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Cypress Creek Basin
Aquatic Life Use and Dissolved Oxygen Concentrations During Low-Flow, High-Stress Summer Conditions, 1995-1996

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Field Operations Division
TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Cypress Creek Basin
Aquatic Life Use and Dissolved Oxygen Concentrations During Low-Flow, High-Stress Summer Conditions 1995-1996

by

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Field Operations Division
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ABSTRACT

The Cypress Creek basin was divided into subwatersheds according to drainage size in order to characterize water quality and aquatic life use during summer low-flow, high-stress conditions. Six size categories were evaluated (<39, 39-65, 66-132, 133-259, 260-518, >518 km^2). Streams within the basin were assigned to one of these six size categories and sample sites were chosen randomly. During the summers of 1995-96, instantaneous flow and dissolved oxygen (DO) were measured at 54 sites throughout the Cypress Creek basin; 24-hour mean and minima DO was measured at a subset of 16 sites; and biological samples were collected at 18 sites. Biological and DO samples were also collected at a reference site on Frazier Creek. Samples were obtained from mid-July through mid-September, and generally reflect low-flow, high-stress conditions.

There was a positive correlation between log drainage area and log flow (R^2=0.53, P< 0.01). The relationship between flow and DO was not significant as initially hypothesized. However, there was a trend for higher DO in drainage basin areas greater than 100 km^2. At sites with zero flow, 15 of 16 had instantaneous DO concentrations ≤2.0 mg/L. Rainfall had a dramatic effect on DO within the first 24-48 hours of the onset of rain. Beyond that, there was no significant correlation. Neither flow nor DO correlated with aquatic life use scores. DO means and minima did not meet even limited criteria at a majority of sites in the basin. However, aquatic life use scores for fish were in the intermediate to high range at all 19 sites. Benthic macroinvertebrate scores were more variable and generally lower than scores for fish, possibly indicating benthic communities are more susceptible to low-flow conditions than the more mobile fish communities. Both types of scores generally increased as watershed size increased. Intermediate to high aquatic life use apparently can be maintained in a variety of stream sizes throughout the basin if low DO conditions are limited to the summer season. Numerical DO criteria may be seasonably unattainable for many streams in the basin due to natural low flow, high temperature, and oxygen demand conditions. Non-salmonid DO criteria developed by the U.S. Environmental Protection Agency are based on health and growth criteria for "warmwater" sports fishes. However, regulatory standards designed to be protective of the criteria have been implemented by the states based on a broader concept involving community structure, trophic composition, abundance, and condition metrics, which may or may not approximate the more narrowly based health and growth criteria.

A gear comparison study indicated the importance of using both electrofishing and seining to collect fish. Aquatic life use scores were one category higher 25% of the time when data from both sampling approaches were combined, compared to scores that did not include seining. A habitat assessment protocol was developed with metrics specific for wadable streams in the East Texas region (South Central Plains and East Central Texas Plains).

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INTRODUCTION

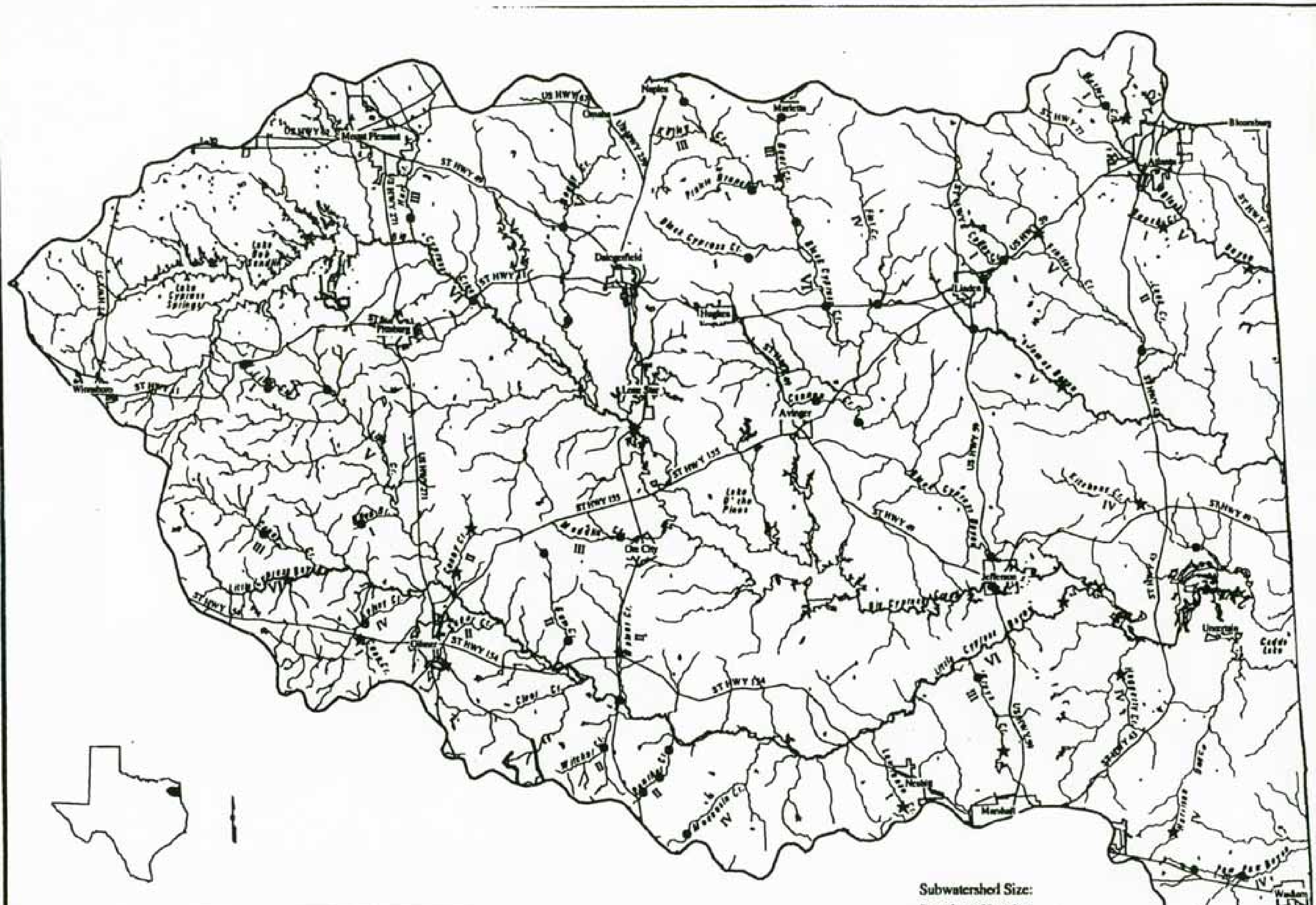
The Texas Natural Resource Conservation Commission (TNRCC) is charged with developing water quality standards for the state's surface waters under Section 303 of the Clean Water Act of 1977. The law requires standards to be based on criteria developed from the best possible scientific data. The United States Environmental Protection Agency (EPA) is mandated under Section 304 of the Clean Water Act to develop these scientific criteria. If criteria developed under Section 304 are adopted as regulations under Section 303, they then become enforceable water quality standards. EPA encourages states to adjust water quality criteria developed under Section 304 to reflect local environmental conditions. EPA developed national criteria for dissolved oxygen (DO) for both warmwater and coldwater fish assemblages, as well as seasonal criteria for early life stages (U.S.EPA, 1986). Criteria include both mean and minimum limits. Criteria are estimates of the threshold concentration below which detrimental effects could be expected (*e.g.* decrease in growth, or increase in disease and pollution stress). Warmwater criteria were developed from data on sports fishes.

TNRCC has developed specific DO standards for over 350 larger, classified waterbodies in the state. However, it is not feasible to individually classify all the smaller streams in the state. Texas Surface Water Quality Standards (TSWQS)(30 Texas Administrative Code, Section 307.4 h) state that DO concentrations for unclassified waters should be sufficient to support the appropriate aquatic life use (ALU) in the stream. Four aquatic life use subcategories are identified in Section 307.7 of the TSWQS (TNRCC, 1995); 24-hour mean and minimum DO concentrations are assigned to each subcategory; and general ecological and habitat attributes associated with these four categories are also described (Table 1).

Table 1. Freshwater dissolved oxygen (DO) criteria versus aquatic life use (ALU) subcategories and attributes.

ALU	DO $\bar{x}$ / Minimum (mg/L)	Spring DO $\bar{x}$/Minimum (mg/L)	Habitat Characteristics	Species Assemblages	Sensitive Species	Diversity	Species Richness	Trophic Structure
Exceptional	6.0/4.0	6.0/5.0	Outstanding natural variability	Exceptional or unusual	Abundant	Exceptionally high	Exceptionally high	Balanced
High	5.0/3.0	5.5/4.5	Highly diverse	Usual association of regionally expected species	Present	High	High	Balanced to slightly imbalanced
Intermediate	4.0/3.0	5.0/4.0	Moderately diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately imbalanced
Limited	3.0/2.0	4.0/3.0	Uniform	Most regionally expected species absent	Absent	Low	Low	Severely imbalanced

-Dissolved oxygen means ($\bar{x}$)are applied as a minimum average over a 24-hour period.
-Daily minima are not to extend beyond 8 hours per 24-hour day. Lower DO minima may apply on a site-specific basis, when natural daily fluctuations below the mean are greater than the difference between the mean and minima of the appropriate criteria.
-Spring criteria to protect fish spawning periods are applied during that portion of the first half of the year when water temperatures are 17-23 °C (63.0-73.0 °F).



Legend
★ 24-Hour D.O.; Flow; Biological Samples
● Instantaneous D.O.; Flow

Subwatershed Size:
Strata I – <39 sq. km.
Strata II – 39-65
Strata III – 66-132
Strata IV – 133-259
Strata V – 260-518
Strata VI – >518

TNRCC

Figure 1. Sample Sites
Cypress Creek Basin
Summer 1995 - 96

TNRCC adopted revisions to the TSWQS on June 14, 1995 which included lowering presumed standards for unclassified, perennial streams in East Texas from high to intermediate aquatic life use. The Sierra Club and a number of private individuals opposed the change, while the Texas Municipal League and several local officials from East Texas cities supported the change. EPA Region 6 disapproved the proposed change to the standards on March 27, 1996. TNRCC amended its rules on March 19, 1997 and changed the presumed standard for unclassified, perennial streams back to high ALU. TNRCC conducts receiving water assessments (RWAs) to determine ALU on unclassified streams where permit actions are forthcoming so that site-specific standards are developed from actual data, rather than being based on presumptions.

STUDY AREA

The Cypress Creek basin has the smallest drainage area of any river basin in Texas. Many streams in the basin have sluggish flow characteristics, seasonally low DO, and naturally high organic loading (TNRCC, 1996). The economy in the basin is dominated by agriculture and forest-related industry. Oil and gas activity is common in the eastern part of the basin. There are several small dairies in the western portion of the basin. TNRCC-regulated industrial wastewater dischargers include Pilgrim's Pride chicken-processing plant located on Tankersley Creek, Lone Star Steel located near the upper end of Lake O'the Pines, and Southwestern Power Company located on Welsh Reservoir. The following is a list of larger municipal wastewater treatment plants in the area, with permitted discharge volumes in million gallons per day (MGD), and the stream that receives the discharge:

- Mount Pleasant (2.53 MGD), Hart Creek;
- Gilmer (1.75 MGD), Sugar Creek;
- Pittsburg (0.97 MGD & 0.20 MGD), Sparks Branch & Dry Creek;
- Atlanta (1.1 MGD), Black Bayou;
- Daingerfield (0.70 MGD), Brutons Creek;
- Jefferson (0.55 MGD), Black Cypress Bayou;
- Hughes Springs (0.49 MGD), Hughes Creek;
- Linden (0.45 MGD & 0.25 MGD), Beach Creek & Jim's Bayou; and
- Naples (0.25 MGD), Watson Creek.

STUDY OBJECTIVES

The study was designed to provide information on actual aquatic life use and dissolved oxygen concentrations in different sized streams in the Cypress Creek basin. Data were collected during mid-summer in order to represent maximal stress. Secondary objectives included comparisons of data collected with different gear types, and the development of metrics for a regional habitat assessment.

METHODS

SITE SELECTION

Named streams within the Cypress Creek basin were placed into one of six size categories (<39, 39-65, 66-132, 133-259, 260-518, >518 km²). Each size category was subdivided into upper, middle, and lower sections. From this population pool, three sites were randomly selected from each strata and each section. This resulted in 54 sites where instantaneous flow and DO concentrations were collected (Figure 1). Twenty-four hour DO concentrations and biological data collections were made at 18 of the 54 sites (Figure 1). Once a section of a stream was selected, sites were chosen based on convenience of access and whether they were representative of the whole reach. Actual drainage area at each site was determined from a computer-generated map using ArcView-GIS.

FIELD DATA

Data were collected between the hours of 0800-1200 from mid-July through mid-September of 1995 and 1996. A full range of flow conditions were encountered during the survey: from flowing streams; to streams with water pooled throughout the reach, but with no measurable flow; to intermittent streams with isolated pools with areas of dry stream bed between the pools; to completely dry streams. Flow was measured using a Marsh-McBirney magnetic flow meter. Streams were divided into 10-20 equal cross-sectional segments. Depth and velocity were recorded at the midpoint of each segment. Total flow was obtained by summing all the individual depth times velocity readings. Instantaneous DO was measured in pool-type habitats with a Hydrolab Surveyor-II. Twenty-four hour DO was collected using either a Hydrolab Datasonde, or Surveyor-II and Data Logger. The Datasonde was deployed on the stream bottom, while the Surveyor-II was deployed near the surface.

FISH

Fish were collected using a Smith-Root backpack electrofisher in wadable streams, a boat-mounted electrofisher in larger streams, and by seining at all locations. Shocking duration at each site was approximately 15 minutes. All habitat types present were sampled. A minimum of six seine hauls were made, with supplemental hauls made until no additional species were collected. Seine hauls were usually of short length (<20m) due to the abundance of snags. Most fish were identified, measured, and returned to the stream. Individual fish not identified in the field (*e.g.* cyprinids) were preserved in formalin and taken to the lab for positive identification. The ALU for fish (Table 2) was a summations of 12 metrics that make up the Index of Biotic Integrity (IBI) (Linam and Kleinsasser, 1987).

BENTHIC MACROINVERTEBATES

Benthic macroinvertebrates were collected from a five-minute sweep of stable benthic habitat using a D-frame kick net. Most sites did not have riffles, and many of the smaller streams had only pools with no interconnecting flow. Therefore, sweeps were made on instream, large woody debris or root mats located along the banks. Benthic macroinvertebrates were picked in the field and placed into vials with 70% ethanol for later identification. An attempt was made to ensure that there were at least 100 individuals in the sample. If the first effort did not produce approximately 100 individuals, a second, five-minute sweep was performed and the sample was concluded. Specimens were identified to genus when possible. The ALU subcategory was then determined using a metric set technique proposed by Harrison (1996, Draft) for ecoregions 33-35 (Table 3). Scoring ranges differed between fish, benthic macroinvertebrate, and habitat assessments. To allow for statistical comparisons between the IBI and RBA values, scores were transformed to a common scale with 1.0= Limited, 2.0=Intermediate, 3.0=High, 4.0=Exceptional.

WATER CHEMISTRY

Surface water samples were evaluated during February, 1996 at sites where 24-hour DO and ALU were determined. Water chemistry was not collected during the summer target period due to time constraints. However, water chemistry at several routine surface water quality monitoring sites within the Cypress Creek basin has not shown much seasonal variation over the last several years. Samples were collected in one-liter cubitainers, preserved, and shipped to the TNRCC Laboratory in Houston for analysis according to U.S.EPA (1983) standard methods. Flow and DO were also measured at selected sites for comparison to summer values.

Table 2. Index of biotic integrity (IBI) scoring and evaluation criteria.

Category and Metric:	Scoring 5	3	1
Species richness and composition			
1. Total number of fish species	*	*	*
2. Total number of darter species	≥3	2-1	0
3. Total number of sunfish species	≥2	1	0
4. Total number of sucker species	≥2	1	0
5. Total number of intolerant species	≥3	2-1	0
6. Proportion of individuals as tolerant	<5	5-20	>20
Trophic composition			
7. Proportion of individuals as omnivores	<20	20-45	>45
8. Proportion of individuals as insectivores	>80	>40-80	≤40
9. Proportion of individuals as piscivores	>5	5-1	<1
Abundance and condition			
10. Number of individuals in sample	>200	>50-200	50
11. Proportion of individuals as hybrids	0	0-1	1
12.Proportion of individuals with defects	2	2-5	5

Scoring: 0-34 Limited; 40-44 Intermediate; 48-52 High; 58-60 Exceptional.
*First-second order streams: ≥7 (5), 6-4 (3), ≤3 (1)
Third-fourth order streams: ≥10 (5), 9-5 (3), ≤4 (1)
Fifth-sixth order streams: ≥16 (5), 15-8 (3), ≤7 (1)
Seventh-eight order streams: ≥22 (5), 21-11 (3), ≤10 (1).

Table 3. Proposed rapid bioassessment (RBA) metrics for kick net samples in ecoregions 33/35.

Metric	Scoring 4	3	2	1
1.Taxa Richness	>21	15-21	8-14	<8
2.EPT Taxa	>9	7-9	4-6	<4
3.Biotic Index	<3.77	3.77-4.52	4.53-5.27	>5.27
4.% Chironomidae	0.79-4.10	4.11-9.48	9.49-16.19	<0.79 or >16.19
5.% Dominant Taxon	<22.15	22.15-31.01	31.02-39.88	>39.88
6.% Dominant Functional Group	<36.50	36.50-45.30	45.31-54.12	>54.12
7.% Predators	4.73-15.20	15.21-25.67	25.68-36.14	<4.73 > 36.14
8.Ratio Intolerant to Tolerant Taxa	>4.79	3.21-4.79	1.63-3.20	<1.63
9.% Trichoptera as Hydropsychidae	<22.50	25.51-50.50	50.51-75.60	>75.50 or 0
10. Non-Insect Taxa	>5	4-5	2-3	<2
11.% Collector-Gatherers	8.00-19.23	19.24-30.46	30.47-41.68	<8.00 > 41.68
12.% Elmidae	0.88-10.04	10.05-20.08	20.09-30.12	<0.88 > 30.12

Scoring: <22 Limited; 22-28 Intermediate; 29-36 High; >36 Exceptional.

EAST TEXAS HABITAT ASSESSMENT (ETHA)

The ETHA is a modification of EPA's rapid bioassessment protocols (Plafkin *et al.*, 1989). It is intended for use in wadable third and fourth-order streams in the south central plains and east central Texas plains, ecoregions 33 and 35 (Omernik and Gallant, 1987). The purpose of any habitat assessment is to document conditions within a stream, and to generate a numerical score that can be compared to another site.

Metrics for the ETHA were developed based on three least-impacted ecoregion reference sites, as well as a number of other typical northeast Texas streams. Frazier Creek (Cass County), the East Fork of the Angelina River (Rusk County), and Catfish Creek (Anderson County) are TNRCC-designated reference sites in ecoregions 33 and 35.

The ETHA follows the general EPA protocol. Metrics within each of three general categories are scored differently. For example, the highest score of a primary metric is 20; highest score for a secondary metric is 15; and highest score for a tertiary metric is 10 (Table 4). Both protocols use three similar groups of metrics: instream biological habitat, channel morphology, and riparian and watershed characteristics.

Two main differences exist between the ETHA and EPA habitat assessment. The ETHA places bank characteristics in the secondary group of metrics, thus increasing its importance. Metrics dealing with embeddedness and channel deposition were not included in the ETHA. Many streams in East Texas have sandy bottoms which are reworked during high flow conditions. Embeddedness consistently scored poorly even at reference sites. Most stable benthic habitat in these ecoregions is off the stream bottom on instream logs and root mats.

Observations are made for primary and secondary metrics through a reach of approximately 500m. A predetermined number of paces equal to approximately 100m are walked off. Observations are made from 10m upstream to 10m downstream of each transect location. Some observations (*e.g.* habitat mix, bends, pools, and bank stability) are made over the total length of the reach. Other observations (*e.g.* available fish and benthic habitat, water between the banks, and canopy cover) are made at five equally spaced intervals over the 500m. If the habitat types are repeating after five observations, then the assessment is complete. If not, then an additional three to five observations are made. The average of ≥ five sets of observations is recorded on the final data sheet.

Instream biological habitat is the primary group, which contains four metrics. Examples of common East Texas fish habitat (Metric 1) and benthic macroinvertebrate habitat (Metric 2) are given in Table 4. Other habitat types should be considered if present (*e.g.* beaver dams, stable backwater channels, oxbows, and adjacent swamps). Mix of available habitat (Metric 3) considers variety rather than amount of habitat. By including this metric, additional weight is given to instream habitat in the overall score. Pools (Metric 4) are important since they provide refuge to all types of aquatic organisms especially during critical low-flow periods. This metric is measured over the entire 500m reach. An attempt is made to provide for seasonal differences during normal versus low-flow periods for this metric.

Channel morphology and bank characteristics constitute the secondary group, which also contains four metrics. Well-developed bends (Metric 5) provide important habitat for many aquatic organisms. Streams that cut back with well-defined (S or C-shaped) bends should be scored higher than streams with less sinuous (L-shaped) bends. Higher scores are given to bends that grade from shallow to deep across the channel width. Bends that have eddies and deep water receive maximal scores. Water between the banks (Metric 6) changes seasonally. During drought conditions, the amount of water in smaller streams can go from suboptimal to poor within two to three weeks. Therefore, habitat comparisons should be made under similar climatic conditions. Canopy cover (Metric 7) provides detrital material for benthic shredders, modifies temperature extremes, and indirectly influences other habitat parameters such as undercut banks and root mats. Canopy cover is estimated on the right and left bank at 5 random locations. A convex mirror (canopy densiometer) is used to obtain an actual measurement (Klemm and Lazorchak, 1994), or a simple estimate can be made. Without the convex mirror, canopy cover is frequently overestimated. Bank stability (Metric 8) is a function of a number of factors, several of which are listed in Table 4. It is possible to have steep yet relatively stable banks if there is abundant root and vegetative cover, and the soil type is stable. Emphasis should be placed on actual observations of sloughing banks, rather than on bank slope or soil type.

Watershed characteristics are the tertiary group, which has two metrics. Information is considered from the immediate sample area, and as far upstream in the watershed as may potentially affect the sample area. Width of stable vegetative cover (Metric 9) includes both sides of the stream. Pollution potential (Metric 10) is dependent on the knowledge and experience of the observer. For this metric to receive a low score, the pollution should have the potential for a substantial negative impact on the instream biota. It may include point sources such as municipal or industrial wastewater dischargers, or nonpoint sources such as runoff from timber, agricultural, or oil field activities. It should not include trash or litter, unless extreme.

Additional habitat information is placed at the bottom of the Table 4 for descriptive purposes. The three groups of metrics add up to a total possible score of 160. Exceptional habitats include scores in the upper 15 percent (>135); limited habitats include scores in the lower 50 percent (<80); intermediate and high scores are divided equally among the remaining numbers. The ETHA takes approximately one hour to complete and score the data.

Table 4. East Texas habitat assessment (ETHA).

Instream Biological Habitat	Poor 0-3	Marginal 6-10	Suboptimal 11-15	Score Optimal 16-20	
Available fish habitat. Average of ≥5 random sites. *e.g.*: undercut banks, pools, large woody debris, root mats, instream trees & knees.	<20% areal coverage	20-29%	30-39%	≥40%	
Available benthic habitat. Average of ≥5 random sites. *e.g.*.: large woody debris, root mats, riffles, instream trees & knees.	<10% areal coverage	10-19%	20-29%	≥30%	
Mix of available habitat over 500m reach. Variety of <u>common</u> habitat types for fish and aquatic insects.	1-2	3	4	≥5	
Number of pools/500m. >1.0m deep at normal flow; >0.5m at low flow.	0-1	2-3	4-5	≥6	
Channel Morphology & Bank Characteristics	**Poor 0-3**	**Marginal 4-7**	**Suboptimal 8-11**	**Optimal 12-15**	
Number of bends/500m. Bends that grade from shallow to deep, and bends with eddies score higher.	0	1-2	3-4	≥5	
Water between lower banks Average of ≥5 random sites. 10m up & 10m downstream of midpoint.	≤25%	26-50%	51-75%	76-100%	
Canopy Cover. Average of ≥5 random sites.	≤25%	26-50%	51-75%	76-100%	

Table 4 (Continued).

Channel Morphology & Bank Characteristics (cont.)	Poor 0-3	Marginal 4-7	Suboptimal 8-11	Optimal 12-15	Score
Bank stability over 500m. function of soil type: slope: flow fluctuation: root and vegetative cover: *N.B.* recent slumping:	Unstable	Moderately Unstable	Moderately Stable	Stable	
Watershed Characteristics	**Poor 0-2**	**Marginal 3-5**	**Suboptimal 6-8**	**Optimal 9-10**	**Score**
Width of stable vegetative cover in the sample area and the upstream watershed, as far upstream as might affect the sample site.	Poor Combined sum of both sides <10m	Moderate Combined sum 10-20m	Wide Combined sum 21-50m	Extensive Combined sum >50m	
Pollution potential. Likelihood of point and nonpoint source dischargers in the upstream watershed.	High	Moderate	Low	Very low	

# Optimal	Exceptional >135
# Suboptimal	High 108-135
# Marginal	Intermediate 80-107
# Poor	Limited <80

Observations made at ≥5 random sites, 10m upstream and 10m downstream.

% Macrophyte beds   % Overhanging brush   % Undercut banks   %Snags

% Sandstone or clay bedrock   % Gravel   % Sand   % Fines

Additional habitat types not listed on other side:

Watershed size in sq. miles <15; 15-25; 25-50; >50-100; >100-200; >200   Stream Order:

-Height to bank full stage: Flow (cfs):

$\bar{x}$ Width of runs: $\bar{x}$ Depth of runs: Depth of pools:

Riparian vegetation:

Amount of leaf matter in pools:

Land development (1=Unimp, 2=Low, 3=Mod, 4=High)

Misc. Observations:

RESULTS

FIELD DATA

Field data collected from all 54 sample sites are found in Table 5.

Table 5. Instantaneous field data, Cypress Creek basin, summers of 1995-96. Sites were selected randomly from upper (U), middle (M), and lower (L) portions of streams from six size strata.

Overall Watershed Size km²	Drainage area at site km²	Days since rain	Flow cfs	D.O. instantaneous mg/L	Temp. °C	pH SU	Spec. Cond. µmhos/cm
<39 km²							
Lawrence (U)	1.8	≤4	0.23	6.8	21.2	5.8	85
Beach (M)	6.5	≥10	0.06	0.5	21.1	6.0	53
Colley (L)	5.4	≤4	0.58	3.9	24.4	6.3	64
Cannon (M)	3.1	≥20	0.37	4.4	24.2	6.4	102
Butler (L)	23.8	≥10	0	0.1	22.0	6.2	100
North Lily (U)	1.6	≥5	0.01	4.2	21.1	5.5	97
North Lily (M)	19.7	≥20	Intermittent*	2.0	23.9	5.8	943
Olive Branch (U)	1.6	≥20	Intermittent*	0.2	24.7	7.0	398
Coon (L)	7.8	≥10	0.03	2.7	25.4	6.4	133
39-65 km²							
Panther (U)	3.6	≤4	0.01	4.6	22.5	6.1	97
Panther (M)	8.8	≤4	0.03	2.4	23.7	6.5	96
Panther (L)	16.3	≤4	0	1.4	25.8	6.2	161
Witcher (M)	28.0	≤4	0.15	4.5	22.7	6.2	703
Sugar (U)	9.6	≥5	0.06	2.4	22.4	6.3	154
Caney (M)	10.9	≥20	Intermittent*	0.9	24.7	6.2	151
Caney (L)	34.2	≥10	0.03	0.2	24.2	6.5	106
Gum (U)	3.4	≥30	Intermittent*	1.0	23.6	6.4	136
Gum (L)	39.4	≤4	0.66	1.7	23.7	6.2	91
66-132km²							
Caney(M)	54.9	≥30	Intermittent*	2.6	22.4	6.3	208
Walnut (M)	34.4	≤4	0.12	4.4	24.5	6.6	109
Hart (L)	105	≥30	1.9	4.5	25.5	6.9	427
Grays (U)	25.9	≥10	0.33	4.2	21.6	5.8	88
Grays (L)	85.0	≥10	0.74	4.8	22.2	6.3	108
Maddin (M)	27.2	≥30	0.06	2.1	22.2	6.2	82
Bear (U)	54.9	≥5	0.23	1.0	23.0	5.9	78
Bear (L)	227	≥15	0	0.8	24.7	6.4	75
Kelley (U)	12.4	≥5	0.23	1.6	23.7	5.8	67

Table 5 (continued).

Overall Watershed Size Site	Drainage area km^2	Days since rain	Flow cfs	D.O. instantaneous mg/L	Temp °C	pH SU	Spec. Cond. µmhos/cm
133-259 km^2							
Flat (L)	140	≥5	5.5	4.3	24.8	6.3	63
Moccasin (U)	4.9	≥5	0.11	2.8	22.2	6.5	95
Paw Paw (U)	18.6	≥30	Intermittent*	0.6	20.9	6.4	146
Paw Paw (M)	52.3	≥5	0	1.0	24.2	6.8	288
Harrison (U)	6.5	≤4	0.22	5.9	24.8	6.7	296
Haggerty (L)	72.0	≥5	Intermittent*	0.2	23.4	6.8	226
Kelsey (M)	85.7	≥30	Intermittent*	0.2	23.4	6.4	140
Kitchen (M)	62.4	≥5	0.80	4.0	25.7	6.1	45
Kitchen (L)	99.2	≥5	0.44	2.0	26.4	6.2	68
260-518 km^2							
Lily (U)	49.2	≥5	0.39	4.0	21.3	6.1	205
Black Bayou (U)	31.6	≤4	0.29	1.1	24.2	6.4	87
Black Bayou (L)	250	≥15	Intermittent*	0.5	26.7	6.5	108
Frasier (M)	112	≥10	0.02	1.6	26.4	6.9	355
Frasier (L)	329	≥15	Intermittent*	0.5	25.2	6.6	98
Boggy (M)	163	≥5	0.18	1.7	22.8	6.1	121
Boggy (L)	230	≥30	Intermittent*	1.0	27.2	6.6	131
Jim's (U)	22.8	≥5	0.36	7.8	21.3	6.5	36
Jim's (M)	86.0	≥10	0.26	2.8	25.4	6.5	98
>518 km^2							
Black Cypress (U)	34.4	≥5	0.49	4.4	22.6	6.1	65
Black Cypress (M)	347	≥5	9.1	4.0	24.4	6.4	67
Black Cypress (L)	741	≥30	2.3	2.2	22.9	6.4	116
Little Cypress (U)	81.1	≥20	1.6	4.4	24.1	6.3	62
Little Cypress (M)	1039	≥30	0	1.4	25.6	6.6	163
Little Cypress (L)	1906	≤4	12	4.4	26.8	6.2	142
Big Cypress (U)	948	≥30	19	4.7	26.6	7.2	922
Big Cypress (M)	1748	≤5	ND	6.2	30.9	6.6	341
Big Cypress (L)	2437	≥30	ND	6.4	24.8	6.5	120
Range			0-19	0.1-7.8	20.9-30.9	5.5-7.2	36-943
Mean ± SD			1.1± 3.3	2.8± 2.0	24.0±1.9		176± 190

ND=No data collected. *Intermittent streams had areas of dry stream bed present between pools, while streams with zero flow had water throughout, but no flow.

The natural acidity of the basin was evident by the fact that all but two of the sites had a pH value less than 7.0 standard units (SU). The majority had pH less than 6.5 SU. Specific conductances were all less than 1000 µmhos/cm; and the majority were less than 150 µmhos/cm.

Sixteen of the 54 sites had zero flow or were intermittent with isolated pools with no interconnecting flow; 15 of these had instantaneous DO concentrations ≤ 2.0 mg/L (Table 5). Thirty-eight sites had measurable flow; 30 of these had instantaneous DO concentrations ≥2.0 mg/l (Figure 2). Only six of the 54 sites had flows greater than 1.8 cfs (Table 5). All six points had DO concentrations greater than 2.0 mg/L. These seven points are not show in figure 2 as they compress the results of the majority of sites making them difficult to read. An absolute minimum DO standard of 1.5 mg/L is applicable for all intermittent streams in Texas, and those streams should maintain a 24-hour dissolved oxygen average of 2.0 mg/l (TNRCC, 1995).

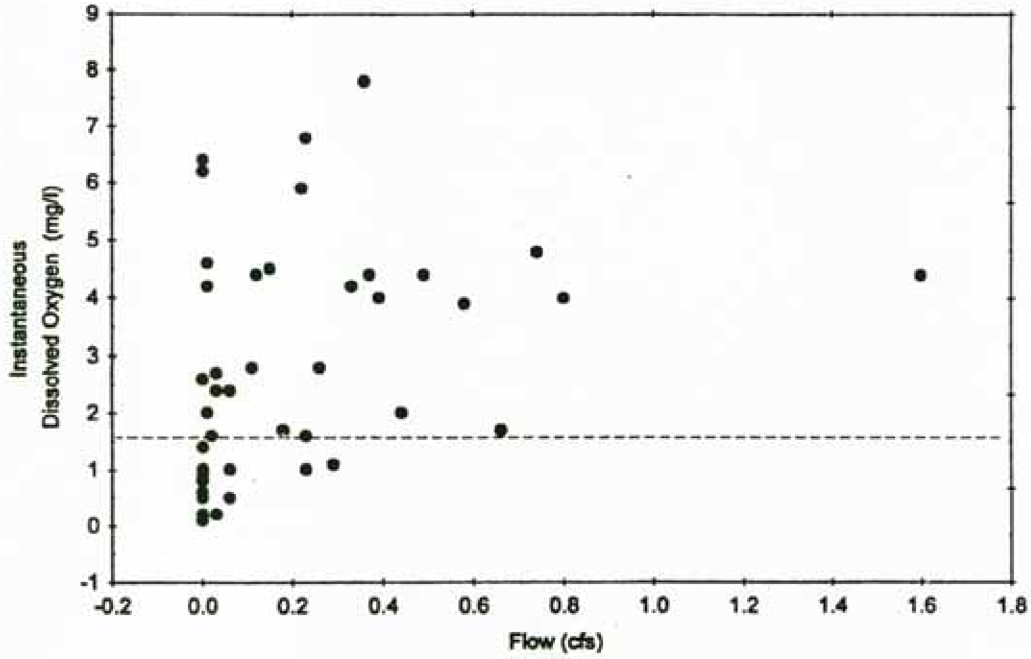


Figure 2. Instantaneous dissolved oxygen concentrations versus flow measurements in forty-seven East Texas streams.

There was a moderate correlation between flow and stream drainage area size (R^2= 0.53). Results of multiple regression analysis showed that changes in flow were best explained by the drainage basin size. Flow and DO were not significantly correlated as originally suspected. In general, streams having larger drainage areas supported higher flows (Figure 3). Of the eight streams with flows > 1 cubic foot per second (cfs), five of those streams were in the largest watershed strata (>518 km^2).

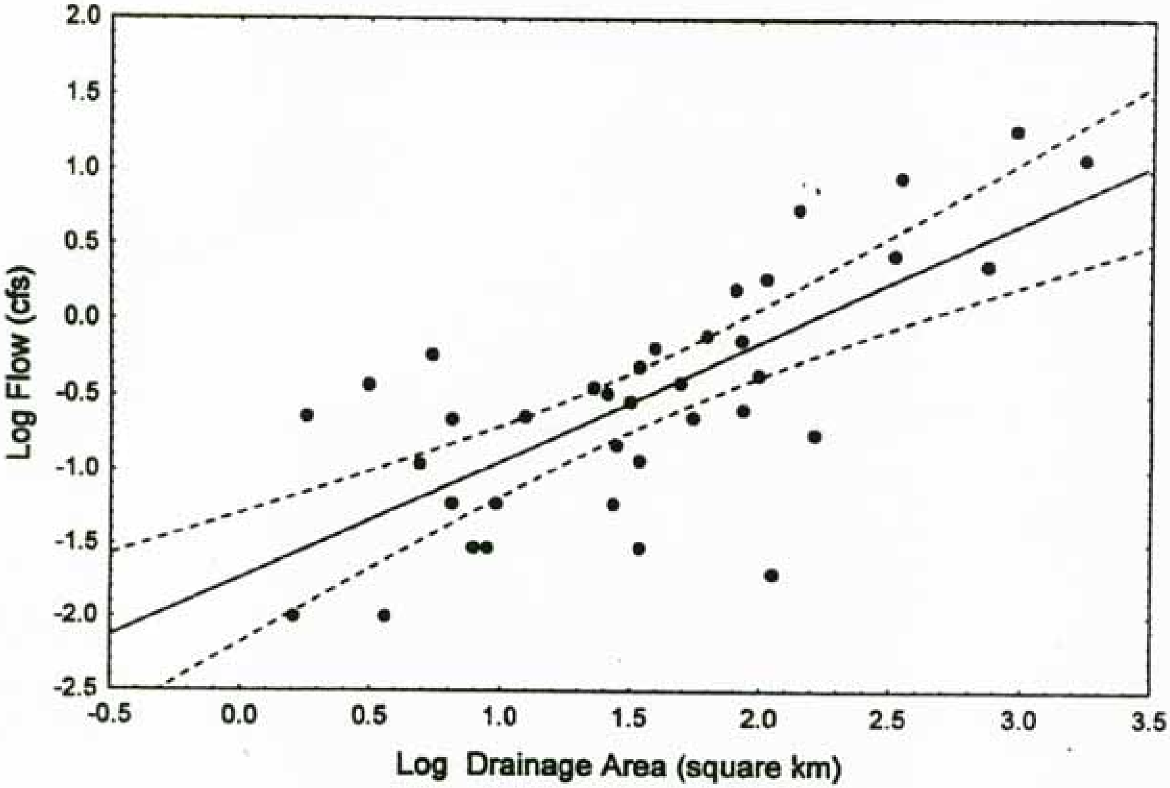


Figure 3. Statistical relationship between log stream flow and log drainage basin area from all streams sampled ($R^2 = 0.52$; $P < 0.05$). Regression equation for individual streams: logflow = -1.738 + 0.7923 log(km^2). Dotted lines are 95% confidence intervals.

The study was conducted during July-September in 1995 and 1996 to include some year-to-year variability. Although 1995-96 were considered dry years across most of Texas, rainfall amounts in East Texas were seasonally normal in 1995 and slightly wetter than normal in 1996 compared to the 100-year average for regional rainfall during July-September (NCDC, 1997). There was a period of rainfall at the end of August 1996 that potentially could have affected some of the samples. Eleven sites were sampled less than five days after the August 1996 rainfall events. However, there was not a significant correlation between the number of days since a rainfall event, as recorded in Table 5, and the instantaneous DO at a site.

Recent rainfall runoff did appear to have a pronounced effect on DO, however. Two separate sites received rainfall while hourly measurements were being made. Although the exact time between when the rain started and when significant runoff began is unknown, there was a dramatic increase in DO concentrations within a two-hour period at the Haggerty Creek site. DO then began a steady fall over the next 30 hours (Figure 4). DO also increased within a similar two-hour period at the Sugar Creek site, but declined more erratically over the remainder of the time the instrument was deployed (Figure 5). Rainfall amount at the Haggerty Creek site was unknown. There was no flow when the instrument was deployed; flow had increased to 0.06 cfs when the instrument was retrieved. The Sugar Creek site received over 25 mm of rain. Flow increased from 0.05 cfs when the instrument was deployed to 0.13 cfs when the instrument was retrieved.

There was no significant difference between instantaneous DO concentrations measured during morning hours (0800-1200) and 24-hour DO averages recorded from the same seventeen locations (Paired t-test; $P < 0.05$) (Table 6). For most of the streams sampled, instantaneous DO data collected during morning hours appeared to be a good indicator of 24-hour DO concentrations, the exceptions being Haggerty Creek and lower Black Bayou (Table 6). There was a highly significant difference (Paired t-test; $P < 0.01$) between wintertime DO concentrations measured under higher stream flow conditions and lower temperatures versus summertime DO concentrations measured under low-flow, high-stress conditions (Appendix B).

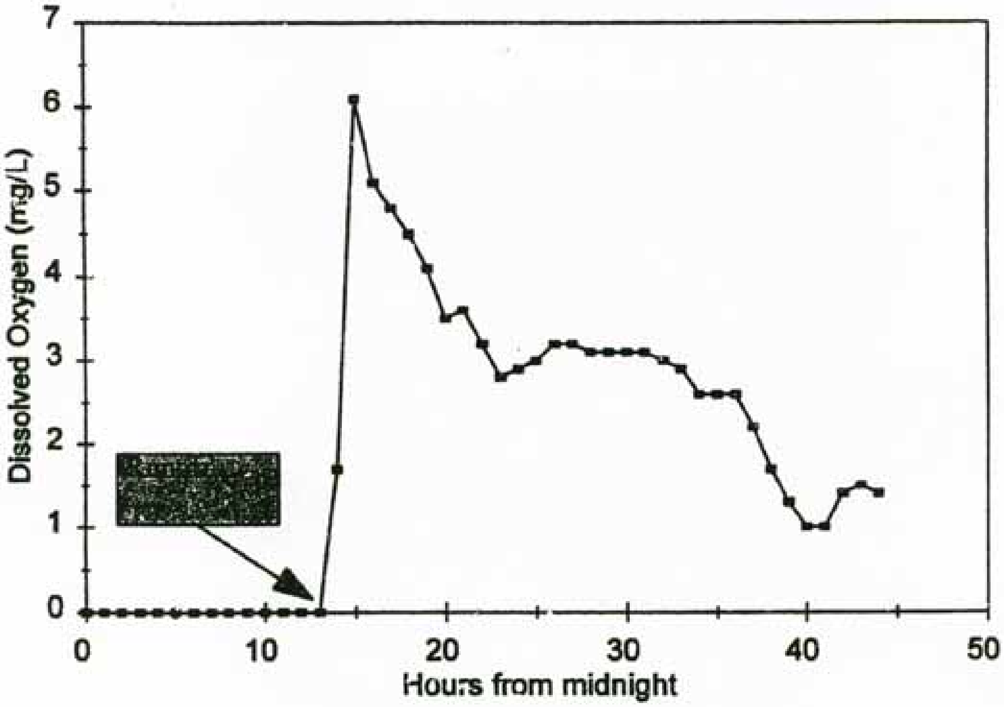


Figure 4. Hourly dissolved oxygen concentrations at Haggerty Creek, 8-30-95.

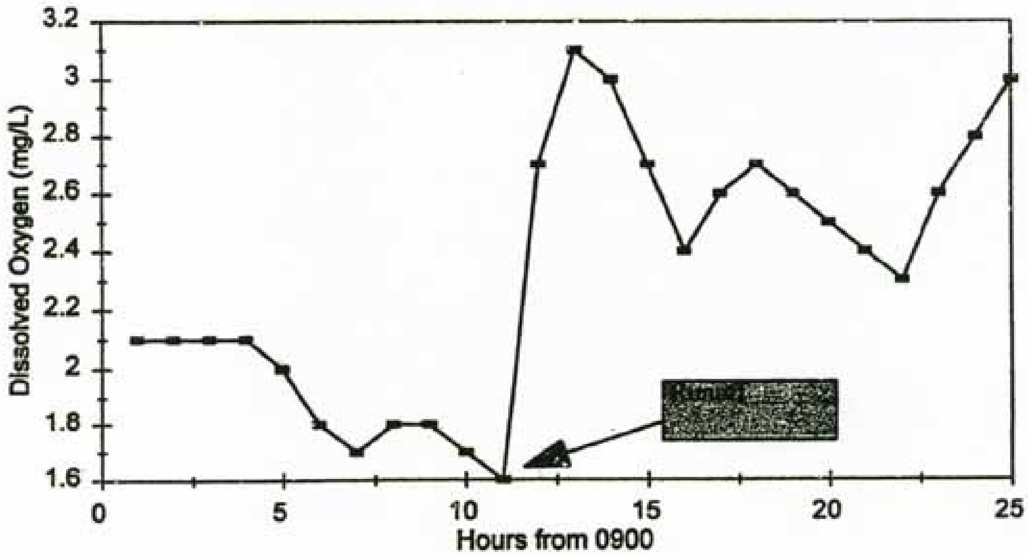


Figure 5. Hourly dissolved oxygen concentrations at Sugar Creek, 8-27-96.

Table 6. Summer low-flow conditions in the Cypress Creek basin, summers of 1995-96. Aquatic life use categories (IBI and RBA) and habitat (ETHA) scores (L=Limited, I=Intermediate, H=High, E=Exceptional). Frazier Creek is included as a reference site.

Watershed Size	Site	Drainage area km^2	Flow cfs	D.O. 24-Hr. $\bar{x}$ mg/L	D.O. Min. mg/L	D.O. Inst. mg/L	IBI	RBA	ETHA
<39 km^2	Lawrence	1.8	0.23	ND	ND	6.8*	I-H	I	I
	Beach	6.5	0.06	0.4±0.5	0.1	0.5	I	L	H
	Coon	7.8	0.03	2.2±0.5	1.2	2.7	I-H	I	L
39-65 km^2	Sugar	9.6	0.06	2.2±0.4**	1.6	2.4	H	I	L
	middle-Caney	10.9	0	1.0±0.6	0.3	0.9	I	H	I
	lower-Caney	34.2	0.03	0.7±0.5	0.3	0.2	H	H	I
66-130 km^2	Grays	25.9	0.33	3.7±0.4	3.0	4.2	H	L	H
	Walnut	34.4	0.12	5.2±0.5*	4.4	4.4*	H	I	I
	Bear	54.9	0	0.03±0.05	0.0	0.8	I-H	I	H
131-259 km^2	Harrison	6.5	0.22	ND	ND	5.9*	H	I	I
	Kitchens	62.4	0.80	4.3±0.6	3.5	4.0	H	H	H
	Haggerty	72.0	0	2.0±1.6**	0.0	0.2	H	I	H
260-518 km^2	upper-Black Bayou	31.6	0.29	1.8±0.6**	0.7	1.1	I-H	I	I
	Frazier-'95	112	0.02	2.0 ±0.6	1.1	1.6	I	I	H
	Frazier-'96	112	2.7	5.7±0.3	5.4	5.9	H	H	ND
	Jim's Bayou	86.0	0.26	3.1±0.1	2.9	2.8	H	H	H
	lower-Black Bayou	250	0	2.7±1.0	1.1	0.5	H	I	L
>518 km^2	upper-Little Cypress	80.5	1.6	4.9±0.2	4.9	4.4	I-H	I	H
	Big Cypress	1748	12	ND	ND	6.2*	H	ND	ND
	lower-Little Cypress	1906	12	4.0±0.2*	3.6	4.4*	H	H	ND

* Rained ≤5 days prior to sample. ** Rained during sampling. ND=No data.

INDIVIDUAL SITE SUMMARIES

Data from individual sites is found in the following appendices: habitat quality (Appendix C), fish collected (Appendix D), index of biotic integrity (IBI) scores for fish (Appendix E), list of regionally expected fish (Appendix H), benthic macroinvertebrates collected (Appendix I), and rapid bioassessment (RBA) scores for benthic macroinvertebrates (Appendix J). Sites are placed into ALU subcategories using both IBI and RBA metrics. In addition, descriptive information is included about general aquatic life attributes (Table 1) such as species assemblages, sensitive species, diversity, species richness, and trophic structure. For this study, the sensitive fish species attribute includes the number and abundance of intolerant species and benthic invertivore species. Cyprinids (minnows) and centrarchids (sunfishes) included the majority of individuals and species at most sites within the basin. The numbers of species from these two important families is listed for each site. The sensitive benthic invertebrate species attribute includes the number and abundance of species with tolerance values less than six.

Lawrence Creek

The sample site was located at Harrison County Road 4308 northwest of Marshall in the upper third (1.8 km^2) of the stream's watershed. Flow (0.23 cfs) and instantaneous DO (6.8 mg/L) were measured within five days of a rainfall event. Twenty-four hour DO was not collected.

Habitat quality was intermediate; five metrics scored optimal, and five marginal. Common habitat types included undercut banks and root mats. Large woody debris and pools were present, but limited in distribution. The amount of available fish and benthic macroinvertebrate habitat were both marginal. Ferric hydroxide precipitates were common, which may have affected the benthic communities. Banks were moderately unstable; two areas of recent bank slumping were noted. Width of vegetative cover was extensive.

The IBI score was intermediate-high. A moderate number of fish (81) were collected from 11 different species, which is less than half the number of regionally expected species. Minnow species (4) were common in the collection, but sunfish species (2) were not well represented. Dominant species were longear sunfish (*L. megalotis*) and bullhead minnow (*Pimephales vigilax*). Several green sunfish (*L. cyanellus*) in the 15 to 18-cm class were caught which either suggests that this section of stream probably has held water for several years, or they migrated from a nearby refuge. The diversity index was moderately high (H=2.59). Trophic structure was moderately to slightly imbalanced. Intolerant species were absent in the sample. Two benthic invertivore species were collected; however, their abundance was low.

The RBA score was in the lower range of intermediate, half the metrics scored in the lowest category. Only 53 individuals were collected from 10 minutes of sampling effort. Fifteen taxa were collected. Sensitive species were present: six intolerant taxa, including three EPT taxa, were collected; this represents 46 percent of the total individuals collected. Dominant taxa were narrow-winged damselfly, *Enallagma* sp. and riffle beetle, *Ancyronyx* sp.. The diversity index was high (H=2.98). A high percentage of predators (63%) caused the trophic structure to be imbalanced.

Beach Creek
The sample site was located at Cass County Road, south of Atlanta in the middle third (6.5 km^2) of the stream's watershed. Flow was very low (0.06 cfs), as were 24-hour DO concentrations (0.4±0.5 mg/L). Lowest DO readings (0.05 mg/L) were between 1800-2100 hours. This site did not meet DO standards for limited ALU based on either 24-hour mean or minima concentrations.

Habitat quality was high; nine metrics scored optimal or suboptimal, and one marginal. Common habitat types included pools and large woody debris. Root mats were present, but limited in distribution. The amount of available fish and benthic habitat were both suboptimal. Portions of the banks were steep, but no evidence of slumping was noted. Vegetative cover was extensive.

The IBI score was intermediate. Very few fish (45) were collected, from 12 different species, which is less than half the number of regionally expected species. Minnow species (1) were uncommon in the collection, but sunfish species (5) were well represented. Dominant species were grass pickerel (*Esox americanus*) and blackspotted topminnow (*Fundulus olivaceus*). The diversity index was high (H=3.19). Trophic structure was moderately imbalanced, the percent invertivores being lower than optimum. Two intolerant species were collected: blackspotted topminnow and cypress darter (*Etheostoma proeliare*). Only one benthic invertivore was collected.

The RBA score was limited; eight of the 12 metrics scored in the lowest category. Fifteen taxa were collected. Sensitive species were present, although low in abundance: seven intolerant taxa, including two EPT taxa, were collected; this represents 19 percent of the total individuals collected. Dominant taxa were chironominae and *Enallagma* sp. The diversity index was intermediate (H=2.45). A high percentage of predators (48%) caused the trophic structure to be moderately imbalanced.

Coon Creek
The sample site was located at Farm to Market Road 49 west of Gilmer in Upshur County in the lower third (7.8 km^2) of the stream's watershed. Flow was minimal (0.03 cfs) and 24-hour DO levels were 2.2± 0.5 mg/L. The minimum DO (1.2 mg/L) occurred at midnight. This site did not meet DO standards for limited ALU based on 24-hour mean DO concentrations.

Habitat quality was limited; nine metrics scored marginal or poor, and one optimal. Common habitat types were root mats and small, shallow pools. The amount of available fish and benthic macroinvertebrate habitat were both poor. Banks were steep, and three areas of recent slumping were noted. Width of vegetative cover was poor. There was a small dairy adjacent to the sample area and cattle were observed watering in the stream.

The IBI score was intermediate-high. A large number of fish (>200) were collected from 11 different species, which is less than half the number of regionally expected species. Only two minnow and one sunfish species were collected, which is lower than expected. Dominant species were western mosquitofish *(Gambusia affinis)* and pirate perch (*Aphredoderus sayanus*). These two species represented seventy five percent of the total fish collected. The diversity index was intermediate (H=2.22). Trophic structure was balanced. No intolerant species were collected. Three benthic invertivores from three different species were collected.

The RBA score was intermediate; half the metrics scored in the lowest category. Eighteen taxa were collected. Sensitive species were present, although very low in abundance: one intolerant taxa and two EPT taxa were collected; this represents two percent of the total individuals collected. Dominant taxa were the gastropod, *Physella* sp., and orthocladiinae. The diversity index was high (3.00). Scrapers were the dominant functional-feeding group. Trophic structure was balanced to slightly imbalanced.

Sugar Creek

The sample site was located at State Highway 300 southeast of Gilmer in Upshur County in the upper third (9.6 km^2) of the stream's watershed. This site received over 25 mm of rain during the time the data recorder was deployed. Although the exact time significant runoff began is unknown, there was a marked increase in DO concentrations around 2030 hours, with DO 1.9±0.2 prior to that time and 2.7±0.2 afterward (Figure 3) . Flow increased from 0.06 cfs before the rain to 0.13 cfs after the rain. The site was resampled six days later. Base flow resumed and 24-hour DO concentrations were 2.2±0.4 mg/L. Minimum DO levels (1.6 mg/L) occurred from 2300-2400 hours. This site did not meet DO standards for limited ALU based on 24-hour mean DO concentrations.

Habitat quality was limited; seven metrics scored marginal, and the rest suboptimal or optimal. Common habitat types included large woody debris and pools, two of which were deep. The amount of available fish and benthic macroinvertebrate habitat were both marginal. Banks were steep and slumping was noted. Width of vegetative cover was moderate. The stream receives nonpoint source runoff from Gilmer, including silt from recent construction activity.

The IBI score was high. A large number of fish (>250) were collected from 20 different species, seven of which were tolerant. Six minnow species and five sunfish species were collected. Dominant species were bluegill (*L. macrochirus)* and longear sunfish (*L. megalotis*). The diversity index was high (H=2.72). Trophic structure was balanced. No intolerant species were collected. Three benthic invertivore species were present.

The RBA score was intermediate, approximating high. Seventeen taxa were collected. Sensitive species were present: six intolerant taxa, including three EPT taxa, were collected; this represents 37 percent of the total individuals collected. Dominant taxa were the small squaregill mayfly, *Caenis* sp., and the mollusk *Sphaerium* sp. The diversity index was high (H=3.15). Trophic structure was balanced. Almost equal numbers of scrapers and collector-gathers were present.

Middle Caney Creek

The sample site was located at an unnamed Upshur County road north of Gilmer in the middle third (10.9 km^2) of the stream's watershed. The stream was intermittent with pools at the site. In the upper third of the drainage, the stream was completely dry during 1995. DO was very low, 1.0±0.6 mg/L. There was a wide fluctuation from minimum to maximum concentrations. The data recorder was set out for 48 hours. The maximum value (2.3 mg/L) occurred at 0200 the first day and fell steadily to 0.5 mg/L by midnight of the next day. This site did not meet DO standards for limited ALU based on either 24-hour mean or minima DO concentrations.

Habitat was intermediate, seven metrics scored optimal or suboptimal, and three marginal or poor. Common habitat types included root mats and pools. Two of the pools were deep. The amount of available fish habitat was marginal, while the amount of available benthic macroinvertebrate habitat was poor. Banks were steep and one area of slumping was observed. Width of vegetative cover was moderate.

The IBI score was intermediate. A moderate number of fish (149) were collected from 18 different species. Five minnow species and six sunfish species were collected. Dominant species were bluegill and longear sunfish. The diversity index was high (H=3.26). Trophic structure was balanced. No intolerant species were collected. Two benthic invertivore species were present.

The RBA score was in the lower portion of the high category. Twenty taxa were collected. Sensitive species were present: six intolerant taxa, including four EPT taxa were collected; this represents 31 percent of the total individuals collected. Dominant taxa were *Enallagma* sp. and broadwinged damselfly, *Hetaerina* sp. The diversity index was exceptional (H=3.90). A high percentage (73%) of predators caused the trophic structure to be imbalanced.

Lower Caney Creek

The sample site was located at Farm to Market Road 852 northwest of Gilmer in Upshur County in the lower third (34.2 km^2) of the stream's watershed. Flow was minimal (0.03 cfs); DO was very low, 0.7±0.5 mg/L. There was a wide fluctuation from minimum to maximum concentrations. The data recorder was set out for 48 hours. The maximum value (2.3 mg/L) occurred at 0200 hours the first day and fell steadily to 0.4-0.5 mg/L by midnight of the next day. This site did not meet DO standards for limited ALU based on either 24-hour mean or minima DO concentrations.

Habitat was intermediate; four metrics scored optimal or suboptimal, and the rest were marginal. There was more available benthic habitat at this site compared to upstream. Common habitat types included pools, root mats, and large woody debris. The amount of available fish and benthic macroinvertebrate habitat were both marginal. Banks were moderately unstable. Width of vegetative cover was moderate.

The IBI score was in the lower range of the high category. A moderate number of fish (>116) representing 16 different species were collected from lower Caney Creek. Minnow species (5) were well represented, but only two sunfish species were collected. Dominant species were western mosquitofish and golden shiner (*Notemigonus crysoleucas*). The diversity index was high (H=2.97). No intolerant species were collected. Two benthic invertivore species were present.

The RBA score was high. Twenty-seven taxa were collected. Sensitive species were abundant: six intolerant taxa, including five EPT taxa, were collected; this represents 55 percent of the total individuals collected. Dominant taxa were alderfly (*Sialis* sp.), and the amphipod, *Hyalella azteca*. The diversity index was exceptional (H=3.84). A high percentage (58%) of predators caused the trophic structure to be imbalanced.

Grays Creek

The sample site was located at Harrison County Road 4011 north of Marshall in the upper third (25.9 km^2) of the stream's watershed. Flow was 0.33 cfs; 24-hour DO was 3.7±0.4 mg/L. The lowest DO (3.0 mg/L) occurred around 0400. This site approximated limited ALU standards for both 24-hour mean and minima DO concentrations.

Habitat quality was high; six metrics scored optimal or suboptimal, and four marginal. Common habitat types included pools, root mats, and large woody debris. The amount of available fish habitat was optimal, while the amount of available benthic macroinvertebrate habitat was marginal. Banks were steep but only minor slumping was noted. Width of vegetative cover was moderate. Pools were maintained by an active beaver colony. The presence of beaver increased the amount of water between the banks, creating long pools and deep beaver runs.

The IBI score was high. A moderate number of fish (61) were collected from 10 different species, which is less than half the number of regionally expected species. Minnow species (1) were not well represented, but there were five sunfish species collected. Dominant species were longear sunfish and bluegill. The diversity index was high (H=2.62). Trophic structure was balanced. Two intolerant species were collected: blackspotted topminnow and cypress darter. One benthic invertivore was collected.

The RBA score was limited, eight of the 12 metrics scored in the lowest category. Thirteen taxa were collected. Sensitive species were present: five intolerant taxa, including two EPT taxa, were collected; this represents 25 percent of the total individuals collected. Dominant taxa were chironominae and *Enallagma* sp. The diversity index was high (H=2.66). A high percentage (54%) of predators caused the trophic structure to be imbalanced.

Walnut Creek

The sample site was located at Farm to Market Road 3245 near the City of Diana in Upshur County in the middle third (34.4 km^2) of the stream's watershed. Flow was 0.12 cfs; DO was 5.2±0.5 mg/L. The sample was collected less than five days since the most recent rainfall event. The lowest DO (4.4 mg/L) occurred between 1000-1200 hours. This site met high ALU standards for both 24-hour mean and minima DO concentrations.

Habitat quality was intermediate; six metrics scored optimal or suboptimal, and four marginal. Common habitat types included root mats, large woody debris, and pools. The amount of available fish habitat was marginal, while the amount of available benthic macroinvertebrate habitat was optimal. Banks were steep; one area of recent slumping was noted. Width of vegetative cover was wide. Beaver dams were noted nearby, but not in the immediate sample area. The sample site was adjacent to the city's wastewater treatment plant.

The IBI score was high. A moderate number (84) of fish were collected from 18 different species. Four minnow species and five sunfish species were collected. Dominant species were emerald shiner (*N. atherinoides*) and longear sunfish. The diversity index was high (H=3.41). Trophic structure was balanced. Two intolerant species were collected: mimic shiner (*N. volucellus)* and brook silverside (*Labidestes sicculus*). Three benthic invertivore species were present.

The RBA score was intermediate, eight of the 12 metrics scored in the lowest category. Twenty-two taxa were collected. Sensitive species were present: eight intolerant taxa, including one EPT taxa, were collected; this represents 26 percent of the total individuals collected. Dominant taxa were *Enallagma* sp. and *Caenis* sp. The diversity index was high (H=2.84). A high percentage (59%) of predators caused the trophic structure to be imbalanced.

Bear Creek

The sample site was located at Cass County Road 2620 south of Marietta in the lower third (54.9 km^2) of the stream's watershed. The stream had continuous water throughout the reach; but the water was pooled and flow was zero; 24-hour DO concentrations were 0.03±0.05 mg/l. This was the lowest DO recorded during the study. Concentrations actually fell to 0.0 mg/L for an 18-hour period. This site did not meet DO standards for limited ALU based on either 24-hour mean or minima DO concentrations.

Habitat quality was high; eight metrics scored optimal or suboptimal, and two marginal. Common habitat types included root mats, pools, and large woody debris. The site was revisited two weeks later and the amount of water metric declined from the suboptimal to the poor category. The stream had become intermittent with sections of dry stream bed between isolated pools. The amount of available fish habitat went from suboptimal to poor, while the amount of available benthic macroinvertebrate habitat went from marginal to poor. Banks were stable; no evidence of recent slumping was noted. Width of vegetative cover was extensive.

The IBI score was intermediate to high. A moderate number of fish (69) were collected from 13 different species. Minnow species (1) were not well represented, and only four sunfish species were collected. Bluegill, longear sunfish, and warmouth (*L. gulosus)* in the 12 to 15-cm class were collected. Grass pickerel and spotted sucker (*Minytrema melanops*) in the 20 to 22-cm class also were collected. This suggests that the stream holds water over extended periods and can support fish from one year to the next in spite of very low DO. Dominant species were small, unidentified shiners (*Notropis* sp.) and bluegill. The diversity index was high (H=2.63). Trophic structure was balanced. No intolerant species were collected. Two benthic invertivores from two different species were collected.

The RBA score was intermediate. Sixteen taxa were collected. Sensitive species were abundant: six intolerant taxa, including two EPT taxa, were collected; this represents 73 percent of the total individuals collected. Dominant taxa were *Sialis* sp. and grass shrimp, *Palaemonetes* sp. The diversity index was high (H=3.32). A high percentage (58%) of predators caused the trophic structure to be imbalanced.

Harrison Bayou

The sample site was located at Farm to Market Road 1988 east of Marshall in Harrison County in the upper third (6.5 km^2) of the stream's watershed. Flow was 0.22 cfs; instantaneous DO was 5.9 mg/L. These were measured three days after a 15-mm rainfall event. No 24-hour DO readings were obtained due to instrument malfunction.

Habitat quality was intermediate: seven metrics scored optimal or suboptimal, and three marginal. Common habitat types included pools and riffles. Root mats, rock ledges, and large woody debris were present but limited in distribution. The amount of available fish habitat was optimal, while the amount of available benthic macroinvertebrate habitat was marginal. Banks were steeply angled; one area of recent slumping was present. Width of vegetative cover was moderate.

The IBI score was high. A large number of fish (>350) representing 17 different species were collected. Five minnow species and five sunfish species were collected. Dominant species were blackspot shiner (*N. atrocaudalis*) and bullhead minnow. The diversity index was high (H=2.93). Trophic structure was balanced. One intolerant species was collected: the blackspotted topminnow. Two benthic invertivore species were present.

The RBA score was intermediate. Fourteen taxa were collected. Sensitive species were present, although low in abundance: six intolerant taxa, including three EPT tax were collected; this represents 17 percent of the individuals collected. Dominant taxa were *Caenis* sp. and *Enallagma* sp. The diversity index was high (2.64). A high percentage of predators (44%) of predators caused the trophic structure to be moderately imbalanced.

Kitchens Creek

The sample site was located at Marion County Road 3406 northwest of Jefferson in the middle third (62.4 km²) of the stream's watershed. Flow was 0.80 cfs; 24-hour DO was 4.3±0.6 mg/L. Minimum DO occurred between 1800-1900 hours. This site met standards for intermediate ALU based on 24-hour mean DO concentrations.

Habitat quality was high; all metrics scored optimal or suboptimal. Common habitat types included pools, large woody debris, instream trees, and root mats. The amount of available fish habitat was optimal, while the amount of available benthic macroinvertebrate habitat was suboptimal. Banks were gently sloping and no evidence of any bank slumping was noted. Width of vegetative cover was extensive.

The IBI score was high. A moderate number of fish (143) were collected from 22 different species, the second highest species count collected. Minnow species (5) and sunfish species (8) were well represented. Dominant species were juvenile shiners (*Notropis* sp.) and longear sunfish. The diversity index was exceptional (H=3.61). Trophic structure was balanced. Two intolerant species were collected: ironcolored shiner (*N. chalybaeus*) and brook silverside. Two benthic invertivore species were present.

The RBA score was high; half the possible metrics scored in the highest category. Twenty-five taxa were collected. Sensitive species were abundant: seven intolerant taxa, including five EPT taxa, were collected; this represents 54 percent of the total individuals collected. Dominant taxa were *Enallagma sp.* and the dragonfly, *Macromia* sp. The diversity index was exceptional (H=4.02). A high percentage (62%) of predators caused the trophic structure to be imbalanced.

Haggerty Creek
The sample site was located at Harrison County Road 2108 (Peter's Chapel Road) northeast of Marshall in the lower third (72.0 km²) of the stream's watershed. Flow was zero and the stream was intermittent; 24-hour DO was 2.0±1.6 mg/L. A rainfall event occurred while the data recorder was deployed. DO went from 0.0 to over 6.0 mg/L in the space of two hours, but dropped steadily thereafter (Figure 2). This site did not meet standards for limited ALU based on either 24-hour mean or minima DO concentrations.

Habitat quality was high; seven metrics scored optimal or suboptimal, and three marginal or poor. Common habitat types included isolated pools, large woody debris, and root mats. The amount of available fish and benthic macroinvertebrate habitat were both suboptimal. Banks were steep in places and some recent slumping was noted. Width of vegetative cover was extensive.

The IBI score was high. A moderate number of fish (89) were collected from 17 different species. Three minnow species and six sunfish species were collected. Dominant species were longear sunfish and golden shiner. The diversity index was high (H=2.96). Trophic structure was balanced. Two intolerant species were collected: dusky darter (*Percina sciera*) and Texas logperch (*P. carbonaria*). Three benthic invertivore species were present.

The RBA score was intermediate. Fourteen taxa were collected. Sensitive species were abundant: seven intolerant taxa, including two EPT taxa were collected; this represents 64 percent of the total individuals collected. Dominant taxa were *Ancyronyx* sp. and the amphipod, *Gammarus* sp. The diversity index was high (3.28). A high percentage (49%) of predators caused the trophic structure to be moderately imbalanced.

Upper Black Bayou
The sample site was located at Farm to Market Road 2791 west of Atlanta in Cass County in the upper third (31.6 km²) of the stream's watershed. Flow was 0.29 cfs; 24-hour DO was 1.8±0.6 mg/L. The sample was collected within two days of a rainfall event. Two bank fishermen were at the site. This site did not meet standards for limited ALU based on 24-hour mean DO concentrations.

Habitat quality was in the upper end of the intermediate range; eight metrics scored optimal or suboptimal, two marginal or poor. Common habitat types included large, deep beaver pools. Large woody debris and root mats were present, but limited in distribution. The amount of available fish habitat was optimal, while the amount of available benthic macroinvertebrate habitat was poor. Banks were gently sloping and stable. Width of vegetative cover was extensive.

The IBI score was intermediate to high. A moderate number of fish (99) were collected from 13 different species. Three minnow and five sunfish species were collected. Dominant species were golden shiner and western mosquitofish. The diversity index was high (H=3.18). Trophic structure was balanced. One intolerant species was collected, the blackspotted topminnow. One benthic invertivore was present.

The RBA score was limited; seven of the 12 metrics scored in the lowest category. Thirteen taxa were collected. Sensitive species were abundant: six intolerant taxa, including one EPT taxa, were collected; this represents 56 percent of the total individuals collected. Dominant taxa were the whirligig beetle, *Dineutus* sp.; the water scorpion, *Ranatra* sp.; and chironominae. The diversity index was high (3.18). A high percentage (63%) of predators caused the trophic structure to be imbalanced.

Frazier Creek

This is an ecoregion reference site for the south central plains ecoregion. The sample site was located at US Highway 59 northeast of Linden in Cass County in the upper third (112 km^2) of the stream's watershed. In the 1995 survey, flow was 0.02 cfs; 24-hour DO was 2.0±0.6 mg/L. In the 1996 survey, flow was 2.7 cfs; 24-hour DO was 5.7±0.3 mg/L. This site did not meet standards for limited ALU in 1995 based on DO minima concentrations. However in 1996, the same site meet DO standards for high ALU based on 24-hour mean and minima DO concentrations.

Habitat quality was high; eight metrics scored optimal or suboptimal, and two marginal or poor. Common habitat types in 1995 included pools and large woody debris. Root mats were present, but were mostly exposed during summer 1995. The amount of available fish and benthic macroinvertebrate was suboptimal. Banks were steep and one area of minor slumping was noted. Width of vegetative cover was extensive.

The IBI score was intermediate to high in 1995 and high in 1996. For the respective years, the number of individuals collected was moderate (108) versus high (220); 17 versus 15 species were collected. From 1995 to 1996, the number of minnow species ranged from five to four; sunfish species from six to three. Dominant species in 1995 were western mosquitofish and longear sunfish. Dominant species in 1996 were emerald shiner and longear sunfish. The diversity index was exceptional (H=3.52) in 1995, while intermediate (H=1.56) in 1996. The reason for the lower score in 1996 was the majority of individuals came from one specie, the emerald shiner. Trophic structure was balanced in 1995 versus slightly imbalanced in 1996. One intolerant species, the dusky darter, was collected in 1995; two intolerant species, the dusky darter and blackspotted topminnow, were collected in 1996. Three benthic invertivore species were present in 1995 versus four in 1996.

The RBA score was intermediate in 1995 and high in 1996. For the respective years, the number of taxa collected was 16 versus 20. Sensitive species were abundant: eight intolerant taxa were collected both years, representing 89 and 51 percent of the total individuals collected, respectively. Dominant taxa in 1995 was *Ancyronyx* sp. Dominant taxa in 1996 was the caddisfly, *Cheumatopsyche* sp. The diversity index was high both years (H=2.60-3.30). Collector-gatherers were the dominant functional-feeding group in 1995-96. Trophic structure was balanced both years.

Jim's Bayou

The sample site was located at Cass County Road 1775 northeast of Jefferson in the middle third (86.0 km^2) of the stream's watershed. Flow was 0.26 cfs; 24-hour DO was 3.1 ±0.1. DO was stable as indicated by the low standard deviation. This site met standards for limited ALU based on 24-hour mean and minima DO concentrations.

Habitat quality was high; nine metrics scored optimal or suboptimal, and one marginal. Common habitat types included pools, large woody debris, root mats, and instream cypress trees. The amount of available fish and benthic macroinvertebrate habitat was optimal. Bank slopes were slight and no slumping was noted. Width of vegetative cover was extensive.

The IBI score was high. A moderate number of fish (182) were collected from 18 species. Four minnow and five sunfish species were collected. Dominant species were bluegill and emerald shiner. The diversity index was high (H=2.81). Trophic structure was balanced. Three intolerant species were collected: ironcolored shiner, brook silverside, and blackside darter (*Percina maculata*). Two benthic invertivore species were present.

The RBA score was high. Twenty-four taxa were collected. Sensitive species were abundant: ten intolerant taxa, including five EPT taxa, were collected; this represents 74 percent of the total individuals collected. Dominant taxa were *Ancyronyx* sp. and *Sialis* sp. The diversity index was high, approaching exceptional (H=3.49). Collector-gatherers were the dominant functional-feeding group. Trophic structure was balanced to slightly imbalanced.

Lower Black Bayou

The sample site was located at Cass County Road 4659 southeast of Atlanta in the lower third (250 km^2) of the stream's watershed. Flow was zero and the stream was intermittent with pools; 24-hour DO was 2.7±1.0 mg/L. The DO minimum (1.1 mg/L) occurred at 1000 hour. This site did not meet standards for limited ALU based on DO mean or minima concentrations.

Habitat quality was limited; five metrics scored optimal or suboptimal, and five marginal or poor. The site was sampled during an extended period of dry weather. The water level was the lowest observed since 1990, when this site was established as a routine water quality monitoring station. Habitat were limited to two pools. The amount of available fish and benthic macroinvertebrate habitat was poor. Two weeks after the sample event one of these pools had gone completely dry, and the other had decreased to half its original size. Banks were stable and there was no evidence of slumping. Width of vegetative cover was extensive.

The IBI score was high. A large number of fish (284) were collected from 24 species. This was the most species that were collected during the study, primarily attributed to the fact that fish were unable to avoid the sampling gear in the isolated pools, allowing for a more through sample. Three minnow and eight sunfish species were collected. Sunfishes, yellow bullhead (*Amerius natalis*), and grass pickerel in the 15 to 25-cm class were numerous, indicating that the stream probably had maintained water for several years. Dominant species were grass pickerel and warmouth. The diversity index was exceptional (H=3.75). Trophic structure was slightly imbalanced due to the large percentage (34%) of piscivores. Two benthic invertivore species were also collected. Two intolerant species, brook silverside and blackspotted topminnow, were collected.

The RBA score was intermediate. Twenty-five taxa were collected. Sensitive species were present: eight intolerant taxa, including one EPT taxa, were collected; this represents 26 percent of the total individuals collected. Dominant taxa were the dragonfly, *Tetragoneuria* sp.; the snail *Somatogyrus* sp.; and predaceous diving beetle, *Hydroporus* sp. The diversity index was high (H=3.32). A high percentage (63%) of predators caused the trophic composition to be imbalanced.

Upper Little Cypress Creek

The sample site was located at Farm to Market Road 852 in Upshur County in the upper third (80.5 km²) of the stream's watershed. Flow was 1.6 cfs; 24-hour DO was 4.9±0.2 mg/L. This site approximated high ALU standards based on 24-hour mean and minima DO concentrations.

Habitat quality was high; eight metrics scored optimal or suboptimal, and two marginal. Common habitat types included root mats, pools, well developed bends, undercut banks, and large woody debris. The amount of available fish habitat was optimal, while the amount of available benthic macroinvertebrate habitat was suboptimal. Banks were steep in many places and two minor areas of slumping were noted. There were several dairies in the area.

The IBI score was high. A moderate numbers of fish (101) were collected from 21 species. Four minnow and seven sunfish species were collected. Dominant species were bluegill and longear sunfish. The diversity index was high (H=3.32). Trophic structure was balanced. One intolerant species, the dusky darter, was collected. Three benthic invertivore species were present.

The RBA score was intermediate. Fifteen taxa were collected. Sensitive species were present: eight intolerant taxa, including two EPT taxa, were collected; this represents 36 percent of the individuals collected. Dominant taxa were *Enallagma* sp. and the riffle beetle, *Stenelmis* sp. The diversity index was high (H=3.21). A high percentage (66%) of predators caused the trophic structure to be imbalanced.

Big Cypress Creek

The sample site was located at US Highway 259 southeast of Lone Star in Morris County in the middle third (1748 km²) of the stream's drainage. Flow was estimated to be 12 cfs; instantaneous DO was 6.2 mg/L. These were measured within five days of a rainfall event.

Habitat data were not collected, since the stream is non-wadable stream and greater than third order. No benthic samples were collected.

The IBI score was high. A large number of fish (285) were collected from 17 species. Three minnow and five sunfish species were collected. Dominant species were blackstripe topminnow, *Fundulus notatus*, and threadfin shad, *Dorosoma petenense*. The diversity index was high (H=3.22). Trophic structure was slightly imbalanced due to a high percentage (13%) of omnivores and a lower than usual percentage (58%) of invertivores. Two intolerant species, brook silverside and cypress darter, were collected. Two benthic invertivore species were collected.

Lower Little Cypress Bayou

The sample site was located at Farm to Market Road 134 in Marion County in the lower third (1906 km²) of the stream's watershed. Flow was 12 cfs; 24-hour DO was 4.0±0.2 mg/L. These were measured within five days of a rainfall event. This site approximated the intermediate ALU standards based on 24-hour mean and minima DO concentrations.

Habitat data were not collected because the stream is greater than third order and non-wadable.

The IBI score was high. A moderate numbers of fish (98) were collected from 19 species. Three minnow and four sunfish species were collected. Emerald shiners were the dominant species collected. The diversity index was high (H=3.40). Trophic structure was balanced. Three intolerant species, brook silverside, dusky darter, and logperch (*Percina caprodes*), were collected. An abundance of benthic invertivores species (4) and individuals were present.

The RBA score was at the upper portion of the high range. Twenty-three taxa were collected and identified. Sensitive species were abundant: thirteen intolerant taxa, including 10 EPT taxa, were collected. This represents 64 percent of the total individuals collected. The dominant taxa were *Stenelmis* sp. and *Gammarus* sp. The diversity index was high (H=3.21). Collector-gatherers were the dominant functional-feeding group. Trophic structure was balanced to slightly imbalanced.

SUMMARY

DISSOLVED OXYGEN AND FLOW VERSUS AQUATIC LIFE USE

No observable relationship was identified between ALU scores and instantaneous DO concentrations (Figure 6), or ALU scores and flow (Figure 7). Twenty-four hour DO concentrations were recorded at 15 randomly selected sites. DO criteria were met or approximated the following ALU subcategories: eleven limited, two intermediate, and two high. ALU subcategories based on biological data did not correspond to ALU subcategories based on DO concentrations. Of the 11 sites which met or approximated limited DO concentrations, the IBI scored two as intermediate, three as intermediate to high, and six as high. The RBA scores for the same sites were two limited, six intermediate, and three high. The year to year variability in DO concentrations and ALU subcategories is evident at the reference site, Frazier Creek. In 1995, Frazier Creek met minimal 24-hr DO criteria (2.0 mg/l) and had an intermediate-high IBI and intermediate RBA score. In 1996, Frazier Creek exceeded the high DO criteria (5.0 mg/l) and had high IBI and RBA scores. The data suggests that the differences in flow, 0.02 cfs in 1995, and 2.7 cfs in 1996, may have played a role in influencing the biological results.

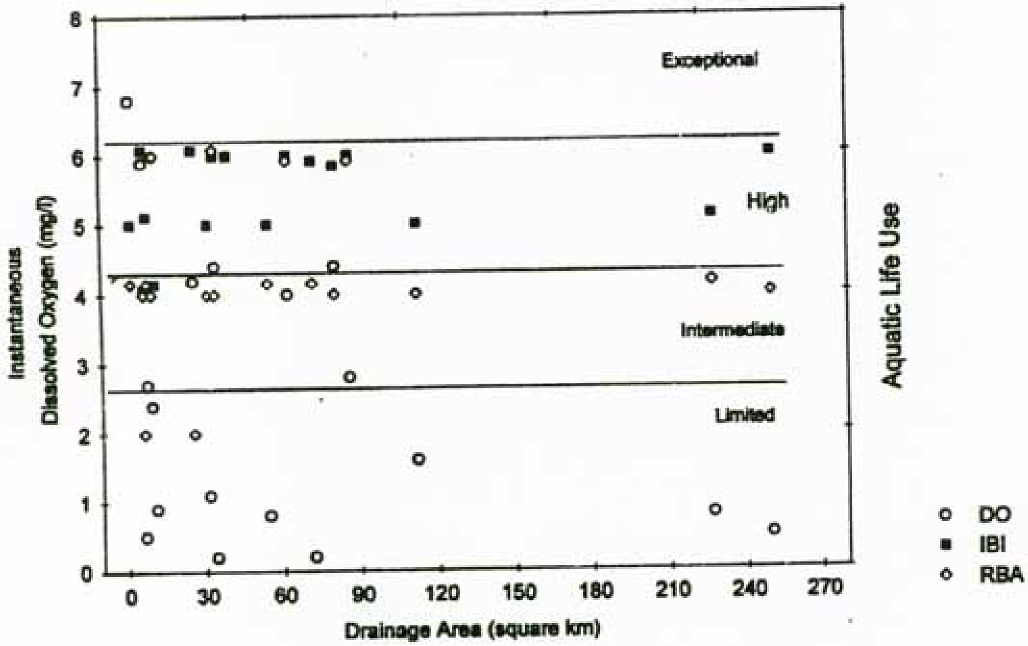


Figure 6. Benthic and fish community index scores vs dissolved oxygen levels.

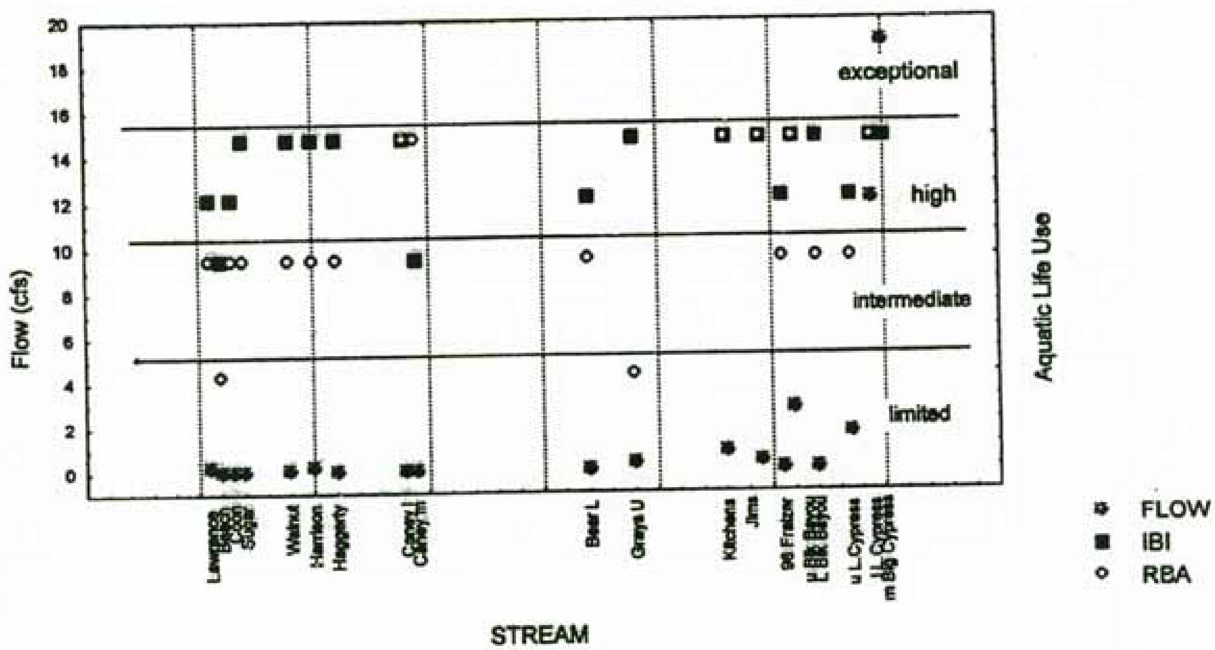


Figure 7. Benthic and fish community index scores vs summer flow.

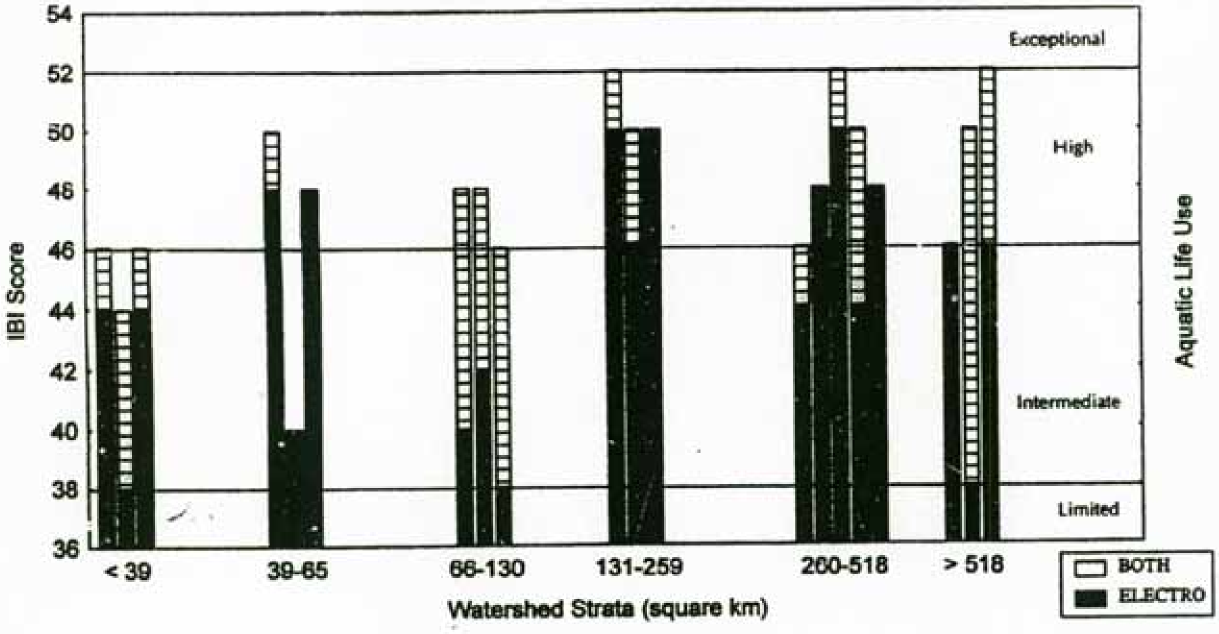


Figure 8. IBI scores from electrofisher and seine (both) combined versus electrofisher (electro) only. Sites are ranked from smaller to larger subwatersheds.

FISH

Fifty-five species were collected during the study (Appendix D); 16 of which were collected at half of the sites. A list of regionally expected species collected at sites with high IBI scores is presented in Appendix H. The most common families represented were Centrarchidae and Cyprinidae. Seven species of sunfishes and five species of shiners were present at a majority of the sites. Several intolerant species were collected throughout the basin: blackspotted topminnow, brook silverside, dusky darter, and cypress darter. The following are proposed attributes for species richness within the Cypress Creek basin: limited <10, intermediate 10-14, high 15-20, exceptional ≥ 21. Trophic structure was balanced at most sites throughout the basin. Individual metrics that scored high at all sites included total number of species; number of sunfish species; percent individuals as omnivores; percent individuals as piscivores; and percent individuals as hybrids. IBI scores ranged from intermediate (2 sites), intermediate-high (6 sites), to high (12 sites). IBI scores generally increased as watershed size increased. Variability at a site is pointed out by the change in the scores at Frazier Creek, which went from intermediate-high in 1995 to high in 1996.

IBI scores with and without seine data included were compared for each site (Appendices E and F; Figure 8). There was a highly significant difference (Paired t-test $P<0.01$) between the two sets of scores. The average IBI score for electrofisher plus seine data was high, compared to intermediate when only electrofisher data were considered. On a station by station basis, electrofisher and seine data combined reflected a higher ALU category in five of 20 cases. The biggest differences in scores related to metrics dealing with number of darter species and number of individuals, followed by total species and percent insectivores. Shiners, darters, silversides, and mosquitofish were more likely to be captured by seining (Appendix G).

IBI and RBA scores were compared for each site (Figure 9), and there was a highly significant difference (Paired t-test P<0.01). The average IBI score was high, while the average RBA score was intermediate (Figure 9). On a station by station basis, the IBI scored one ALU category higher than the RBA in eight of 19 instances, while the RBA scored higher than the IBI only one time.

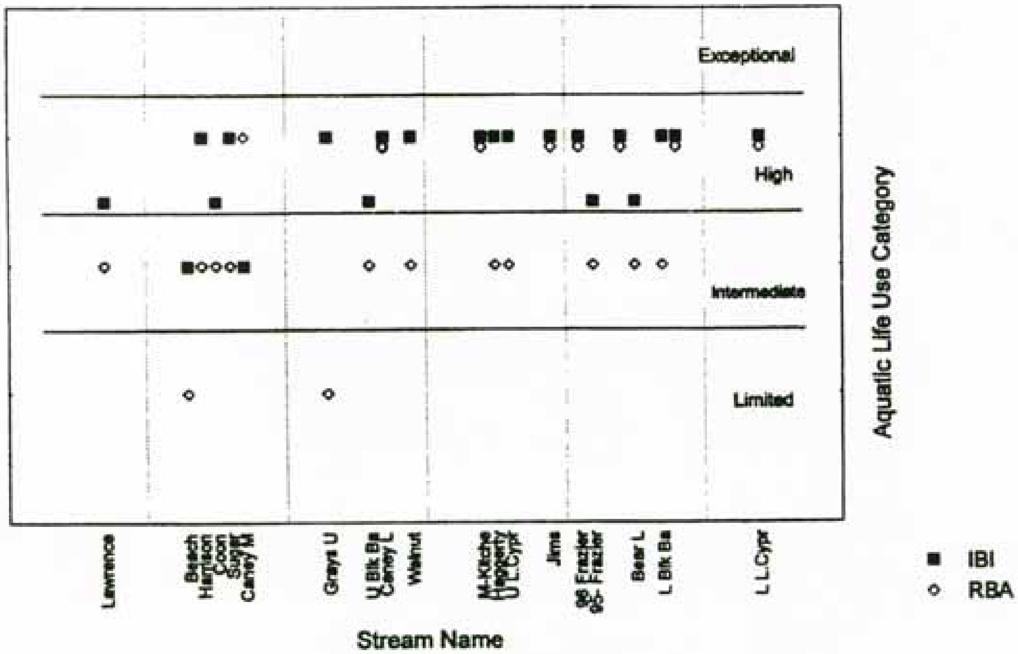


Figure 9. Benthic versus fish community aquatic life use scores for 19 streams. Streams listed in increasing drainage area (km²) size.

BENTHIC MACROINVERTEBRATES

Eight-one taxa were collected during the study, 10 of which were collected at half of the sites (Appendix I). RBA scores ranged from limited (3 sites) to high (6 sites), with the majority (10 sites) in the intermediate category (Appendix J). In general, total taxa richness was relatively high throughout the basin. Sensitive species were present at all site; they generally increased in abundance as watershed size increased. The number of EPT taxa were not well represented, except at a relatively few sites. The ratio of intolerant to tolerant individuals generally was poor. A high percentage of predators at most sites caused trophic structure to be imbalanced and lowered overall RBA scores. Three families of odonates were common: Aeshnidae, Coenagrionidae, and Gomphidae. Other common insect taxa included Sialidae, Dytiscidae, Elmidae, and Chironomidae. Among non-insect taxa, Cambaridae and Palaemonidae were common.

EAST TEXAS HABITAT ASSESSMENT (ETHA)

ETHA scores ranged from limited to high (Appendix C). The ecoregion reference site at Frazier Creek scored high. One purpose of having a reference site is to compares scores from other sites to the reference. Thirteen of 16 sites surveyed had scores comparable or supportive (≥ 72 percent) to that for Frazier Creek. Habitat scores for Coon Creek, Sugar Creek, and lower Black Bayou were not supporting (≤58 percent), or only partially supportive (≥ 58 to ≤72 percent)of the reference site.

CONCLUSIONS

DISSOLVED OXYGEN CONCENTRATION

Several factors are important in evaluating instream DO concentrations for standards compliance including subwatershed size, recent rainfall, and season. Based on data from the present study, drainage area had a moderate influence on flow. Flow volume in turn, affects dissolved oxygen concentrations, although the two were not statistically correlated in the streams sampled for this study. In the East Texas streams surveyed, dissolved oxygen did not seen to be a limiting factor for fish or benthic communities. This finding does not conform to the standards for DO and aquatic life use as published in the state's surface water quality standards. Based on numerical DO criteria, even limited ALU was not being met at many streams within the basin. Aquatic communities within the Cypress Creek basin have apparently adapted to withstand low flow and high stress associated during normal summer conditions. Although decreased growth, increased disease, predation, and some mortality may occur during low-flow periods, fish communities in many different sized streams throughout the basin appear to survive until conditions improve and, in general, a high aquatic life use is maintained. The streams surveyed in the Cypress Creek basin are typical of similar sized streams in surrounding river basins.

Standards for dissolved oxygen may be unattainable for a majority of streams within the basin due to seasonal low flow, high temperature, and natural oxygen demanding conditions. If standards are not being met because of naturally occurring conditions, this should not be considered a violation of standards. However, it does supports the argument for setting regional, as well as seasonal DO criteria. Dissolved oxygen criteria were designed to be protective of health and growth of sports fishes. This may or may not approximate the current practice of utilizing biological metrics (species richness and composition, trophic composition, abundance, and condition) to determine aquatic life use and DO standards. The water quality standards program is currently investigating the de-coupling of the standard default aquatic life use and dissolved oxygen concentrations in East Texas streams.

GEAR COMPARISONS

Electrofishing proved to be the best technique for collecting fish from East Texas streams, although it appeared selective against collecting certain species, particularly minnows, darters, silversides, and mosquitofish. When seining and electrofishing results were combined, IBI scores increased due to higher metric scores for number of darter species, number of individuals, and total number of species, as well as an increase in the percent insectivores. Combined data therefore appears to give the best representation of overall fish community and characteristics.

METRIC COMPARISONS

Differences in aquatic life use classifications indicated by fish and benthic macroinvertebrate communities were interesting and somewhat unexpected. There are several explanations. Most of the sites where benthic macroinvertebrates were collected did not have riffle/run type habitats. Riffles are not common in most East Texas streams. Runs are common; but since samples were collected during the dry season, even this habitat type was scarce. Samples were collected from the most stable benthic habitat available, which at many sites included root mats located along stream banks. As a result, taxa generally associated with such habitat (*eg.* dragonflies, crayfish, and grass shrimp) commonly were collected. The proposed RBA metrics were designed for benthic communities from riffle/run habitats, so sampling a different habitat type may have been partially responsible for reduced scores. It is also possible that benthic organisms are more sensitive to low DO concentrations than are fish, and lower overall scores for the RBA versus the IBI may reflect this. Since benthic communities are nonmobile, they integrate all conditions, including drought, into their aquatic life use designation. Fish are more mobile than aquatic insects, and they are able to move into remaining pool habitats as drought conditions worsen and survive there until conditions improve. Because the chance of avoiding capture in isolated pools is reduced, a more complete sample of the fish community normally is obtained during drought conditions. Coefficient of variation (CV) can be used to measure variability from two unrelated groups of numbers, or in this case, mean ALU values from across the Cypress Creek basin. The CV for the benthic macroinvertebrate data was over three times that for the fish data. The CV for habitat data was similar to that of benthic macroinvertebrates data.

Fish and benthic macroinvertebrate data may give slightly different ALU indications, but both are important. It should not be expected that ALU designations for fish and benthic macroinvertebrates agree in all cases. When attempting to classify a dynamic ecosystem such as a stream into one of four categories, a risk of oversimplification exists. Since most biological surveys are limited spatially and temporally, it is best to include as much information as possible in an ALU determination. Both fish and benthic macroinvertebrates should be part of any biological assessment. The ideal situation would be to collect both types of information over multiple years; average the ALU for fish and benthic macroinvertebrates separately; and if different, protect for the higher of the two aquatic life uses.

INDEX OF BIOTIC INTEGRITY

Despite low flow and low dissolved oxygen concentrations, the majority of the streams sampled had aquatic life uses equal to or greater than high. Six of 12 IBI metrics scored high at every sample site. These included total number of species, number of sunfish species, percent omnivores, percent piscivores, percent hybrids, and percent of individuals with defects. Resolution between sites is lost when so many individual metrics consistently score high. A metric dealing with the number of minnow species would be useful in this part of the state. The metric dealing with percent hybrids is difficult to evaluate, since it requires interpretation of sometimes vague physical characteristics. It is suggested that some modification to scoring criteria for individual metrics be considered on a regional basis.

EAST TEXAS HABITAT ASSESSMENT

This study provides a preliminary survey of metrics that may be suitable for low-gradient streams. However, there were not enough sites with clear differences between individual metric scores to evaluate whether differences between aquatic communities could be correlated to habitat. EPA has developed a set of metrics for low-gradient streams that eliminated one of the metrics, embeddedness, which caused many East Texas streams to score poorly in the riffle-run habitat assessment. The new habitat assessment for low-gradient streams (Barbour and Stribling, 1991) needs to be verified in a variety of geographical areas to determine if differences in habitat scores can predict differences in IBI and RBA scores.

ECOREGION REFERENCE SITES

One useful result of this study that included a lot of new sample sites is that potential new ecoregion reference sites were identified. Frazier Creek and the East Fork Angelina River are current reference sites in the South Central Plains ecoregion. Both support diverse biological communities, have balanced trophic structure, and support intolerant species. Little Cypress Bayou, Jim's Bayou, and Kitchens Creek had habitat, fish, and benthic macroinvertebrate scores similar to Frazier Creek. Least impacted reference sites should represent realistic, attainable conditions for aquatic ecosystems (Omernik, 1995). As more reference streams are surveyed within an ecoregion, the better understanding there is of the potential aquatic life communities therein.

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Appendix A. Water quality data Cypress Creek basin, winter 1996. All concentrations mg/L, except Chl_a and $Pheo_a$, µg/L.

Site	TKN	NH_3-N	NO_2+NO_3	TOC	OP	T-P	Chl_a	$Pheo_a$	T-Alk	Cl	SO_4	TDS	VSS	TSS
<39 km²														
Lawrence	0.18	<0.01	<0.1	3	<0.1	0.03	<1.0	14.2	<5	11.4	19.5	105	4	33
Colley	0.48	0.06	<0.1	7	<0.1	0.03	<1.0	<1.0	10	5.7	4.6	46	6	37
Coon	2.43	1.10	<0.1	11	<0.1	0.78	<1.0	26.5	20	10	17	143	18	96
Beach	1.01	0.20	<0.1	9	<0.1	0.05	2.9	<1.0	8	6	6	78	8	31
39-65 km²														
Panther	0.32	0.10	<0.1	3	<0.1	0.03	3.6	<1.0	16	18.5	7.6	108	2	6
Witcher	0.36	0.09	<0.1	5	<0.1	0.02	1.8	1.4	15	28.6	7.4	121	4	5
Caney-up	0.32	0.03	<0.1	8	<0.1	0.05	<1.0	8.8	<5	12.9	25.2	132	3	12
Caney-mid	0.29	<0.1	<0.1	5	<0.1	0.04	7.2	<1.0	<5	12.3	39.1	143	2	9
Caney-low	0.25	<0.1	<0.1	4	<0.1	0.04	5.0	5.0	7	11.2	18.6	96	1	4
Sugar	0.92	0.18	0.14	15	<0.1	0.23	11.2	0	30	59	33	145	4	15
66-132 km²														
Walnut	0.48	0.04	<0.1	7	<0.1	0.04	<1.0	19.9	19	11.7	9.2	87	2	12
Meddlin	0.37	0.05	<0.1	5	<0.1	0.04	<1.0	7.4	6	13.8	9.6	95	4	11
Gray	0.75	0.11	1.05	1	<0.1	0.06	<1.0	<1.0	5	8	23	107	8	50
133-259 km²														
Harrison	0.31	<0.1	<0.1	6	<0.1	0.05	2.5	7.1	34	32.2	47	178	3	17
Haggerty	0.26	0.01	<0.1	2	<0.1	0.13	3.3	0	84	39.7	18.1	220	7	62
Black Bayou	1.35	0.08	<0.1	23	<0.1	0.17	13.6	0	29	6	3	119	8	22
260-518 km²														
Frazier	0.37	0.02	<0.1	6	<0.1	0.04	<1.0	3.8	<5	5.5	6.7	55	2	8
Jim's	0.44	0.03	<0.1	8	<0.1	0.04	<1.0	2.5	16	13	8.3	84	2	5
>518 km²														
L.Cypress-up	0.43	0.01	0.27	6	<0.1	0.05	3.0	0	6	7.7	7.0	51	4	29
L.Cypress-mid	0.48	0.10	<0.1	8	<0.1	0.08	<1.0	3.0	17	16.5	14.7	109	7	11
L.Cypress-low	0.69	0.07	0.19	10	<0.1	0.11	<1.0	<1.0	13	18	13	130	2	10
Mean	0.59	0.11	0.12	7	<0.1	0.10	2.6	4.8	16	16.5	16.1	112	5	23
Std. Deviation	0.51	0.23	0.22	5	0	0.16	3.8	7.3	18	13.3	11.9	41	4	23

Appendix B. Summer versus winter flows and D.O. (24 hour mean ± sd) and instantaneous. Cypress Creek basin, 1995-96.

Watershed Size	Site	Summer flow (cfs)	Winter flow (cfs)	Summer D.O. (mg/L)	Winter D.O. (mg/L)
<39 km²	Lawrence	0.23	0.42	6.8	8.0±0.2
	Colley	0.58	0.71	3.9	6.0±0.7
	Coon	0.03	2.1	2.7	11.3
	Beach	0.06	7.8	0.5	7.8
39-65 km²	Panther	0.01	0.10	4.6	8.2±1.2
	Witcher	0.15	1.8	4.5	7.3±0.6
	Caney-upper	Dry	0.01	NA	3.9±0.5
	Caney-middle	0	0.57	0.9	6.9
	Caney-lower	0.03	1.2	0.7±0.5	9.6±0.6
	Sugar	0.06	1.8	2.4	11.6
66-130 km²	Walnut	0.12	1.2	5.2±0.5	6.2±0.3
	Meddlin	0.06	0.19	2.1	7.2±1.0
	Bear	0.23	11	1.0	8.6
	Grays	0.33	2.2	4.2	9.6
131-259 km²	Harrison	0.22	0.29	5.9	7.9±0.6
	Haggerty	0	1.8	2.0±1.6	7.7±0.2
	Kitchens	0.80	15	4.3± 0.6	8.8
260-518 km²	Frazier	2.7	4.3	5.7±0.3	9.5±0.4
	Jim's	0.26	8.3	3.1±0.1	7.5±0.2
	Black Bayou-upper	0.29	13	1.1	9.9
>518 km²	Little Cypress-upper	1.6	6.1	4.9±0.2	11.4±0.5
	Little Cypress-middle	0	27	1.4	7.0±0.2

Appendix C. East Texas habitat assessments Cypress Creek basin, 1995-96.
Range of possible score: Metric #1-4=0-20; Metric #5-8=0-15; Metric #9-10=0-10.

Site	Metrics										
	Fish	BN	Mix	Pools	Bends	Water	Canopy	Bank	Veg.	Pollution	Sum	Category
Lawrence	8	6	8	8	12	12	15	5	9	9	92	Intermediate
Beach	11	11	7	16	15	10	13	10	9	8	110	High
Coon	3	3	2	1	5	5	14	5	2	5	45	Limited
Sugar	9	6	8	9	9	13	11	5	3	4	77	Limited
Middle Caney	11	4	9	11	15	8	14	6	7	8	93	Intermediate
Lower Caney	10	8	8	8	9	7	15	6	7	8	86	Intermediate
Grays	18	10	10	18	11	13	15	8	4	4	111	High
Walnut	9	20	10	16	8	8	8	5	6	6	96	Intermediate
Bear	11	10	8	15	12	11	14	13	9	9	112	High
Harrison	18	9	13	12	8	9	12	5	4	7	97	Intermediate
Kitchens	17	14	15	18	8	8	14	15	9	8	126	High
Haggerty	15	12	11	18	15	3	14	5	9	9	111	High
Upper Black Bayou	16	3	8	14	8	14	10	12	10	9	104	Intermediate
Frazier 96	14	12	10	18	13	4	15	9	9	9	113	High
Jim's	18	16	14	12	10	7	14	9	10	10	120	High
Lower Black Bayou	3	3	5	7	8	1	11	15	10	10	73	Limited
Upper Little Cypress	18	15	18	16	12	15	15	7	6	4	126	High
Mean	12.3	9.5	9.6	12.8	10.4	8.7	13.2	8.2	7.2	7.5	99.5±21.0	

Appendix D. Fish collected by electrofisher and seine Cypress Creek basin, 1995-96. Juvenile cyprinids and centrarchids are not included in these counts.

Genus/species	Common name	Lawrence	Beach	Coon	Sugar	mid-Caney	low-Caney	Grays	Walnut	Bear
		Sites < 260 km²								
Lepisosteidae-Gars										
Lepisosteus oculatus	Spotted gar									
Clupeidae-Herrings										
Dorosoma cepedianum	Gizzard shad									
D. petenense	Threadfin shad									
Esocidae-Pikes										
Esox americanus	Grass pickerel		9		4		7		1	7
E. niger	Chain pickerel									
Cyprinidae-Minnows										
Cyprinus carpio	Common carp									
Cyprenella venusta	Blacktail shiner									
Hybognathus nuchalis	Miss. silvery shiner				1					
H. hayi	Cypress minnow								5	
Lythurus chrysocephalus	Stripped shiner	2								
L. umbratilis	Redfin shiner	1			3	5				
Notemigonus crysoleucas	Golden shiner		5		3	1	13			
Notropis athernoides	Emerald shiner				19		1		1	
N. atrocaudalis	Blackspot shiner					4				
N. chalybaeus	Ironcolored shiner									
N. hubbsi	Bluehead shiner									
N. shumardi	Silverband shiner						3			
N. texanus	Weed shiner			8	4		1		20	
Pimephales vigilax	Bullhead minnow	22				1	3		5	
Semotilus atromaculatus	Creek chub	6		2	1			3		
Catostomidae-Suckers										
Erimyzon oblongus	Creek chubsucker	6	4	12			1			
E. sucetta	Lake chubsucker				1			5		
Minytrema melanops	Spotted sucker								1	1
Moxostoma poecilurum	Blacktailed redhorse				1		1			
Ictaluridae-Catfishes										
Ameiurus melas	Black bullhead				5	1	1			
A. natalis	Yellow bullhead	1		5		7	1	1	2	1
Aphredoderidae-Pirate Perches										
Aphredoderus sayanus	Pirate perch		6	62	4	2	8		2	3

Appendix D (continued)

		Sites ≤ 260 km²								
		Lawrence	Beach	Coon	Sugar	mid-Caney	low-Caney	Grays	Walnut	Bear
Cyprinodontidae-Killifish										
Fundulus blairae	Blaire's starhead topminnow									
F. chrysotus	Golden topminnow									
F. notatus	Blackstripe topminnow	3		7	18	17	3		3	3
F. olivaceus	Blackspotted topminnow		8					6		
Poeciliidae-Livebearers										
Gambusia affinis	Western mosquitofish			91	3	9	45		2	3
Atherinidae-Silversides										
Labidesthes sicculus	Brook silverside								1	
Centrarchidae-Sunfishes										
Centrarchus macropterus	Flier		2							
Lepomis cyanellus	Green sunfish	7	1		3	12			1	
L. gulosus	Warmouth				5	7		1		3
L. macrochirus	Bluegill		1		50	39	8	14	7	8
L. megalotis	Longear sunfish	27	1		38	29	8	23	19	6
L. microlophus	Redear sunfish									
L. punctatus	Spotted sunfish							4	2	1
Micropterus punctulatus	Spotted bass					1				
M. salmoides	Largemouth bass		2	9	1	3		3	7	
Pomoxis annularis	White crappie									
Elassomatidae-Pygmy Sunfishes										
Erimyzon zonatum	Banded pygmy sunfish		4							1
Percidae-Perches										
Etheostoma chlorosomum	Bluntnose darter			1	1				4	
E. fusiforme	Swamp darter			1					1	
E. gracile	Slough darter	1		4	3	2	4			1
E. proeliare	Cypress darter		1					1		
E. spectable	Orangethroat darter	1				2				
Percina caprodes	Log perch									
P. carbonaria	Texas logperch									
P. maculata	Blackside darter									
P. sciera	Dusky darter									
P. shumardi	River darter									
Sciaenidae-Drums										
Aplodinotus grunniens	Freshwater drum									

Appendix D, continued.

Genus/species	Common name	Harr.	Kitch.	Hag.	up-Bl.	Fraz. 1996	Jim's	low-Bl.	up-L.Cyp.	Big Cyp.	low-L.Cypress
		Sites ≥ 260 km^2									
Lepisosteidae-Gars											
Lepisosteus oculatus	Spotted gar									5	4
Clupeidae-Herrings											
Dorosoma cepedianum	Gizzard shad									26	
D. petenense	Threadfin shad									48	8
Esocidae-Pikes											
Esox americanus	Grass pickerel		6	3	2		13	48	1		1
E. niger	Chain pickerel										1
Cyprinidae-Minnows											
Cyprinus carpio	Common carp									1	
Cyprenella venusta	Blacktail shiner					5			1		
Hybognathus nuchalis	Miss. silvery shiner										
Lythurus chrysocephalus	Stripped shiner										
L. umbratilis	Redfin shiner	59	2			2	9		11		2
Notemigonus crysoleucas	Golden shiner			18	27			5	2	1	
Notropis athernoides	Emerald shiner	1	1	1	1	170	11	1			33
N. atrocaudalis	Blackspot shiner	109									
N. chalybaeus	Ironcolored shiner		2				3				
N. hubbsi	Bluehead shiner		4								
N. shumardi	Silverband shiner										
N. texanus	Weed shiner		9	1		1	3	2			4
Pimephales vigilax	Bullhead minnow	63							1		
Semotilus atromaculatus	Creek chub	14									
Catostomidae-Suckers											
Erimyzon oblongus	Creek chubsucker	11		1				1			
E. sucetta	Lake chubsucker										
Minytrema melanops	Spotted sucker									2	10
Moxostoma poecilurum	Blacktailed redhorse		1					1			
Ictaluridae-Catfishes											
Ameiurus melas	Black bullhead								1		
A. natalis	Yellow bullhead	8	1	2	1		1	10	2		
Aphredoderidae-Pirate Perches											
Aphredoderus sayanus	Pirate perch		8	2	6	6	13	10	2		1

Appendix D , continued.

		Sites >260 km²									
		Harr.	Kitch.	Hag.	Up-Bl.	Fraz. 1996	Jim's	low-Bl.	up-L.Cyp.	Big Cyp.	low-L.Cypr.
Cyprinodontidae-Killifish											
Fundulus blairae	Blaire's starhead topminnow									1	
F. chrysotus	Golden topminnow							7			
F. notatus	Blackstripe topminnow	3	2	4		5	1	6	6	55	1
F. olivaceus	Blackspotted topminnow	2			8	2		9			
Poeciliidae-Livebearers											
Gambusia affinis	Western mosquitofish	55	2		14	4		14	2	4	1
Atherinidae-Silversides											
Labidesthes sicculus	Brook silverside		1				1	4		38	1
Centrarchidae-Sunfishes											
Centrarchus macropterus	Flier				10		2	28			
Lepomis cyanellus	Green sunfish	2	3	2	1		5	1	3		
L. gulosus	Warmouth	2	1	1				39	10		
L. macrochirus	Bluegill	3	15	14	4		19	32	27	7	
L. megalotis	Longear sunfish	49	25	28	10	11	7	35	22	24	12
L. microlophus	Redear sunfish		1	1				1		8	3
L. punctatus	Spotted sunfish		12			1	6	18	2	1	
Micropterus punctulatus	Spotted bass		1					5	1		4
M. salmoides	Largemouth bass	1	2		5	6	1	4	1	31	4
Pomoxis annularis	White crappie								1		
Elassomatidae-Pygmy Sunfishes											
Erimyzon zonatum	Banded pygmy sunfish						7	1			
Percidae-Perches											
Etheostoma chlorosomum	Bluntnose darter	3				2					3
E. fusiforme	Swamp darter					2					
E. gracile	Slough darter	2	4	1	2	2	2	2	1		
E. proeliare	Cypress darter									1	
E. spectable	Orangethroat darter										
Percina caprodes	Log perch										1
P. carbonaria	Texas logperch			1							
P. maculata	Blackside darter						1				
P. sciera	Dusky darter			2		1			1		3
P. shumardi	River darter								1		
Sciaenidae-Drums											
Aplodinotus grunniens	Freshwater drum										1

Appendix E. IBI scores Cypress Creek basin, 1995-96. Electrofisher and seine data combined.

Site	Metrics													Category
	# sp.	Darters	Sunfish	Suckers	Intol. sp.	% Tol.	Omnivor.	Insectvor.	Piscvor.	# Indiv.	% Hybrid	% Defect	Sum	
Lawrence	5	3	5	3	1	3	5	3	5	3	5	5	46	Inter.-High
Beach	5	3	5	3	3	3	5	3	5	1	5	3	44	Intermediate
Coon	5	5	1	3	1	1	5	5	5	5	5	5	46	Inter.-High
Sugar	5	3	5	5	1	1	5	5	5	5	5	5	50	High
middle Caney	5	3	5	1	1	1	5	3	5	3	5	3	40	Intermediate
lower Caney	5	3	5	5	1	1	5	5	5	3	5	5	48	High
Grays	5	3	5	3	3	3	5	3	5	3	5	5	48	High
Walnut	5	3	5	3	3	3	5	5	5	3	5	5	48	High
Bear	5	3	5	3	1	1	5	5	5	3	5	5	46	Inter.-High
Harrison	5	3	5	3	3	3	5	5	5	5	5	5	52	High
Kitchens	5	3	5	3	3	3	5	5	5	3	5	5	50	High
Haggerty	5	5	5	3	3	1	5	5	5	3	5	5	50	High
upper Black Bayou	5	3	5	1	3	1	5	5	5	3	5	5	46	Inter.-High
Frazier '95	5	3	5	3	3	1	5	3	5	3	5	5	46	Inter.-High
Frazier '96	5	5	5	1	3	5	5	5	3	5	5	5	52	High
Jim's	5	3	5	1	5	3	5	5	5	3	5	5	50	High
lower Black Bayou	5	3	5	5	3	1	5	3	5	5	5	3	48	High
upper Little Cypress	5	5	5	1	3	1	5	3	5	3	5	5	46	Inter.-High
Big Cypress	5	3	5	3	3	3	5	3	5	5	5	5	50	High
lower Little Cypress	5	5	5	3	5	3	5	3	5	3	5	5	52	High
Mean	5.0	3.5	4.8	2.8	2.6	2.1	5.0	4.1	4.9	3.5	5.0	4.7	48±3	High

Appendix F. IBI scores Cypress Creek basin, 1995-96. Electrofisher data only.

Site	Metrics													
	# sp.	Darters	Sunfish	Suckers	Intol. sp.	% Tol.	Omnivor.	Insectvor.	Piscvor.	# Indiv.	% Hybrid	% Defect	Sum	Category
Lawrence	3	3	5	3	1	5	5	3	5	3	5	5	44	Intermediate
Beach	3	1	5	3	3	1	5	3	5	1	5	3	38	Limited-Inter.
Coon	5	5	1	3	1	1	5	5	5	3	5	5	44	Intermediate
Sugar	5	3	5	5	1	1	5	3	5	5	5	5	48	High
middle Caney	5	3	5	1	1	1	5	3	5	3	5	3	40	Intermediate
lower Caney	5	3	5	5	1	1	5	5	5	3	5	5	48	High
Grays	3	1	5	1	3	1	5	3	5	3	5	5	40	Intermediate
Walnut	5	1	5	3	1	3	5	3	5	1	5	5	42	Intermediate
Bear	3	1	5	3	1	1	5	3	5	1	5	5	38	Limited-Inter.
Harrison	5	3	5	3	3	3	5	5	5	3	5	5	50	High
Kitchens	5	3	5	1	3	1	5	5	5	3	5	5	46	Inter.-High
Haggerty	5	5	5	3	3	1	5	5	5	3	5	5	50	High
upper Black Bayou	5	1	5	1	3	1	5	5	5	3	5	5	44	Intermediate
Frazier '95	5	3	5	3	3	3	5	3	5	3	5	5	48	High
Frazier '96	5	5	5	1	3	5	5	5	5	1	5	5	50	High
Jim's	5	3	5	1	3	1	5	3	5	3	5	5	44	Intermediate
lower Black Bayou	5	3	5	5	3	1	5	3	5	5	5	3	48	High
upper Little Cypress	5	5	5	1	3	1	5	3	5	3	5	5	46	Inter.-High
Big Cypress	5	1	5	3	1	1	3	3	5	3	5	3	38	Limited-Inter.
lower Little Cypress	5	3	5	3	3	3	5	3	5	1	5	5	46	Inter.-High
Mean	4.6	2.8	4.8	2.6	2.3	1.8	4.9	3.7	5.0	2.7	5.0	4.6	45±4	Inter.-High

Appendix G. Species collected exclusively by seining from Cypress Creek basin, 1995-96.

Site	Species	Common name
Lawrence	*Lythurus umbratalis*	Redfin shiner
	Etheostoma gracile	Slough darter
Sugar	*Hybognathus nuchalis*	Mississippi silvery minnow
	Notropis texanus	Weed shiner
	Semotilus atromaculatus	Creek chub
middle Caney	*L. umbratilis*	Redfin shiner
	N. texanus	Weed shiner
	N. crysoleucas	Golden shiner
	Gambusia affinis	Western mosquitofish
lower Caney	*N. texanus*	Weed shiner
Grays	*Etheostoma proeliare*	Cypress darter
Walnut	*N. athernoides*	Emerald shiner
	G. affinis	Western mosquitosish
	Labidesthes sicculus	Brook silverside
	E. chlorosomum	Bluntnose darter
	E. fusiforme	Swamp darter
Bear	*Notropis* sp.	Unidentified shiner
	G. affinis	Western mosquitofish
Kitchens	*L. umbratilis*	Redfin shiner
	N. texanus	Weed shiner
	Moxostoma poecilurum	Blacktail redhorse
	G. affinis	Western mosquitofish
	L. sicculus	Brook silverside

Appendix G (continued).

Site	Species	Common name
Haggerty	*N. athernoides*	Emerald shiner
upper Black	*N. athernoides*	Emerald shiner
	E. gracile	Slough darter
Frazier	*Cyprenella venusta*	Blacktail shiner
	L. umbratilis	Redfin shiner
	N. texanus	Weed shiner
	G. affinis	Western mosquitofish
	Fundulus olivaceus	Blackspotted shiner
Jim's	*N. texanus*	Weed shiner
	L. sicculus	Brook silverside
Big Cypress	*Notropis* sp.	Unidentified shiner
	G. affinis	Western mosquitofish
	F. blairae	Blaire's starhead topminnow
	L. sicculus	Brook silverside
	Lepomis punctatus	Spotted sunfish
	E. proeliare	Cypress darter
lower Little Cypress	*Esox niger*	Chain pickerel
	Cyprinella lutrensis	Redfin shiner
	N. athernoides	Emerald shiner
	N. texanus	Weed shiner
	Aphredoderus sayanus	Pirate perch
	G. affinis	Western mosquitofish
	L. sicculus	Brook silverside
	E. chlorosomum	Bluntnose darter
	P. sciera	Dusky darter

Appendix H. Regionally expected fish species from the Cypress Creek basin and tolerance designations.

Family/Species	Common name	Tolerance Level
Esocidae-Pikes		
Esox americanus	Grass pickerel	
Cyprinidae-Minnows		
Lythurus umbratilis	Redfin shiner	
Notemigonus chrysoleucas	Golden shiner	Tolerant
Notropis athernoides	Emerald shiner	
Notropis texanus	Weed shiner	
Pimephales vigilax	Bullhead minnow	
Catostomidae-Suckers		
Erimyzon sucetta	Lake chubsucker	
Ictaluridae-Catfishes		
Ameiurus natalis	Yellow bullhead	
Aphredoderidae-Pirate Perches		
Aphredoderus sayanus	Pirate perch	
Cyprinodontidae-Killifishes		
Fundulus notatus	Blackstripe topminnow	
Fundulus olivaceus	Blackspotted topminnow	Intolerant
Poeciliidae-Livebearers		
Gambusia affinis	Western mosquitofish	Tolerant
Atherinidae-Silversides		
Labidesthes sicculus	Brook silverside	Intolerant
Centrarchidae-Sunfishes		
Lepomis cyanellus	Green sunfish	Tolerant
Lepomis gulosus	Warmouth	Tolerant
Lepomis macrochirus	Bluegill	Tolerant
Lepomis megalotis	Longear sunfish	
Lepomis microlophus	Redear sunfish	
Lepomis punctatus	Spotted sunfish	
Micropterus punctulatus	Spotted bass	
Micropterus salmcides	Largemouth bass	
Percidae-Perches		
Etheostoma chlorosomum	Bluntnose darter	
Etheostoma gracile	Slough darter	
Etheostoma proeliare	Cypress darter	Intolerant
Percina sciera	Dusky darter	Intolerant

Appendix I. Benthic macroinvertebrates collected in the Cypress Creek basin, 1995-96.

	Sites ≤ 260 km²								
Taxa	Lawrence	Beach	Coon	Sugar	mid-Caney	low-Caney	Grays	Walnut	Bear
Non-Insect									
--Gastropoda									
----Hydrobiidae									
Somatogyrus sp.									
----Physidae									
Physella sp.			44	3		1		3	
----Planorbidae									
Helisoma sp.									
Planorbula sp.									
----Valvatidae									
Valvata sp.			1					5	
--Pelecypoda									
----Sphaeriidae									
Pisidium sp.									
Sphaerium sp.									
----Unionidae				15					
--Decapoda									
----*Cambaridae	2	1				4	2	1	1
----Palaemonidae									
**Palaemonetes* sp.		3				4		12	19
--Amphipoda									
Gammarus sp.							5	10	
Hyalella azteca				1		24			
--Isopoda									
Asellus sp.			4			1			
Lirceus sp.			2						
--Hirudinea									
--Oligochaeta									
Insecta									
--Ephemeroptera									
----Baetidae									
Baetis sp.									
Callibaetis sp.					1				
----Caenidae									
Caenis sp.		1	1	31	2	1	2	46	
----Ephemeridae									
Hexagenia sp.						1			1
----Heptageniidae									
Stenonema sp.		2		3		2			
Stenacron sp.	1				2	1			1

Appendix I, continued.

	Sites ≤ 260 km²								
Taxa	Lawrence	Beach	Coon	Sugar	mid-Caney	low-Caney	Grays	Walnut	Bear
—Leptophlebiidae									
Chloroterpes sp.									
—Tricorythidae									
Tricorythodes sp.									
–Trichoptera									
—Glossosomatidae									
Glossosoma sp.									
—Hydropsychidae									
Cheumatopsyche sp.	1		5	3			1		
—Leptoceridae									
Nectopsyche sp.						1			
Oecetis sp.									
Triaenodes sp.									
—Polycentropodidae									
Cernotina sp.									
Micrasema sp.					5				
Phylocentropus sp.	1								
Polycentropus sp.									
–Odonata–Anisoptera									
—Aeshnidae									
Basiaeschna sp.			1						
**Boyeria* sp.	1	3			1			1	
—Corduliidae									
Helocordulia sp.	1		4						
Somatochlora sp.				1				1	
Tetragoneuria sp.					6	18			13
—Gomphidae									
**Gomphus* sp.	1					1	1	1	4
Lanthus sp.									
Progomphus sp.									
—Libellulidae									
Perithemis sp.							7	18	
—Macromiidae									
Macromia sp.						2		1	4
–Odonata–Zygoptera									
—Calopterygidae									
Calopteryx sp.								2	
Hetaerina sp.	16				7	2			

Appendix I, continued.

Taxa	Sites <260 km²								
	Lawrence	Beach	Coon	Sugar	mid-Caney	low-Caney	Grays	Walnut	Bear
--Odonata--Zygoptera									
---Coenagrionidae									
Enallagma sp. *	7	5	1	3	10	14	15	83	4
--Megaloptera									
---Corydalidae									
Corydalus cornutus									
---Sialidae									
**Sialis* sp.	1	2			6	34	2	6	21
--Coleoptera									
---Dryopidae									
Helichus sp.				2					
---Dytiscidae									
**Hydroporus* sp.		4		1	1	11	1	4	
Laccophilus sp.		1							
Laccodytes sp.					1	3			
Matus sp.									
Neobidessus sp.	1								
---Elmidae									
**Ancyronyx* sp.	14	1	2	7	1	17	1	2	6
**Stenelmis* sp.			1	6		2		1	
Macronychus sp.	1								
---Gyrinidae									
Dineutus sp.		1				1			
Gyrinus sp.									
---Haliplidae									
Brychius sp.				1					
Peltodytes sp.									
---Helodidae									
Elodes sp.			6					1	
---Hydrophilidae									
Berosus sp.									
Helobata sp.		2							
Hydrochara sp.									
Hydrochus sp.								2	1

Appendix I, continued.

Taxa	Sites <260 km²								
	Lawrence	Beach	Coon	Sugar	mid-Caney	low-Caney	Grays	Walnut	Bear
-Hemiptera									
—Belostomidae									
Belostoma sp.			4						
—Corixidae			1	2	5	6			6
—Gerridae							3		
Gerris sp					7				
Trepobates sp	2								
—Hydrometridae									
Hydrometra sp.					1				
—Nephidae									
Ranta sp.		4			1				
—Pleidae									
—Veliidae									
Rhagovelia sp.	3							1	
Macrovelia sp.				3		1		2	
Paravelia sp.						4			1
-Diptera									
—Chironomidae									
—*Chironominae		44	2	2	3	6	30		2
—Orthocladiinae			10		2	6			3
—Tanypodinae			8			1	1		2
—Simuliidae									
Simulium sp.									
—Tabanidae									
Tabanus sp.			1						

Appendix I, continued.

Taxa	Harr.	Kitch.	Sites > 260 km² Hag.	up-Bl.	Fraz.	Jim's	low-Bl.	up-L.Cyp.	low-L.Cyp.
Non-Insect									
–Gastropoda									
—Hydrobiidae									
Somatogyrus sp.							10		
—Physidae									
Physella sp.	1								
—Planorbidae									
Helisoma sp.							5		
Planorbula sp.									
—Valvatidae									
Valvata sp.		1							
–Pelecypoda									
—Sphaeriidae									
Pisidium sp.							2		
Sphaerium sp.				2					6
—Unionidae		1							
–Decapoda									
—*Cambaridae	5			3				2	
—Palaemonidae									
**Palaemonetes sp.*		1	2	7	20	10	3	1	8
–Amphipoda									
Gammarus sp.			9		1	1			14
Hyalella azteca	6	3		1			4		
–Isopoda									
Asellus sp.									1
Lirceus sp.						4	4		
–Hirudinea		1				1	2	3	
–Oligochaeta		3			1		2		
Insecta									
–Ephemeroptera									
—Baetidae									
Baetis sp.									2
Callibaetis sp.						1			
—Caenidae									
Caenis sp.	32			4		1	1		
—Ephemeridae									
Hexagenia sp.			1			3			1
—Heptageniidae									
Stenonema sp.	1	4			19				1
Stenacron sp.		1	4			3		3	8

Appendix 1, continued.

Taxa	Sites > 260 km²								
	Harr.	Kitch.	Hag.	up-Bl.	Fraz..	Jim's	low-Bl.	up-L.Cyp.	low-L.Cyp.
—Leptophlebiidae									
Chloroterpes sp									1
—Tricorythidae									
Tricorythodes sp.		1							
–Trichoptera									
—Glossosomatidae									
Glossosoma sp.									3
—Hydropsychidae									
Cheumatopsyche sp.	3				28				
—Leptoceridae									
Nectopsyche sp.									1
Oecetis sp.									4
Triaenodes sp.									1
—Polycentropodidae									
Cernotina sp.									
Micrasema sp.		1							
Phylocentropus sp.		4				1			
Polycentropus sp.								10	6
–Odonata–Anisoptera									
—Aeshnidae									
Basiaeschna sp.	2							1	
**Boyeria sp.*			5	4	1	2	1		1
—Corduliidae									
Helocordulia sp.								7	1
Somatochlora sp.				2					
Tetragoneuria sp.							51		
—Gomphidae									
**Gomphus sp.*		4	8		1	1	1		2
Lanthus sp.		1							
Progomphus sp.	4								
—Libellulidae									
Perithemis sp.	2								
—Macromiidae									
Macromia sp.		12	1			2			2
–Odonata–Zygoptera									
—Calopterygidae									
Calopteryx sp.			2		1	1			
Hetaerina sp.		1							

Appendix I, continued.

Taxa	Harr.	Kitch.	Hag.	up-Bl.	Fraz.	Jim's	low-Bl.	up-L.Cyp.	low-L.Cyp.
	Sites > 260 km²								
-Odonata--Zygoptera									
---Coenagrionidae									
**Enallagma sp.*	29	12	9	4	9	4	5	28	2
-Megaloptera									
---Corydalidae									
Corydalus cornutus	2								
---Sialidae									
**Sialis sp.*		8			4	19	4	5	1
-Coleoptera									
---Dryopidae									
Helichus sp.									
---Dytiscidae									
**Hydroporus sp.*		1	1		2	2	10	1	1
Hydrovatus sp.					1				
Laccophilus sp.				2					
Laccodytes sp.									
Matus sp.		2							
Neobidessus sp.									
---Elmidae							1		
**Ancyronyx sp.*		10	13		3	31		5	
**Stenelmis sp.*	1		1		8	1		10	23
Macronychus sp.								1	
---Gyrinidae									
Dineutus sp.				22	3				
Gyrinus sp.		1					1		
---Haliplidae									
Brychius sp.									
Peltodytes sp.							3		
---Helodidae									
Elodes sp.					1				
---Hydrophilidae									
Berosus sp.		1							
Helobata sp.									
Hydrochara sp.							1		
Hydrochus sp.						1			

Appendix I, continued.

Taxa	Sites > 260 km²								
	Harr.	Kitch.	Hag.	up-Bl.	Fraz.	Jim's	low-Bl.	up-L.Cyp.	low-L.Cyp.
--Hemiptera									
---Belostomidae									
Belostoma sp.					1				
---Corixidae				4	2	1	1		
---Gerridae							1		
Gerris sp			3						
Trepobates sp									
---Hydrometridae							1		
Hydrometra sp.									
---Nephidae									
Ranta sp.				13					
---Pleidae									1
---Veliidae									
Rhagovelia sp.		2							
Macrovelia sp.					1				
Paravelia sp.									
--Diptera									
---Chironomidae									
-----*Chironominae	1	1		11	2	4	2	3	
-----Orthocladinae		1				4			
-----Tanypodinae			1			1		5	
---Simuliidae									
Simulium sp.	1								
---Tabanidae									
Tabanus sp.						1	1		

*Species collected at ≥9 sites.

Appendix J. RBA scores for Cypress Creek basin, 1995-96.

Site	Metrics: # Taxa	EPT	Bio.Index	%Chiro.	Dom sp.	DomFFG	%Pred.	Int/Tol	%Hydro	NonInsec	%CG	%Elmid	Sum	Classification
Lawrence	3	1	2	1	3	1	1	1	3	1	3	2	22	Intermediate
Beach	3	1	1	1	1	2	1	1	1	2	3	4	21	Limited
Coon	3	1	1	1	1	2	2	1	1	3	4	4	24	Intermediate
Sugar	3	1	1	4	2	4	4	1	1	2	2	3	28	Intermediate
middle Caney	3	2	1	3	4	1	1	1	4	1	4	4	29	High
lower Caney	4	2	2	3	4	1	1	1	4	3	3	3	31	High
Grays	2	1	1	1	1	1	1	1	1	2	3	4	19	Limited
Walnut	4	1	1	1	1	1	1	1	1	4	3	4	23	Intermediate
Bear	3	1	2	2	4	1	1	2	1	2	2	4	25	Intermediate
Harrison	2	1	1	4	2	3	1	1	1	2	3	4	25	Intermediate
Kitchens	4	2	2	4	4	1	1	1	4	4	4	3	34	High
Haggerty	2	1	3	4	4	2	1	2	1	2	2	2	26	Intermediate
upper Black Bayou	2	1	1	2	3	1	1	1	1	3	3	1	20	Limited
Frazier '95	3	1	4	4	1	3	3	4	1	1	2	1	28	Intermediate
Frazier '96	3	1	4	4	3	4	3	1	1	2	2	3	31	High
Jim's	4	2	3	3	3	3	1	2	4	3	2	1	31	High
lower Black Bayou	4	1	1	4	1	1	1	1	4	2	4	3	27	Intermediate
upper Little Cypress	3	1	2	3	2	1	1	1	4	2	4	3	27	Intermediate
lower Little Cypress	4	4	3	1	3	3	4	2	4	3	2	2	35	High
Mean	3.1	1.4	2.4	2.6	2.5	1.9	1.4	1.4	2.1	1.9	2.8	2.8	26±5	Intermediate