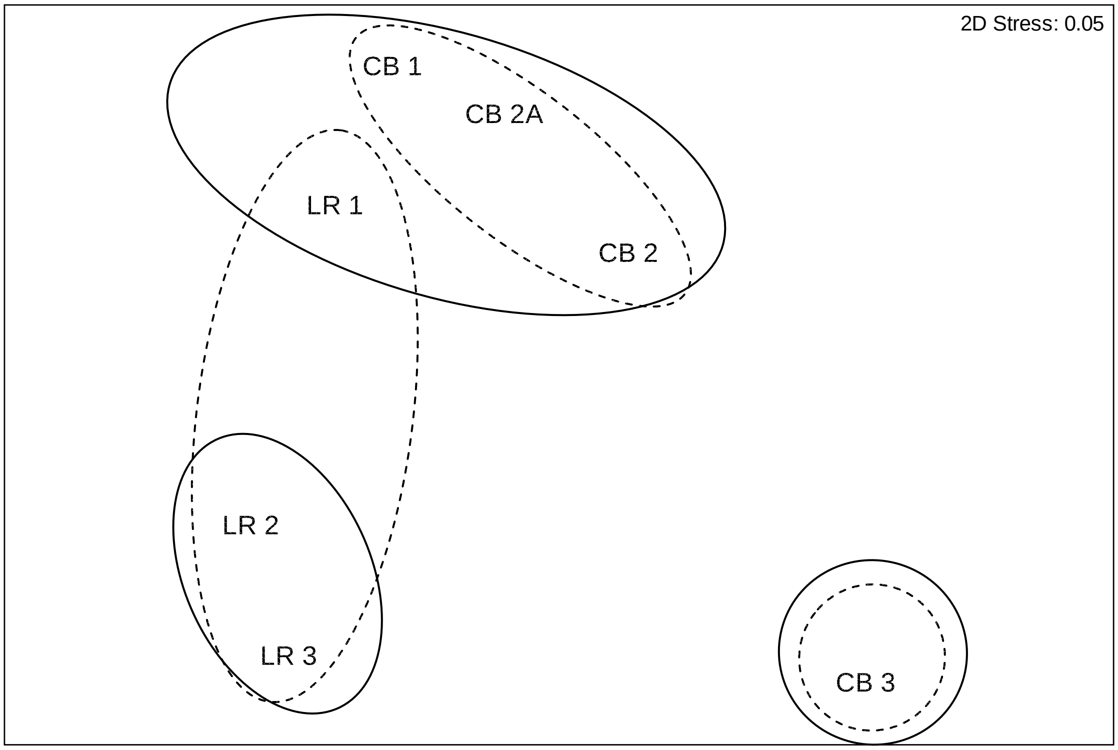


Figure 65.—Means plot MDS ordination of the stations based on Ekman dredge samples from the middle of the channel in Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM $p > 0.05$).

A total of 15,128 organisms were identified and enumerated from the samples collected at the side of the channel (Table 49). Individual tables of results by station and by trip are in Appendix A.

Table 49.—Number of organisms and totals by taxon (higher-level taxonomy, usually family level) for each station collected at the side of the channel by Ekman dredge in Cow Bayou and Lost River, 2003-2004.

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Acarina		4					1	5
Aeshnidae	1							1
Ampharetidae	271	7	16	14	1	20	46	375
Anisoptera					1			1
Arachnidae		2						2
Araneae	27	9	12	83		75	23	229
Assimineidae	5			4				9
Baetidae			77		5	24	5	111
Belastomatidae					1		2	3
Bivalvia		8		1	3			12
Bopyridae		1	1		2			4
Branchiobdellidae		6		1				7
Caenidae			1	1	18	3	2	25
Cambaridae				1				1
Capitellidae	16	1	3	2	12	1		35
Carabidae						1		1
Ceratopogonidae	20	18	2	25		4	1	70
Chaoboridae						1	2	3
Chironomidae	982	86	142	326	97	223	242	2,098
Coenagrionidae	4		2	3	2		1	12
Coleoptera							1	1
Collembola						4		4
Corbulidae			1					1
Corixidae	637	40	46	91	124	13	16	967
Corophiidae	32	2		7	13			54
Culicidae						2		2
Curculionidae	7	1				2		10
Diptera	31		1				2	34
Dreissenidae	10			3			6	19
Dysticidae	1	1	1	1	1		1	6
Dytiscidae							2	2
Ephemerellidae	1							1
Ephemeroptera	19	5	2	14			2	42
Gammaridae	39	61	4	11	65	1	2	183
Gelastocoridae		1						1
Gerridae	34	5	21	6		108	3	177

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Glossiphoniidae		1						1
Haliplidae			8		1		4	13
Hebridae				1		3		4
Hemiptera							1	1
Homoptera	4	8	1	1		82	29	125
Hyalellidae			2		2		3	7
Hydrobiidae	540	25	3	51	10	14	35	678
Hydrophilidae	1	7	1	5	2	23	3	42
Idoteidae	10		24		8			42
Isopoda	3			1				4
Janiridae	13	4	16	1				34
Lepidoptera	4	1	1	5	8	7	2	28
Leptohyphidae							12	12
Libellulidae							8	8
Lymnaeidae						1	1	2
Macroveliidae			1					1
Mactridae	34	20	8	1		4	5	72
Megaloptera			1					1
Melitidae	3							3
Mysidacea	22	1,447	1,694	3,166	1,165	43	655	8,192
Mytilidae				1				1
Naucoridae			1					1
Nemata	3	22	2	1			2	30
Nemertea	4		4	1	2		2	13
Nepidae						1	1	2
Nereididae	4		26	4	4		1	39
Odonata		1	2	1				4
Oedicerotidae			2	2			2	6
Oligochaeta	391	289	206	96	19	139	39	1,179
Orthoptera						1		1
Paraonidae				1				1
Physidae				6	15			21
Pilargidae		3	4					7
Planorbidae	5						3	8
Pleidae			1	1			1	3
Polygyridae	8							8
Portunidae	5	46	1	14	2		2	70
Protoneuridae				1				1
Pyramidellidae		1		21	2	3		27
Rhynchobdellida				4				4
Saldidae	1							1
Scirtidae							1	1
Sphaeromatidae	4	5	2	11			1	23

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Spionidae	5	36	14	29			1	85
Staphylinidae						1		1
Stratiomyidae							7	7
Taltridae	1	7	3	3	1		9	24
Taltroidea				10	19	7		36
Tellinidae	10	1		1				12
Tipulidae							1	1
Trichoptera	1					2		3
Tricorythidae							19	19
Xanthidae	5			1				6
Zygoptera				1	1	2	1	5
Grand Total	3,218	2,182	2,360	4,036	1,606	815	1,211	15,428

MDS configuration of the Ekman dredge samples from the side of the stream are shown in Figure 66. Although samples were processed separately (five replicates) they were combined for statistical analysis.

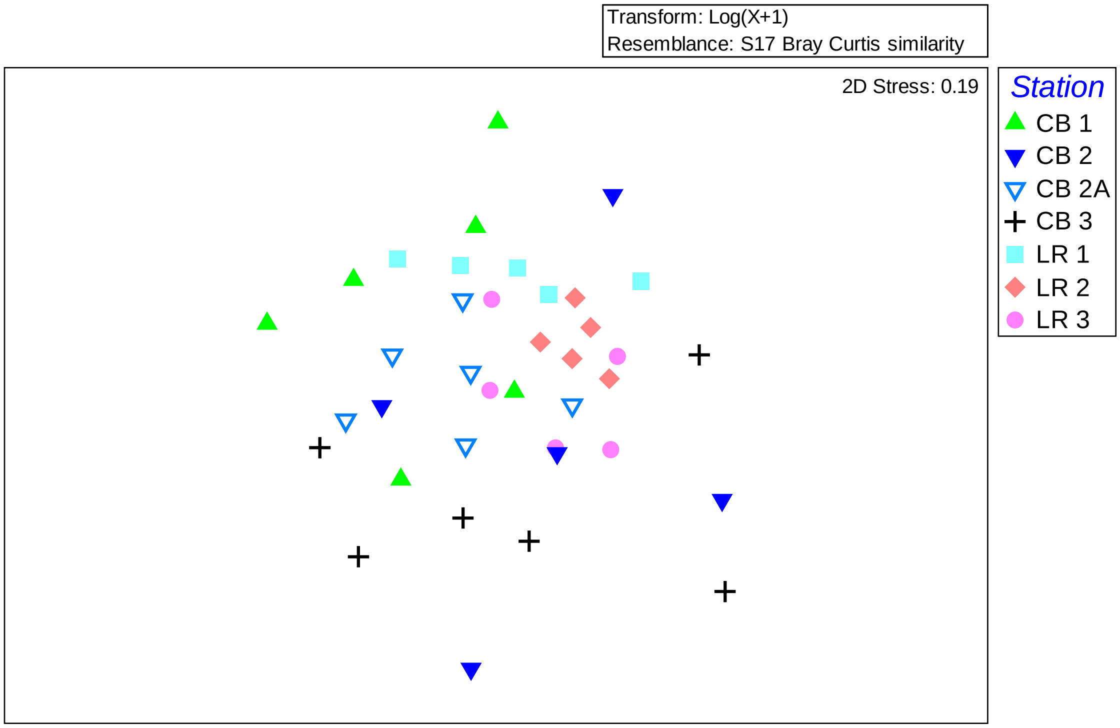


Figure 66.— MDS configuration of the Ekman dredge samples from the side of the channel in Cow Bayou and Lost River. Graph has been oriented so that downstream stations in each stream (stations CB 3 and LR 3) are more or less near the bottom of the graph and upstream stations are nearer the top of the graph. This orientation is followed in successive graphs of the same data.

ANOSIM found no differences between stations in either Cow Bayou (Global R = -0.041, *p* > 0.622) or Lost River (Global R = 0.028, p > 0.444). Furthermore there was no difference among seasons in either Cow Bayou (Global R = -0.106, *p* < 0.717) or Lost River (Global R = -0.083, *p* > 0.70).

Means plot MDS of the stations are displayed in Figure 67.

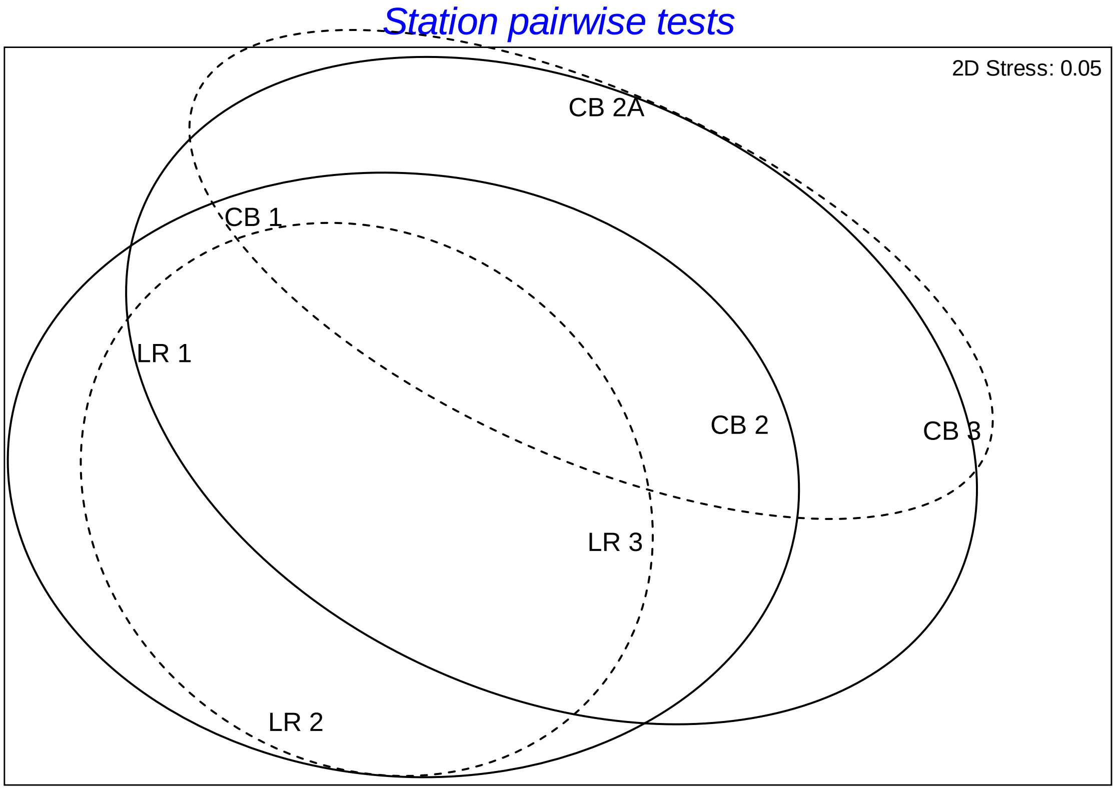


Figure 67.—Means plot MDS ordination of the stations based on Ekman dredge samples from the side of the channel in Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM *p* > 0.05).

D-frame Net Collections

A total of 8,014 individual organisms were identified and enumerated from the D-frame net collections in Cow Bayou and Lost River (Table 50). Individual tables of results by station and by trip are in Appendix A.

Table 50.—Organisms by taxon (higher-level taxonomy, usually family level) and number that were collected by D-frame nets in Cow Bayou and Lost River, 2003-2004.

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Acarina	1							1
Ampharetidae	24	7	5	42	2	14	15	109
Anisoptera				4				4
Araneae	7	16	7	23	36	24	25	138
Arthropoda				1				1
Assimineidae	2							2
Baetidae				16				16
Belastomatidae				1			1	2
Belostomatidae				1	1			2
Bopyridae	2				3			5
Brachyura	1							1
Caenidae	2		1	18			1	22
Canaceidae						1		1
Capitellidae		1		7		1		9
Ceratopogonidae	2	3		23	2		3	33
Chaoboridae				1			1	2
Chironomidae	83	42	38	302	317	74	307	1,163
Coenagrionidae	1			1		1	1	4
Coleoptera		1				9		10
Collembola						1		1
Corixidae	7			168	99	8	33	315
Corophiidae	14	32	13	14	7	29	33	142
Corydalidae					1			1
Culicidae				8				8
Curculionidae		1		6			1	8
Cyrenoididae		1						1
Diptera					10	2		12
Dreissenidae		1	3	2	4			10
Dysticidae				4				4
Elmidae						1		1
Ephemeroptera	4	3	1	6	4	4	28	50

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Gammaridae	51	50	1,126	7	7	103	171	1,515
Gelastocoridae					2			2
Gerridae	39	38	106	26	27	52	92	380
Glyceridae						1		1
Haliplidae		7		2				9
Hemiptera	1			2		1		4
Heteroptera		1					1	2
Homoptera	1	4	1	29	57		10	102
Hyalellidae	3	9		2	14			28
Hydrobiidae	67	10	7	148	29	139	179	579
Hydrophilidae	1	4		3	10	2		20
Idoteidae		1		6	10	2	5	24
Janiridae							1	1
Lepidoptera			1	33	4	7	3	48
Leptohyphiidae					1			1
Limnephilidae				3				3
Macroveliidae				1				1
Mactridae	1	3	1	2	6	3	1	17
Mysidacea	53	39	6	906	33	942	108	2,087
Mytilidae				2				2
Nemata	3	1			1			5
Nemertea		9		3	2	1		15
Nepidae				1	2		2	5
Nereididae	10	4	1	5		17	8	45
Oligochaeta	107	25	3	82	138	112	138	605
Orthoptera					2	2		4
Panopeidae				2				2
Phyllodocidae				1				1
Physidae				9		1		10
Pilargidae		2						2
Pisidiidae				1				1
Planorbidae				1	1	1		3
Plecoptera						1		1
Portunidae	3	2		6	25	4	9	49
Pyramidellidae		3		41			2	46
Ranidae							1	1
Saldidae						28	11	39
Sminthuridae				5				5
Sphaeromatidae	1	2		7	2	1		13
Spionidae	30	24	2	66	6	6	7	141
Stratiomyidae		1	1			8		10
Taeniopterygidae					1			1
Taltridae	6		10	3	2	42	18	81

Taxon	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3	Total
Taltroidea				5				5
Tetrigidae		2						2
Tridactylidae						1		1
Uenoidae		1						1
Xanthidae	1							1
Zygoptera		3		11		1		15
Grand Total	528	353	1,333	2,069	868	1,647	1,216	8,014

MDS configuration of the D-frame net samples from Cow Bayou and Lost River are shown in Figure 68.

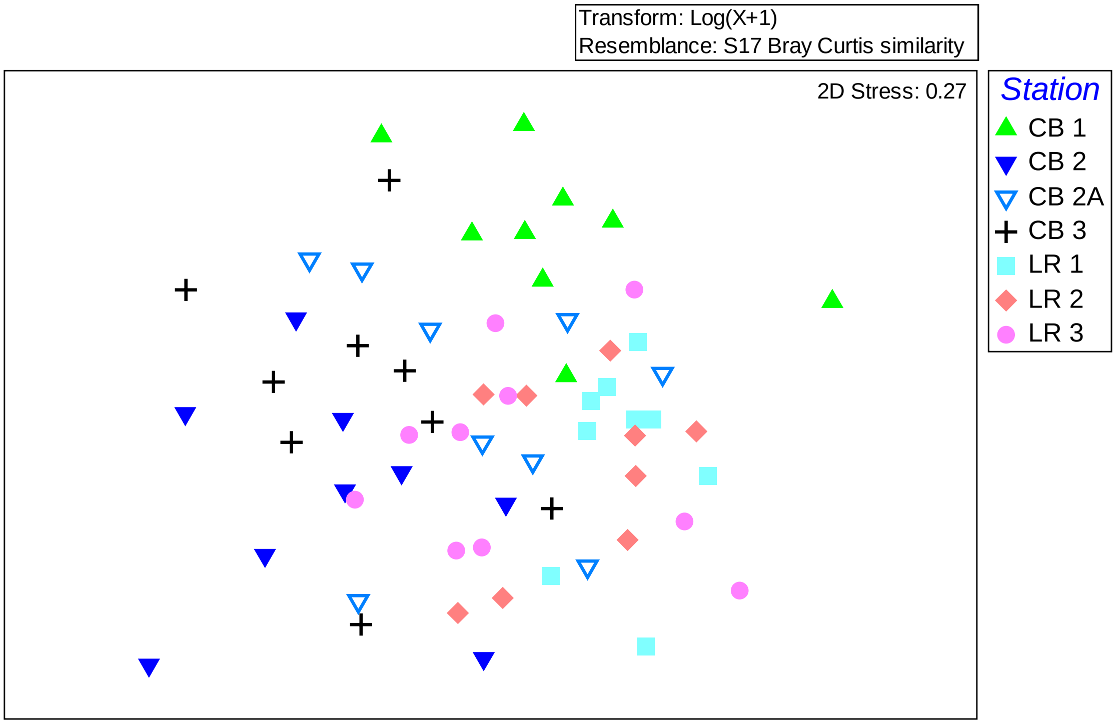


Figure 68.—MDS configuration of the D-frame net samples from Cow Bayou and Lost River.

ANOSIM revealed a weak pattern among stations in Cow Bayou (Global R = 0.189, $p <$ 0.019. The significance of the test was driven by differences between CB 1 and the other Cow Bayou stations. ANOSIM showed no difference between stations on Lost River. Means plot MDS reflects these findings, as well as similarities between samples from LR 3 and those from the lowermost three stations of Cow Bayou (Figure 69).

CB 1 and CB 2 were the two most dissimilar stations (average dissimilarity = 76.9). The dissimilarity was driven by greater abundance of oligochaetes, mysids (fairy shrimps), and janirids (isopods) at CB 1, and greater abundance of gammarids (amphipods), chironomids, and caenid mayflies at CB 2 (Table 51).

Table 51.—The contributions of selected individual species to the total average dissimilarity between invertebrate assemblages collected by D-frame nets found in stations CB 1 and CB 2. Average abundances of species, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 1 Av.Abund	CB 2 Av.Abund	Diss/SD	Cum.%
Gammaridae	0.28	3.01	1.94	10.21
Oligochaeta	2.86	0.67	1.46	18.42
Mysidacea	1.54	1.44	1.26	24.41
Chironomidae	2.43	2.74	1.12	29.32
Caenidae	1.14	1.36	1.47	33.94
Janiridae	1.29	0.29	1.23	37.98
Corophiidae	0.00	1.25	0.90	42.00
Hydrobiidae	0.20	1.26	1.17	45.78
Baetidae	0.15	1.06	0.98	49.52
Assimineidae	0.82	0.23	0.72	52.20
Corixidae	0.64	0.08	0.70	54.54
Idoteidae	0.00	0.58	0.64	56.59
Hyalellidae	0.33	0.56	0.79	58.63
Dreissenidae	0.08	0.58	0.60	60.59
Taltroidea	0.00	0.61	0.34	62.32
Ephemeroptera	0.12	0.48	0.59	64.01
Araneae	0.40	0.28	0.93	65.65
Capitellidae	0.00	0.38	0.46	67.29
Ceratopogonidae	0.32	0.40	0.71	68.87
Gerridae	0.35	0.33	0.81	70.43
Coenagrionidae	0.15	0.40	0.75	71.97
Anisoptera	0.00	0.52	0.67	73.50
Culicidae	0.08	0.37	0.59	74.80
Hydrophilidae	0.15	0.28	0.73	76.05
Bivalvia	0.61	0.00	0.49	77.24
Collembola	0.00	0.42	0.51	78.40
Planorbidae	0.62	0.08	0.41	79.52
Nereididae	0.28	0.23	0.80	80.63
Acarina	0.23	0.08	0.66	81.65
Lepidoptera	0.15	0.20	0.59	82.67
Taltridae	0.08	0.20	0.45	83.61
Melitidae	0.00	0.23	0.45	84.42
Sphaeromatidae	0.00	0.24	0.51	85.18
Gastropoda	0.00	0.22	0.34	85.89
Pisidiidae	0.12	0.08	0.41	86.59

Species	CB 1 Av.Abund	CB 2 Av.Abund	Diss/SD	Cum.%
Ancylidae	0.43	0.00	0.35	87.26
Nemata	0.12	0.08	0.47	87.94
Nepidae	0.00	0.15	0.44	88.60
Ampharetidae	0.00	0.26	0.46	89.25
Portunidae	0.08	0.20	0.58	89.86
Physidae	0.00	0.26	0.34	90.46

Neither Cow Bayou nor Lost River samples reflected seasonality.

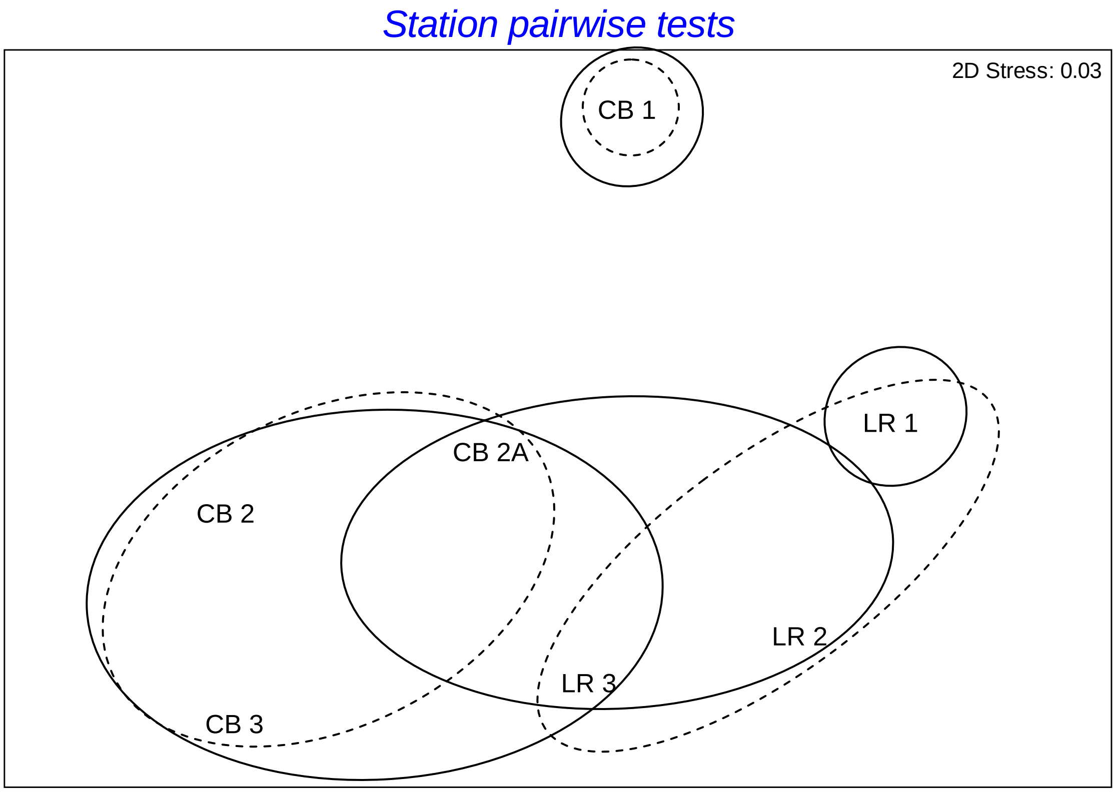


Figure 69.—Means plot MDS ordination of the stations based on D-frame net samples from Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM *p* > 0.05).

Nekton

Nekton were collected from April 2003 to November 2004 at seven sites on Lost River and Cow Bayou, using electrofishing, gill netting, seining and trawling. Over the course of the study 79,232 individuals were collected in Lost River and Cow Bayou. At least 104 species were collected over the course of the study. Of these, 92 were fish species, 7 were crustaceans, and 5 were representatives of other taxa that were incidentally captured by the nekton sampling gear.

In Cow Bayou a total of 18,663 individuals were collected (Table 52). Individual tables of results by station and by trip are in Appendix A.

Table 52.—Total nekton catch (number of individuals) and totals by gear type from Cow Bayou, Apr 2003 through Nov 2004.

Scientific Name	Common Name	Electrofish	Gill net	Seine	Trawl
Alligator mississippiensis	American alligator		1		
Alosa chrysochloris	Skipjack herring		11		
Amia calva	Bowfin	8	1		
Anchoa mitchilli	Bay anchovy	13		1,129	6,051
Aphredoderus sayanus	Pirate perch	4		7	3
Aplodinotus grunniens	Freshwater drum		4		
Archosargus probatocephalus	Sheepshead	1	5		
Ariopsis felis	Hardhead catfish		4		
Atractosteus spatula	Alligator gar		1		
Bagre marinus	Gafftopsail catfish		5		
Bairdiella chrysoura	Silver perch			5	
Brevoortia gunteri	Finescale menhaden		1		
Brevoortia patronus	Gulf menhaden	63		2,633	164
Callinectes sapidus	Blue crab	1	36	266	70
Caranx hippos	Crevalle jack		1		1
Citharichthys spilopterus	Bay whiff			21	2
Ctenogobius boleosoma	Darter goby			10	5
Ctenogobius shufeldti	Freshwater goby			5	
Cynoscion arenarius	Sand seatrout			1	123
Cynoscion nebulosus	Spotted seatrout		3	11	
Cyprinodon variegatus	Sheepshead minnow			5	
Cyprinus carpio	Common carp	3	13		
Dorosoma cepedianum	Gizzard shad	11	55		
Dorosoma petenense	Threadfin shad	17		1	2
Elops saurus	Ladyfish	1	1	3	1
Esox americanus	Grass pickerel	1		2	
Eucinostomus argenteus	Spotfin mojarra	9		7	
Family Astacidae	Crayfish			18	1
Family Atherinidae	Silverside	7		27	
Family Centrarchidae	Lepomis species			2	

Scientific Name	**Common Name**	**Electrofish**	**Gill net**	**Seine**	**Trawl**
	(sunfish)				
Family Fundulidae	killifishes, topminnows			1	
Family Macrobrachium	freshwater prawn/shrimp			3	452
Family Penaeidae	shrimp				2
Family Xanthidae	mud crabs			16	4
Fundulus chrysotus	Golden topminnow	1		8	
Fundulus grandis	Gulf killifish			10	
Fundulus notatus	Blackstripe topminnow	4		25	
Fundulus olivaceous	Blackspotted topminnow			1	
Fundulus pulvereus	Bayou killifish			41	
Gambusia affinis	Western mosquitofish	1		588	
Genus Palaemonetes	Grass shrimp			209	240
Genus Pseudemys	Cooter (freshwater turtle)		2		
Genus Rana	Tadpole			18	2
Genus *Rangia*	Rangia clam			2	1
Gobiosoma bosc	Naked goby				3
Gobiosoma robustum	Code goby			3	7
Hemicaranx amblyrhynchus	Bluntnose jack			2	
Heterandria formosa	Least killifish			2	
Ictalurus furcatus	Blue catfish	13	27		329
Ictalurus punctatus	Channel catfish	73	20	1	120
Ictiobus bubalus	Smallmouth buffalo	43	71		
Labidesthes sicculus	Brook silverside			2	
Lagodon rhomboides	Pinfish	2		16	
Leiostomus xanthurus	Spot	1	1	34	137
Lepisosteus oculatus	Spotted gar	118	176	9	33
Lepisosteus osseus	Longnose gar	3	14		
Lepomis auritus	Redbreast sunfish			3	
Lepomis gulosus	Warmouth	71	2	9	24
Lepomis macrochirus	Bluegill	333	8	227	173
Lepomis megalotis	Longear sunfish	64		6	2
Lepomis microlophus	Redear sunfish	254	7	63	55
Lepomis miniatus	Redspotted sunfish	110		102	
Lucania parva	Rainwater killifish			33	
Lythrurus fumeus	Ribbon shiner			10	
Macrobrachium ohione	Macrobrachium ohione				82

Scientific Name	**Common Name**	**Electrofish**	**Gill net**	**Seine**	**Trawl**
Menidia beryllina	Inland silverside	3		34	
Menidia peninsulae	Tidewater silverside			72	
Micropogonias undulatus	Atlantic croaker	1	1	11	418
Micropterus salmoides	Largemouth bass	246	10	111	2
Minytrema melanops	Spotted sucker	1			
Morone chrysops	White bass		2		
Morone mississippiensis	Yellow bass	4	15		
Morone saxatilis	Striped bass		2		
Mugil cephalus	Striped mullet	460	7	1	1
Mugil curema	White mullet			9	
Notemigonus crysoleucas	Golden shiner	5		16	
Notropis atrocaudalis	Blackspot shiner			1	
Notropis shumardi	Silverband shiner	1			
Notropis texanus	Weed shiner	2		1	
Oligoplites saurus	Atlantic leatherjacket			3	
Opsopoeodus emiliae	Pugnose minnow	6		17	
Paralichthys lethostigma	Southern flounder	9	7	35	4
Penaeus aztecus	Brown shrimp			74	142
Penaeus setiferus	White shrimp			110	1,081
Pimephales vigilax	Bullhead minnow			1	
Poecilia latipinna	Sailfin molly			11	
Pogonias cromis	Black drum	1	6		1
Pomoxis annularis	White crappie	5		4	4
Pomoxis nigromaculatus	Black crappie	15	14	5	66
Porichthys plectrodon	Atlantic midshipman				4
Pylodictis olivaris	Flathead catfish	1	2		1
Sciaenops ocellatus	Red drum	3	12		1
Selene vomer	Lookdown				1
Stellifer lanceolatus	Star drum			1	146
Strongylura marina	Atlantic needlefish	1		2	
Syngnathus floridae	Dusky pipefish			2	
Syngnathus louisianae	Chain pipefish			2	
Syngnathus scovelli	Gulf pipefish			17	
Trachemys scripta elegans	Red ear slider turtle		1		
Trinectes maculatus	Hogchoker			5	17
	Grand Total:	1,994	549	6,142	9,978

A total of 60,978 individuals were collected in Lost River using the nekton gear (Table 53). Individual tables of results by station and by trip are in Appendix A.

Table 53.—Total nekton catch (number of individuals) and totals by gear type from Lost River, Apr 2003 through Nov 2004.

Scientific Name	Common Name	Electrofish	Gill net	Seine	Trawl
Achirus lineatus	Lined sole			6	1
Alligator mississippiensis	American alligator		1		
Alosa chrysochloris	Skipjack herring	1	8		
Anchoa mitchilli	Bay anchovy	34		2,603	17,463
Aphredoderus sayanus	Pirate perch				1
Aplodinotus grunniens	Freshwater drum	10	11		12
Atractosteus spatula	Alligator gar		2		2
Brevoortia gunteri	Finescale menhaden		2		
Brevoortia patronus	Gulf menhaden	1063		24,655	1,528
Callinectes sapidus	Blue crab	4	79	549	272
Carcharhinus leucas	Bull shark		2		
Citharichthys spilopterus	Bay whiff	7		5	6
Class Pelecypoda	Mussel				5
Ctenogobius boleosoma	Darter goby			1	7
Ctenogobius shufeldti	Freshwater goby			2	
Ctenopharyngodon idella	Grass carp	1			
Cynoscion arenarius	Sand seatrout			9	37
Cynoscion nebulosus	Spotted seatrout			18	
Cyprinodon variegatus	Sheepshead minnow			5	
Cyprinus carpio	Common carp	17	12		18
Dasyatis sabina	Atlantic stingray				1
Dorosoma cepedianum	Gizzard shad	57	52		4
Dorosoma petenense	Threadfin shad	6			
Elops saurus	Ladyfish	2	4	9	2
Family Astacidae	Crayfish			25	
Family Atherinidae	Silverside	4		33	
Family Bothidae	flounder			3	
Family Centrarchidae	Lepomis species (sunfish)	2			
Family Cyprinidae	minnow and shiner species	3			1
Family Fundulidae	killifishes, topminnows			3	

Scientific Name	**Common Name**	**Electrofish**	**Gill net**	**Seine**	**Trawl**
Family Gobiidae	gobies			1	1
Family Ictaluridae	bullhead catfishes		1		
Family Macrobrachium	freshwater prawn/shrimp			26	247
Family Unionidae	freshwater clams				1
Family Xanthidae	mud crabs			1	4
Fundulus chrysotus	Golden topminnow			4	
Fundulus grandis	Gulf killifish	2		6	
Fundulus pulvereus	Bayou killifish			7	
Gambusia affinis	Western mosquitofish	2		310	
Genus Eucinostomus	Mojarra species			1	
Genus Palaemonetes	Grass shrimp			4,507	473
Genus Pseudemys	Cooter (freshwater turtle)		1		
Genus Rana	Tadpole			1	
Genus *Rangia*	Rangia clam				5
Gobiosoma bosc	Naked goby			11	1
Ictalurus furcatus	Blue catfish	66	64		1,959
Ictalurus punctatus	Channel catfish	51	19	5	266
Ictiobus bubalus	Smallmouth buffalo	110	142		19
Leiostomus xanthurus	Spot	2			12
Lepisosteus oculatus	Spotted gar	61	66	2	53
Lepisosteus osseus	Longnose gar	1	3		
Lepomis cyanellus	Green sunfish	1			
Lepomis gulosus	Warmouth	8	4		4
Lepomis macrochirus	Bluegill	58	2	114	23
Lepomis megalotis	Longear sunfish	42		32	9
Lepomis microlophus	Redear sunfish	3		5	
Lepomis miniatus	Spotted sunfish	18		27	
Lepomis symmetricus	Bantam sunfish	1			
Lucania parva	Rainwater killifish			39	
Macrobrachium ohione	Macrobrachium ohione			3	324
Menidia beryllina	Inland silverside	6		24	1
Menidia peninsulae	Tidewater silverside	5		40	
Microgobius gulosus	Clown goby			2	
Micropogonias undulatus	Atlantic croaker	9		67	766
Micropterus salmoides	Largemouth bass	113	14	26	
Morone chrysops	White bass	15	17		1
Morone mississippiensis	Yellow bass	7	7		10

Scientific Name	**Common Name**	**Electrofish**	**Gill net**	**Seine**	**Trawl**
Morone saxatilis	Striped bass			3	1
Mugil cephalus	Striped mullet	439	33	3	1
Mugil curema	White mullet			1	
Notemigonus crysoleucas	Golden shiner	3			
Notropis shumardi	Silverband shiner	9		53	1
Opsopoeodus emiliae	Pugnose minnow			2	
Order Anguilliformes	Eel	1			
Paralichthys lethostigma	Southern flounder	21	3	13	34
Penaeus setiferus	White shrimp	20		514	323
Poecilia latipinna	Sailfin molly			15	
Pogonias cromis	Black drum		3		
Pomoxis annularis	White crappie	6	2	1	6
Pomoxis nigromaculatus	Black crappie	35	15	7	51
Pylodictis olivaris	Flathead catfish	1	2		
Sciaenops ocellatus	Red drum	1			
Stellifer lanceolatus	Star drum			6	
Syngnathus scovelli	Gulf pipefish			7	
Trinectes maculatus	Hogchoker	2		106	203
	TOTALS:	2,330	571	33,918	24,159

Over the course of the study, the majority of the individuals from Cow Bayou and Lost River were collected by seine (40,057) and trawl (33,731), but 4,324 individuals were collected by electrofishing and 1,120 by gill net.

The first year of the study (2003) there were 73 nekton species collected in Cow Bayou and 62 in Lost River. The second year (2004) produced 16 additional species in Cow Bayou) and 7 in Lost River (Figure 70) The last sampling event in November 2004 produced 6 new species in Cow Bayou and none in Lost River.

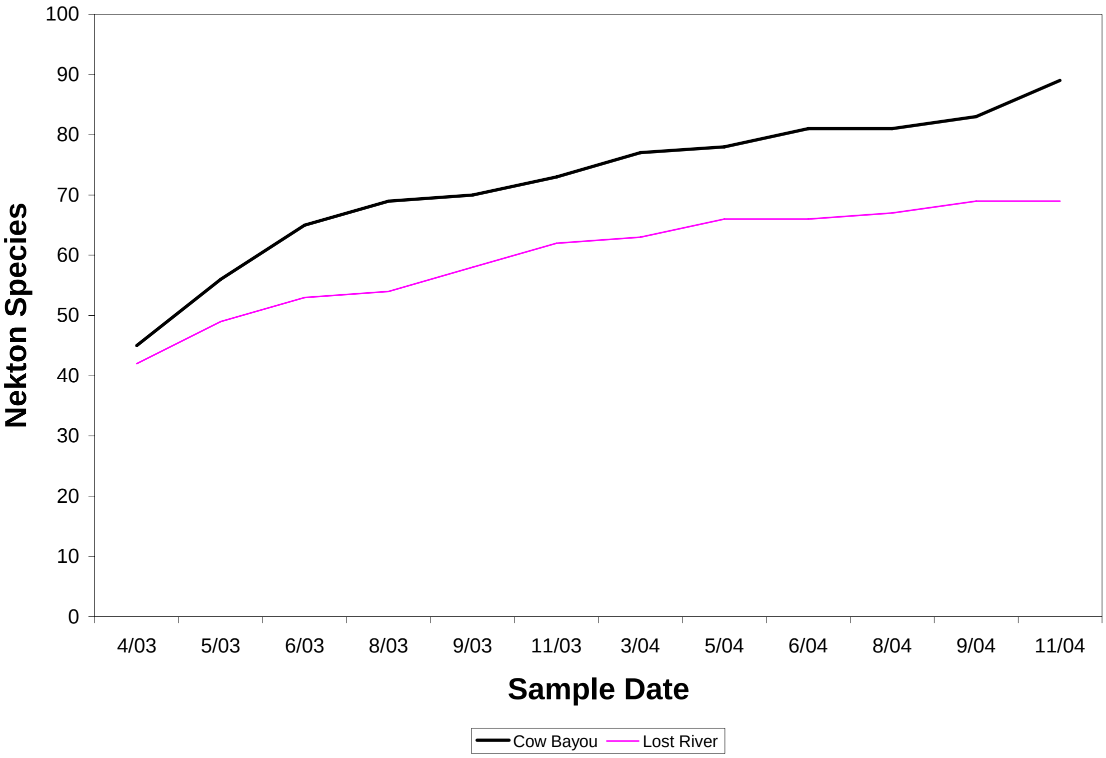


Figure 70.—Cumulative number of nekton species collected over the course of the study in Cow Bayou and Lost River, 2003-2004.

Nekton results by station are shown in Table 54.

Table 54.— Total nekton catch (number of individuals) and totals by station for Cow Bayou and Lost River, Apr 2003 through Nov 2004.

Scientific Name	Common Name	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3
Achirus lineatus	Lined sole					3	1	3
Alligator mississippiensis	American alligator		1			1		
Alosa chrysochloris	Skipjack herring		9	1	1	7	1	1
Amia calva	Bowfin	3	1	4	1			
Anchoa mitchilli	Bay anchovy	150	1,580	2,975	2,488	10,222	8,952	926
Aphredoderus sayanus	Pirate perch	11		3		1		
Aplodinotus grunniens	Freshwater drum	1	1	2		5	14	14
Archosargus probatocephalus	Sheepshead				6			
Ariopsis felis	Hardhead catfish		1		3			
Atractosteus spatula	Alligator gar			1		2	1	1
Bagre marinus	Gafftopsail catfish				5			
Brevoortia gunteri	Finescale menhaden				1		1	1
Brevoortia patronus	Gulf menhaden	537	376	1,458	489	4,457	11,252	11,537
Callinectes sapidus	Blue crab	8	154	13	198	58	150	696
Carcharhinus leucas	Bull shark							2
Citharichthys spilopterus	Bay whiff	1	16		6	1	7	10
Class Pelecypoda	Mussel						4	1
Ctenogobius boleosoma	Darter goby		7		8		4	4
Ctenogobius shufeldti	Freshwater goby		1		4	2		
Ctenopharyngodon idella	Grass carp					1		
Cynoscion arenarius	Sand seatrout		67	8	49	2	14	30

Scientific Name	**Common Name**	**CB 1**	**CB 2**	**CB 2A**	**CB 3**	**LR 1**	**LR 2**	**LR 3**
Cynoscion nebulosus	Spotted seatrout				14	1	17	
Cyprinodon variegatus	Sheepshead minnow	3			2	1		4
Cyprinus carpio	Common carp	3	2	5	6	25	20	2
Dasyatis sabina	Atlantic stingray							1
Dorosoma cepedianum	Gizzard shad	19	26	13	8	55	40	18
Dorosoma petenense	Threadfin shad	12	4	4		5	1	
Elops saurus	Ladyfish		4		2	3	5	9
Esox americanus	Grass pickerel	2		1				
Eucinostomus argenteus	Spotfin mojarra		4		12			
Family Astacidae	Crawfish	5	11	3		3	16	6
Family Atherinidae	Silverside		7	1	26	3	6	28
Family Bothidae	flounder							3
Family Centrarchidae	Lepomis species (sunfish)			2			2	
Family Cyprinidae	minnow and shiner species						1	3
Family Fundulidae	killifishes, topminnows	1						3
Family Gobiidae	gobies						2	
Family Ictaluridae	bullhead catfishes							1
Family Macrobrachium	freshwater prawn/shrimp		315	3	137	28		245
Family Penaeidae	shrimp			2				
Family Unionidae	freshwater clams						1	
Family Xanthidae	mud crabs				20		2	3
Fundulus chrysotus	Golden topminnow	1	4	4				4
Fundulus grandis	Gulf killifish				10		1	7
Fundulus notatus	Blackstripe topminnow	26		3				
Fundulus olivaceous	Blackspotted topminnow				1			

Scientific Name	Common Name	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3
Fundulus pulvereus	Bayou killifish		27	1	13		1	6
Gambusia affinis	Western mosquitofish	486	90	11	2	67	198	47
Genus *Eucinostomus*	Mojarra species							1
Genus *Palaemonetes*	Grass shrimp	7	279	75	88	917	2,094	1,969
Genus *Pseudemys*	Cooter (freshwater turtle)		2			1		
Genus *Rana*	Tadpole	18	2					1
Genus *Rangia*	Rangia clam			1	2	1		4
Gobiosoma bosc	Naked goby		3			1	2	9
Gobiosoma robustum	Code goby		9	1				
Hemicaranx amblyrhynchus	Bluntnose jack			1	3			
Heterandria formosa	Least killifish		1	1				
Ictalurus furcatus	Blue catfish	13	289	24	43	206	187	1,696
Ictalurus punctatus	Channel catfish	9	100	70	35	92	94	155
Ictiobus bubalus	Smallmouth buffalo	25	44	42	3	125	97	49
Labidesthes sicculus	Brook silverside	2						
Lagodon rhomboides	Pinfish				18			
Leiostomus xanthurus	Spot		112	12	54			14
Lepisosteus oculatus	Spotted gar	68	99	94	75	79	55	48
Lepisosteus osseus	Longnose gar	6	8	1	2	4		
Lepomis auritus	Redbreast sunfish	3						
Lepomis cyanellus	Green sunfish					1		
Lepomis gulosus	Warmouth	46	16	43	1	15		1
Lepomis macrochirus	Bluegill	203	154	368	16	181	14	2
Lepomis megalotis	Longear sunfish	51	9	12		57	26	
Lepomis microlophus	Redear sunfish	39	73	207	60	5	3	

Scientific Name	Common Name	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3
Lepomis miniatus	Redspotted sunfish	15	78	90	29	9	31	5
Lepomis symmetricus	Bantam sunfish					1		
Lucania parva	Rainwater killifish		18	3	12	6	17	16
Lythrurus fumeus	Ribbon shiner	10						
Macrobrachium ohione	Macrobrachium ohione		24		58		6	321
Menidia beryllina	Inland silverside		8	22	7	3	9	19
Menidia peninsulae	Tidewater silverside				72	17	8	20
Microgobius gulosus	Clown goby						2	
Micropogonias undulatus	Atlantic croaker		194	93	144	62	247	533
Micropterus salmoides	Largemouth bass	45	82	202	40	98	51	4
Minytrema melanops	Spotted sucker			1				
Morone chrysops	White bass		1		1	11	20	2
Morone mississippiensis	Yellow bass	4	1		14	13	8	3
Morone saxatilis	Striped bass				2	3	1	
Mugil cephalus	Striped mullet	29	66	81	293	198	137	141
Mugil curema	White mullet	3	2	1	3			1
Notemigonus crysoleucas	Golden shiner	20		1		3		
Notropis atrocaudalis	Blackspot shiner		1					
Notropis shumardi	Silverband shiner	1				4	46	13
Notropis texanus	Weed shiner	3						
Oligoplites saurus	Atlantic leatherjacket		2		1			
Opsopoeodus emiliae	Pugnose minnow	23				1	1	
Order Anguilliformes	Eel						1	
Paralichthys lethostigma	Southern flounder	1	8	3	43	16	36	19
Penaeus aztecus	Brown shrimp		67	48	101			

Scientific Name	Common Name	CB 1	CB 2	CB 2A	CB 3	LR 1	LR 2	LR 3
Penaeus setiferus	White shrimp		782	109	300	15	40	802
Pimephales vigilax	Bullhead minnow	1						
Poecilia latipinna	Sailfin molly	1	6		4	1	9	5
Pogonias cromis	Black drum		1	1	6		1	2
Pomoxis annularis	White crappie	5	1	7		10	4	1
Pomoxis nigromaculatus	Black crappie	11	11	78		81	24	3
Porichthys plectrodon	Atlantic midshipman				4			
Pylodictis olivaris	Flathead catfish	1	3			1		2
Sciaenops ocellatus	Red drum		1	1	14		1	
Selene vomer	Lookdown				1			
Stellifer lanceolatus	Star drum				147	3	2	1
Strongylura marina	Atlantic needlefish				3			
Syngnathus louisianae	Chain pipefish		1		1			
Syngnathus scovelli	Gulf pipefish	1	1	3	14		4	3
Trachemys scripta elegans	Red ear slider turtle			1				
Trinectes maculatus	Hogchoker	4	11	2	5	59	100	152
	TOTALS:	1,937	5,278	6,217	5,231	17,253	24,092	19,633

Seine

MDS configurations of the seine collections for both Cow Bayou and Lost River are shown in Figure 71.

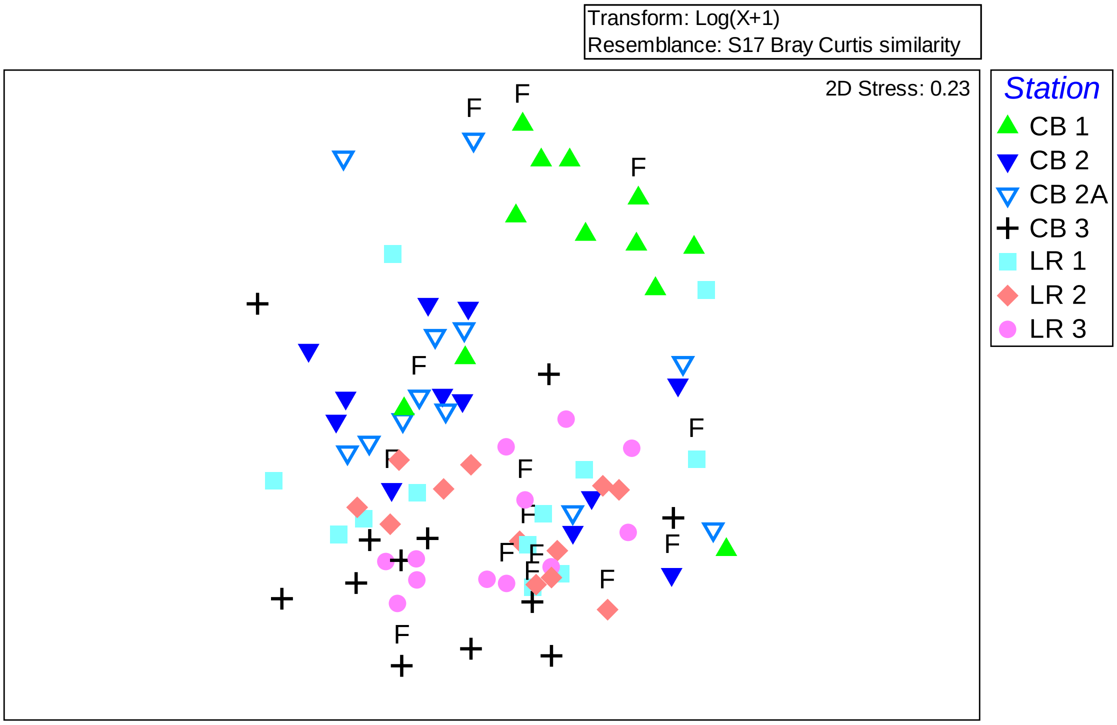


Figure 71.—MDS configuration of the seine samples in Cow Bayou and Lost River. Graph has been oriented so that downstream stations in each stream (stations CB 3 and LR 3) are more or less near the bottom of the graph and upstream stations are nearer the top of the graph. This orientation is followed in successive graphs of the same data. "F" denotes samples collected during trips which were categorized as flood conditions.

Apparent differences among the stations were confirmed by ANOSIM analysis for stations within both Cow Bayou (Global R = 0.337, prob. = 0.001) and Lost River (Global R = 0.209, prob. = 0.003).

With respect to the seine data, CB 1 stood out by itself (Figure 72). The nekton assemblages from CB 1 seine samples were significantly different from those of the other six stations except perhaps CB 2A (R statistic = 0.259, prob. = 0.005). According to the means plot MDS analysis, the pairs of stations which were most similar to each other are LR 1 and LR 2, followed by CB 2 and CB 2A.

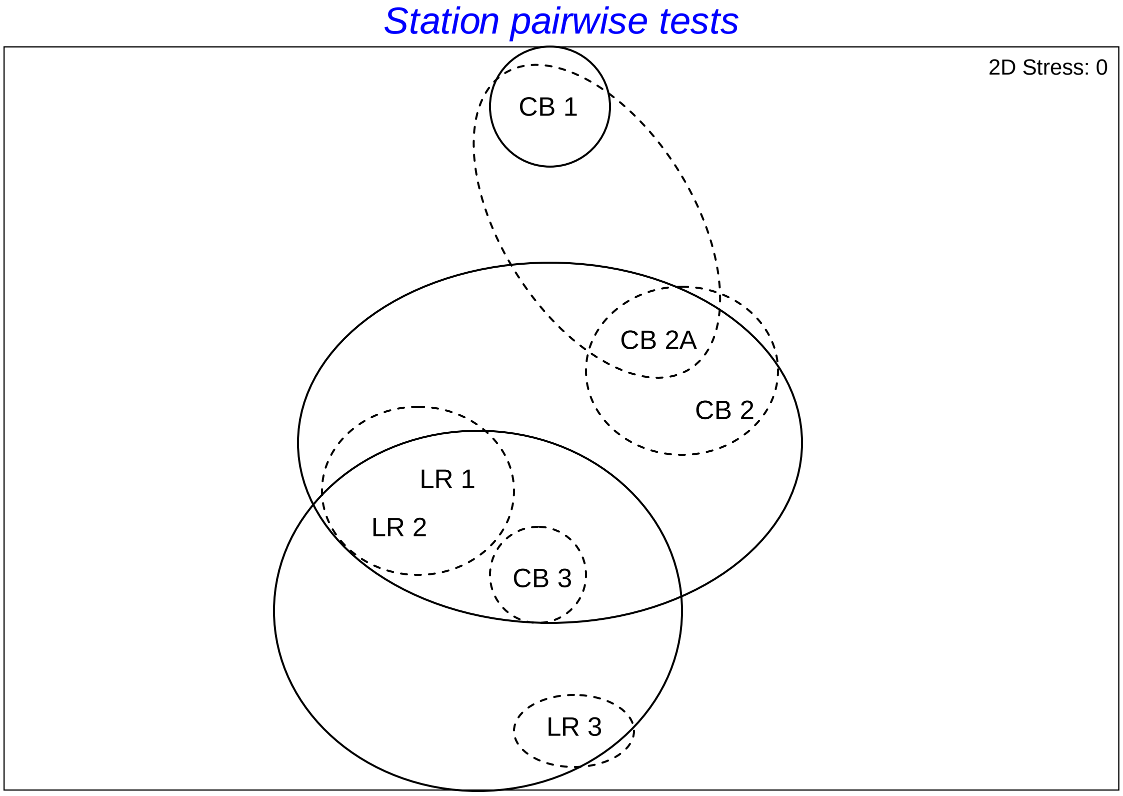


Figure 72.—Means plot MDS ordination of the stations based on seine collections from Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM $p > 0.05$).

The reasons for the differences between CB 1 and the other stations can be seen by examining the differences between CB 1 and CB 3 (Table 55). While Gulf menhaden made up the majority of the catch within both station groups, there was reduced abundance at CB 1 relative to CB 3. Other differences included reduced abundances or absence of estuarine species such as bay anchovy and blue crab at CB 1. Conversely CB 1 had higher abundances of freshwater species such as bluegill, western mosquitofish, and blackstripe topminnow than CB 3.

Table 55.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by seines found in stations CB 1 and CB 3. Average abundances of species collected by seine at stations CB 1 and CB 3, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 1 Av.Abund	CB 3 Av.Abund	Diss/SD	Contrib%
Bay anchovy	0.48	2.02	1.40	12.18
Gulf menhaden	0.50	1.22	0.75	7.98
Bluegill	1.39	0.18	1.85	7.64
Western mosquitofish	1.29	0.04	0.89	6.65
Blue crab	0.20	1.23	1.36	6.14
White shrimp	0.00	0.97	0.82	6.14
Grass shrimp	0.12	0.67	0.71	3.48
Blackstripe topminnow	0.54	0.00	1.01	3.39
Brown shrimp	0.00	0.39	0.43	2.43
Spot	0.00	0.40	0.52	2.41
Tidewater silverside	0.00	0.44	0.43	2.34
Pugnose minnow	0.36	0.00	0.69	2.25
Silverside	0.00	0.38	0.65	2.19
Pinfish	0.00	0.30	0.53	2.04
Largemouth bass	0.30	0.11	0.76	2.01
Family Xanthidae (mud crabs)	0.00	0.34	0.67	1.98
Redear sunfish	0.34	0.10	0.92	1.91
Golden shiner	0.28	0.00	0.49	1.54
Spotfin mojarra	0.00	0.18	0.50	1.35
Gulf pipefish	0.04	0.26	0.62	1.30
Spotted sunfish	0.16	0.09	0.80	1.12
Tadpole	0.24	0.00	0.38	1.03
Darter goby	0.00	0.16	0.42	1.01
Spotted seatrout	0.00	0.16	0.29	0.98
Bay whiff	0.03	0.14	0.61	0.95
Longear sunfish	0.14	0.00	0.66	0.89
Ribbon shiner	0.18	0.00	0.40	0.87
Southern flounder	0.03	0.19	0.35	0.84
White mullet	0.08	0.08	0.41	0.82
Spotted gar	0.10	0.03	0.62	0.79
Hogchoker	0.13	0.00	0.52	0.79
Warmouth	0.17	0.00	0.44	0.79
Pirate perch	0.16	0.00	0.42	0.77
Rainwater killifish	0.00	0.17	0.41	0.71
White crappie	0.10	0.00	0.29	0.70

Many of the same species dominate in the nekton assemblages of two stations that were very similar, CB 2 and CB 2A (Table 56). Differences between six species explain about 58% of the dissimilarity: bay anchovy, Gulf menhaden, blue crab, spotted sunfish, bluegill, and largemouth bass. There was greater abundance of bay anchovy, spotted sunfish, bluegill and largemouth bass at CB 2A. There was greater abundance of blue crab at CB 2. The differences in species abundances are generally not as marked as with the comparison of CB 1 to CB 3.

Table 56.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by seines found in stations CB 2 and CB 2A. Average abundances of species collected by seine at stations CB 2 and CB 2A, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 2 Av.Abund	CB 2A Av.Abund	Diss/SD	Contrib%
Bay anchovy	1.42	1.85	1.23	14.47
Gulf menhaden	1.05	1.01	0.72	13.51
Blue crab	1.36	0.23	1.34	9.72
Spotted sunfish	0.62	0.92	1.17	7.38
Bluegill	0.86	1.16	1.35	6.77
Largemouth bass	0.31	0.75	0.87	5.95
Redear sunfish	0.49	0.62	1.16	5.01
Grass shrimp	0.35	0.49	0.58	3.67
Brown shrimp	0.29	0.21	0.62	3.42
Western mosquitofish	0.35	0.32	0.60	2.95
Inland silverside	0.17	0.21	0.45	2.92
Bay whiff	0.32	0.00	0.58	2.39
Crayfish	0.22	0.11	0.63	2.00
Spot	0.22	0.00	0.52	1.67
Rainwater killifish	0.22	0.14	0.49	1.54
Atlantic croaker	0.19	0.00	0.42	1.41
Silverside	0.11	0.03	0.38	1.39
Bayou killifish	0.25	0.04	0.37	1.27
Spotted gar	0.12	0.11	0.68	1.22
Golden topminnow	0.13	0.13	0.53	1.16
Southern flounder	0.17	0.07	0.52	1.05

Looking at the Lost River seine results, the biggest difference in the pairwise station comparisons is between LR 2 and LR 3 (R = 0.344, $p < 0.008$) Under the SIMPER analysis the two groups had an average dissimilarity of 61.80. Over half of the difference between the two stations can be explained by higher abundance of Gulf menhaden and bay anchovy at LR 2, and higher abundance of grass shrimp, white shrimp, and blue crab at LR 3 (Table 57).

Table 57.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by seines found in stations LR 1 and LR 3. Average abundance, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	LR 2 Av.Abund	LR 3 Av.Abund	Diss/SD	Contrib%
Gulf menhaden	3.32	2.19	1.23	17.05
Grass shrimp	1.78	2.53	1.37	11.59
White shrimp	0.28	1.71	0.97	9.71
Bay anchovy	3.23	2.61	1.27	8.77
Blue crab	1.12	2.67	1.64	8.76
Western mosquitofish	0.72	0.69	0.94	5.28
Hogchoker	0.56	0.57	1.05	3.81
Silverband shiner	0.65	0.22	0.94	3.32
Atlantic croaker	0.04	0.55	0.70	2.51
Crayfish	0.39	0.18	0.86	2.31
Silverside	0.12	0.33	0.59	2.11
Tidewater silverside	0.17	0.33	0.65	2.10
Spotted sunfish	0.39	0.11	0.72	2.05
Inland silverside	0.13	0.28	0.62	1.99
Rainwater killifish	0.18	0.26	0.63	1.60
Naked goby	0.04	0.23	0.69	1.22
Sailfin molly	0.19	0.14	0.69	1.20
Southern flounder	0.07	0.17	0.55	1.07
Bluegill	0.16	0.06	0.59	1.04
Ladyfish	0.09	0.14	0.60	1.00
Black crappie	0.16	0.00	0.59	0.97
Gulf pipefish	0.12	0.10	0.73	0.93

Seasonality was an important factor in the seine collections (ANOSIM Global R = 0.214, prob. = 0.001 for Cow Bayou; ANOSIM Global R = 0.4, prob. = 0.001 for Lost River). Spring and fall collections had distinct nekton communities, with the summer nekton communities spanning the two seasons (Figure 73).

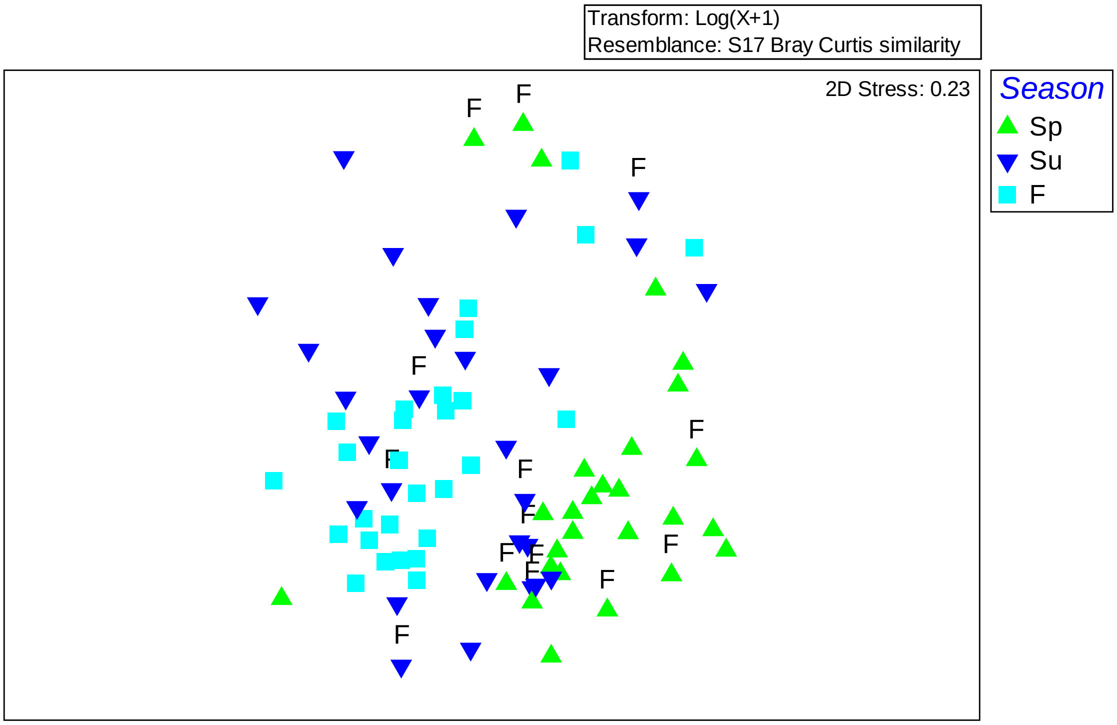


Figure 73.—MDS configuration of seine collections from Cow Bayou and Lost River stations. Station configuration based on Figure 71, but labeled by season of collection. “F” denotes samples collected during trips which were categorized as flood conditions.

The average dissimilarity between spring and fall samples was 82.9. About half of the relative dissimilarity was explained by the relative abundances of five species. Spring was dominated by greater abundance of Gulf menhaden, bluegill, and western mosquitofish. Fall was characterized by higher abundance of bay anchovy and blue crab.

Table 58.—The contributions of selected individual species to the total average dissimilarity between fish assemblages collected in spring and fall, as measured by seine samples from Cow Bayou and Lost River. Average abundances of species collected by seine at all Cow Bayou and Lost River stations in each season, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two seasons.

Species	Spring Av.Abund	Fall Av.Abund	Diss/SD	Contrib%
Gulf menhaden	2.67	0.00	1.09	17.71
Bay anchovy	0.71	2.17	1.17	13.08
Blue crab	0.49	1.08	1.16	6.76
Bluegill	0.90	0.88	1.41	6.21
Western mosquitofish	0.79	0.26	0.63	5.09
Spotted sunfish	0.43	0.66	0.99	4.89
Grass shrimp	0.85	0.19	0.78	4.28
White shrimp	0.00	0.65	0.57	4.11
Redear sunfish	0.34	0.39	0.89	3.45
Blackstripe topminnow	0.14	0.12	0.54	2.10
Brown shrimp	0.17	0.11	0.39	1.98
Pugnose minnow	0.05	0.22	0.53	1.91
Tidewater silverside	0.24	0.09	0.35	1.80
Largemouth bass	0.33	0.05	0.46	1.76
Silverside	0.18	0.04	0.49	1.63
Crayfish	0.10	0.21	0.62	1.61
Bay whiff	0.19	0.00	0.47	1.27
Rainwater killifish	0.34	0.00	0.46	1.26
Bayou killifish	0.30	0.03	0.42	1.25
Family Xanthidae (mud crabs)	0.19	0.02	0.45	1.24
Southern flounder	0.29	0.00	0.47	1.16
Spotted gar	0.11	0.11	0.68	1.13
Golden shiner	0.12	0.03	0.31	1.07
Spot	0.18	0.03	0.50	1.04
Gulf pipefish	0.19	0.00	0.52	0.94
Golden topminnow	0.16	0.07	0.51	0.91
Darter goby	0.03	0.12	0.39	0.85

Spring and summer were also very dissimilar (average dissimilarity = 82.91). Spring samples had higher abundance of Gulf menhaden and western mosquitofish than summer samples (Table 59). Summer samples had higher abundance of bay anchovy, largemouth bass, and blue crab. Bluegill was a characteristic component of both assemblages with roughly the same abundance for both seasons.

Table 59.—The contributions of selected individual species to the total average dissimilarity between fish assemblages in spring and summer, as measured by seine samples from Cow Bayou and Lost River. Average abundances of species collected by seine at all Cow Bayou and Lost River stations in each season, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two seasons.

Species	Spring Av.Abund.	Summer Av.Abund.	Diss/SD	Contrib%
Gulf menhaden	2.67	0.18	1.10	16.53
Bay anchovy	0.71	1.45	0.90	9.81
Bluegill	0.90	0.91	1.32	5.83
Largemouth bass	0.33	0.72	0.99	5.35
Western mosquitofish	0.79	0.46	0.66	5.24
Blue crab	0.49	0.69	1.06	4.67
Grass shrimp	0.85	0.19	0.73	4.06
Redear sunfish	0.34	0.43	1.07	3.17
Brown shrimp	0.17	0.39	0.54	2.97
Spotted sunfish	0.43	0.26	0.70	2.88
Spot	0.18	0.26	0.54	2.36
Blackstripe topminnow	0.14	0.21	0.57	2.24
Inland silverside	0.05	0.29	0.41	2.06
Silverside	0.18	0.17	0.56	2.03
Bay whiff	0.19	0.18	0.67	1.88
Rainwater killifish	0.34	0.05	0.57	1.51
Gulf pipefish	0.19	0.16	0.73	1.48
Pinfish	0.02	0.21	0.42	1.46
Southern flounder	0.29	0.06	0.53	1.32
Family Xanthidae (mud crabs)	0.19	0.04	0.47	1.29
Tidewater silverside	0.24	0.00	0.27	1.27
White mullet	0.00	0.19	0.55	1.15
Golden shiner	0.12	0.06	0.34	1.14
Atlantic croaker	0.05	0.14	0.43	1.06
Bayou killifish	0.30	0.00	0.37	1.06
Warmouth	0.14	0.06	0.49	0.97
Tadpole	0.04	0.14	0.31	0.89
Spotted gar	0.11	0.05	0.57	0.78
Sailfin molly	0.11	0.10	0.43	0.77
Spotted seatrout	0.12	0.00	0.25	0.76
White crappie	0.07	0.00	0.25	0.68
Pirate perch	0.03	0.09	0.35	0.68
White shrimp	0.00	0.10	0.32	0.66

Trawl

MDS configurations of the trawl data for both Cow Bayou and Lost River are shown in Figure 74.

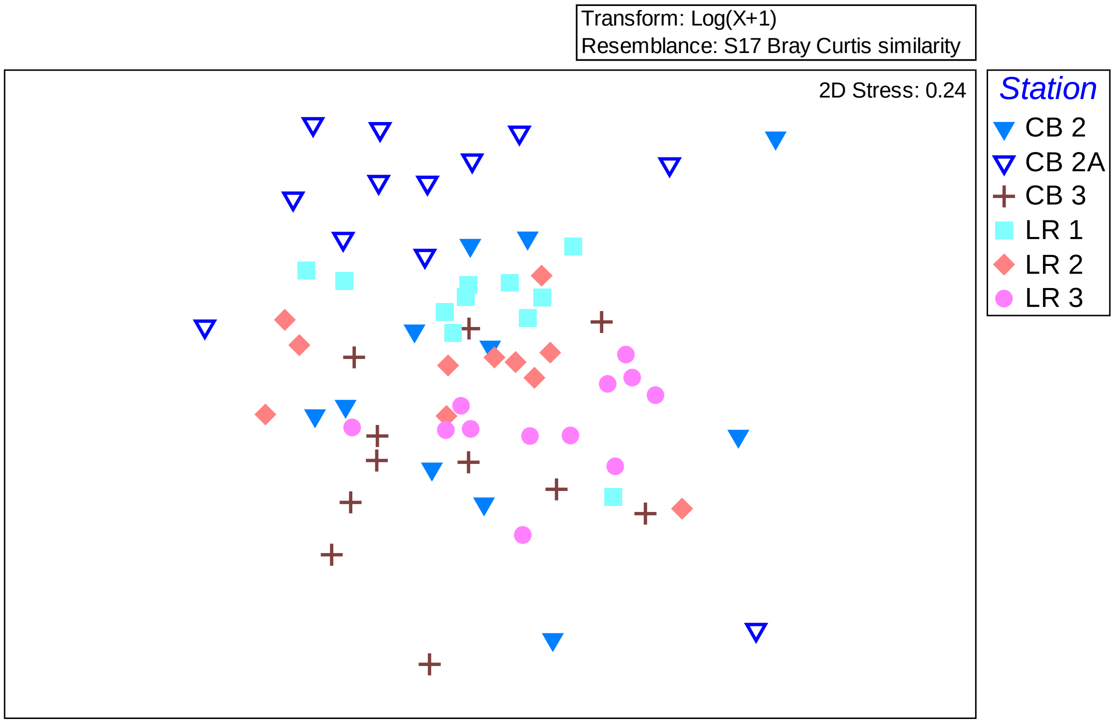


Figure 74.—MDS configuration of the trawl samples in Cow Bayou and Lost River. Graph has been oriented so that downstream stations in each stream (stations CB 3 and LR 3) are more or less near the bottom of the graph and upstream stations are nearer the top of the graph. This orientation is followed in successive graphs of the same data.

Apparent differences among the stations were confirmed by ANOSIM analysis for stations within both Cow Bayou (Global R = 0.3, prob. = 0.001) and Lost River (Global R = 0.274, prob. = 0.008). Means plot MDS ordination of all seven stations is depicted in Figure 75.

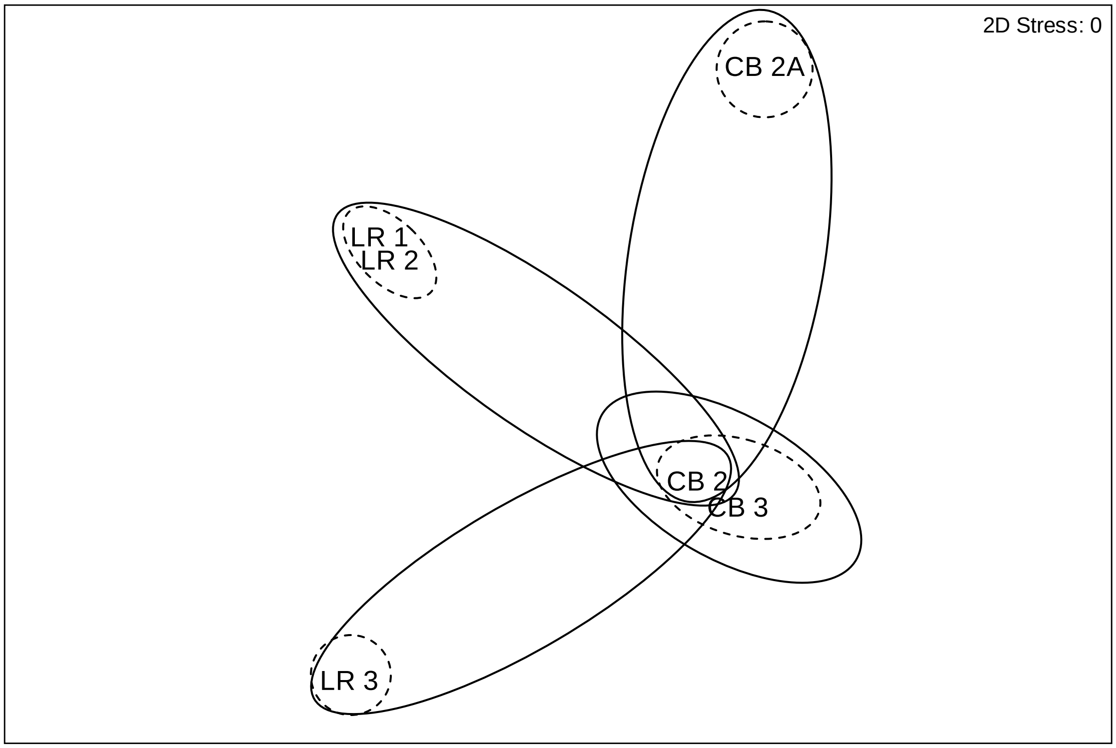


Figure 75.—Means plot MDS ordination of the stations based on trawl collections from Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM *p* > 0.05).

In Cow Bayou the only significant difference was between CB 2A and CB 3 (R = 0.579, $p < 0.001$). SIMPER analysis showed an average dissimilarity of around 74.1 between those two stations. The difference was based largely on greater abundances of bay anchovy, bluegill, black crappie, and channel catfish at CB 2A, and greater abundances of white shrimp, Atlantic croaker, blue crab, and blue catfish at CB 3 (Table 60).

Table 60.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by trawl samples from stations CB 2A and CB 3. Average abundances, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 2A Av.Abund	CB 3 Av.Abund	Diss/SD	Cum.%
Bay anchovy	4.39	3.68	1.12	10.26
Bluegill	2.85	0.00	1.54	18.28
White shrimp	1.13	2.63	1.22	25.78
Atlantic croaker	1.89	3.05	1.33	33.26
Blue crab	0.13	1.99	1.44	38.83
Blue catfish	0.74	1.88	1.16	44.12
Black crappie	1.63	0.00	0.80	49.00
Channel catfish	1.71	1.06	1.05	53.77
Family Macrobrachium (freshwater prawn/shrimp)	0.42	1.34	0.80	58.07
Spot	0.59	1.23	0.95	62.26
Warmouth	1.54	0.00	1.22	66.43
Sand seatrout	0.30	1.32	0.73	70.25
Redear sunfish	1.31	0.00	0.68	73.49
Spotted gar	1.22	0.00	0.91	76.69
Grass shrimp	0.13	1.08	0.83	79.88
Brown shrimp	0.41	0.94	0.64	82.85
Gulf menhaden	1.04	0.30	0.67	85.75
Macrobrachium ohione	0.00	0.69	0.42	87.40
Family Xanthidae (mud crabs)	0.00	0.50	0.56	88.93
Hogchoker	0.14	0.41	0.48	90.32

In Lost River LR 1 and LR 3 were significantly different (R = 0.572, $p < 0.0001$). LR 2 and LR 3 were also significantly different (R = 0.404, $p < 0.0002$). Average dissimilarity between LR 2 and LR 3 was 59.2. Differences were due largely to greater abundances of bay anchovy at LR 1 and greater abundances of white shrimp, freshwater prawn, Atlantic croaker, Gulf menhaden, and blue catfish at LR 3.

Table 61.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by trawl samples from stations LR 1 and LR 3. Average abundances, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	LR 1 Av.Abund	LR 3 Av.Abund	Diss/SD	Cum.%
Bay anchovy	5.92	1.99	1.45	11.86
White shrimp	0.37	2.26	0.89	18.35
Family Macrobrachium (freshwater prawn/shrimp)	0.20	2.45	1.08	24.34
Atlantic croaker	2.26	3.28	1.33	30.30
Gulf menhaden	2.10	2.61	1.14	36.18
Blue catfish	3.60	5.84	1.68	42.05
Hogchoker	1.12	2.61	1.44	47.40
Grass shrimp	1.01	1.64	0.88	52.32
Blue crab	1.46	2.60	1.22	57.24
Macrobrachium ohione	0.00	1.79	0.75	62.03
Black crappie	1.72	0.13	1.09	66.29
Spotted gar	1.64	0.98	1.12	70.29
Channel catfish	2.60	3.11	1.33	73.82
Sand seatrout	0.00	1.22	0.89	77.21
Southern flounder	0.72	0.45	0.78	79.56
Bluegill	0.96	0.00	0.67	81.68
Smallmouth buffalo	0.64	0.57	0.80	83.78
Freshwater drum	0.16	0.55	0.59	85.26
Yellow bass	0.52	0.13	0.64	86.72
Spot	0.00	0.58	0.53	88.17
White crappie	0.55	0.13	0.64	89.60
Rangia clam	0.15	0.54	0.73	91.00

SIMPER analysis revealed the average dissimilarity between LR 2 and LR 3 was 59.4. Differences were due to higher abundances of bay anchovy at LR 2, and higher abundances of Atlantic croaker, Gulf menhaden, white shrimp, freshwater prawn, and hogchoker at LR 3 (Table 62).

Table 62.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by trawl samples from stations LR 2 and LR 3. Average abundances, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	LR 2 Av.Abund	LR 3 Av.Abund	Diss/SD	Cum.%
Bay anchovy	5.97	1.99	1.40	12.09
Atlantic croaker	2.53	3.28	1.25	19.57
Gulf menhaden	2.47	2.61	1.24	26.80
White shrimp	0.61	2.26	0.90	33.44
Family Macrobrachium (freshwater prawn/shrimp)	0.00	2.45	1.00	39.59
Hogchoker	1.30	2.61	1.32	45.49
Blue catfish	3.70	5.84	1.57	51.37
Macrobrachium ohione	0.42	1.79	0.86	56.58
Channel catfish	2.27	3.11	1.21	61.33
Blue crab	2.00	2.60	1.11	65.93
Grass shrimp	0.15	1.64	0.82	69.84
Sand seatrout	0.78	1.22	1.00	73.67
Southern flounder	1.13	0.45	0.96	76.44
Spotted gar	0.59	0.98	0.91	79.16
Common carp	1.06	0.00	0.87	81.57
Smallmouth buffalo	0.44	0.57	0.78	83.37
Freshwater drum	0.15	0.55	0.60	84.92
Black crappie	0.53	0.13	0.51	86.41
Spot	0.00	0.58	0.52	87.89
Family Xanthidae (mud crabs)	0.29	0.27	0.59	89.32
Rangia clam	0.00	0.54	0.67	90.64

Cow Bayou trawl data showed a weak but statistically significant seasonal signal (Global R = 0.132, $p < 0.042$; Figure 76). Spring and summer were significantly different from each other (R = 0.239, $p < 0.012$).

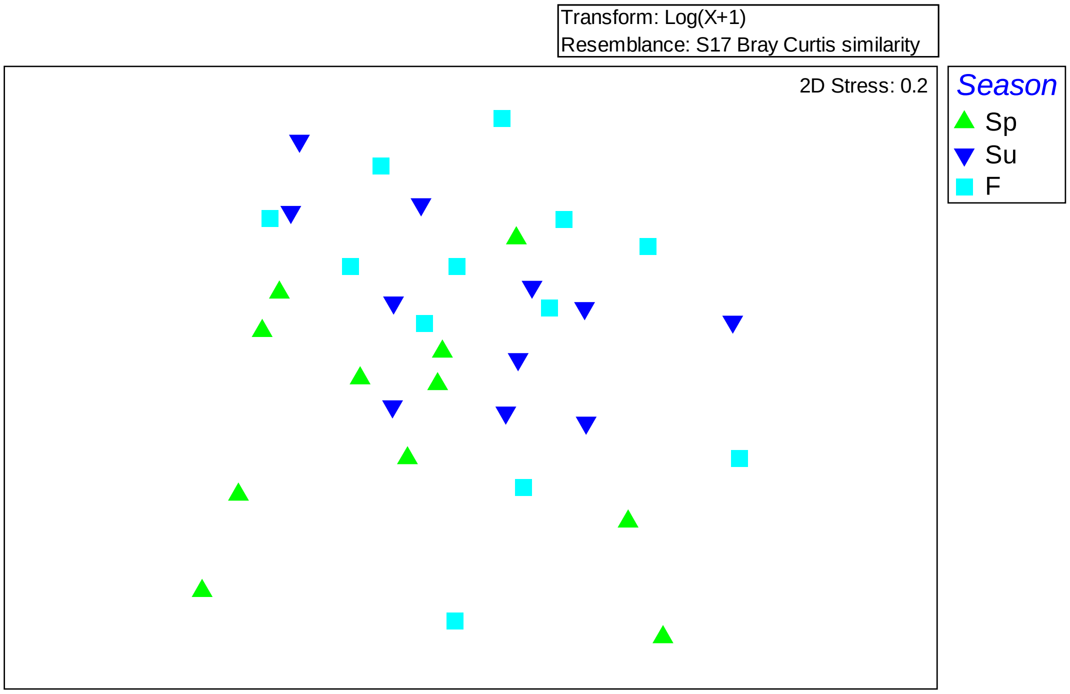


Figure 76.—MDS configuration of Cow Bayou trawl samples, labeled by season.

The average dissimilarity between spring and summer samples was 70.8. Differences between spring and summer were primarily due to greater abundances of Atlantic croaker and channel catfish in spring, and greater abundances of bay anchovy, blue catfish, spot, and Gulf menhaden in summer (Table 63).

Table 63.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by trawl samples from spring and summer in Cow Bayou. Average abundances, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two seasons.

Species	Spring Av.Abund	Summer Av.Abund	Diss/SD	Cum.%
Bay anchovy	2.79	4.58	1.08	10.64
Atlantic croaker	3.67	1.37	1.39	19.75
Blue catfish	1.10	2.72	1.23	27.09
Channel catfish	2.19	1.44	1.11	33.15
Spot	0.40	1.92	1.03	38.85
Gulf menhaden	1.27	1.57	1.03	44.34
Family Macrobrachium (freshwater prawn/shrimp)	0.87	1.41	0.89	49.61
White shrimp	0.20	1.62	0.94	54.68
Bluegill	0.92	0.98	0.79	59.55
Sand seatrout	0.38	1.78	0.89	64.36
Blue crab	0.86	1.07	0.96	68.89
Grass shrimp	0.69	1.40	0.87	73.40
Black crappie	0.61	0.80	0.54	77.50
Brown shrimp	0.15	1.42	0.66	81.29
Spotted gar	0.99	0.76	0.86	84.93
Warmouth	0.78	0.39	0.73	87.61
Redear sunfish	0.73	0.00	0.46	89.24
Macrobrachium ohione	0.00	0.47	0.46	90.54

Lost River trawl samples also showed a weak seasonality (Global R = 0.162, $p < 0.034$; Figure 77). This trend was due to differences between spring and fall samples (R = 0.43, $p < 0.006$).

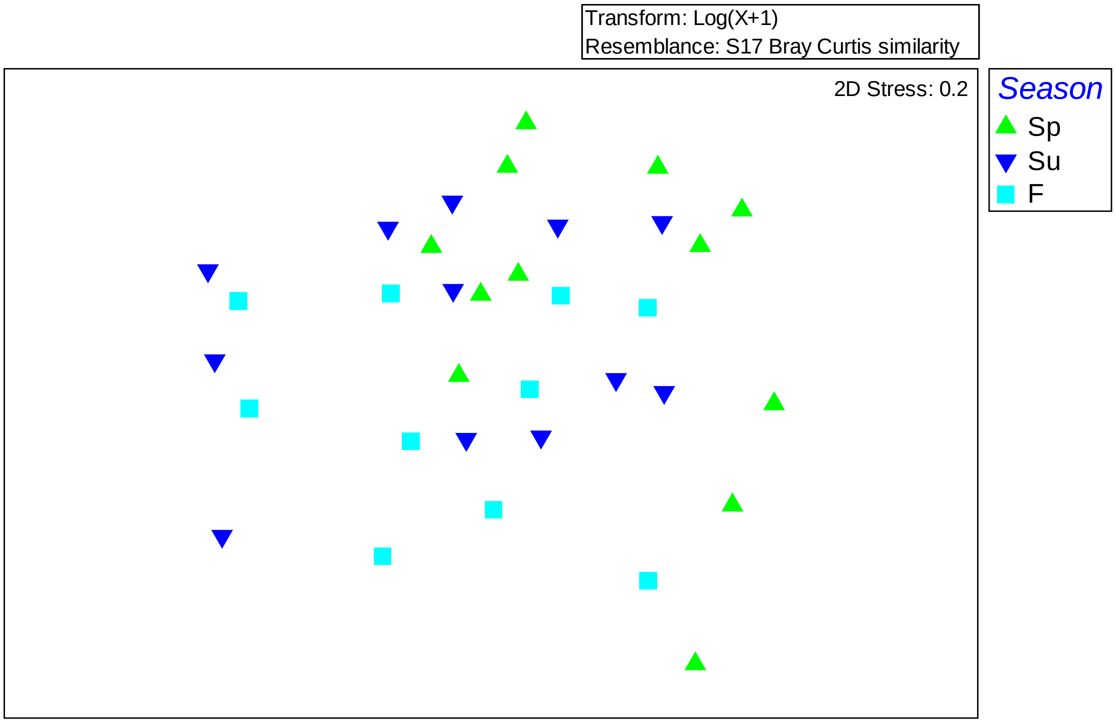


Figure 77.—MDS configuration of Lost River trawl samples, labeled by season.

Average dissimilarity between spring and fall samples was 59.7. Differences between the two seasons were primarily due to higher abundances of Atlantic croaker, Gulf menhaden, blue crab, and hogchoker in spring, and higher abundances of bay anchovy and white shrimp in fall (Table 64).

Table 64.—The contributions of selected individual species to the total average dissimilarity between fish assemblages as measured by trawl samples from spring and fall. Average abundances, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two seasons.

Species	Spring Av.Abund	Fall Av.Abund	Diss/SD	Cum.%
Bay anchovy	2.81	5.89	1.11	12.71
Atlantic croaker	4.37	1.47	1.63	22.05
White shrimp	0.00	2.43	0.89	28.73
Gulf menhaden	2.79	1.24	1.20	35.01
Blue crab	3.22	1.04	1.45	41.25
Hogchoker	1.92	1.64	1.18	46.69
Grass shrimp	1.36	1.00	0.76	51.51
Blue catfish	4.37	4.38	1.34	56.17
Family Macrobrachium (freshwater prawn/shrimp)	1.47	0.22	0.71	60.33
Channel catfish	3.09	2.56	1.35	64.35
Southern flounder	1.32	0.42	0.98	67.87
Spotted gar	1.41	0.16	1.04	71.32
Black crappie	0.78	0.48	0.70	74.02
Macrobrachium ohione	0.13	0.87	0.53	76.63
Sand seatrout	0.22	0.79	0.78	79.02
Common carp	0.70	0.00	0.67	80.96
Bluegill	0.82	0.00	0.55	82.89
Smallmouth buffalo	0.79	0.16	0.72	84.79
Family Xanthidae (mud crabs)	0.40	0.16	0.60	86.43
Longear sunfish	0.65	0.00	0.56	88.00
Darter goby	0.00	0.54	0.48	89.27
Spot	0.13	0.37	0.43	90.36

Gill Net

MDS configuration of the gill net samples from Cow Bayou and Lost River are shown in Figure 78.

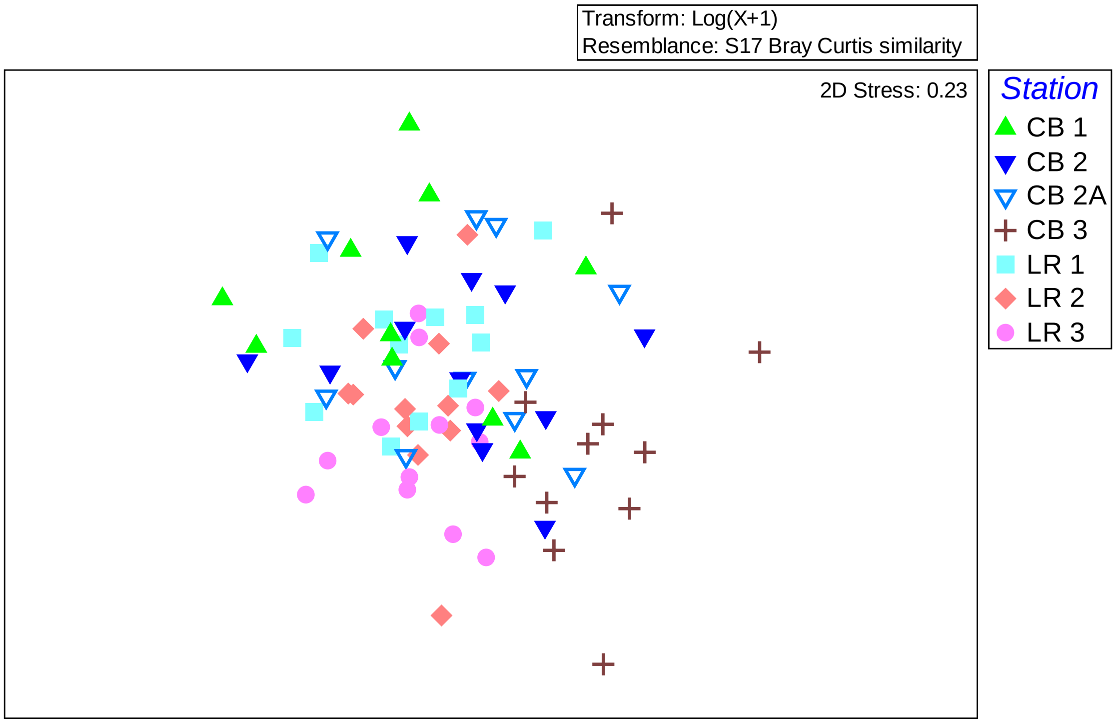


Figure 78.—MDS configuration of the gill net samples in Cow Bayou and Lost River. Graph has been oriented so that downstream stations in each stream (stations CB 3 and LR 3) are more or less near the bottom of the graph and upstream stations are nearer the top of the graph. This orientation is followed in successive graphs of the same data.

ANOSIM analysis confirmed apparent differences for both Cow Bayou (Global R = 0.155, $p < 0.013$) and Lost River (Global R = 0.119, $p < 0.046$). Within Cow Bayou, the only station that was significantly different from the others was CB 3 (Figure 79). Within Lost River, LR 1 was not significantly different from LR 3, and LR 1 was not significantly different from LR 2, but LR 2 and LR 3 were significantly different from each other (R = 0.278, $p < 0.013$).

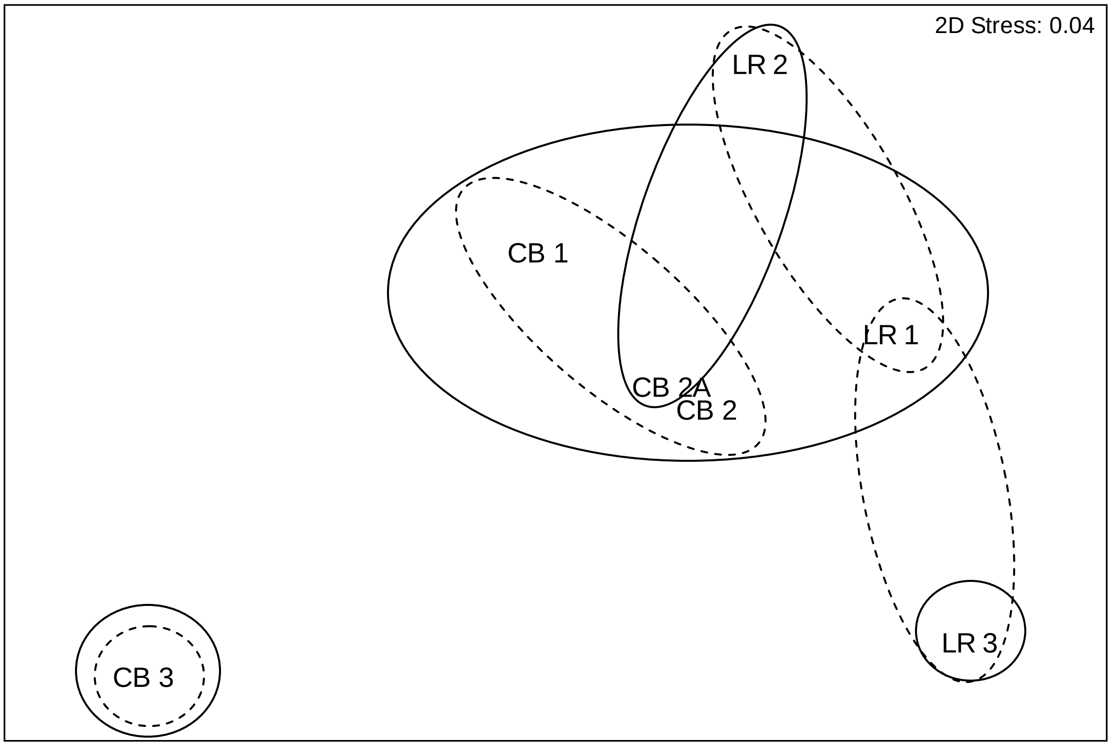


Figure 79.— Means plot MDS ordination of the stations based on gill net collections from Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM *p* > 0.05).

A comparison of CB 1 and CB 3 showed an average dissimilarity of 89.2. The species contributing most to the dissimilarity were smallmouth buffalo and gizzard shad (found in more abundance at CB 1) and spotted gar, red drum, yellow bass, and blue crab (found in more abundance at CB 3) (Table 65).

Table 65.—The contributions of selected individual species to the total average dissimilarity between fish assemblages in CB 1 and CB 3, as measured by gill net samples from Cow Bayou and Lost River. Average abundances of species collected by gill net at CB 1 and CB 3, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 1 Av.Abund	CB 3 Av.Abund	Diss/SD	Cum.%
Spotted gar	0.18	0.21	1.46	23.10
Smallmouth buffalo	0.10	0.02	0.96	32.29
Red drum	0.00	0.07	0.79	40.81
Gizzard shad	0.08	0.03	1.04	47.69
Yellow bass	0.02	0.07	0.62	54.17
Blue crab	0.01	0.06	0.58	60.13
Blue catfish	0.05	0.01	0.88	65.21
Sheepshead	0.00	0.03	0.54	69.01
Common carp	0.01	0.02	0.46	72.65
Longnose gar	0.04	0.00	0.48	76.24
Channel catfish	0.00	0.04	0.68	79.04
Southern flounder	0.00	0.03	0.52	81.64
Black drum	0.00	0.02	0.56	83.82
Gafftopsail catfish	0.00	0.03	0.56	85.84
Black crappie	0.02	0.00	0.73	87.85
Hardhead catfish	0.00	0.02	0.55	89.57
Spotted seatrout	0.00	0.01	0.44	91.15

SIMPER comparison of CB 2A and CB 3 showed an average dissimilarity of 83.1. The species contributing most to the dissimilarity were smallmouth buffalo, and gizzard shad (more abundant at CB 2A) and spotted gar, red drum, and blue crab (more abundant at CB 3) (Table 66).

Table 66.—The contributions of selected individual species to the total average dissimilarity between fish assemblages in CB 2A and CB 3, as measured by gill net samples from Cow Bayou and Lost River. Average abundances of species, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 2A Av.Abund	CB 3 Av.Abund	Diss/SD	Cum.%
Spotted gar	0.19	0.21	1.32	19.78
Smallmouth buffalo	0.13	0.02	0.77	31.44
Red drum	0.00	0.07	0.87	39.01
Gizzard shad	0.07	0.03	0.72	45.98
Blue crab	0.01	0.06	0.59	51.62
Yellow bass	0.00	0.07	0.60	57.15
Channel catfish	0.04	0.04	0.99	61.59
Common carp	0.03	0.02	0.72	65.77
Blue catfish	0.04	0.01	0.92	69.86
Sheepshead	0.00	0.03	0.58	73.30
Black crappie	0.02	0.00	0.64	76.27
Southern flounder	0.00	0.03	0.52	78.78
Bluegill	0.03	0.00	0.64	81.03
Black drum	0.00	0.02	0.58	83.10
Gafftopsail catfish	0.00	0.03	0.56	85.11
Striped mullet	0.01	0.02	0.62	86.88
Hardhead catfish	0.00	0.02	0.57	88.53
Largemouth bass	0.01	0.01	0.62	90.01

Within Lost River, LR 2 and LR 3 were different (R = 0.278, p <0.013). A comparison of the two groups revealed an average dissimilarity of 68.5. This reflects higher abundances of almost all the dominant species at LR 2, especially smallmouth buffalo, blue crab, and blue catfish (Table 67).

Table 67.—The contributions of selected individual species to the total average dissimilarity between fish assemblages in LR 2 and LR 3, as measured by gill net samples from Cow Bayou and Lost River. Average abundances of species collected by gill net at LR 2 and LR 3, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	LR 2 Av.Abund	LR 3 Av.Abund	Diss/SD	Cum.%
Smallmouth buffalo	0.32	0.15	1.41	19.32
Blue crab	0.15	0.12	0.66	34.55
Blue catfish	0.18	0.03	1.05	46.26
Spotted gar	0.13	0.13	1.23	56.50
Gizzard shad	0.14	0.06	1.08	64.77
Striped mullet	0.07	0.08	1.10	72.25
White bass	0.06	0.01	0.62	77.26
Channel catfish	0.04	0.02	1.12	81.12
Freshwater drum	0.04	0.02	0.88	84.56
Black crappie	0.03	0.01	0.64	87.39
Common carp	0.02	0.01	0.70	89.29
Largemouth bass	0.02	0.01	0.74	91.12

Gill net results did not exhibit seasonality.

Electrofishing

MDS configurations of the electrofishing collections for both Cow Bayou and Lost River are shown in Figure 80. Apparent differences between stations were confirmed by ANOSIM for Cow Bayou (Global R = 0.136, $p < 0.04$) and Lost River (Global R = 0.372, $p < 0.008$).

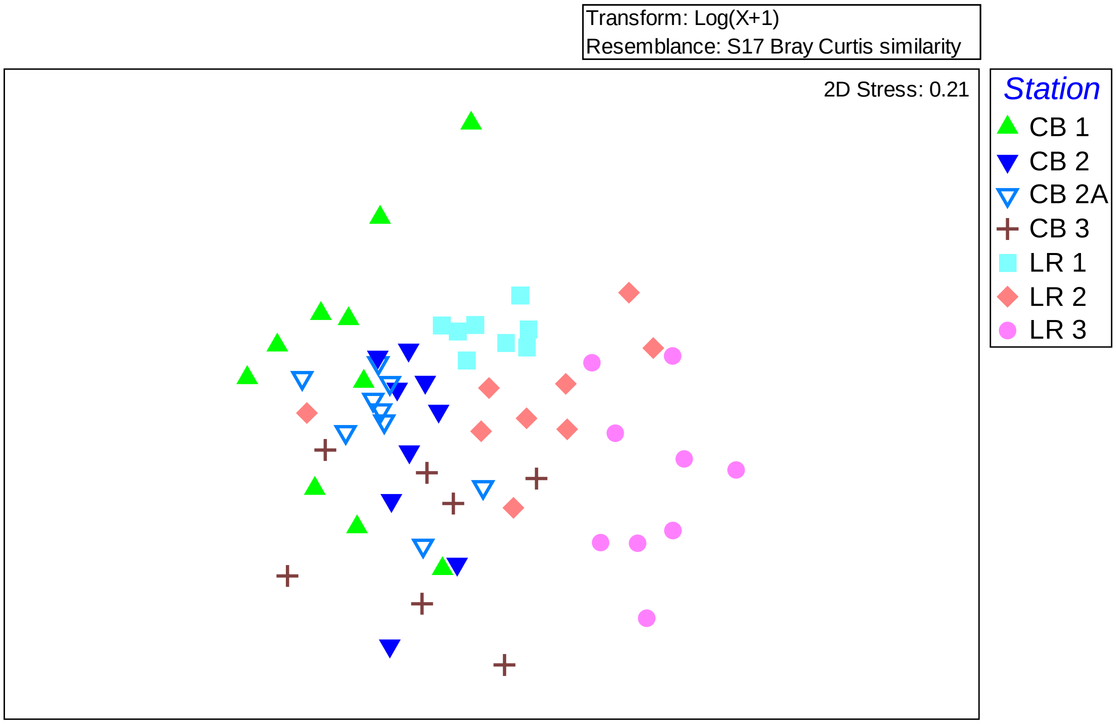


Figure 80.—MDS configuration of the electrofishing samples in Cow Bayou and Lost River. Graph has been oriented so that downstream stations in each stream (stations CB 3 and LR 3) are more or less near the bottom of the graph and upstream stations are nearer the top of the graph. This orientation is followed in successive graphs of the same data.

In Cow Bayou the pairs of stations which were different were CB 1 and CB 3 and CB 2A and CB 3. Comparison of CB 1 to CB 3 exhibited an average dissimilarity of 69.4. Species contributing to the difference between CB 1 and CB 3 included bluegill, longear sunfish, and warmouth (more abundant at CB 1) and striped mullet, redear sunfish, and largemouth bass (more abundance at CB 3) (Table 68).

Table 68.—The contributions of selected individual species to the total average dissimilarity between fish assemblages in CB 1 and CB 3, as measured by electrofisher samples from Cow Bayou and Lost River. Average abundances of species, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	CB 1 Av.Abund	CB 3 Av.Abund	Diss/SD	Cum.%
Striped mullet	1.67	3.97	1.45	9.75
Bluegill	2.69	0.23	1.63	17.48
Longear sunfish	2.24	0.00	1.96	24.73
Redear sunfish	1.55	2.87	1.23	31.68
Warmouth	1.75	0.22	1.09	36.68
Largemouth bass	2.07	2.51	1.09	41.64
Spotted gar	1.93	2.34	1.01	46.40
Spotted sunfish	0.75	1.44	0.94	51.06
Channel catfish	0.89	1.06	0.96	55.07
Gulf menhaden	0.00	1.14	0.60	58.31
Southern flounder	0.00	0.93	0.72	61.08
Threadfin shad	0.64	0.00	0.44	63.53
Smallmouth buffalo	0.64	0.00	0.46	65.93
Gizzard shad	0.58	0.46	0.83	68.10
Spotfin mojarra	0.00	0.62	0.54	70.11
Red drum	0.00	0.68	0.81	72.09
Common carp	0.16	0.46	0.60	74.07
Yellow bass	0.16	0.46	0.59	76.04
Pugnose minnow	0.64	0.00	0.62	77.95
Blackstripe topminnow	0.64	0.00	0.75	79.79
Blue catfish	0.44	0.22	0.58	81.59
Bowfin	0.48	0.22	0.70	83.37
Golden shiner	0.64	0.00	0.78	85.13
Pirate perch	0.54	0.00	0.63	86.53
Silverside	0.00	0.48	0.40	87.76

In Lost River the only pair of stations which was different was LR 1 and LR 3. This pair of stations had an average dissimilarity value of 62.1. Overall species abundances were higher at LR 1. Species predominantly responsible for the dissimilarity included largemouth bass, smallmouth buffalo, and spotted gar (more abundant at LR 1). Gulf menhaden and striped mullet were more abundant at LR 3 (Table 69).

Table 69.—The contributions of selected individual species to the total average dissimilarity between fish assemblages in LR 1 and LR 3, as measured by electrofisher samples from Cow Bayou and Lost River. Average abundances of species, dissimilarity divided by standard deviation, and percent contribution of the relative dissimilarity to the average dissimilarity for the two stations.

Species	LR 1 Av.Abund	LR 2 Av.Abund	Diss/SD	Cum.%
Gulf menhaden	2.40	2.78	1.24	9.76
Largemouth bass	2.14	0.28	1.43	16.98
Smallmouth buffalo	2.08	1.00	1.40	22.61
Spotted gar	1.88	0.78	1.27	27.94
Channel catfish	1.90	1.02	1.23	32.85
Bay anchovy	1.35	0.99	1.16	37.42
Southern flounder	1.24	0.96	1.18	41.53
Gizzard shad	1.12	0.60	1.03	45.43
Striped mullet	3.60	3.76	1.45	49.29
Blue catfish	0.98	0.60	1.00	53.02
White bass	1.07	0.18	1.06	56.72
Atlantic croaker	0.24	0.89	0.90	60.16
White shrimp	0.44	0.73	0.75	63.51
Bluegill	0.89	0.00	1.07	66.55
Freshwater drum	0.84	0.18	0.90	69.47
Bay whiff	0.28	0.46	0.63	71.55
Longear sunfish	0.60	0.00	0.50	73.60
Blue crab	0.37	0.36	0.70	75.64
Black crappie	0.60	0.00	0.67	77.67
Common carp	0.60	0.00	0.69	79.68
Spotted sunfish	0.58	0.00	0.49	81.50
Silverband shiner	0.28	0.33	0.49	83.30
Inland silverside	0.42	0.18	0.62	85.08
Yellow bass	0.43	0.00	0.50	86.80
Silverside	0.24	0.24	0.49	88.21
Redear sunfish	0.42	0.00	0.52	89.51
Hogchoker	0.00	0.35	0.53	90.66

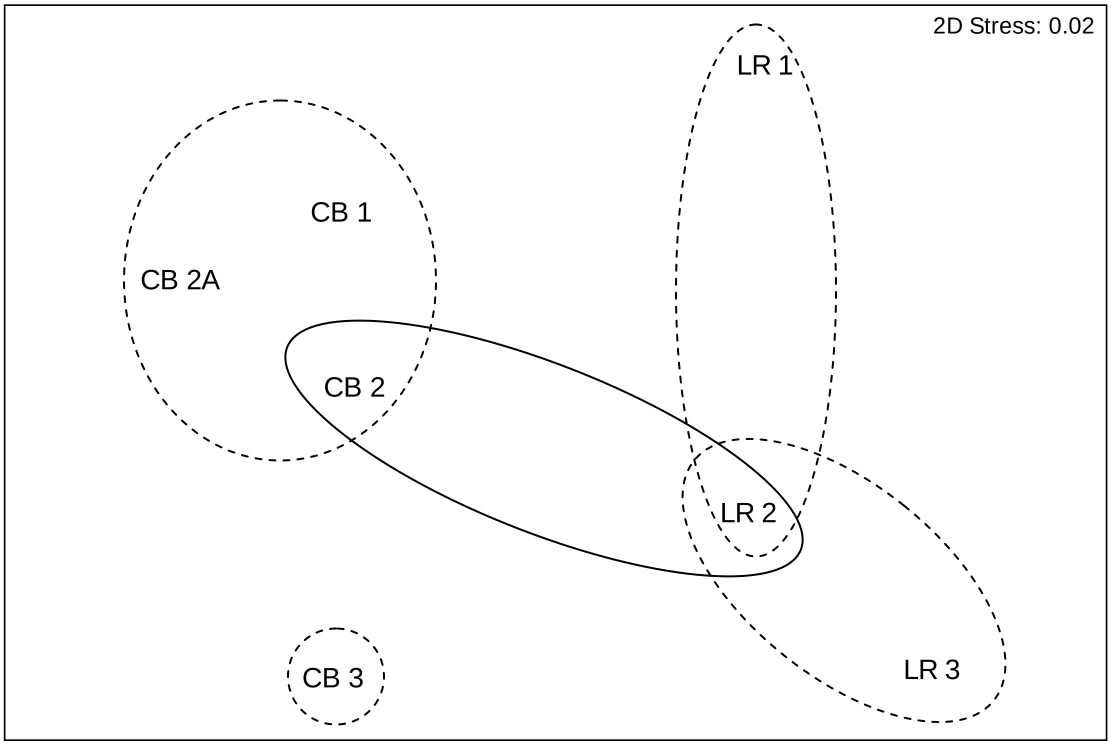


Figure 81.—Means plot MDS ordination of the stations based on electrofishing collections from Cow Bayou and Lost River. Stations within an ellipse (dashed lines represent within-stream comparisons; solid lines across stream comparisons) are not significantly different (ANOSIM $p > 0.05$).

Electrofishing results did not exhibit seasonality.

MDS Configuration Agreements

Spearman's rank correlation (ρ_s) was used to quantify the degree of agreement among the biological, chemical, and physical MDS configurations. Biological sampling for this study was designed to address temporal and spatial changes in community composition across many different trophic levels and life history stages. The only sampling gears that revealed consistent patterns among the stations were the nekton collections of seines and benthic infauna (Table 70). No other biological collections (gill nets, electrofishing, or aquatic invertebrates) had significant correlations among their MDS configurations. BEST (Biota and/or Environmental Matching) analysis revealed that the agreement between the seines and benthic infauna configurations was driven primarily by four nekton species (hogchoker, longear sunfish, silverband shiner, and star drum) and three infaunal taxa (Anisoptera, Dytiscidae, and Pisidiidae). The MDS configuration of the infaunal organisms was used as the basis for comparing the biological agreements. The relationship between hogchokers and silverband shiners to the overall benthic infaunal collections can be seen in the Lost River samples (Figure 82). The pattern of nekton abundance matched the infaunal MDS most closely within Lost River for three of these four nekton taxa. Only star drum differed from the general pattern, with this species being collected only from the lowermost station on Cow Bayou. The benthic organisms that displayed significant distributional matching in their abundance with the nekton were all collected exclusively from CB 1 (Figure 83).

No significant agreements ($\rho_s > 0.3$) between the biotic and abiotic components of ecosystem health were identified between any of the gears used for this study (Table 70). The highest correlations were found between the benthic infauna and water quality measurements, aquatic invertebrates and water quality measurements, as well as electrofishing and water column profiles. Similarily, the seine and trawl collections were each correlated with water column profiles, but each was below the ρ_s criteria established for this study. This general lack of significant agreement between the biotic and abiotic components is not surprising, given the clear differences in abiotic characters between the reference and impacted streams (Figure 42, Figure 59) coupled with the broad overlap in biotic characters between these same streams (Figure 71, Figure 78). As an example, Figure 84 shows the MDS configuration of the stations based on water column profile measurements, overlaid with surface salinity and DO concentrations. While stations on Lost River were generally lower in salinity and higher in DO, those abiotic differences did not translate into consistent differences in the biological communities recorded. Bay anchovy catch rates overlaid onto the water column profile MDS configuration (Figure 84C) shows that this characteristic estuarine species did not appear to respond to the general gradients in abiotic characters found within these two streams.

Table 70.—Matrix of Spearman's rank correlations between MDS configurations of the biological, chemical, and physical components of ecosystem health measures in Cow Bayou and Lost River. Only the lower panel of the correlation matrix is presented. Probability of obtaining a larger correlation coefficient by random chance (based on 1,000 permutations) denoted by: * = *prob.* < 0.01, ** = *prob.* < 0.001. Significant correlations ($\rho_s > 0.3$) identified in bold.

	Seine[a]	**Trawl[b]**	**Gill Net[c]**	**Electrofishing[d]**	**Aquatic Invertebrates[e]**	**Benthic Infauna[f]**	**Water Column Profile**	**Water Quality**	**Sediments**
Seine	___								
Trawl	0.288**	___							
Gill Net	0.137*	0.165*	___						
Electrofishing	0.194**	0.114	0.206*	___					
Aquatic Invertebrates	0.257**	0.139	0.132	0.065	___				
Benthic Infauna	**0.328****	0.136	0.139	0.209	0.266**	___			
Water Column Profile	0.212**	0.221**	0.090	0.245**	0.172*	0.207	___		
Water Quality	0.136*	0.158	0.032	0.110	0.246**	0.253	**0.479****	___	
Sediments	0.095	0.046	-0.086	-0.075	0.066	0.096	0.006	-0.033	___

[a] Seines related to surface measurements from the water column profiles and side sediments; [b] trawls related to bottom measurements from the water column profiles and middle sediments; [c] gill nets, [d] electrofishing, and [e] aquatic invertebrates related to surface measurements from the water column profiles and side sediments; [f] benthic infauna related to bottom measurements from the water column profile and middle sediments.

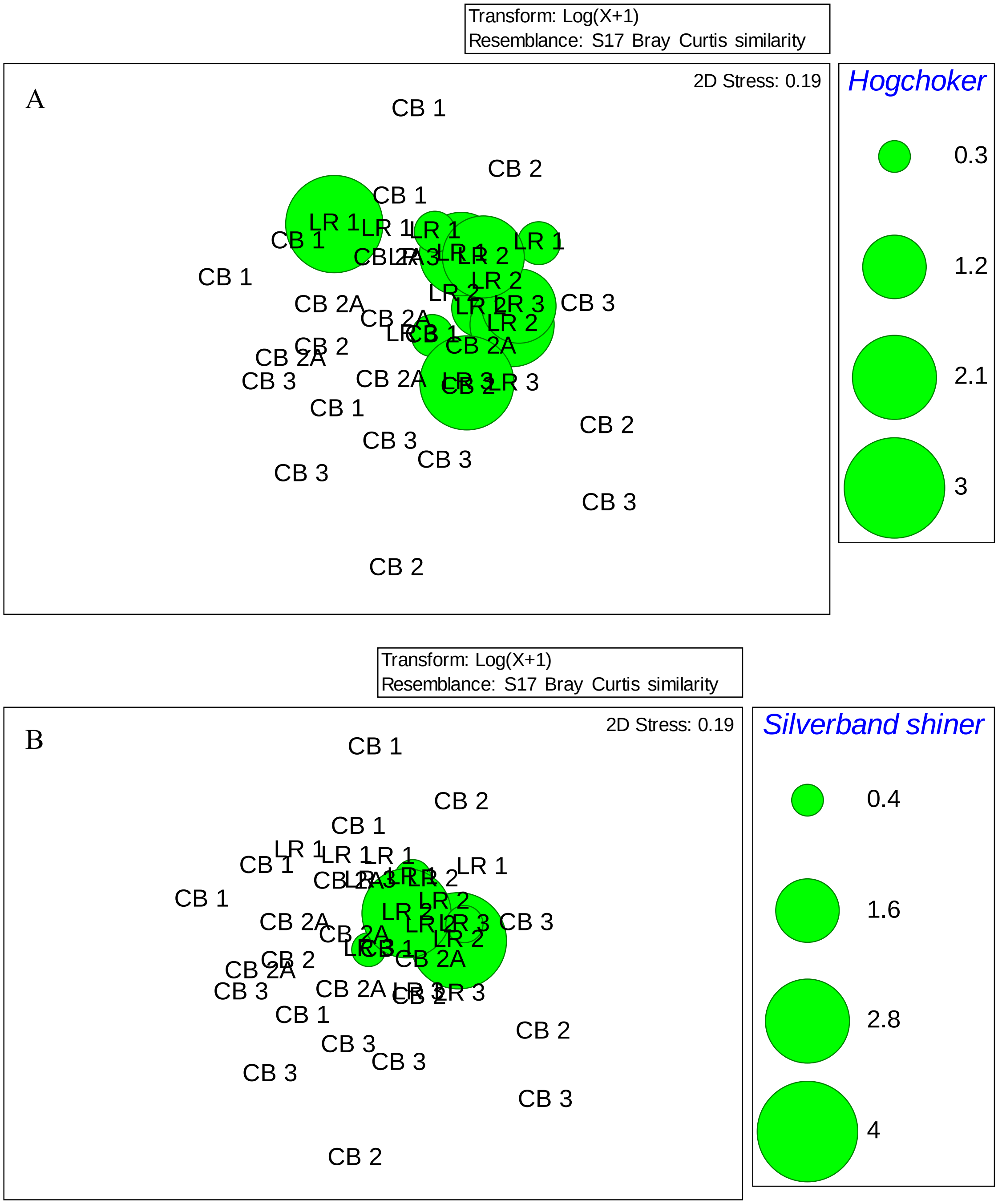


Figure 82.—MDS configuration of the stations based on benthic infaunal collections from Cow Bayou and Lost River. Overlaid onto each station is the catch rate of A, hogchoker, and B, silverband shiner, as collected by seines. Size of each circle is represented by the scale at the right.

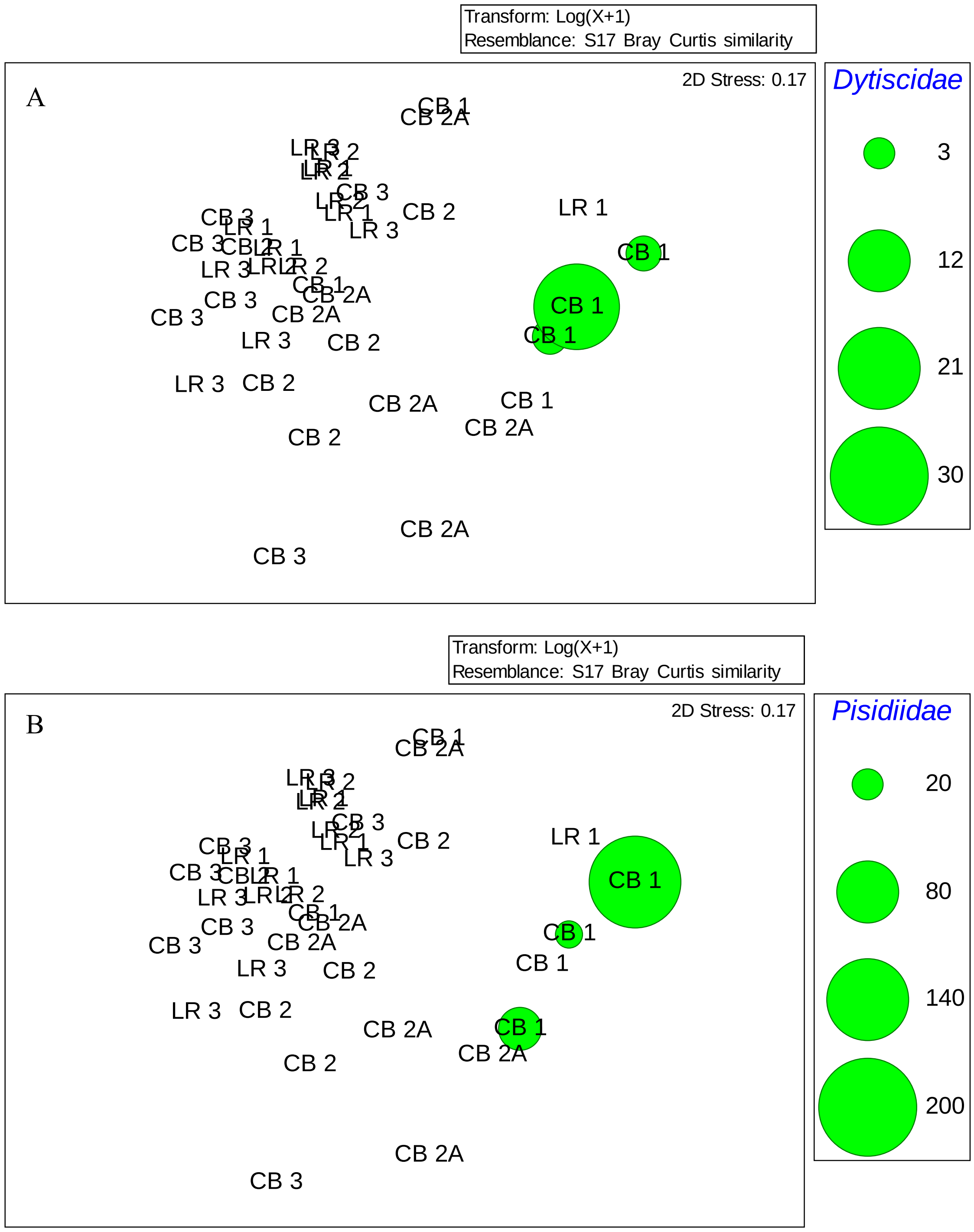


Figure 83.—MDS configuration of the stations based on seine collections from Cow Bayou and Lost River. Overlaid onto each station is the catch rate of A, Dytiscidae, and B, Pisidiidae, as collected by Ekman dredge. Size of each circle is represented by the scale at the right.

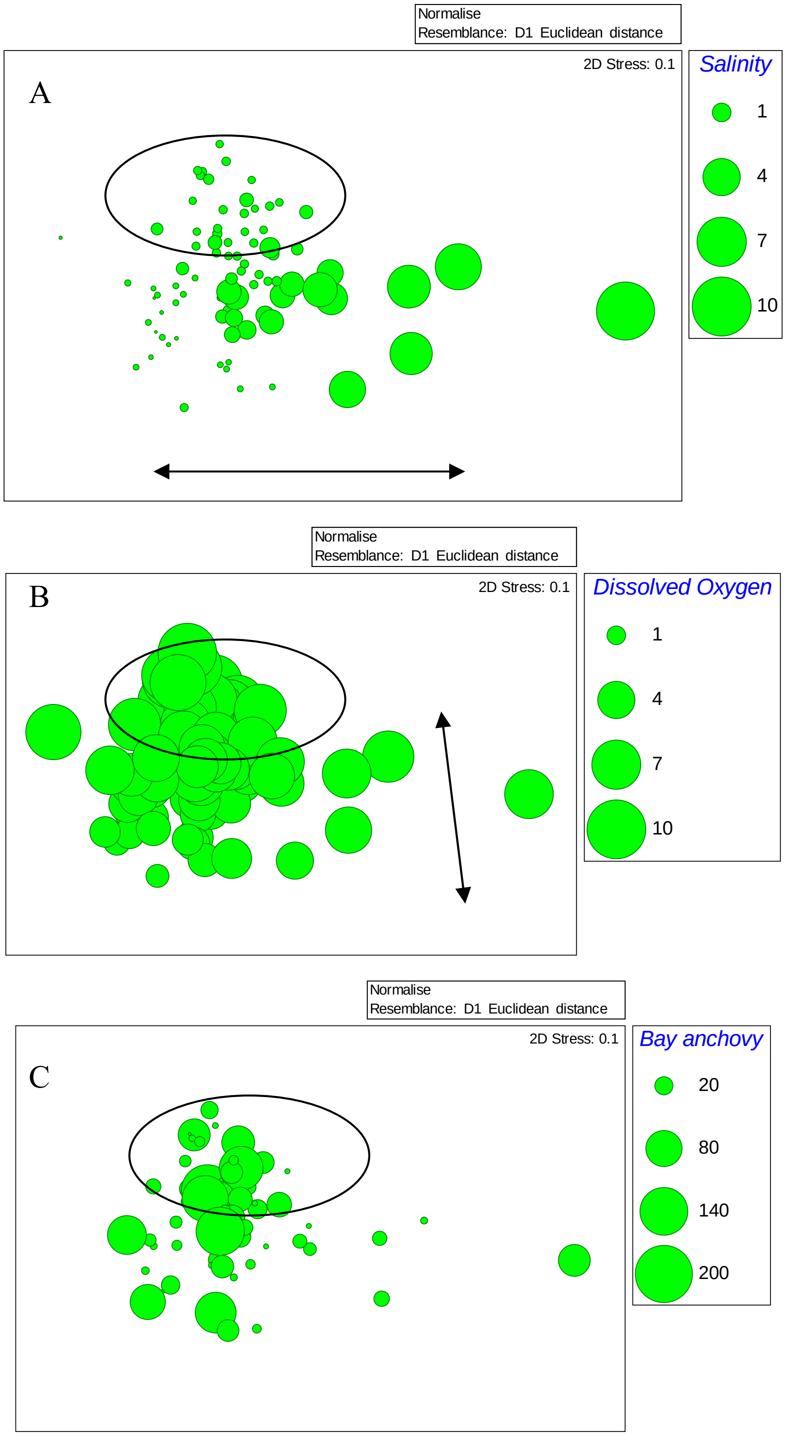


Figure 84.—MDS configuration of the stations based on electrofishing collections from Cow Bayou and Lost River (samples from Lost River are enclosed in the ellipse). A = MDS configuration overlaid with surface water column salinity measurements (in PSU); B = surface dissolved oxygen measurements (in mg/l); and C = catch rates for bay anchovy. Size of each circle is represented by the scale at the right.

Average Taxonomic Distinctness

The Average Taxonomic Distinctness measure (Δ*, identified in all subsequent figures as Delta+) takes the form of Delta+ = 0 if two individuals drawn at random from a sample are the same species; Delta+ = 20, different species from the same genera; Delta+ = 40, different genera from the same family, etc. In order to simplify the biological interpretation of this measure, all invertebrates were excluded from the nekton collections such that the distinctness measures for seines, trawls, gill nets, and electrofishing reflects the taxonomic breadth of the fish communities only. Invertebrate collections of the benthics infauna (both side and middle collections) and the aquatic invertebrates sampled by D-frame nets include the entire lists of invertebrates encountered.

Average Delta+ values for the seine collections revealed that much of taxonomic diversity was at the family level (mean Δ* = 27.39 ± 17.69 SD, Figure 85). While the ANOSIM procedure found significant differences in the composition of the nekton communities among the stations (see Nekton – Seines; Figure 72), a parametric Analysis of Variance of the Delta+ values failed to find any statistical difference among the stations due to a high degree of taxonomic overlap, with many taxa common to each sampling station (Figure 85A). Although seasonality was far more evident within Lost River (the community composition test of the ANOSIM revealed a greater degree of separation of the seasons within the reference stream; R = 0.400, $p < 0.001$), the parametric test failed to detect a significant difference in taxonomic distinctness across each season ($F_{2,82} = 2.279$, $p = 0.099$; Figure 78B). This lack of taxonomically-derived seasonality reinforces the overlapping seasonal signal found in the MDS configuration presented in Figure 73. With seines, Delta+ values were not affected by flooding conditions, as the overall diversity of the communities collected during these periods were similar. Compared to the reference stream, Cow Bayou had more total species (72 vs. 47 nekton taxa) as well as a more taxonomically diverse collection of nekton (pooled variance $t = -2.311$, df = 82, $p = 0.023$, seeFigure 85D).

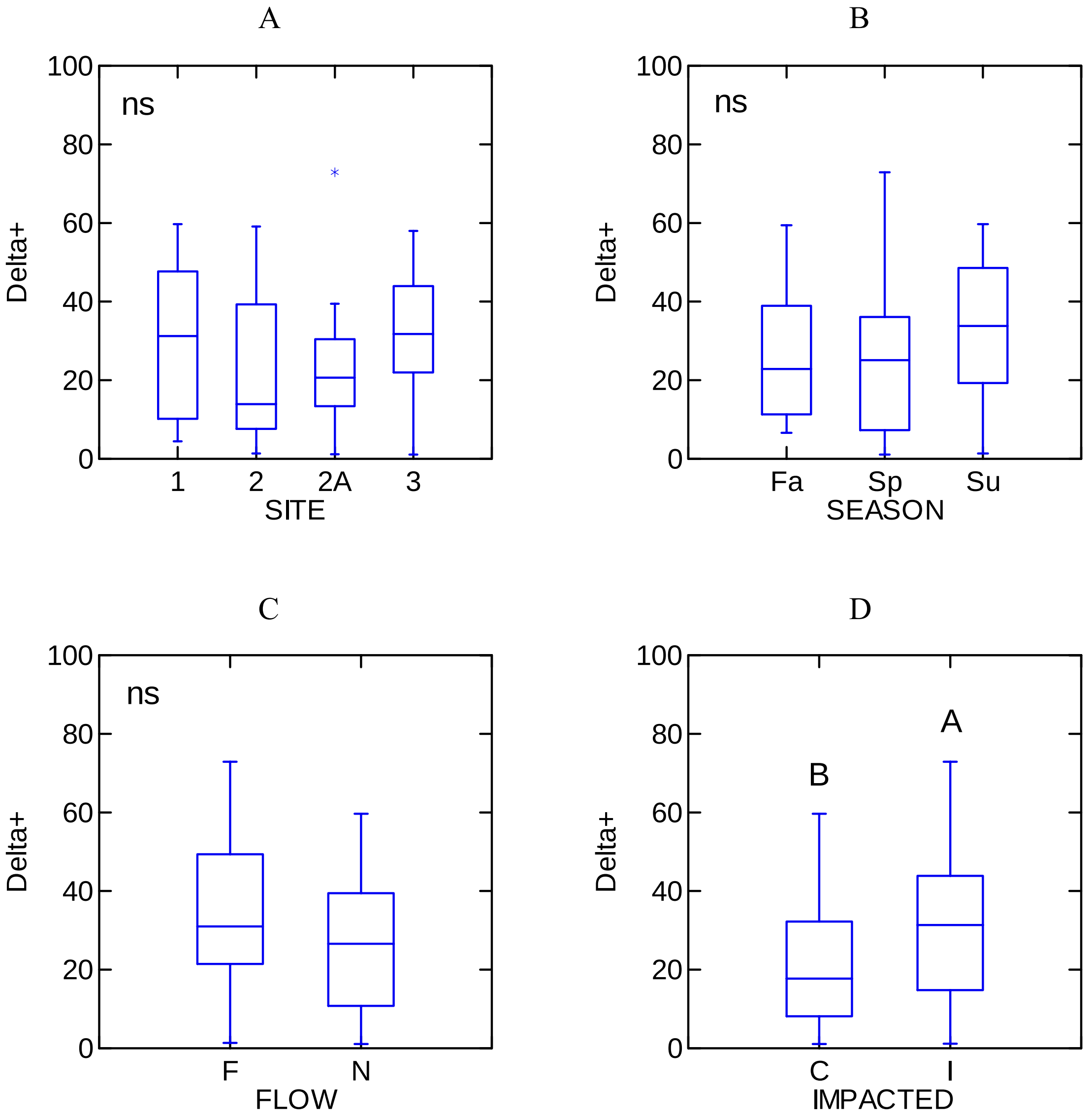


Figure 85.—Box plots of Average Taxonomic Diversity values (Delta+) of nekton as recorded by seine collections from Cow Bayou and Lost River. A = among Site comparisons (1 = upper, 2 = middle, 2A = off-channel, 3 = lower); B = among Season comparisons (Fa = Fall, Sp = Spring, Su = Summer); C = Flow condition comparison (F = Flood, N = Normal); and D = Impacted comparison (C = control – Lost River, I = Impacted, Cow Bayou). Categories within each plot with the same letter are not significantly different (test results and probability levels for each significant difference reported in the text). No significant difference identified by "ns."

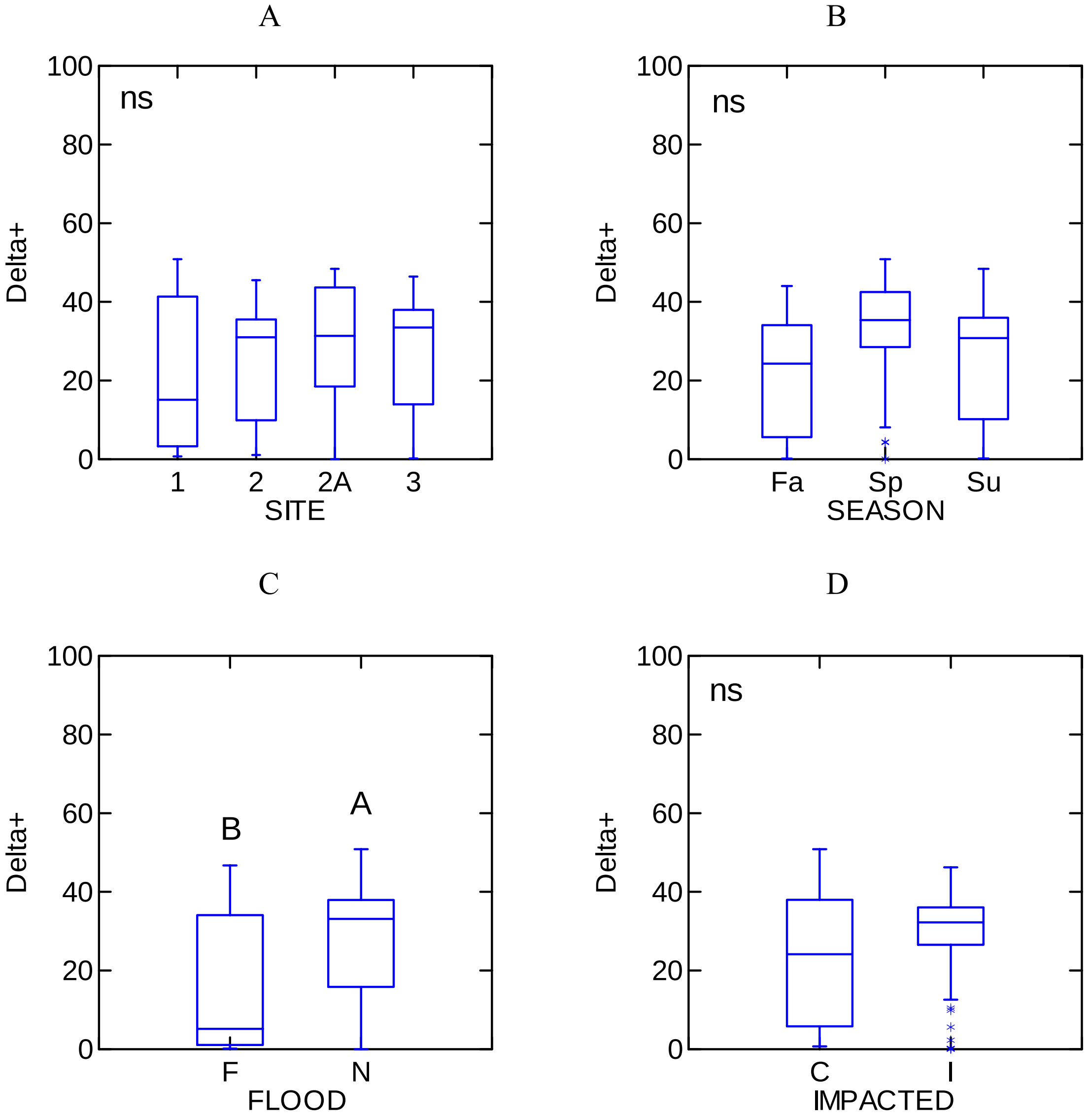


Figure 86.—Box plots of Average Taxonomic Diversity values (Delta+) of nekton as recorded by trawl collections from Cow Bayou and Lost River. Plot designations follow Figure 85.

Trawl collections had average Delta+ values that were similar to the seine collections (mean $\Delta^* = 25.99 \pm 15.67$ SD), reflecting equal susceptibility of many of the same taxa to each of these gears (Figure 86A). While not statistically significant, the uppermost station on Lost River (LR 1) had the lowest degree of taxonomic distinctness, where many of the more marine/estuarine families were not encountered (Gobiidae, Mugilidae, and Sciaenidae). Only Atlantic croaker and freshwater drum represented the sciaenids at the uppermost station on Lost River. Seasonality was also not significantly different among the trawl collections ($F_{2,65} = 2.826$, $p = 0.067$), although the spring season did have the highest degree of diversity with this gear (Figure 86B). Total abundance was more evenly distributed among a number of genera within a few families (i.e., Clupeidae, Engraulidae, Ictaluridae, and Centracharidae). Flooding events were typically characterized by communities with a lower overall community distinctness measure (separate variance $t = -2.480$, df = 17.3, $p = 0.024$). Similar numbers of taxa were recorded with this gear in both study streams (44 taxa in Cow Bayou vs. 45 taxa in Lost River, see Figure 86D).

Average Delta+ values for the gill net collections revealed that much of taxonomic diversity was recorded at the order level (mean $\Delta^* = 47.07 \pm 13.63$ SD, Figure 87A). The gill nets were dominated by a few freshwater taxa; spotted gar (Lepisosteiformes), gizzard shad (Clupeiformes), blue catfish (Siluriformes), and smallmouth buffalo (Cypriniformes). These taxonomically distant orders led to an overall increase in Delta+ values. Similar to the results obtained with the ANOSIM procedure, the lowermost stations on each stream were taxonomically distinct from the remainder of the sampling locations ($F_{3,76} = 3.322$, $p = 0.024$). Marine taxa encountered most frequently at the lowermost stations led to this difference in the distinctness measure. While no differences among seasons (Figure 87), or flow conditions (Figure 87C) were noted, the reference stream did have a higher degree of taxonomic distinctness (Figure 87D) even though more total taxa were recorded from the impacted stream (37 taxa collected from Cow Bayou vs. 28 taxa collected from Lost River). This discrepancy can be reconciled by noting that many of the species that were unique from Cow Bayou, and thus led to the increased total number of taxa from this stream, were multiple species within a few primarily marine families (e.g., sciaenids, sparids, ariids, and carangids). Numerous taxa from the same family or same genus has the effect of lowering overall taxonomic diversity. These marine forms were not encountered in the lower salinity waters of Lost River.

Average Delta+ values for the electrofishing collections were similar to the order level differences observed with the gill nets (mean $\Delta^* = 41.09 \pm 11.28$ SD, see Figure 88A). In agreement with the lack of a clear seasonal signal seen with the ANOSIM procedure (see Nekton – Electrofishing), the taxonomic distinctness measure was also equivalent among the seasons sampled (Figure 88B). Community composition was relatively unaffected by changing flow conditions (Figure 88C), and the overall communities were taxonomically similar between Cow Bayou and Lost River (Figure 88D). While more total taxa were recorded from the impacted stream (46 taxa collected from Cow Bayou vs. 45 taxa collected from Lost River), both streams contained similar communities as measured by taxonomic distinctness.

Benthic collections were far more diverse than the nekton, with average Delta+ values for both the side collections (mean $\Delta^* = 53.47 \pm 17.03$ SD) and middle collections (mean $\Delta^* = 46.52 \pm 15.84$ SD) characterized by differences at the class and order levels (Figure 89, Figure 90). While overall taxonomic diversity was highest in the benthic invertebrates, no significant differences were detected among the factors of interest for this study (among the sampling stations or seasons, or between the reference and control streams) except for a difference in the side benthic collections between the control and impacted stream (Figure 89D). In this case, the side benthic collections had a higher level of overall taxonomic diversity within Cow Bayou. These results (a general lack of difference between sites, seasons, or flow conditions) are in agreement with the ANOSIM tests that failed to detect significant differences among the benthic infaunal collections.

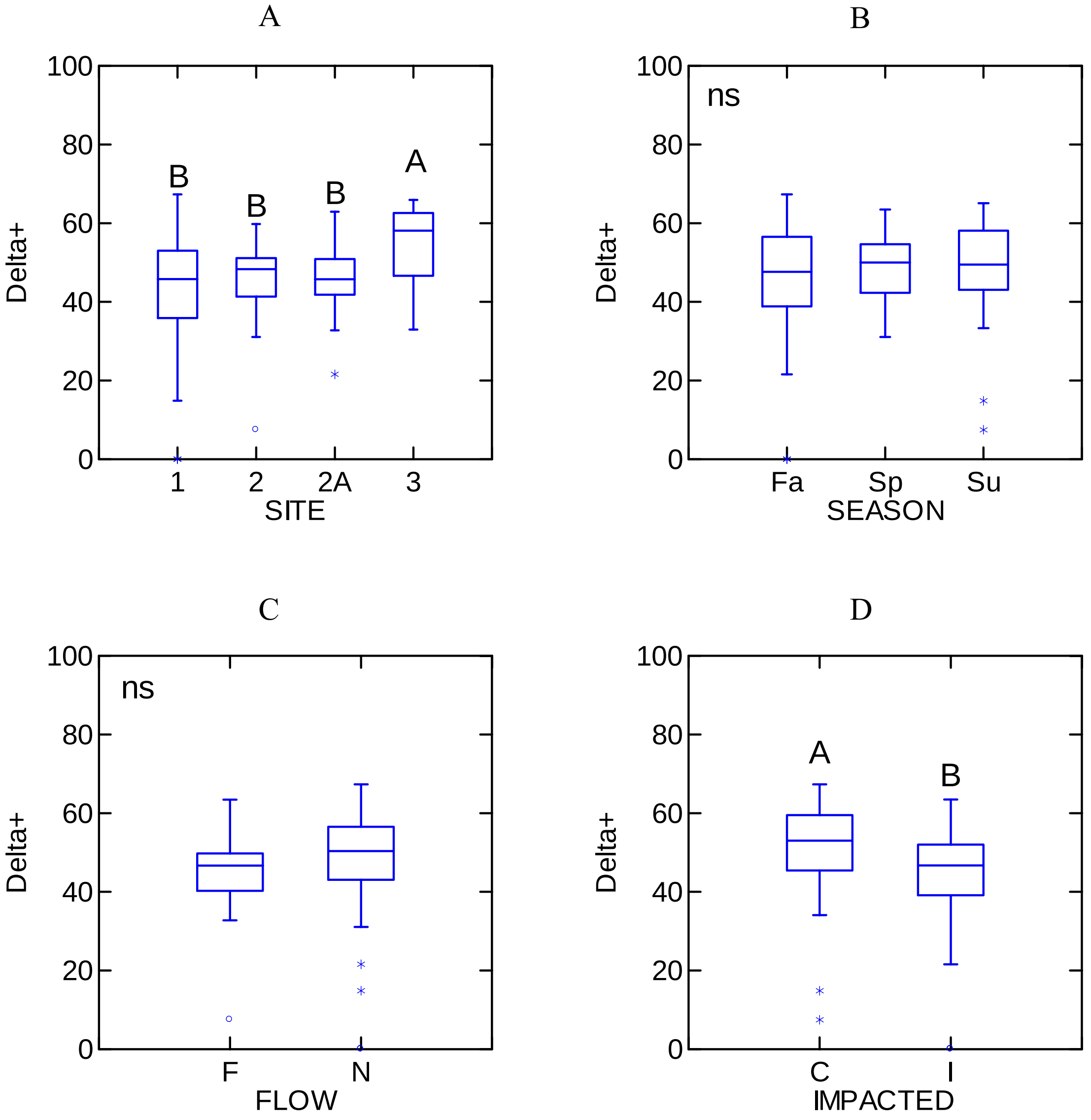


Figure 87.—Box plots of Average Taxonomic Diversity values (Delta+) of nekton as recorded by gill net collections from Cow Bayou and Lost River. Plot designations follow Figure 85.

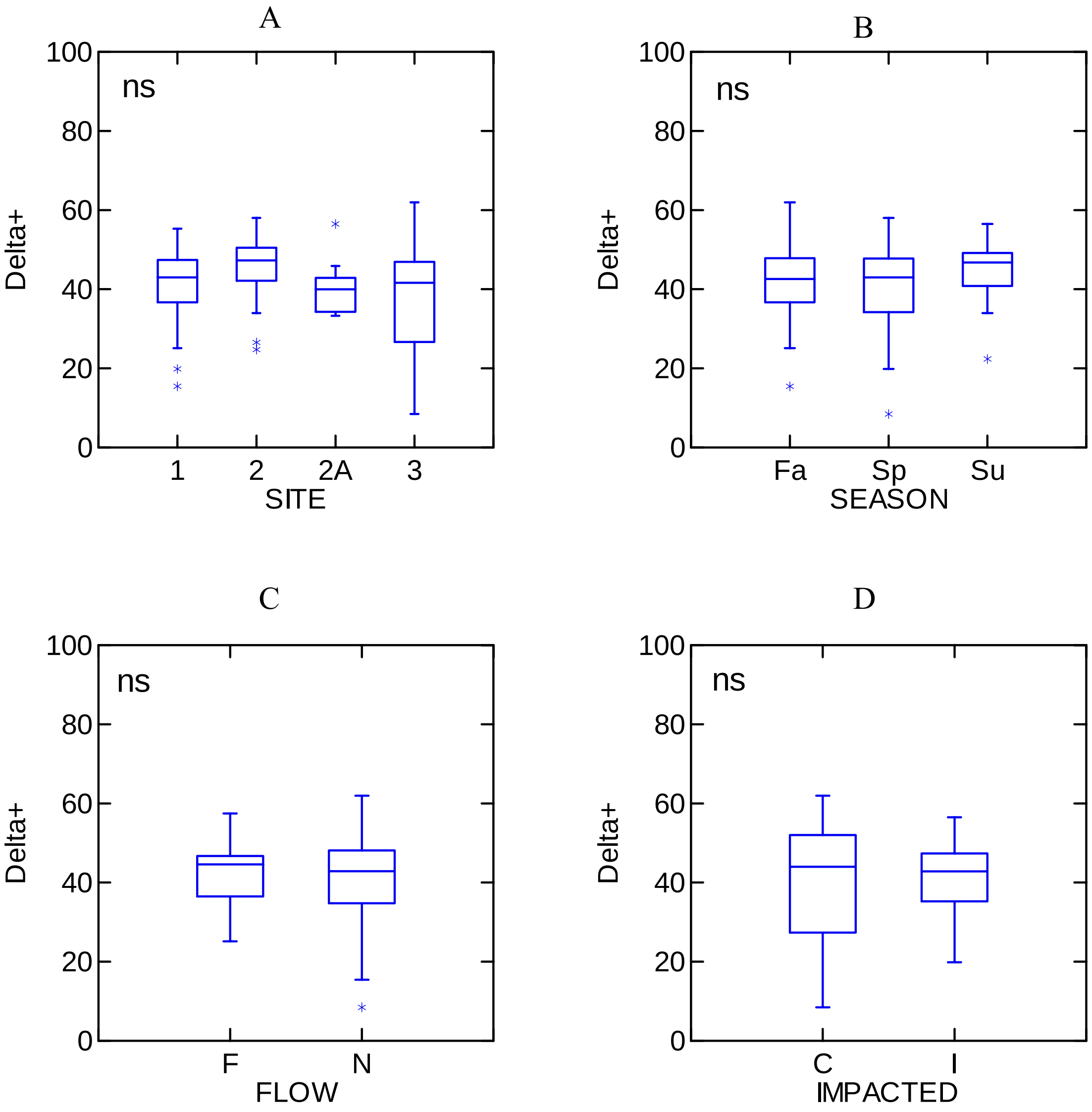


Figure 88.—Box plots of Average Taxonomic Diversity values (Delta+) of nekton as recorded by electrofishing collections from Cow Bayou and Lost River. Plot designations follow Figure 85.

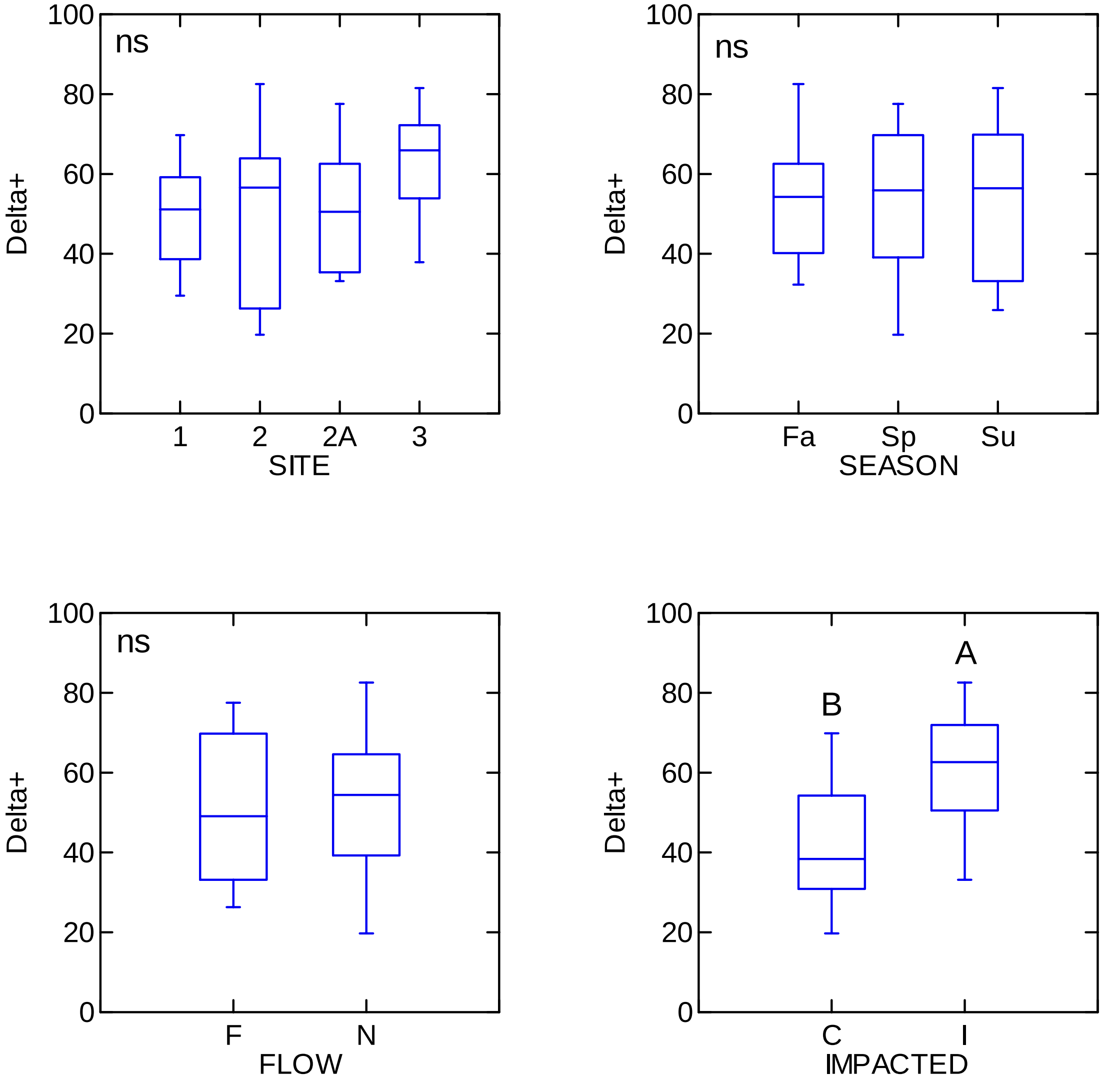


Figure 89.—Box plots of Average Taxonomic Diversity values (Delta+) of infaunal invertebrates as recorded by Side Benthic collections from Cow Bayou and Lost River. Plot designations follow Figure 85.

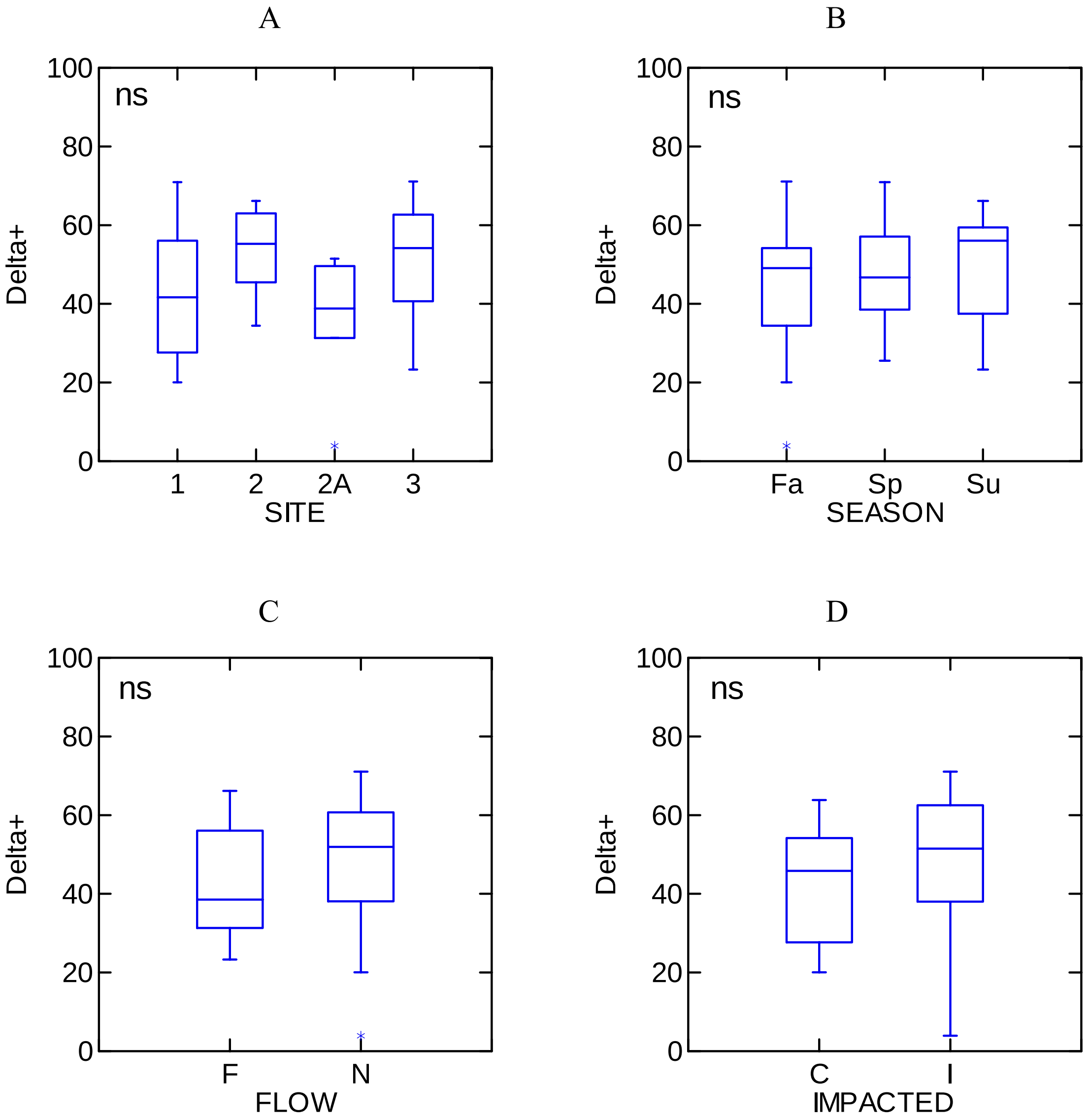


Figure 90.—Box plots of Average Taxonomic Diversity values (Delta+) of infaunal invertebrates as recorded by middle benthic collections from Cow Bayou and Lost River. Plot designations follow Figure 85.

Aquatic invertebrates collected with the D-frame nets were only identified to the family level, so the Delta+ values for this group takes on the form of Delta+ = 25 if two individuals drawn at random from a sample are from the same family; Delta+ = 50, from different orders; Delta+ = 75; different class; Delta+ = 100, different phyla. Diversity values for the D-frame nets were similar to the benthic collections (mean Δ^* = 47.06 ± 19.62 SD), ranging mainly between the class and order levels. Similar to the benthic infauna, consistent patterns of aquatic invertebrate community structure were generally lacking (Figure 91). Only the control vs. impacted test revealed any difference in taxonomic structure, with a higher degree of diversity found in the impacted stream (Figure 91D). In all of the invertebrate collections, average taxonomic diversity was highest in the impacted stream.

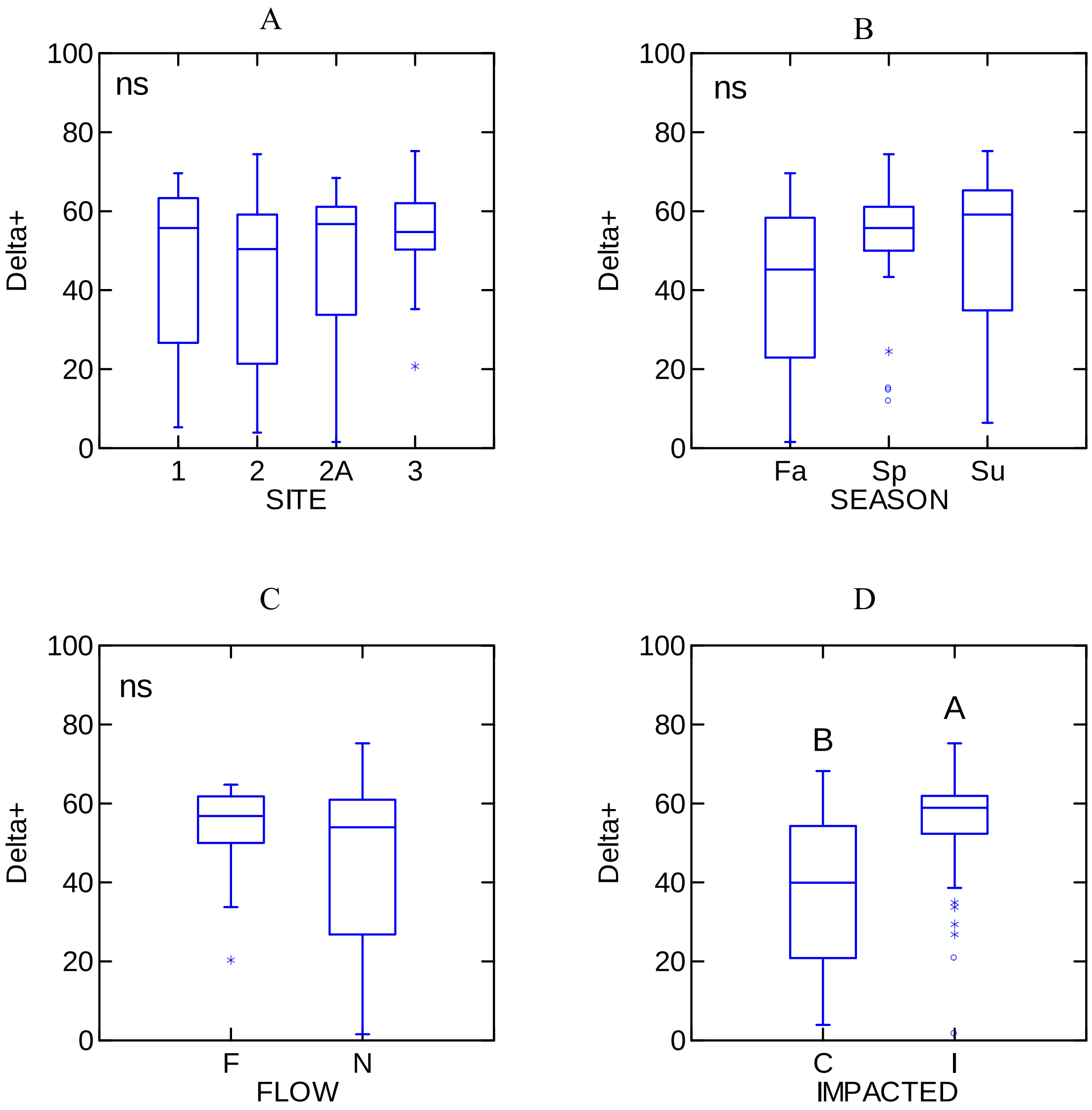


Figure 91.—Box plots of Average Taxonomic Diversity values (Delta+) of aquatic invertebrates as recorded by D-frame nets collections from Cow Bayou and Lost River. Plot designations follow Figure 85.

Discussion

Hydrology

Using data collected by the TPWD between April 2003 and November 2004, basic patterns of flow in Cow Bayou and Lost River have been characterized. The coastal streams studied are small, with limited channel inputs between stations. Flow within streams and at particular stations is highly variable over time. Peak flows occurred in May, June, and September. High flows also were recorded in March 2004. Flows were generally lower in April and August. Although during these events all study sites (upper, middle and downstream reaches) on a particular stream increase in flow, generally, flows at upstream and middle stations are nearly half of the measured flows at the downstream station.

For all study streams, tidal influence in the middle reaches was documented by characteristic oscillations in the direction and magnitude of flow. This oscillation pattern is present during most events indicating regular tidal influence. There is no similarly recorded information for the upstream and downstream stations. However, tidal influence was expected to be relatively greater at downstream sites. For the upstream sites, tidal influence was expected to be weaker. Because the relative contribution of tidal currents depended on downstream discharge, strength of the tidal cycle and river morphology, under low flow conditions or during a weak tidal cycle, upstream stations may not be influenced by tides. Additional data collection will be required to address this point.

The narrow width and shallow depth of the study streams, combined with the ameliorating effects of the bays and estuaries, decrease the likelihood that tidal currents will create a salt-wedge and hence bi-directional flow within the water column. However, the absence of bi-directional flows in the study streams does not indicate a lack of tidal impact, but rather the absence of a distinct layer of freshwater overlying saltwater within the water column at sites in the middle reaches of these study streams during the periods of observation. Tidal impact to flow was evident in the varied estimates of stream discharge obtained from replicate transects (ADCP data) during sampling events.
The results of this study provide a quantitative assessment of the influence of tidal cycles on flows within coastal streams and rivers. However, additional studies are needed to determine an appropriate methodology for collecting and analyzing flow data in tidally influenced streams. Such a methodology will help to standardize measurements, thus reducing variation and improving estimates of tidal influence. From this point, it then will be possible to better assess the impacts of tidal cycles on aquatic life use of coastal streams, particularly in relation to seasonal variation in instream flow.

Instream and Riparian Habitat

Cow Bayou had a much deeper thalweg likely because of dredging/channelization in the mid and lower sites. There is also some anecdotal information that at least parts of the uppermost site may have been dredged. Channel side depths at the upper-most reach in Cow Bayou were quite deep relative to the typical shelving seen along the sides at other locations. The gradual shallowing along the sides of both streams downstream may be due to the increased tidal nature of these portions of the streams. With flows alternately traveling up and down these streams at these locations, sediments would be expected to fall out of suspension and accumulate due to the decreased flow velocities and variable direction of flows.

The slow flowing nature of Texas tidal streams was apparent in the stream habitat data, as well. Both streams were characterized as pools or glides at all their sampling reaches. These streams pass through very flat coastal landscapes, so there are rarely instances where water flows down any significant gradient such as a riffle or rapid. Thus the low stream gradients and relatively flat watersheds associated with them resulted in only calm flowing stream habitat types in the reaches sampled (Rosgen 1996).

The high amount of fine materials in the sediments of these two streams is also possibly a reflection of their slow moving nature. Fine materials dominated along the channel bottoms, sides and banks of both streams. Low stream flows would allow for such an accumulation of fine sediment. However, it is also likely that the sediment types found in these streams were heavily influenced by the local source material, the soils in the immediate area, which are fine in nature as well.

Channel width increased from upper to lower reaches and bank incision (and bank angle) either decreased (Lost River) or stayed fairly constant (Cow Bayou). These measurements are typical of most rivers and streams (Rosgen 1996). Areas lower in the watershed receive more water, thus requiring a wider channel in order to conduct those materials (water and sediments) to their eventual destination in the bay. Incision was likely greater in the upper reaches because the more woody vegetative cover found in these reaches (see below) would better hold sediments and resist erosive forces during flooding thus confining flows and their erosive forces mainly to the channel itself.

Vegetation followed a similar pattern in both streams, with woody materials, especially trees, being more dominant in the upper reaches and herbaceous species and low growing shrubs dominating the lower reaches. This is a reflection of the increasing influence of salt and tides in the lower reaches of both streams as well as the tolerance limits of local plant species and is generally typical of the entire Texas coast. Since there are no endemic tree species adapted to surviving higher salinities in this part of Texas, this cover component falls out of the vegetative measurements at the lower reaches and is replaced by more salt tolerant herbaceous and woody marsh species to some degree. The edges of both streams generally appeared to transition from a swamp type of wetland community in their upper reaches to a brackish marsh type of wetland community at their lower reaches.

Both streams had more in-channel fish cover in their upper reaches than in their lower ones. This was due mainly to a decrease in the amount of woody material (i.e., trees) present in-stream as well as along the immediate stream edges in lower stream reaches. However, this does not necessarily indicate that these lower reaches were poor fish habitat. Many parts of the lower portions of each stream were edged by thick macrophyte cover along their borders, which provide quality fish cover. In addition, other characteristics present throughout these streams provide valuable habitat for fish, such as the steep slopes created at the transition from the shelving along the shorelines into the deeper thalweg. Furthermore, as revealed in the land cover analysis section, large portions of these lower reaches, not directly measured by the instream and riparian habitat classification study, were composed of swamps and marsh wetlands, which are excellent fish habitat.

Indicators of human influence in these two streams appear to be dominated mainly by evidence of direct human habitation in the immediate area. Though more agriculturally-based in the past, the local economies near both of these streams are now based more on industries such as manufacturing and petrochemical extraction and refinement. Lost River is very close to the Houston area, the largest city in the state, and Cow Bayou is in the middle of the "golden triangle" of Port Arthur, Beaumont, and Orange which are heavily involved in the petrochemical industry. As such, land surrounding these two streams is now used more for homes and businesses, and this is reflected by the kinds of human influence reported in the results section. The relatively lower degree of human influence in Lost River is likely due to the immediate area's increased overall susceptibility to flooding by the nearby Trinity River.

Land cover

Large differences in percent of bottomland forest, pine forest and grassland imply potentially significant differences in land use in the two watersheds. The Lost River watershed is dominated by bottomland forests, which do not support significant residential development. Whereas the Cow Bayou watershed is dominated by upland deciduous forests, grasslands and pine forests (75% of available area), all of which support development (upland deciduous forest) or are subject to large chemical and nutrient loads (pine forest and grassland). These land cover differences point to major differences in the inputs to the stream systems in the watershed. Cold deciduous forest in this part of the Texas coast is often developed as residential areas, and grasslands are intensively managed for grazing of cattle and/or horses. Pine plantations are subject to intensive management and chemical treatment, especially during the first 10 years of their planting cycle. These classes have a greater impact, usually negative, on nutrient loads, sediment loads and speed of runoff, than classes representing less human development. Bottomland forests act to slow runoff, trap sediment and absorb excess nutrients, buffering their impact to the stream system. So the overall results of the different land cover distributions in the two watersheds have potentially large impacts on the water quality of the streams.

The differences are accentuated in the 200 meter buffer analysis. The percent cover of bottomland hardwoods is highest in the Lost River watershed, 23 percent more of the watershed than in the Cow Bayou watershed. This difference increases in the buffer zone analysis with 30% more of the Lost River buffer zone composed of bottomland hardwoods than in the Cow Bayou buffer zone. The total percent cover of bottomlands is larger in the Cow Bayou buffer, but the difference with Lost River is 7.7% higher than the overall watershed. The pine plantation, cold deciduous forest and grassland classes are a smaller absolute percentage of each buffer area, but the difference is 6.4% higher for Cow Bayou. Much of this difference is in the grassland and upland deciduous forest classes, the classes with the highest potential negative impact to water quality.

Urban index analysis indicates 10% larger relative amount of urban-influenced areas in the Cow Bayou watershed. This reinforces differences noted in land cover analysis. More industrial / residential development would place higher impacts on the stream.

The differences between the two watersheds lead to questions about the similarity of the watersheds in an undisturbed state. The Lost River system is part of a complex of channels dominated by the adjacent Trinity River system. This stream is within the floodplain of the Trinity River, and during high flow events the Trinity River will dominate it. The overall size of the watershed is dwarfed by the Trinity River watershed, and is also smaller by at least a factor of two than that of Cow Bayou. Cow Bayou is a tributary of the Sabine River. It drains a large area between the Neches and Sabine rivers. The land in the watershed is mostly out of the floodplain of the Sabine River. The floodplain of the stream is significantly narrower, especially in the upper two-thirds of the watershed, and is much more reticulated than Lost River.

Further study on the amount and kind of development in the upland cold deciduous forest and grassland classes is needed to document the potential runoff quality and what contributions these classes make in the stream system. There could also be work done to document the effects of channels, water movement and drainage systems, and how these systems may decrease the benefits of marsh and bottomlands in buffering the systems.

Water and Sediment Quality

Several instances of low DO were recorded in Cow Bayou during this study. This is consistent with historical data and the results of the contemporaneous Orange County TMDL (TCEQ 2007). While exceedances of the standards occurred at all four stations, the problem was more severe at CB 1, the most upstream station. On numerous occasions, DO at CB 1 was markedly lower than at the other Cow Bayou stations or the Lost River stations. This area has been recognized to have depressed DO for decades (Kirkpatrick 1988, Kirkpatrick 1985). The draft Orange County TMDL recommends a 60% reduction in DO load for this reach of Cow Bayou (TCEQ 2007).

In general DO was the lowest in Cow Bayou during the warmer months of the year (June through September). Water temperature followed a predictable seasonal pattern. Specific conductance was variable but there was a pattern of lower values at the upstream end of the study area and higher values downstream, closer to the mouth of Cow Bayou. There was also a tendency for specific conductance to be higher during the warmer months. pH tended to increase in an upstream to downstream direction.

Lost River did not exhibit depressed DO during the study. Water temperature followed a predictable seasonal pattern. Specific conductivity was variable with a tendency toward higher values during the warmer months, but the range of specific conductance observed was not as great as that in Cow Bayou. pH did not vary significantly among the stations.

Datasonde measurements differed greatly between Cow Bayou and Lost River. This difference was depicted graphically on MDS ordination and PCA plots (Figure 42 through Figure 44). The water quality measurements essentially fell into two adjacent populations with very little overlap. PCA analysis showed that differences in DO and pH were largely responsible for the separation between measurements from the two streams.

Water chemistry also confirmed a distinct separation between the two streams. Stations on Cow Bayou tended to have higher TOC and ammonia. Stations on Lost River tended to have higher TSS, total phosphorus and alkalinity. Nutrient concentrations from each stream did not appear to be unusually high, although some chlorophyll *a* measurements from both streams exceeded the screening levels applied by TCEQ during surface water quality assessments.

Sediment analysis revealed differences between the two streams, although there was a little more scatter and variability in the data. CB 1 was different from the other Cow Bayou stations, mainly because of a higher percentage of silt-sized particles. Sediment TOC levels differed markedly between the two streams, with Cow Bayou having the higher concentrations, on the average. Some of the levels at Cow Bayou were high enough to be considered poor quality for benthic communities.

Biological Evaluation

Invertebrates

Tidal streams are variable in salinity, depth, flow, DO, and other parameters that can affect aquatic invertebrates. The expectation is that these systems will be dominated by pioneering or colonizing taxa and taxa that are tolerant of stress and disturbance. The full benefit of the invertebrate collections could not be realized since not all organisms were identified to the lowest taxonomic level as originally planned.

Benthic Infauna

The dominant invertebrate taxa collected by Ekman dredge in Cow Bayou and Lost River included chironomids, oligochaetes, amphipods, clams, mysid crustaceans, hydrobiid snails, and polychaetes. Most of these taxa are tolerant of disturbance or ubiquitous. Many of the annelids belong to pioneering or colonizing families. Some of the capitellid polychaetes collected in the study can be used as environmental indicators, but the natural variability and stress in the system are confounding factors to making a clear determination.

D-frame Net Collections

The dominant invertebrate taxa collected by D-frame net in Cow Bayou and Lost River included mysid crustaceans, clams, amphipods, caenid mayflies, hydrobiid snails, oligochaetes, chironomids, and hemipterans. Most of these taxa are either widespread in a variety of lentic and lotic habitats, or stress-tolerant. A few of the taxa, such as Ephemeroptera (mayflies) can be indicative of good water quality. None of the dominant taxa were indicative of polluted or highly degraded conditions.

Nekton

Nekton abundance was much higher at Lost River, but Cow Bayou had more species. This apparent pattern of diversity was reflected in Average Taxonomic Distinctness for the seine and gill net collections. During many of the sampling trips to Lost River, thousands of bay anchovy or Gulf menhaden were picked up in seine pulls. On at least one occasion a few hundred juvenile catfish were picked up in trawl hauls. These occasional events elevated the abundance numbers for Lost River and occurred to a lesser degree in Cow Bayou. Whether this disparity in abundance between the two streams has ecological significance has yet to be explored. As far as the difference in numbers of species collected at the two streams, one possibility is that there was more overall habitat in Cow Bayou than in Lost River. The area sampled in Lost River stretched about five miles from the uppermost station to the lowermost station. The area sampled in Cow Bayou was roughly twice that. Cow Bayou received more sampling effort since four stations were sampled rather than three (although only three gear types were used at CB 1 and four gear types at the other six stations). There was also more variety of habitat in Cow Bayou. The lower end of Cow Bayou, encompassing CB 2 and CB 3, has been channelized. CB 2A was a relict of the original winding stream channel before channelization. CB 1 had a very deep, V-shaped and winding channel, with predominantly freshwater throughout the study. There were more episodes of higher salinity in Cow Bayou than in Lost River during the study, and some of the species which were found in Cow Bayou and not in Lost River were estuarine species.

Referring to previous studies, in July 1987 TPWD sampled Cow Bayou with seines and gill nets (Linam and Kleinsasser 1987). They sampled four stations – the uppermost was at IH-10, far above CB 1. Their lower 3 stations were all in the main channel, somewhat consistent (respectively) with CB 2, a station at Round Bunch Road, and CB 3. Although the effort was much higher for this study, it is interesting to see the differences between the two collections.

Comparing the fish species caught in the two sampling efforts, Linam and Kleinsasser caught four species that were not collected as part of this study: bluntnose darter, Blair's starhead topminnow, clown goby, and dusky darter. All of those except the clown goby were only collected at IH-10, which was several miles upstream from CB 1, which seems to be a truly freshwater site near the upper boundary of Segment 0511. During this study, 34 species were recorded that were not reported in Linam and Kleinsasser (1987):

- Pirate perch
- Sheepshead minnow
- Grass pickerel
- Brook silverside
- Redbreast sunfish
- Ribbon shiner
- Golden shiner
- Silverband shiner
- Weed shiner
- Skipjack herring
- Bowfin
- Hardhead catfish
- Freshwater goby
- Sand seatrout
- Common carp
- Threadfin shad
- Ladyfish
- Spotfin mojarra
- Bayou killifish
- Code goby
- Least killifish
- Longnose gar
- Warmouth
- Longear sunfish

- White bass
- White mullet
- Blackspot shiner
- Leatherjacket
- Sailfin molly
- Black drum
- Flathead catfish
- Red drum
- Chain pipefish
- Hogchoker

These are a mix of freshwater (shiners, pirate perch, more sunfish, bowfin, etc.) and estuarine (sciaenids, the occasional estuarine species such as spotfin mojarra).

Recommendations for Future Studies in Tidal Streams

A major component of this study was the reference stream approach. Finding a relatively unimpacted tidal stream on the Texas coast is extremely difficult. An exhaustive effort was made to identify and investigate potential reference streams for Cow Bayou Tidal. Lost River had value as a reference stream based on a relatively low level of human influence. Flow and water quality data revealed that Lost River was a tidally-influenced stream with DO levels meeting the ALU subcategory of "high." This is important to document, because many Texas tidal streams exhibit depressed DO and some have speculated that this is the result of natural conditions. Future efforts might consider sampling multiple tidal streams across a gradient of human influence (see mention of the Tiered Aquatic Life Use work group in the Conclusions section).

Continuous (24-hour or longer) sampling of field parameters remains an important component of any aquatic study. Regulatory water quality assessments are based on this type of information when it is available. In tidal streams the 24-hour data provides a useful summary of conditions over at least one tidal cycle. Profiles are important for identifying stratification in tidal streams. Collecting this information makes it possible to compare trawl samples with bottom DO concentrations, rather than using the surface DO measurement.

Even when the water column is stratified, water chemistry results from this study show that little new information is to be gained by analyzing water samples collected at depth. A single sample from the mixed surface layer is sufficient to characterize the water chemistry at a site.

Habitat was collected once in the early spring. For future studies that encompass more than one season, it will be important to note any changes in habitat throughout the study so additional information can be collected to characterize the riparian and instream habitat. During this study we observed changes in macrophyte densities throughout the study that may have influenced instream habitat. After the study was complete, Hurricane Rita may have made significant changes to the habitat in Cow Bayou. This hurricane hit the Gulf Coast less than a year after the field work for this study concluded.

Hurricane Rita came ashore as a category 3 storm in Jefferson and Orange counties on September 24, 2005. The ten-foot tidal storm surge and rainfall runoff caused anoxic conditions and black water to develop in all the coastal streams of the two counties. Cow Bayou experienced a low dissolved oxygen fish kill throughout the tidal and much of the above tidal segment. Dead fish were observed by investigators in the tidal segment from FM 1442 to the confluence with the Sabine River. No studies have been conducted following the storm event to determine its effects on the fish populations that were documented in this study. Lost River had a different impact from the storm. The heavy rains washed mats of water hyacinth into the mainstem of Lost River. These mats covered the stream from bank to bank, preventing investigators from navigating upstream to assess dissolved oxygen concentrations. It is likely that low dissolved oxygen concentrations occurred following the storm due to the mats of water hyacinth that covered the surface, interfering with photosynthesis and increasing oxygen demand in the water column.

The ADP flow meters collected reliable velocity and discharge data. The boat-mounted ADP was an easy way to collect discharge data in tidal streams. The equipment was expensive, and drew field staff and a boat away from other sampling activities. The bottom profiler or Argonaut flow meter may collect useful information if deployed for several tidal cycles, especially if deployed simultaneously with multi-parameter datasondes to help characterize tidal influence on physicochemical water quality parameters.

All of the four nekton gear types used in this study had advantages and drawbacks in tidal streams. Use of seines is recommended for all tidal streams. Seining was effective in this study for collecting high numbers of individuals and species. PRIMER analysis showed that the seine collections were distinguished by upstream-downstream location along the stream (station) and by season. Since tidal streams are a refuge and nursery area for many estuarine species, some species are represented mainly by juveniles found along the shore. Seines can be deployed almost anywhere along the shores of tidal streams, and are inexpensive. A ten-foot seine was used in this study. At times a longer seine could have been deployed to more efficiently sample available habitat. We would recommend of seines as long as 30 feet, depending on the habitat in the area being sampled. Weather and alligators are usually not problems when seining.

Trawls are another gear type that is recommended for tidal streams. Trawling is a good complement for seining since the technique samples the stream channel rather than the shoreline as with the seine. A smaller trawl is used in tidal streams than would normally be deployed in open bays. However even the smaller otter trawls will hang up on submerged woody debris and other obstacles. A trawl would be difficult to deploy along a narrow stream with bends and snags from woody debris. Recovering from hang-ups is time consuming, and sometimes the trawl cannot be salvaged and must be cut free and replaced with a new net.

Gill nets were the only passive gear used on the study. Gill netting was the least effective nekton sampling technique in the study, especially in the larger mesh panels (three- and four-inch bar mesh). Gill nets results did not display seasonality. Gill nets were prone to alligator damage. Gill nets were usually set an angle from the shoreline, to prevent the nets being disturbed by boat traffic. However we believe there is potential for gill nets if they can be set perpendicular to the stream channel. The smaller mesh panels were more effective in collecting fish. We would recommend experimental gill nets with mesh no larger than two-inch (bar) be tried in tidal streams.

Electrofishing proved to be an effective collection technique in this study, although electrofishing results did not display strong seasonality. Electrofishing targets species found along the shoreline. Boat electrofishing gear is limited to use in lower-salinity conditions and requires more expense than the other sampling gears discussed. In studies where sample sites would encompass a wide salinity range, we would not recommend electrofishing since results could not compared across sites.

One nekton gear type that was considered but not tried for this study was hoop nets. Hoop nets would be another passive gear type that might be useful in tidal streams. The hoop nets might be more resistant to alligator damage than the gill nets.

Ekman dredges are capable of sampling the benthic infauna at various depths. Samples from the side and middle of the channel can vary in number and composition. The Ekman made it possible to collect sediment samples at the same time and place as the benthic infauna, which aided in characterizing the available benthic habitat. D-frame net sweeps for aquatic invertebrates did not display seasonality and tended to collect many terrestrial forms which were not the target of the sampling.

Conclusions

Despite low DO Cow Bayou appears to have a diverse biological community. A previous study concluded that Cow Bayou holds the potential for a diverse and healthy fish community (Linam and Kleinsasser 1987.) Fish abundance was much higher at Lost River, but Cow Bayou had more species. Possible reasons for this are put forward in the Discussion, but more work could be done to ferret out the underlying reasons for these differences. Cow Bayou should continue to be designated in the high ALU category. Based on DO alone, Lost River could be designated with a “high” or even an “exceptional” ALU.

Cow Bayou experienced several low DO episodes during the study, whereas the reference stream, Lost River, did not exhibit depressed DO. Water quality of the two streams were distinctly different, as demonstrated in the statistical analysis. Almost every previous study of Cow Bayou has mentioned sewage systems in the watershed, whether aging or malfunctioning, as a contributor of oxygen-demanding substances (Parsons 2006, SRA 1999, Twidwell 1988, Kirkpatrick 1985). Natural causes including high sediment oxygen demand, and low atmospheric re-aeration due to quiescent hydrology in the upper portion of the segment have also been implicated as sources of low DO (Kirkpatrick 1988, Kirkpatrick 1985). An SRA special study (SRA 1999) put forth that sewage systems in the watershed have functioned poorly if at all in the past. The Orange County TMDL mentions sewage systems as well as agriculture as sources of oxygen-demanding substances to Cow Bayou. As mentioned in the Introduction, there are fifteen permitted dischargers to Cow Bayou. The land cover analysis presented in this study revealed several categories of human influence on Cow Bayou. The combined load of wastewater discharges, stormwater runoff, and potential leaks of partially-treated wastewater from OSSs are an obvious source of anthropogenic stress on this system. The habitat results show clearly that the observations of human influence in Cow Bayou outweigh those in Lost River. The index of human influence has twelve observation categories. Ten of the twelve categories were observed at Cow Bayou while only three were observed at Lost River. Excluding CB 2A from the comparison, a human influence category was observed nineteen times in Cow Bayou and only five times in Lost River. These reasons point toward the need for a TMDL study to better evaluate how potential sources are affecting the water quality of Cow Bayou.

Looking forward, a promising development is the formation of a Tiered Aquatic Life Use (TALU) work group to study tidal streams. In fall 2005 a meeting was convened by EPA and hosted at the University of Houston in Clear Lake. Participants included staff from federal and state agencies including EPA, TCEQ, Louisiana Department of Environmental Quality, and TPWD. A core group of representatives from EPA, TCEQ and TPWD is carrying forward an effort to fit tidal stream data in the TALU conceptual framework. Current tasks of the group include pulling together existing land use, water quality and biological data on tidal streams and evaluating tidal streams across a gradient of environmental stress.

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