Regionalization of the Index of Biotic Integrity for Texas Streams

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Executive Summary

Aquatic life use designations dictate the level of protection streams receive in accordance with the surface water quality standards prepared by the Texas Natural Resource Conservation Commission. Streams can be assigned one of four aquatic life use categories (exceptional, high, intermediate, or limited). Although streams in Texas are diverse, a statewide Index of Biotic Integrity (IBI) has been applied historically in conjunction with water quality, benthic macroinvertebrate, and habitat data to set aquatic life uses in streams. This study was conducted to regionalize the IBI for Texas' wadeable streams. Fish were collected from 62 least disturbed reference streams located within 11 of the 12 aquatic ecoregions described for the state. An array of metrics was screened to determine which ones were most suited for Texas. Scoring criteria were developed for each of the respective metrics. Metrics suited for all regions of the state include: total number of species; number of native cyprinid species; number of sunfish species; percentage of individuals as omnivores; percentage of individuals as invertivores; number of individuals per unit effort; percentage of individuals as non-native species; and percentage of individuals with disease or other anomaly. Other metrics used in selected ecoregions include: number of benthic invertivore species; number of benthic species; number of intolerant species; percentage of individuals as tolerant species (excluding western mosquitofish *Gambusia affinis*); and percentage of individuals as piscivores. When applied to the least disturbed streams sampled in this study, the statewide IBI produced lower overall scores and aquatic life uses. Scores from the statewide IBI demonstrated a geographical trend, declining from east to west, and resulted in no exceptional aquatic life use designations even though the streams were selected through a screening process and were among the least disturbed in a region. These lower IBI values (and aquatic life uses) result from using a single index over a large land area comprised of a diversity of land forms, soil types, vegetation, climatic conditions, and zoogeographic factors. Regional criteria consider these natural differences and consequently provide a better representation of the integrity of the fish assemblage.

REGIONALIZATION OF THE INDEX OF BIOTIC INTEGRITY FOR TEXAS STREAMS

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Within its 691,030 km^2, Texas encompasses a diversity of land forms, soil types, vegetation, climatic conditions, and land uses. Elevation climbs from sea level along the Gulf Coastal Plain to 2,651 m in far west Texas. Precipitation ranges from a normal annual average of 148 cm (58.3 in) in Orange, on the Gulf Coast, to 22 cm (8.8 in) in El Paso (Ramos 1997). The 307,319 km (191,000 mi) of streams and rivers (64,360 km of which are perennial) contained within the 15 major river basins of the state reflect the state's diversity and include slow moving bayous with substantial organic loading and dense canopies to clear, bedrock-lined central Texas streams to wide, shallow, and sandy streams with no riparian cover.

Fish assemblages also vary widely across the state and are influenced by both climatic and zoogeographic factors. For instance, the greatest richness of darters, minnows, and suckers occur in the eastern half of the state (Hubbs et al. 1991). Streams in the more arid western and southern regions of the state tend to have greater proportions of more tolerant families such as Cyprinodontidae (Anderson et al. 1995). Prairie streams in northwest Texas are mostly dominated by a few hardy minnow species (Cross and Moss 1987). Hubbs (1957) concluded that the basic factors controlling distributional patterns of fishes are climatic and geological ones, those that determine the properties of the water. McAllister et al. (1986) reported species richness as mirroring precipitation values with the greatest richness occurring in east Texas. Conner and Suttkus (1986) observed that the ichthyofauna of the Sabine and Neches river systems (which drain into Sabine Lake) were the richest of the western Gulf Slope drainages they examined, with numbers of strictly freshwater species declining in successive drainages as one moves west toward the Nueces River.

The Texas Surface Water Quality Standards (Texas Natural Resource Conservation Commission [TNRCC] 1995) provide a framework for protecting aquatic life in public waters. Depending on the nature of a particular waterbody and its biota, it may be classified as having limited, intermediate, high, or exceptional aquatic life and would be afforded varying levels of protection based upon a tiered set of water quality criteria, most principally, dissolved oxygen standards. These levels of aquatic life are termed "aquatic life use subcategories" and their ecological characteristics are defined qualitatively in the Texas Surface Water Quality Standards (TNRCC 1995). Assignments of aquatic life use subcategories are based upon site-specific studies that examine the water quality, habitat, and more recently the biological assemblage. Historically, larger streams have been classified into one of these aquatic life use subcategories since rating smaller, wadeable streams has been problematic given the number of stream miles and lack of resources to conduct extensive site-specific studies.

The U.S. Environmental Protection Agency (USEPA) (1987a) has strongly emphasized the need to accelerate the development and application of biological monitoring techniques in state monitoring programs, but at the same time stressed the importance of combining these new biological criteria and assessment methods with traditional chemical and physical procedures (USEPA 1987b). Stream assessments in Texas have evolved from emphasizing water quality parameters to now including water quality, habitat, and biological evaluations. Twidwell and Davis (1989) proposed a statewide index of numerical criteria for assessing fish assemblages when determining aquatic life uses in small (usually wadeable) Texas streams that had no site-specific criteria established. These criteria were based upon the Index of Biotic Integrity (IBI) and were translated directly from the original integrity classes proposed by Karr et al. (1986) which were developed as a means of assessing fish assemblage degradation in streams located in the midwestern United States. In its unmodified form, the IBI is comprised of twelve metrics which fall into three broad categories: species composition, trophic composition, and fish abundance and condition (Karr et al. 1986). It has been identified by USEPA as a suitable technique for conducting biological monitoring (Plafkin et al. 1989);

however, Karr et al. (1986) recommended caution in establishing such criteria without validation. Since the original integrity classes were developed after sampling streams in the midwestern United States they are not applicable to all geographical regions. The statewide IBI consistently underestimated the aquatic life use when compared to other assessment methods in the six streams sampled by Twidwell and Davis (1989). Consequently, the investigators recognized the need to further refine the IBI for use in Texas (Steve Twidwell pers. comm.). Nevertheless, this index has been applied statewide without modification since being proposed by Twidwell and Davis (1989).

Many modifications have been made to the original metrics as the IBI has been tailored for use across the United States (Miller et al. 1988; Simon and Lyons 1995). Other states such as Arkansas, Ohio, Indiana, and Florida have performed studies to develop region-specific biocriteria (Bennett et al. 1987; Giese et al. 1987; Ohio Environmental Protection Agency 1987; Simon 1991; Barbour et al. 1996). A number of previous efforts have been made in Texas to adapt IBI to site-specific situations, such as river basins. Several such endeavors include work on the Trinity River (Kleinsasser and Linam 1989), Rio Grande (Davis et al. 1994), San Antonio River (San Antonio River Authority 1996), and Colorado River (Morales 1991).

Attempting to establish biological criteria, such as is represented by multi-metric indices like the IBI, can prove to be difficult given the diverse nature of the habitats and corresponding assemblages within the state. A single statewide index does not recognize the aforementioned diversity of fish communities. This study was conducted to develop biological criteria specific to regions of the state rather than using generic statewide criteria which do not represent all geographical regions well. Valid regional classifications of biotic attributes have the potential to be used for regulatory decisions or resource management since they delineate geographic areas within which a policy applied to different sites should yield similar results (Lyons 1989). Given the number of stream miles in Texas, such an approach is appealing since it would reduce the need for intensive site-specific studies of every watershed; however, it is important to determine whether the data actually display common attributes within a region. Trying to build an IBI or other biotic index based upon ecologically dissimilar streams could result in metrics that do not respond predictably to changes at individual sites within a region, and consequently, would be of little value in making regulatory decisions.

The primary objective of this report is to propose regional IBI criteria that can be used to determine the aquatic life use of wadeable streams that do not have a site-specific index. Fish sampling was performed as part of a larger study that involved sampling a series of least disturbed reference streams statewide for water quality, habitat, and benthic macroinvertebrates. The data from these streams established a baseline from which criteria were developed. Those criteria are presented here along with a brief description of each reference site, a fish species list, and a discussion concerning IBI metric development and application. Earlier published work on all aspects of the study can be found in Twidwell and Davis (1989), Bayer et al. (1992), and Hornig et al. (1995).

Methods

Site Selection

Candidate reference streams were selected from all but one of the twelve ecoregions described for Texas by Omernik (1987; Figure 1). No streams were selected from the Arizona/New Mexico Mountains since that region extends only slightly into the state (at Guadalupe Mountains National Park) and few if any perennial streams are present. Based upon the premise that habitat and biological complexity varies with stream size (Vannote et al. 1980; Karr et al. 1986), streams within a range of watershed sizes (less than 130 km^2, 259-518 km^2, and greater than 777 km^2) were identified within each ecoregion as candidates for sampling. Streams whose entire watershed was within the “most typical” portion of an ecoregion (Omernik and Gallant 1987) were the primary candidates for sampling; however, some streams with watersheds in the “generally typical” areas of the map had to be selected because few perennial streams existed in some ecoregions. This was particularly true for the more arid portions of the state. An attempt was made to exclude watersheds with urban

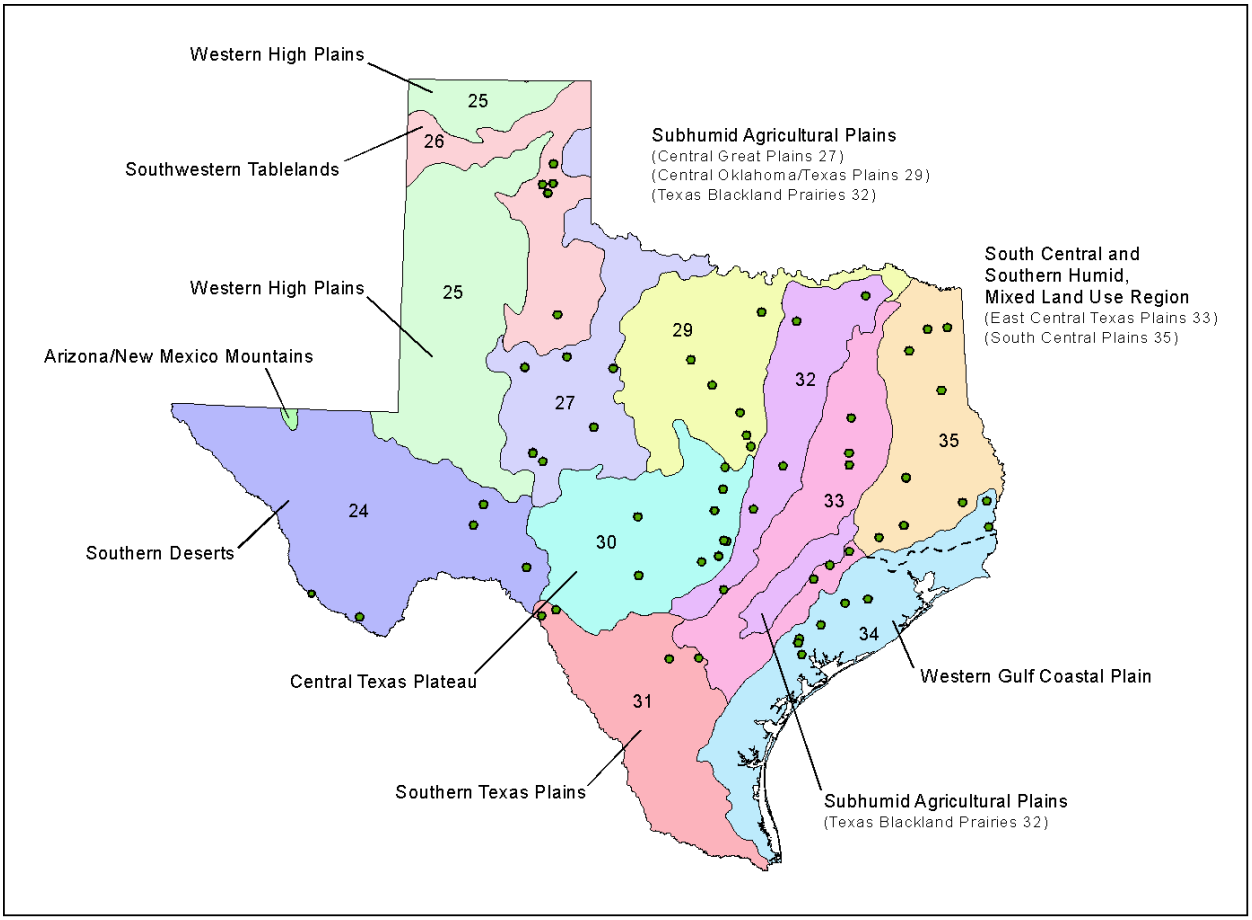

FIGURE 1.—Least disturbed reference site locations (modified from Omernik 1987 and Omernik and Gallant 1989). Sites in dashed area were more typical of ecoregion 35 and included in it for analysis. The boundary was subsequently modified (USEPA 1997).

development, point sources of pollution, channelization, and/or other atypical nonpoint sources of pollution. Candidate streams were further screened by utilizing knowledge of Texas Water Commission (since renamed TNRCC) District Office personnel regarding land use, existing monitoring sites, access points, location of point and nonpoint pollution sources, and anomalous physical features. Proposed reference stream sites were then plotted on a map and visually inspected to ensure adequate spatial coverage within each ecoregion. Final selection was made at the stream site after inspecting the stream and its immediate watershed for any unmapped or unknown disturbances of channel or riparian areas. Several sites were later eliminated because collections were atypical and not considered good representations of least disturbed sites. These sites included: Davidson Creek (Ecoregion 33) in Burleson County (intermittent with extremely low dissolved oxygen); Croton Creek (Ecoregion 26) in Kent County (highly elevated specific conductivity); Mud Creek (Ecoregion 31) in Kinney County (little flow and marsh type habitat); Las Moras Creek (Ecoregion 31) in Kinney County (disturbed habitat); and Palo Duro Creek (Ecoregion 25) in Hansford County (no fish).

Fish Sampling

The goal of the fish sampling effort was to collect a representative sample of the species present in their relative abundances. Given the variability of habitats, flow regimes, and water chemistry, professional judgment was used to assess the sampling effort necessary for an adequate characterization of the fish assemblage. Seines, backpack electrofishing, and boat electrofishing were the gear types employed, respectively, at 100%, 81%, and 8% of the sites. Fish were collected using a combination of seines

and electrofishing gear, where possible (84% of the streams). Six effective seine hauls and 15 minutes of actual shocking time were set as the desired effort; however, sampling continued until species additions ceased and all habitats were sampled in near proportion to their presence. At sites where a combination of gear was used, the mean number of seine hauls was 7.4, with a total length of 61 m of stream sampled. The mean duration of backpack shocking was 13 min. Additional effort was required at sites where only one collection method was used (mean of 8.0 seine hauls and 74 m of stream sampled).

Backpack electrofishing was conducted in an upstream direction to eliminate effects of turbidity caused by bottom sediment disturbance. In deeper waters at five stream sites, a boat-mounted, boom electrofisher powered by a 5,000 watt gasoline generator producing 220 volt, pulsed DC current was employed. Boat electrofishing was conducted in a downstream direction.

Seining was the primary method employed in streams where specific conductivities were greater than those feasible for electrofishing; however, it served as a complementary technique at most sites, used to sample habitats where backpack electrofishing might not be as effective such as deep pools where wading would be difficult or shallow riffles where staking out a seine and kicking would more effectively capture fish. The principal seine employed measured 4.6 m x 1.8 m with 4.8 mm mesh; however, conditions in a number of streams dictated complementary seining with the following size seines: 9.1 m x 1.8 m (6.4 mm mesh) and 1.8m x 1.2 m (3.2 mm mesh). All seines were constructed of delta weave mesh with double lead weights.

Streams were sampled during June through September 1988-1990. By limiting sampling to these months, it was generally assured that sampling would be conducted during low flow, high temperature periods that are critical for regulatory considerations and observing steady state conditions. This period is also advantageous since fish sampling is more efficient during low flows.

Fishes that were easily identified were enumerated and released in the field. All others were preserved in 10% formalin and transported to the office for positive identification. Taxonomic references included Hubbs et al. (1991), Robison and Buchanan (1988), Pflieger (1975), Moore (1968), and Douglas (1974). Common and scientific names follow Robins et al. (1991). All fishes were examined for external deformities, disease, lesions, tumors, and skeletal abnormalities. Linam and Kleinsasser (1998) was used to classify fish into trophic and tolerance categories. Hubbs et al. (1991) was used to determine native status of fish species.

Data Analysis

Detrended correspondence analysis [DCA (ter Braak and Šmilauer 1998)] was used as an exploratory technique to evaluate regional trends in the fish assemblage data. An attempt was made to use existing classification schemes, including ecoregions described by Omernik (1987) and USEPA (1997). Given that ten ecoregions were sampled in Texas and the number of sites sampled in some was small, it was anticipated that fewer regions might be distinct and useful for developing suites of metrics. Consequently, ecoregion aggregations described by Omernik and Gallant (1989) were also evaluated.

Stations were ordered using fish data and then visually compared to membership in ecoregions and aggregated ecoregions. Though similar sampling efforts were employed at each site, it was thought that quantitative data would tend to obscure relationships because of the variation in numbers of organisms and consequently, presence/absence data were employed. In large data sets, quantitative data can have more variability than presence/absence data (Hawkes et al. 1986). Rare species--those present at less than five percent of the sites--were eliminated, since they often make interpretation of results more difficult (Lyons 1989) and similar conclusions may result whether rare species are included or not (Gauch 1982).

An array of metrics was screened to determine which ones were most suited for Texas streams based upon the fish collections made in this study. This initial determination was based upon whether taxa were present to support the metric and the range of values associated with each potential metric. These metrics were further evaluated to determine which ones could be applied statewide and which metrics were more suited for specific ecoregions.

Once statewide and ecoregion specific metrics were selected, scoring criteria were developed in a similar manner to that previously performed by Karr et al. 1986 and Ohio EPA 1987. This involved ranking the respective data in

descending order, computing the 95th percentile, and then taking the value at the 95th percentile and dividing it into thirds (with the thirds representing scoring criteria of 5, 3, and 1). These criteria were then adjusted where necessary to make a minimum of 50% of the data fall within scores of 5 and 3. This adjustment was made since we believed a majority of the values for each metric should receive a score of either 5 or 3 since streams sampled in this study represented some of the best case conditions. Adjustments were necessary in only a few instances and included: number of intolerant species (Central Texas Plateau); number of individuals per seine haul (Subhumid Agricultural Plains; Central Texas Plateau; South Central and Southern Humid, Mixed Land Use Region); and number of individuals per minute electrofishing (Subhumid Agricultural Plains). Number of benthic invertivore species in the Southern Deserts could not be adjusted as described since none were collected in 60% of the streams sampled. This metric was nevertheless considered important since 40% of the streams yielded more than one benthic invertivore species. Scoring criteria for total number of fish species was determined differently in that species richness was plotted against the log of the drainage basin size, to recognize that richness varies with stream basin size (Whiteside and McNatt 1972; Horwitz 1978). A maximum species line was fitted by eye, then the area below this line was trisected to represent scoring criteria of 5, 3, and 1 (Fausch et al. 1984).

To establish aquatic life use criteria, the IBI metrics from each least disturbed reference stream, a select number of streams sampled during receiving water assessments (TNRCC unpublished data), and several streams sampled during a study of the Rio Grande (Davis et al. 1994) were scored, summed, and ranked by region. Additional streams were added for this analysis to obtain a wider representation of stream conditions. Without the addition of these streams, the aquatic life use rating criteria being developed would have been skewed too high and the ranges of each of the respective use classes would have been very small since the overall range of scores for the least disturbed reference streams was correspondingly small. Guidelines were established for selecting these additional streams in an attempt to ensure a similar level of data quality in the field collections used. These criteria included: minimum of six fish species; minimum of 50 individuals; sampling effort recorded; and collection made upstream of known discharges. Modifying an approach used in other studies (Kleinsasser and Linam 1989; Ohio EPA 1987) and recommended by Hughes (1995) and Barbour et al. (1995), exceptional aquatic life use was defined as any IBI score equalling or exceeding the 90th percentile value. The 50th percentile value was selected as the lower limit for high use, intermediate use was defined as the scores represented by the 10th-49th percentile values, while those scores less than this were considered limited use.

Results

Regionalization

When DCA results were evaluated, site location on the first axis related to geographical location and generally demonstrated an east to west orientation (Figure 2). This geographical pattern is reflected in biological attributes such as species richness (Figure 3). Sites in ecoregions 33 and 35 formed a distinct grouping equivalent to the South Central and Southern Humid, Mixed Land Use Region. Ecoregions 24 (Southern Deserts), 26 (Southwestern Tablelands), and 34 (Western Gulf Coastal Plain) were also identifiable as groups. Substantial overlap occurred among ecoregions 27, 29, and 32 (Subhumid Agricultural Plains). When aggregated, they formed a recognizable grouping somewhat distinct from Ecoregion 30 (Central Texas Plateau), though overlap was present. Ecoregion 31 (Southern Texas Plains) did not fit any particular trend, but that is not surprising given that only four sites were sampled. Two spring-influenced sites were largely associated with Ecoregion 30; whereas, two runoff dominated sites were more closely allied with the coastal streams in Ecoregion 34. This was clearly a region in which additional sampling is necessary to characterize the variation in stream assemblages and it was treated separately. Based upon this analysis, attempts were made to define suites of metrics with the following groupings: ecoregions 33-35, 27-29-32, 24, 26, 34, 30, and 31. Site-specific information on sampling location, drainage basin size, soil types, flora, land use, and stream characteristics for each of the streams sampled in this study is reported in Appendix A.

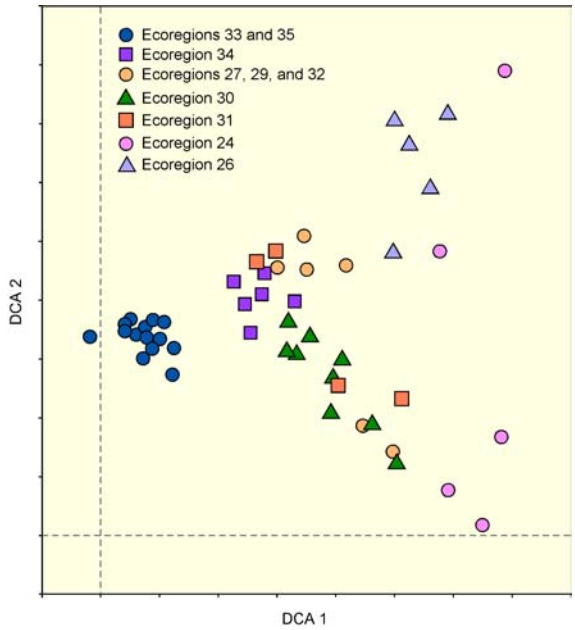

FIGURE 2.—Detrended correspondence analysis (DCA) results on regional trends in fish assemblage data.

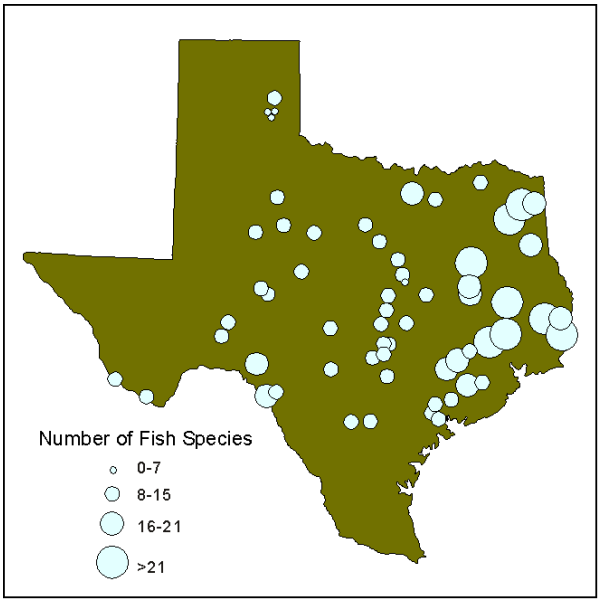

FIGURE 3.—Number of fish species collected from each least disturbed reference stream.

Ecoregion 24, Southern Deserts.—The Southern Deserts occupy the western section of the state (Figure 1). It is bordered on the northeast by the Western High Plains and on the east by the Central Texas Plateau and Southern Texas Plains. Potential natural vegetation is grama/tobosa shrub-steppe and Trans-Pecos shrub savanna (tarbush and creosote); whereas, land surface form is mostly comprised of plains with high hills to high mountains and open high mountains with aridisols and rock outcrops making up the majority of the soil (Omernik and Gallant 1987). The ecoregion can generally be categorized as having poor to no grazing potential and very poor to no non-irrigated cropland potential, intensive irrigated agriculture activity near major water sources, and nonpoint source stressors primarily associated with sparse grazing activity, mining, oil and gas extraction, and irrigated agriculture (Omernik and Gallant 1989).

Many of the streams in this ecoregion are spring-fed and as a consequence contain relatively clear water. The large number of threatened aquatic taxa from this ecoregion reflects the fragile nature of these ecosystems comprised of many small springs and runs flowing onto the desert floor or as tributaries to the Pecos River or Rio Grande (Edwards et al. 1989).

Streams selected to represent the Southern Deserts include: Live Oak Creek, Terlingua Creek, Alamito Creek, Independence Creek, and the Devils River.

Ecoregions 25 and 26, Western High Plains and Southwestern Tablelands.—The Western High Plains and Southwestern Tablelands extend over the Texas panhandle south to the Southern Deserts and east to the Subhumid Agricultural Plains (Figure 1). The land surface is smooth to irregular plains to tablelands with moderate to considerable relief, soils are predominantly comprised of dry mollisols, and the potential natural vegetation is made up of grama/buffalo grass, sandsage/bluestem prairie, mesquite/buffalo grass, and bluestem/grama prairie (Omernik and Gallant 1987). Most of this ecoregion aggregate is in grazing or cropland (Omernik and Gallant 1989).

Streams of the Western High Plains and Southwestern Tablelands are typically wide and shallow, with much variation in discharge. Sluggish flow, direct insolation, and photosynthesis combine to produce harsh diel and annual physicochemical fluctuations, with extremes approaching or exceeding limits of tolerance for many fish species (Matthews 1987). Substrates are typically sand which contribute to high turbidity, especially during high flow events (Cross and Moss 1987). In general, these streams are reported to have high nutrient

concentrations (Omernik and Gallant 1989). Data collected in this study corroborate that generalization (Bayer et al. 1992).

Major river basins draining portions of this region are the Canadian, Red, Brazos, Colorado, and Rio Grande (Texas Water Commission 1992). Streams selected to represent this region include: Saddlers Creek, Lelia Lake Creek, Whitefish Creek, McClellan Creek, and Wolf Creek.

Ecoregions 27, 29, and 32 - Subhumid Agricultural Plains.—The Subhumid Agricultural Plains enter north Texas and extend southerly to the Central Texas Plateau (Figure 1). It is bordered on the west by the Southwestern Tablelands and the east by the South Central and Southern Humid, Mixed Land Use Region. The Subhumid Agricultural Plains are characterized by irregular plains whose soils are comprised of dry mollisols, alfisols, and vertisols (Omernik and Gallant 1987). Land use is predominantly non-irrigated cropland and high quality grazing land (Omernik and Gallant 1989). Potential natural vegetation shifts from bluestem/grama prairie, bluestem prairie, and buffalo grass in the western range of this ecoregion aggregate to cross timbers (oak and bluestem) and a mosaic of bluestem prairie (bluestem, panic, and indiangrass) and oak/hickory in the central section to blackland prairie (bluestem and needlegrass) and Fayette prairie (bluestem and buffalo grass) in the east (Omernik and Gallant 1987).

It is common for streams within this ecoregion aggregate to have high concentrations of nutrients, alkalinity, suspended sediment, and dissolved solids (Omernik and Gallant 1989). Environmental conditions tend to vary widely, including a tremendous variation in flow conditions (Edwards et al. 1989). Major river basins draining portions of this region include the Red, Brazos, Colorado, Rio Grande, Trinity, Sabine, Sulphur, San Jacinto, Lavaca, Guadalupe, and San Antonio (Texas Water Commission 1992). Streams selected to represent the Subhumid Agricultural Plains include: Geronimo Creek, Willis Creek, Bluff Creek (McLennan County), Ioni Creek, Wilson Creek, Bluff Creek (Scurry County), Auds Creek, Deadman Creek, Colony Creek, Steele Creek, West Rocky Creek, Deer Creek, Neils Creek, Cottonwood Creek, Clear Creek, Mill Creek, Cummins Creek, Spring Creek, and Elm Creek.

Ecoregion 30, Central Texas Plateau.—The Central Texas Plateau is located in the center of the state (Figure 1). Potential natural vegetation is juniper/oak savanna (bluestem) and mesquite/oak savanna (bluestem), land surface forms include tablelands with moderate relief, plains with high hills, and open high hills, and the soils are predominantly dry mollisols (Omernik and Gallant 1987).

Streams for the most part contain clear water and flow over bedrock substrate. Many of the streams within this ecoregion originate from springs. Due to the dominance of limestone substrate, the streams are well buffered. Major river basins draining this ecoregion are the Brazos, Colorado, Guadalupe, San Antonio, Nueces, and Rio Grande (Texas Water Commission 1992). Streams selected to represent the Central Texas Plateau include: Little Barton Creek, Oatmeal Creek, Little Blanco River, Barton Creek, Rocky Creek, Onion Creek, South Llano River, Medina River, and Cowhouse Creek.

Ecoregion 31, Southern Texas Plains.—The Southern Texas Plains extend from the southern tip of Texas northward to the Central Texas Plains, Texas Blackland Prairies, and East Central Texas Plains (Figure 1). It is bordered on the east by the Western Gulf Coastal Plain. Soils are predominantly comprised of dry alfisols and dry vertisols, potential natural vegetation is made up of mesquite/acacia savanna (bluestem and bristlegrass) and mesquite/live oak savanna (bluestem), and the land surface form is smooth to irregular plains (Omernik and Gallant 1987). Most of this region is in grazing or cropland (Omernik and Gallant 1989).

Major river drainages within this ecoregion are the Rio Grande, Nueces, and Nueces-Rio Grande (Texas Water Commission 1992). Streams selected to represent the Southern Texas Plains include: Pinto Creek, Metate Creek, Sycamore Creek, and San Miguel Creek.

Ecoregions 33 and 35, South Central and Southern Humid, Mixed Land Use Region.—The South Central and Southern Humid, Mixed Land Use Region occupies east Texas and extends southwest to the Southern Texas Plains (Figure 1). It is bordered on the southeast by the Western Gulf Coastal Plain. The area is predominantly made up of plains and low hills, soils shift from dry alfisols in the western parts of the region to moist ultisols in the east, and potential natural vegetation is oak/hickory/pine with extensive areas of commercial forests (predominantly pine) present (Omernik and Gallant 1987, 1989).

Water quality problems are common (specifically high turbidity and low dissolved oxygen) due to imposed (agricultural activity and local urbanization and industrialization) and natural characteristics (Omernik and Gallant 1989). Least disturbed reference streams sampled in this study yielded the lowest mean dissolved oxygen concentrations of all the ecoregions sampled (Bayer et al. 1992). Canopy cover was usually extensive, subtrates were typically silt and sand, pH was usually in the acidic range, and the waters were generally very low in conductivity (Bayer et al. 1992).

The major river basins crossing these ecoregions are the Sulphur, Cypress, Sabine, Neches, Trinity, San Jacinto, Brazos, Colorado, Lavaca, Guadalupe, San Antonio, San Antonio-Nueces, and Nueces (Texas Water Commission 1992). Streams selected to represent the South Central and Southern Humid, Mixed Land Use Region include: Ponds Creek, Wheelock Creek, Black Cypress Creek, Beech Creek, White Oak Creek, Frazier Creek, Irons Bayou, Piney Creek, Keechi Creek, East Fork of the San Jacinto River, Big Cypress Creek, Catfish Creek, Little Cypress Creek, and Lake Creek.

Ecoregion 34, Western Gulf Coastal Plain.—The Western Gulf Coastal Plain runs along the Texas coastline from the Louisiana border to the southernmost tip of Texas (Figure 1). Much of the land is used for cropland and grazing as the ecoregion is characterized by flat plains, potential natural vegetation of bluestem/sacahuista prairie (bluestem and cordgrass), and soils predominantly comprised of vertisols (Omernik and Gallant 1987). Environmental stressors are mostly related to agricultural activities, petroleum extraction, industrialization, and urbanization (Omernik and Gallant 1989).

Streams typically flow over sand and silt substrates, are often turbid, are variable in canopy cover and conductivity, and can have extensive water quality fluctuations given the usual sluggishness associated with coastal streams. Nearly every major river basin in Texas drains some part of the Western Gulf Coastal Plain (Texas Water Commission 1992). Streams selected to represent this ecoregion include: Placedo Creek, West Carancahua Creek, Big Creek, Arenosa Creek, West Mustang Creek, and West Bernard Creek.

Metric Development

The metrics and scoring criteria developed in this study were based on fish collections from 62 least disturbed reference streams (Figure 1). Many of the metrics selected were used in all of the ecoregion or ecoregion aggregates (Table 1). Metrics used for all regions include: total number of fish species; number of native cyprinid species; number of sunfish species; percentage of individuals as omnivores; percentage of individuals as invertivores; number of individuals per unit effort; percentage of individuals as non-native species; and percentage of individuals with disease or other anomaly. Other metrics used include: number of benthic invertivore species; number of benthic species; number of intolerant species; percentage of individuals as tolerant species (excluding western mosquitofish *Gambusia affinis*); and percentage of individuals as piscivores. Information concerning the application of these metrics is included in Appendix B.

Metrics that were evaluated in this study but appeared to have less utility include: number of darter species; number of catfish species; number of sucker species; percentage of individuals as tolerant species; number of individuals in sample; percentage of individuals as hybrids; percentage of omnivorous non-native species; percentage of introduced species; and percentage of dominant species.

Variations from the metrics developed by Karr et al. (1986) include substitution of tolerant species (excluding western mosquitofish) for green sunfish *Lepomis cyanellus*, substitution of percentage of individuals as invertivores for insectivorous cyprinids, and substitution of non-native species for hybrids. Karr et al. (1986), in their suite of species richness metrics, used darters, suckers, and sunfish as target groups. We retained sunfish as a target group, but combined attributes of the darter and sucker metrics into a single group encompassing benthic invertivores (which also includes madtoms). Native cyprinid species were also added as a target group.

Native cyprinid species were selected as a target group because they were collected in every stream, appeared to suffer from few distributional limitations (Figure 4), and overall are reported to be sensitive to habitat and water quality

TABLE 1.—Comparison of metrics developed for each Texas ecoregion or ecoregion aggregate.

Metric	Karr et al.	24	25,26	27,29,32	30	31	33,35	34
Total number of fish species	X	X	X	X	X	X	X	X
Number of darter species	X							
Number of native cyprinid species		X	X	X	X	X	X	X
Number of benthic invertivore species		X		X	X		X	X
Number of benthic species						X		
Number of sunfish species	X	X	X	X	X	X	X	X
Number of sucker species	X							
Number of intolerant species	X	X			X		X	X
% of individuals as green sunfish	X							
% of individuals as tolerant species (excluding western mosquitofish)		X		X	X	X	X	X
% of individuals as omnivores	X	X	X	X	X	X	X	X
% of individuals as insectivorous	X							
% of individuals as invertivores		X	X	X	X	X	X	X
% of individuals as piscivores	X			X	X	X	X	
Number of individuals in sample	X							
Number of individuals per unit effort		X	X	X	X	X	X	X
% of individuals as hybrids	X							
% of individuals as non-native species		X	X	X	X	X	X	X
% of individuals with disease or other anomaly	X	X	X	X	X	X	X	X

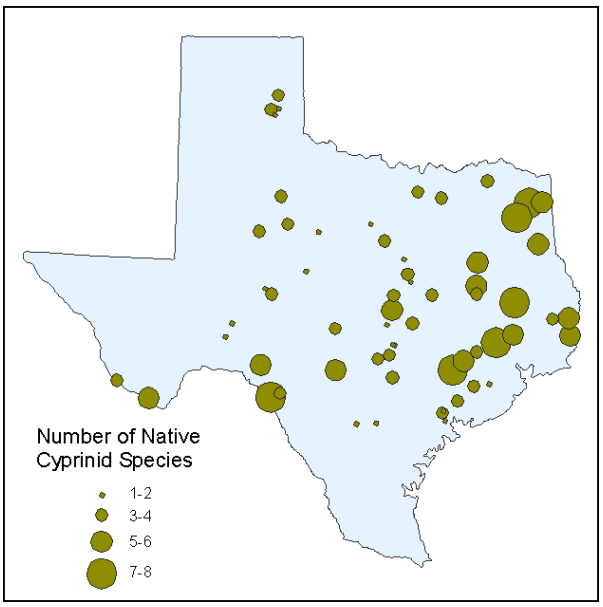

FIGURE 4.—Number of native cyprinid species collected from each least disturbed reference stream.

degradation. Anderson et al. (1995) reported that cyprinids accounted for the greatest proportion of the species richness from stream collections made across the state. Hughes and Gammon (1987) used cyprinids as a target group in an IBI study of the Willamette River, citing the responsiveness of that family to deterioration of habitat structure (Minckley 1973; Moyle 1976). Ramsey (1968) proposed that many species in the minnow family could be good indicators of water quality, though he cautioned that specific habitat requirements for many species are unknown. Cyprinids have successfully been used as a target group in previous Texas stream studies on the Bosque (Linam and Kleinsasser 1989) and Trinity rivers (Kleinsasser and Linam 1989) and Rio Grande (Davis et al. 1994).

Benthic invertivores was chosen as a metric to compensate for distributional limitations associated with exclusively using sucker or darter species. Requiring the species to be invertivorous provides additional sensitivity to this metric as the relative abundance of invertivorous species decreases with degradation, probably in response

to variability in the invertebrate supply, which in turn reflects alterations of water quality, energy sources, and/or instream habitat (Karr et al. 1986). Darters suffer from distributional limitations in Texas (Figure 5), with many western drainages having few if any species (Hubbs et al. 1991). Darter species richness varies greatly between river basins and has decreased in the relative proportion they comprise of the species richness in Texas streams by more than half since 1953 (Anderson et al. 1995). Like darters, sucker species richness and distribution is also limited across the state (Figure 6; Hubbs et al. 1991). Anderson et al. (1995) report catostomids as accounting for a small proportion of the species richness in Texas streams.

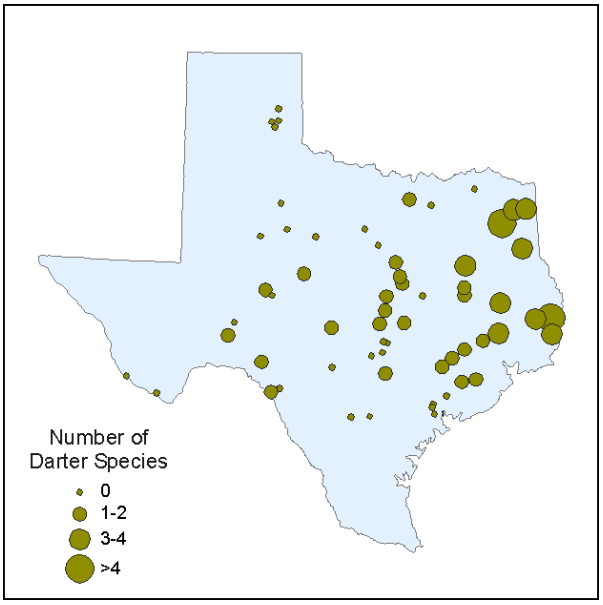

FIGURE 5.—Number of darter species collected from each least disturbed reference stream.

The substitution of percentage of individuals as tolerant species for percentage of individuals as green sunfish was recommended by Karr et al. (1986) as a means of avoiding weighting this metric too heavily on a single species. They selected green sunfish as a species that tends to overpopulate disturbed areas, but offered percentage of tolerant individuals as an alternative metric. Further refinement of this metric was necessary in order for it to be useful in Texas. Specifically, western mosquitofish was excluded as a tolerant species since they dominated many of the least disturbed reference stream collections, thereby reducing the sensitivity of this

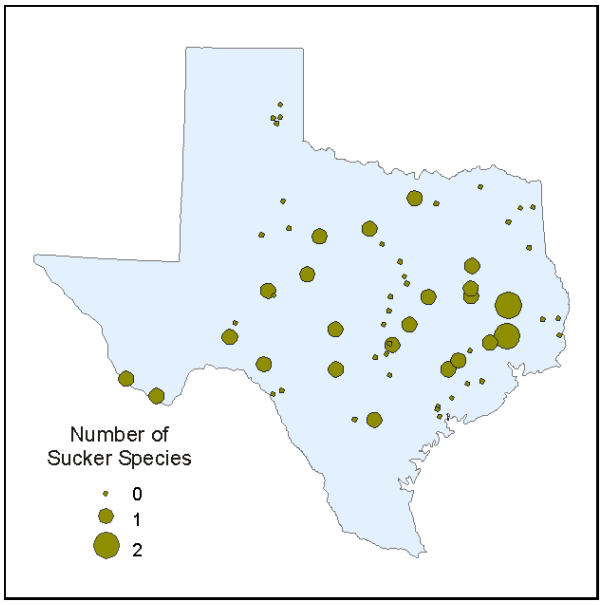

FIGURE 6.—Number of sucker species collected from each least disturbed reference stream.

metric. Karr et al. (1986) also supported the substitution of total invertivores for insectivorous cyprinids stating that total invertivores may provide better information for this metric in large rivers and in areas of the country where insectivorous cyprinids are not as dominant as they are in the Midwest.

Since hybrids are not always easily recognized, percentage of individuals as non-native species was substituted for this metric. Non-native species are often capable of hybridizing or competing with native species and represent a deviation from natural conditions as they disrupt the original, highly structured fish assemblage (Echelle and Connor 1989; Miller et al. 1989; Williams et al. 1989; Garrett 1991; Anderson et al. 1995). Designation of non-native status is based upon whether the species is native to the state, as opposed to a specific river basin, to lessen the complexity of using this metric.

Scoring criteria specific to each ecoregion and ecoregion aggregate were developed for all but five metrics which were assigned statewide criteria. These five metrics were: percentage of individuals as tolerant species (excluding western mosquitofish); percentage of individuals as omnivores; percentage of individuals as invertivores; percentage of individuals as non-native species; and percentage of individuals with disease or other anomaly. Statewide scoring criteria were developed for these metrics for two reasons. First, the distribution of the regional

values was similar to the statewide distribution in the cases of tolerant species (when the Western High Plains and Southwestern Tablelands were omitted), omnivores, and invertivores. Although the percentage of individuals as non-native species was greater in the Central Texas Plateau than the other ecoregions and ecoregion aggregates, this metric as well as the percentage of individuals with disease or other anomaly is expected to be consistently low in least disturbed streams regardless of their geographical position within the state.

Ecoregion 24, Southern Deserts.—Five streams were sampled within the Southern Deserts (Figure 1), from which a total of 31 fish species and one hybrid were collected (Table 2). Mean species richness was 12, with collections ranging from nine to 18 species (Appendix C). Mexican tetra *Astyanax mexicanus* was the most ubiquitous species, collected in four of the five streams; while, Cyprinidae was the richest family. The most common cyprinids were proserpine shiner *Cyprinella proserpina* and roundnose minnow *Dionda episcopa*. Longear sunfish *Lepomis megalotis* was the most common centrarchid species.

Only one darter species (Rio Grande darter *Etheostoma grahami*) was collected from the least disturbed reference streams in this ecoregion. This is the only darter species expected in this part of Texas (Lee et al. 1980; Smith and Miller 1986; Hubbs et al. 1991). Two sucker species, gray redhorse *Moxostoma congestum* and river carpsucker *Carpiodes carpio*, were collected. Six sucker species are reported from this region of Texas; however, three of them, blue sucker *Cycleptus elongatus*, smallmouth buffalo *Ictiobus bubalus*, and black buffalo *Ictiobus niger*, are considered large river fishes while west Mexican redhorse *Moxostoma austrinum* has a limited distribution (Lee et al. 1980; Robison and Buchanan 1988; Sublette et al. 1990; Hubbs et al. 1991).

Eleven metrics were developed for evaluating the biotic integrity of streams in this ecoregion (Table 3; Figure 7).

Ecoregions 25 and 26, Western High Plains and Southwestern Tablelands.—Scoring criteria (except for the four statewide metrics used) were developed for the Western High Plains and Southwestern Tablelands based on five streams sampled within the Southwestern Tablelands (Figure 1). The one stream that was sampled

TABLE 2.—Fish species collected from the Southern Deserts (Ecoregion 24).

Species	Common Name
Campostoma ornatum	Mexican stoneroller
Cyprinella lutrensis	Red shiner
Cyprinella proserpina	Proserpine shiner
Cyprinella venusta	Blacktail shiner
Cyprinus carpio	Common carp
Dionda episcopa	Roundnose minnow
Macrhybopsis aestivalis	Speckled chub
Notropis amabilis	Texas shiner
Notropis braytoni	Tamaulipas shiner
Notropis chihuahua	Chihuahua shiner
Notropis stramineus	Sand shiner
Pimephales promelas	Fathead minnow
Moxostoma congestum	Gray redhorse
Carpiodes carpio	River carpsucker
Astyanax mexicanus	Mexican tetra
Ictalurus furcatus	Blue catfish
Ictalurus lupus	Headwater catfish
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Cyprinodon eximius	Conchos pupfish
Cyprinodon pecosensis x variegatus	Pecos pupfish x sheepshead minnow
Fundulus zebrinus	Plains killifish
Gambusia affinis	Western mosquitofish
Gambusia geiseri	Largespring gambusia
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis megalotis	Longear sunfish
Micropterus dolomieu	Smallmouth bass
Micropterus salmoides	Largemouth bass
Etheostoma grahami	Rio Grande darter
Cichlasoma cyanoguttatum	Rio Grande cichlid
Tilapia aurea	Blue tilapia

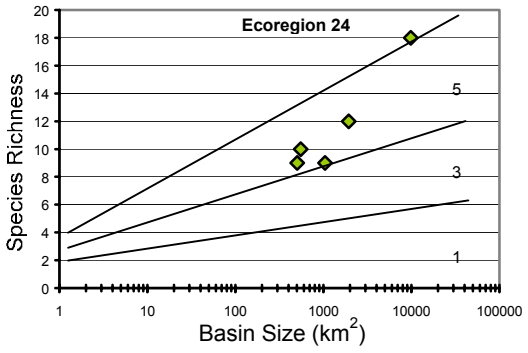

FIGURE 7.—Fish species richness versus drainage basin size in Southern Desert streams.

TABLE 3.—Scoring criteria developed to assess stream fish assemblages in the Southern Deserts (Ecoregion 24).

Metric	Scoring Criteria 5	3	1
1. Total number of fish species		See Figure 7	
2. Number of native cyprinid species	>4	3-4	<3
3. Number of benthic invertivore species	>1	1	0
4. Number of sunfish species	>1	1	0
5. Number of intolerant species	>1	1	0
6. % of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
7. % of individuals as omnivores	<9%	9-16%	>16%
8. % of individuals as invertivores	>65%	33-65%	<33%
9. Number of individuals in sample			
a. Number of individuals/seine haul	>160.4	80.2-160.4	<80.2
b. Number of ind/min electrofishing	>26.5	13.3-26.5	<13.3
10. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
11. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: ≥43 Exceptional; 37-42 High; 35-36 Intermediate; <35 Limited

within the Western High Plains was not included as it yielded no fish. The Western High Plains likely best fit with the Southwestern Tablelands given its proximity to it and the fact that Omernik and Gallant (1989) include these two ecoregions as part of the Semi-arid Section of the Western Xeric Region on their ecoregion aggregation map. This region had the most depauparate fish assemblage of the study with only 15 species being collected (Table 4). Mean species richness was seven, and ranged from six to nine (Appendix D). Red shiner *Cyprinella lutrensis*, plains killifish *Fundulus zebrinus*, and green sunfish (all tolerant species) were collected from each stream, while western mosquitofish (also a tolerant species) were collected in all but one. The families Cyprinidae and Centrarchidae comprised 66% of the species collected.

No darters, suckers, benthic invertivores, nor intolerant species were collected from the least disturbed reference streams in this region. Only two benthic invertivore species (black buffalo and river carpsucker) and no darter species are reported as inhabiting this region of Texas (Lee et al. 1980; Hubbs et al. 1991).

Eight metrics (the fewest of any region) were developed for evaluating the biotic integrity of streams in this region (Table 5; Figure 8). This

TABLE 4.—Fish species collected from the Southwestern Tablelands (Ecoregion 26).

Species	Common Name
Cyprinella lutrensis	Red shiner
Hybognathus placitus	Plains minnow
Notropis bairdi	Red River shiner
Notropis stramineus	Sand shiner
Phenacobius mirabilis	Suckermouth minnow
Pimephales promelas	Fathead minnow
Ameiurus melas	Black bullhead
Ameiurus natalis	Yellow bullhead
Cyprinodon rubrofluviatilis	Red River pupfish
Fundulus zebrinus	Plains killifish
Gambusia affinis	Western mosquitofish
Lepomis cyanellus	Green sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Micropterus salmoides	Largemouth bass

was the only region where the percentage of individuals as tolerant species was not used given three of the streams had percentages greater than 80% (even after the exclusion of western mosquitofish).

Ecoregions 27, 29, and 32, Subhumid Agricultural Plains.—Nineteen streams were sampled within the Subhumid Agricultural Plains (Figure 1), from which a total of 47 fish species were collected (Table 6). Mean species richness

TABLE 5.—Scoring criteria developed to assess stream fish assemblages in the Western High Plains and Southwestern Tablelands (Ecoregions 25 and 26).

	Scoring Criteria		
Metric	5	3	1
1. Total number of fish species		See Figure 8	
2. Number of native cyprinid species	>2	2	<2
3. Number of sunfish species	>1	1	0
4. % of individuals as omnivores	<9%	9-16%	>16%
5. % of individuals as invertivores	>65%	33-65%	<33%
6. Number of individuals/seine haul	>41.7	20.9-41.7	<20.9
7. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
8. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: ≥36 Exceptional; 34-35 High; 24-33 Intermediate; <24 Limited

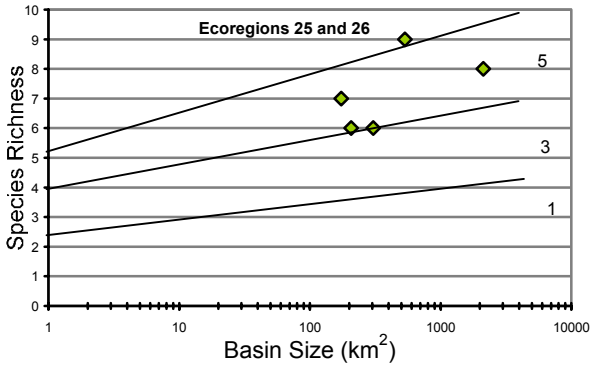

FIGURE 8.—Fish species richness versus drainage basin size in Western High Plains and Southwestern Tablelands streams.

TABLE 6.—Fish species collected from the Subhumid Agricultural Plains (Ecoregions 27, 29, and 32).

Species	Common Name
Lepisosteus osseus	Longnose gar
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Campostoma anomalum	Central stoneroller
Cyprinella lutrensis	Red shiner
Cyprinella venusta	Blacktail shiner
Cyprinus carpio	Common carp
Hybognathus sp.	
Notemigonus crysoleucas	Golden shiner
Notropis amabilis	Texas shiner
Notropis stramineus	Sand shiner
Notropis texanus	Weed shiner
Notropis volucellus	Mimic shiner
Phenacobius mirabilis	Suckermouth minnow

TABLE 6. Cont.

Species	Common Name
Pimephales promelas	Fathead minnow
Pimephales vigilax	Bullhead minnow
Carpiodes carpio	River carpsucker
Ictiobus bubalus	Smallmouth buffalo
Minytrema melanops	Spotted sucker
Moxostoma congestum	Gray redhorse
Astyanx mexicanus	Mexican tetra
Ameiurus melas	Black bullhead
Ameirus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Noturus gyrinus	Tadpole madtom
Noturus nocturnus	Freckled madtom
Pylodictis olivaris	Flathead catfish
Fundulus notatus	Blackstripe topminnow
Gambusia affinis	Western mosquitofish
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis humilis	Orangespotted sunfish
Lepomis hybrid	Sunfish hybrid
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Lepomis macrochirus	Bluegill
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Micropterus treculi	Guadalupe bass
Pomoxis annularis	White crappie
Etheostoma gracile	Slough darter
Etheostoma spectabile	Orangethroat darter
Percina carbonaria	Texas logperch
Percina macrolepida	Bigscale logperch
Percina sciera	Dusky darter
Cichlasoma cyanoguttatum	Rio Grande cichlid

was 13, with collections ranging from seven to 21 species (Appendix E). Longear sunfish was collected from every stream. Western mosquitofish was collected from 18 streams, and green sunfish and largemouth bass *Micropterus salmoides* from 17. The most ubiquitous cyprinids were red shiner and. bullhead minnow *Pimephales vigilax*. The most common catfish was channel catfish *Ictalurus punctatus*. Orangethroat darter *Etheostoma spectabile* was collected from eight streams. The families Cyprinidae and Centrarchidae made up over one-half of the species.

Eleven metrics were developed for evaluating the biotic integrity of streams in this region (Table 7; Figure 9).

Ecoregion 30, Central Texas Plateau.—Nine streams were sampled within the Central Texas Plateau (Figure 1), from which a total of 27 fish species were collected (Table 8). Mean species richness was 12, with collections ranging from eight to 15 species (Appendix F). Blacktail shiner *Cyprinella venusta* and longear sunfish were collected from every stream, while central stoneroller *Campostoma anomalum* and green sunfish were collected from all but one. The families Centrarchidae and Cyprinidae comprised 70% of the species. Channel catfish and orangethroat darter were the most common catfish and darter species, respectively.

Twelve metrics were developed for evaluating the biotic integrity of streams in this ecoregion (Table 9; Figure 10).

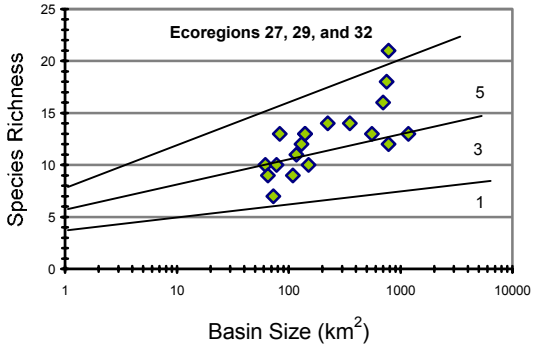

FIGURE 9.—Fish species richness versus drainage basin size in Subhumid Agricultural Plains streams.

TABLE 7.—Scoring criteria developed to assess stream fish assemblages in the Subhumid Agricultural Plains (Ecoregions 27, 29, and 32).

	Scoring Criteria		
Metric	5	3	1
1. Total number of fish species		See Figure 9	
2. Number of native cyprinid species	>3	2-3	<2
3. Number of benthic invertivore species	>1	1	0
4. Number of sunfish species	>3	2-3	<2
5. % of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
6. % of individuals as omnivores	<9%	9-16%	>16%
7. % of individuals as invertivores	>65%	33-65%	<33%
8. % of individuals as piscivores	>9%	5-9%	<5%
9. Number of individuals in sample			
a. Number of individuals/seine haul	>87	36-87	<36
b. Number of ind/min electrofishing	>7.1	3.3-7.1	<3.3
10. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
11. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: ≥49 Exceptional; 41-48 High; 35-40 Intermediate; <35 Limited

TABLE 8.—Fish species collected from the Central Texas Plateau (Ecoregion 30).

Species	Common Name
Campostoma anomalum	Central stoneroller
Cyprinella lutrensis	Red shiner
Cyprinella venusta	Blacktail shiner
Dionda episcopa	Roundnose minnow
Notemigonus crysoleucas	Golden shiner
Notropis amabilis	Texas shiner
Notropis stramineus	Sand shiner
Notropis volucellus	Mimic shiner
Pimephales vigilax	Bullhead minnow
Moxostoma congestum	Gray redhorse
Ameiurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Gambusia affinis	Western mosquitofish
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis humilis	Orangespotted sunfish
Lepomis hybrid	Sunfish hybrid
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Micropterus treculi	Guadalupe bass
Etheostoma lepidum	Greenthroat darter
Etheostoma spectabile	Orangethroat darter
Percina carbonaria	Texas logperch
Cichlasoma cyanoguttatum	Rio Grande cichlid

Ecoregion 31, Southern Texas Plains.—Four streams were sampled within the Southern Texas Plains (Figure 1), from which a total of 31 fish species were collected (Table 10). Mean species richness was 14, with collections ranging from eight to 21 (Appendix G). Red shiner, western mosquitofish, and bluegill *Lepomis macrochirus* were collected from every stream. Black bullhead *Ameiurus melas* was the most common catfish species. The families Cyprinidae and Centrarchidae comprised over one-half of the species. Only one darter species (Rio Grande darter) was collected from the least disturbed reference streams in this ecoregion; however, only two darter species (Rio Grande darter and slough darter *Etheostoma gracile* are reported to occur in this area of Texas (Lee et al. 1980; Hubbs et al. 1991).

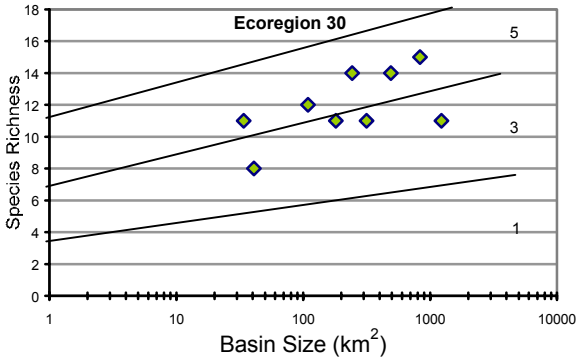

FIGURE 10.—Fish species richness versus drainage basin size in Central Texas Plateau streams.

Eleven metrics were developed for evaluating the biotic integrity of streams in this ecoregion (Table 11; Figure 11). One metric unique to this ecoregion was the number of benthic species (as opposed to number of benthic invertivores). Benthic species was used instead of benthic invertivore species because three of the five benthic invertivores reported to live in the Southern Texas Plains have very limited distributions (Lee et al. 1980; Hubbs et al. 1991), of which only one was collected in this study, Rio Grande darter.

Ecoregions 33 and 35, South Central and Southern Humid, Mixed Land Use Region.—Fifty-nine fish species (the most of any region; Table 12) were collected from the 14 streams sampled within the South Central and Southern Humid, Mixed Land Use Region (Figure 1). Mean species richness was 21, with collections ranging from 14 to 25 species (Appendix H). Ribbon shiner *Lythrurus fumeus* and longear sunfish were collected from every stream while pirate perch *Aphredoderus sayanus* and bluegill were collected from all but one stream. The most common suckers were spotted sucker *Minytrema melanops* and blacktail redhorse *Moxostoma poecilurum*, though each were only collected from three streams. Yellow bullhead *Ameiurus natalis* and dusky darter *Percina sciera* were the most common catfish and darter species, respectively. Cyprinidae was the richest family, closely followed by Centrarchidae and Percidae.

Twelve metrics were developed for evaluating the biotic integrity of streams in this region (Table 13; Figure 12).

TABLE 9.—Scoring criteria developed to assess stream fish assemblages in the Central Texas Plateau (Ecoregion 30).

Metric	Scoring Criteria 5	3	1
1. Total number of fish species		See Figure 10	
2. Number of native cyprinid species	>4	3-4	<3
3. Number of benthic invertivore species	>1	1	0
4. Number of sunfish species	>3	2-3	<2
5. Number of intolerant species	>1	1	0
6. % of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
7. % of individuals as omnivores	<9%	9-16%	>16%
8. % of individuals as invertivores	>65%	33-65%	<33%
9. % of individuals as piscivores	>8.4%	3.9-8.4%	<3.9%
10. Number of individuals in sample			
a. Number of individuals/seine haul	>48	37-48	<37
b. Number of ind/min electrofishing	>5.0	2.5-5.0	<2.5
11. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
12. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: >52 Exceptional; 42-51 High; 30-41 Intermediate; <30 Limited

TABLE 10.—Fish species collected from the Southern Texas Plains (Ecoregion 31).

Species	Common Name
Lepisosteus oculatus	Spotted gar
Dorosoma cepedianum	Gizzard shad
Campostoma anomalum	Central stoneroller
Cyprinella lutrensis	Red shiner
Cyprinella proserpina	Proserpine shiner
Cyprinella venusta	Blacktail shiner
Cyprinus carpio	Common carp
Dionda episcopa	Roundnose minnow
Notropis amabilis	Texas shiner
Notropis stramineus	Sand shiner
Pimephales vigilax	Bullhead minnow
Ictiobus bubalus	Smallmouth buffalo
Astyanax mexicanus	Mexican tetra
Ameiurus melas	Black bullhead
Ameiurus natalis	Yellow bullhead

TABLE 10. Cont.

Species	Common Name
Ictalurus lupus	Headwater catfish
Ictalurus punctatus	Channel catfish
Gambusia affinis	Western mosquitofish
Poecilia latipinna	Sailfin molly
Lepomis gulosus	Warmouth
Lepomis humilis	Orangespotted sunfish
Lepomis hybrid	Hybrid sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Etheostoma grahami	Rio Grande darter
Cichlasoma cyanoguttatum	Rio Grande cichlid
Tilapia aurea	Blue tilapia

TABLE 11.—Scoring criteria developed to assess stream fish assemblages in the Southern Texas Plains (Ecoregion 31).

Metric	Scoring Criteria 5	3	1
1. Total number of fish species		See Figure 11	
2. Number of native cyprinid species	>5	3-5	<3
3. Number of benthic species (catfish, suckers, darters)	>2	2	<2
4. Number of sunfish species	>4	3-4	<3
5. % of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
6. % of individuals as omnivores	<9%	9-16%	>16%
7. % of individuals as invertivores	>65%	33-65%	<33%
8. % of individuals as piscivores	>9%	5-9%	<5%
9. Number of individuals in sample			
a. Number of individuals/seine haul	>39.5	19.7-39.5	<19.7
b. Number of ind/min electrofishing	>8.9	4.4-8.9	<4.4
10. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
11. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: ≥42 Exceptional; 37-41 High; 25-36 Intermediate; <25 Limited

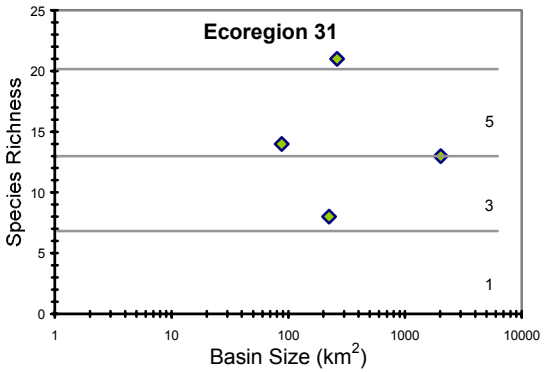

FIGURE 11.—Fish species richness versus drainage basin size in Southern Texas Plains streams.

Ecoregion 34, Western Gulf Coastal Plain.—Twenty-three fish species (Table 14) were collected from the six streams sampled within the Western Gulf Coastal Plain (Figure 1). Mean species richness was 12, with collections ranging from nine to 16 (Appendix I). Red shiner, western

TABLE 12.—Fish species collected from the South Central and Southern Humid, Mixed Land Use Region (Ecoregions 33 and 35).

Species	Common Name
Lepisosteus oculatus	Spotted gar
Lepisosteus spatula	Alligator gar
Dorosoma cepedianum	Gizzard shad
Cyprinella lutrensis	Red shiner
Cyprinella venusta	Blacktail shiner
Hybognathus hayi	Cypress minnow
Hybognathus nuchalis	Mississippi silvery minnow
Luxilus chrysocephalus	Striped shiner
Lythrurus fumeus	Ribbon shiner
Lythrurus umbratilis	Redfin shiner
Notemigonus crysoleucas	Golden shiner
Notropis atrocaudalis	Blackspot shiner
Notropis chalybaeus	Ironcolor shiner
Notropis sabinae	Sabine shiner
Notropis texanus	Weed shiner

TABLE 12. Cont.

Species	Common Name
Opsopoeodus emiliae	Pugnose minnow
Pimephales vigilax	Bullhead minnow
Erimyzon oblongus	Creek chubsucker
Erimyzon sucetta	Lake chubsucker
Minytrema melanops	Spotted sucker
Moxostoma poecilurum	Blacktail redhorse
Ameiurus melas	Black bullhead
Ameiurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Noturus gyrinus	Tadpole madtom
Noturus nocturnus	Freckled madtom
Pylodictus olivarus	Flathead catfish
Esox americanus vermiculatus	Grass pickerel
Aphredoderus sayanus	Pirate perch
Fundulus notatus	Blackstripe topminnow
Fundulus olivaceus	Blackspotted topminnow
Gambusia affinis	Western mosquitofish
Labidesthes sicculus	Brook silverside
Centrarchus macropterus	Flier
Elassoma zonatum	Banded pygmy sunfish
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis marginatus	Dollar sunfish
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Lepomis symmetricus	Bantam sunfish
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis nigromaculatus	Black crappie
Ammocrypta vivax	Scaly sand darter
Etheostoma asprigene	Mud darter
Etheostoma chlorosomum	Bluntnose darter
Etheostoma gracile	Slough darter
Etheostoma parvipinne	Goldstripe darter
Etheostoma proeliare	Cypress darter
Etheostoma radiosum	Orangebelly darter
Etheostoma whipplei	Redfin darter
Percina carbonaria	Texas logperch
Percina macrolepida	Bigscale logperch
Percina sciera	Dusky darter
Aplodinotus grunniens	Freshwater drum

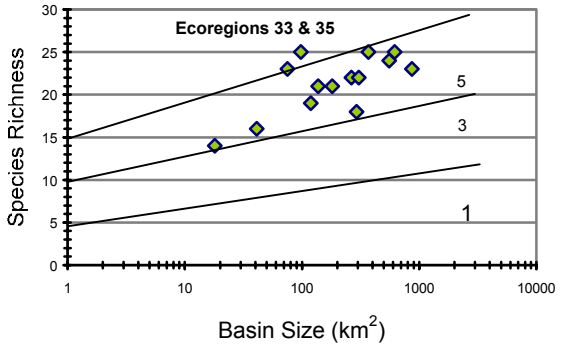

FIGURE 12.— Fish species richness versus drainage basin size in South Central and Southern Humid, Mixed Land Use Region streams.

mosquitofish, and longear sunfish were collected from every stream. Channel catfish, green sunfish, and bluegill were collected from all but one. Dominant families were Centrarchidae (seven species), Cyprinidae (five species), and Ictaluridae (four species).

Eleven metrics were developed for evaluating the biotic integrity of streams in this ecoregion (Table 15; Figure 13). Scoring for the intolerant species metric was modified (only scores of 5 or 1 instead of 5, 3, or 1 can be assigned) since the most intolerant species collected in any individual stream was one. The inclusion of this metric (with its modified scoring) was considered appropriate since intolerant species were collected from one-half of the streams in this ecoregion.

Discussion

When statewide criteria (Twidwell and Davis 1989) were applied to the least disturbed reference streams only 37% of the streams rated high or greater (Table 16). No stream rated exceptional despite the fact these were least disturbed streams selected using a screening process. If any streams were candidates for an exceptional rating, it should have been one of these. In contrast, 79% of the streams were rated as high or exceptional when evaluated with the regional criteria. The regional criteria consistently rated the reference streams higher than the statewide criteria, and the higher ratings appear justified as the reference streams did not receive

TABLE 13.—Scoring criteria developed to assess stream fish assemblages in the South Central and Southern Humid, Mixed Land Use Region (Ecoregions 33 and 35).

Metric	Scoring Criteria 5	3	1
1. Total number of fish species		See Figure 12	
2. Number of native cyprinid species	>4	2-4	<2
3. Number of benthic invertivore species	>4	3-4	<3
4. Number of sunfish species	>4	3-4	<3
5. Number of intolerant species	>3	2-3	<2
6. % of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
7. % of individuals as omnivores	<9%	9-16%	>16%
8. % of individuals as invertivores	>65%	33-65%	<33%
9. % of individuals as piscivores	>9%	5-9%	<5%
10. Number of individuals in sample			
a. Number of individuals/seine haul	>28	14-28	<14
b. Number of ind/min electrofishing	>7.3	3.6-7.3	<3.6
11. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
12. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: ≥52 Exceptional; 42-51 High; 36-41 Intermediate; <36 Limited

permitted discharges and had fewer watershed disturbances at the time of sampling.

Rankings using statewide criteria most closely correspond with the results of the regional criteria developed for the South Central and Southern Humid, Mixed Land Use Region. Statewide criteria results were quite different from the regional criteria results for the other regions (Table 16) and showed an overall decline in total score in an east to west direction (Figure 14). Even though the regional criteria better represent the least disturbed streams overall, criteria for several of the ecoregions still need fine tuning. Forty percent of the Southern Deserts reference streams rated as intermediate or less. This is likely a function of the small sample size (only five streams), but does warrant a closer look.However, using statewide criteria, 60% of these collections rate as intermediate or less. Central Texas Plateau reference streams also had a disparate percentage (33%) of streams rating as intermediate or less when evaluated with the regional criteria. Once again this may be a function of a relatively small sample size (nine streams), but more likely actually reflects the true conditions given the higher percentages of non-native species encountered in these streams and consequently the likelihood of greater disturbance. By comparison, application of statewide criteria in this ecoregion results in 67% of the streams rating as intermediate or less. The Subhumid Agricultural Plains was the only region where the regional criteria yielded limited aquatic life use ratings (Bluff and Deer creeks). These ratings were not related to membership in a specific ecoregion as the streams were located in two different ecoregions (ecoregions 27 and 32). Benthic macroinvertebrate data indicated these two streams had the two lowest mean point scores of all the least disturbed reference streams sampled within the Subhumid Agricultural Plains (Bayer et al. 1992). Mean point scores are based

TABLE 14.—Fish species collected from the Western Gulf Coastal Plain (Ecoregion 34).

Species	Common Name
Lepisosteus oculatus	Spotted gar
Lepisosteus osseus	Longnose gar
Anguilla rostrata	American eel
Dorosoma cepedianum	Gizzard shad
Cyprinella lutrensis	Red shiner
Cyprinella venusta	Blacktail shiner
Cyprinus carpio	Common carp
Opsopoeodus emiliae	Pugnose minnow
Pimephales vigilax	Bullhead minnow
Ameiurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Noturus gyrinus	Tadpole madtom
Pylodictis olivaris	Flathead catfish
Aphredoderus sayanus	Pirate perch
Gambusia affinis	Western mosquitofish
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis humilis	Orangespotted sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Etheostoma gracile	Slough darter

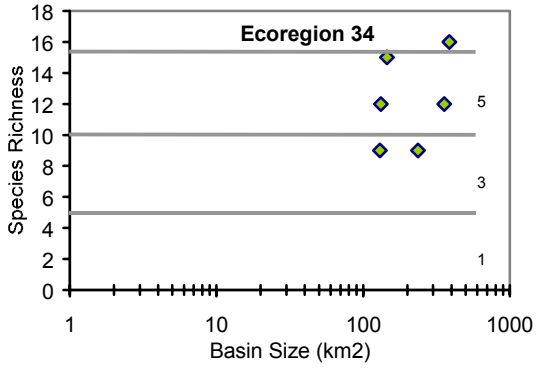

FIGURE 13. Fish species richness versus drainage basin size in Western Gulf Coastal Plain streams.

upon species richness, standing crop, the Ephemeroptera: Plecoptera: Trichoptera index, species diversity, equitability, and community trophic structure (Twidwell and Davis 1989). Given the benthic macroinvertebrate analysis, the limited aquatic life use ratings appear appropriate. A comparison was conducted between statewide and regional criteria on streams sampled by TNRCC personnel during receiving water assessments (Table 17). One hundred eighteen stream stations dating back to 1988 were analyzed using both criteria. Stream stations

TABLE 15.—Scoring criteria developed to assess stream fish assemblages in the Western Gulf Coastal Plain (Ecoregion 34).

Metric	Scoring Criteria 5	3	1
1. Total number of fish species		See Figure 13	
2. Number of native cyprinid species	>2	2	<2
3. Number of benthic invertivore species	>1	1	0
4. Number of sunfish species	>3	2-3	<2
5. Number of intolerant species	>1	-	0
6. % of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
7. % of individuals as omnivores	<9%	9-16%	>16%
8. % of individuals as invertivores	>65%	33-65%	<33%
9. Number of individuals in sample			
a. Number of individuals/seine haul	>174.7	87.4-174.7	<87.4
b. Number of ind/min electrofishing	>7.7	3.9-7.7	<3.9
10. % of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
11. % of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

AQUATIC LIFE USE: ≥49 Exceptional; 39-48 High; 31-38 Intermediate; <31 Limited

TABLE 16.—Comparison of statewide versus regional index of biotic integrity scoring criteria results when applied to least disturbed reference streams.

SOUTHERN DESERTS (ECOREGION 24)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	40%	Exceptional (n=0)	-	-	-	-
High	40%	20%	High (n=2)	50%	50%	0%	0%
Intermediate	20%	40%	Intermediate (n=1)	0%	0%	100%	0%
Limited/Intermediate	20%	-	Limited/Intermediate (n=1)	100%	0%	0%	0%
Limited	20%	0%	Limited (n=1)	0%	0%	100%	0%

WESTERN HIGH PLAINS AND SOUTHWESTERN TABLELANDS (ECOREGIONS 25 AND 26)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	40%	Exceptional (n=0)	-	-	-	-
High	0%	40%	High (n=0)	-	-	-	-
Intermediate	20%	20%	Intermediate (n=1)	100%	0%	0%	0%
Limited/Intermediate	80%	-	Limited/Intermediate (n=4)	25%	50%	25%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

SUBHUMID AGRICULTURAL PLAINS (ECOREGIONS 27,29,32)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	11%	Exceptional (n=0)	-	-	-	-
High	26%	53%	High (n=5)	40%	40%	20%	0%
Intermediate/High	26%	-	Intermediate/High (n=5)	0%	100%	0%	0%
Intermediate	37%	26%	Intermediate (n=7)	0%	43%	29%	29%
Limited/Intermediate	11%	-	Limited/Intermediate (n=2)	0%	0%	100%	0%
Limited	0%	11%	Limited (n=0)	-	-	-	-

CENTRAL TEXAS PLATEAU (ECOREGION 30)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	33%	Exceptional (n=0)	-	-	-	-
High/Exceptional	11%	-	High/Exceptional (n=1)	100%	0%	0%	0%
High	11%	33%	High (n=1)	100%	0%	0%	0%
Intermediate/High	11%	-	Intermediate/High (n=1)	0%	100%	0%	0%
Intermediate	67%	33%	Intermediate (n=6)	17%	33%	50%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

SOUTHERN TEXAS PLAINS (ECOREGION 31)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	25%	Exceptional (n=0)	-	-	-	-
High	0%	75%	High (n=0)	-	-	-	-
Intermediate	100%	0%	Intermediate (n=4)	25%	75%	0%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

SOUTH CENTRAL AND SOUTHERN HUMID, MIXED LAND USE REGION (ECOREGIONS 33 AND 35)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	36%	Exceptional (n=0)	-	-	-	-
High/Exceptional	21%	-	High/Exceptional (n=3)	33%	67%	0%	0%
High	71%	64%	High (n=10)	40%	60%	0%	0%
Intermediate	7%	0%	Intermediate (n=1)	0%	100%	0%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

WESTERN GULF COASTAL PLAIN (ECOREGION 34)

Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Regional Criteria: Exceptional	Regional Criteria: High	Regional Criteria: Intermediate	Regional Criteria: Limited
Exceptional	0%	17%	Exceptional (n=0)	-	-	-	-
High	17%	50%	High (n=1)	100%	0%	0%	0%
Intermediate	83%	33%	Intermediate (n=5)	0%	60%	40%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

TABLE 17.—Comparison of statewide versus regional index of biotic integrity scoring criteria results when applied to Texas Natural Resource Conservation receiving water assessment data.

SUBHUMID AGRICULTURAL PLAINS (ECOREGIONS 27,29,32)

					Regional Criteria		
Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Exceptional	High	Intermediate	Limited
Exceptional	0%	15%	Exceptional (n=0)	-	-	-	-
High	7%	33%	High (n=2)	100%	0%	0%	0%
Intermediate	70%	48%	Intermediate (n=19)	11%	42%	47%	0%
Limited/Intermediate	19%	-	Limited/Intermediate (n=5)	0%	20%	80%	0%
Limited	4%	4%	Limited (n=1)	0%	0%	0%	100%

CENTRAL TEXAS PLATEAU (ECOREGION 30)

					Regional Criteria		
Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Exceptional	High	Intermediate	Limited
Exceptional	0%	0%	Exceptional (n=0)	-	-	-	-
High	0%	0%	High (n=0)	-	-	-	-
Intermediate	100%	100%	Intermediate (n=2)	0%	0%	100%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

SOUTHERN TEXAS PLAINS (ECOREGION 31)

					Regional Criteria		
Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Exceptional	High	Intermediate	Limited
Exceptional	0%	0%	Exceptional (n=0)	-	-	-	-
High	0%	50%	High (n=0)	-	-	-	-
Intermediate	50%	50%	Intermediate (n=1)	0%	100%	0%	0%
Limited/Intermediate	50%	-	Limited/Intermediate (n=1)	0%	0%	100%	0%
Limited	0%	0%	Limited (n=0)	-	-	-	-

SOUTH CENTRAL AND SOUTHERN HUMID, MIXED LAND USE REGION (ECOREGIONS 33 AND 35)

					Regional Criteria		
Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Exceptional	High	Intermediate	Limited
Exceptional	0%	2%	Exceptional (n=0)	-	-	-	-
High/Exceptional	2%	-	High/Exceptional (n=1)	0%	100%	0%	0%
High	22%	29%	High (n=13)	8%	77%	15%	0%
Intermediate/High	15%	-	Intermediate/High (n=9)	0%	67%	33%	0%
Intermediate	48%	59%	Intermediate (n=28)	0%	21%	61%	18%
Limited/Intermediate	8%	-	Limited/Intermediate (n=5)	0%	20%	60%	20%
Limited	5%	10%	Limited (n=3)	0%	0%	67%	33%

WESTERN GULF COASTAL PLAIN (ECOREGION 34)

					Regional Criteria		
Aquatic Life Use	Statewide Criteria	Regional Criteria	Statewide Criteria	Exceptional	High	Intermediate	Limited
Exceptional	0%	10%	Exceptional (n=0)	-	-	-	-
High/Exceptional	2%	-	High/Exceptional (1)	100%	-	-	-
High	12%	43%	High (n=6)	17%	83%	0%	0%
Intermediate/High	8%	-	Intermediate/High (n=4)	25%	75%	0%	0%
Intermediate	39%	37%	Intermediate (n=19)	10%	53%	37%	0%
Limited/Intermediate	25%	-	Limited/Intermediate (n=12)	0%	25%	58%	17%
Limited	14%	10%	Limited (n=7)	0%	0%	57%	43%

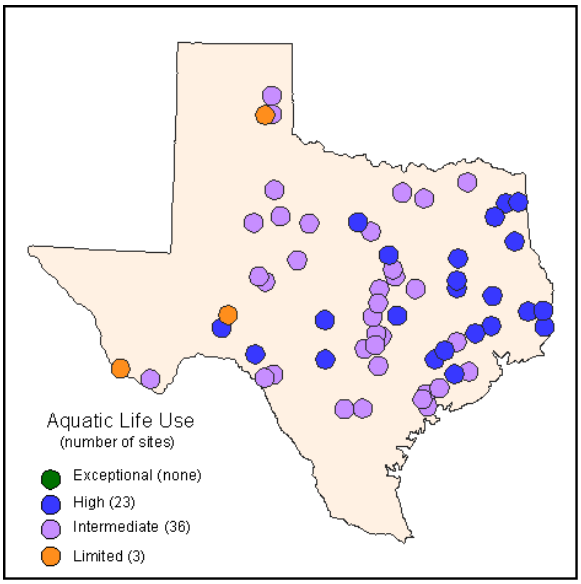

FIGURE 14.—Aquatic life use designations for least disturbed reference streams based upon statewide criteria.

that yielded fewer than six fish species and/or 50 individuals were not included in an attempt to eliminate inadequate sampling efforts. No data were available from the Southern Deserts or Western High Plains and Southwestern Tablelands. Overall, results from the regional criteria were equal to or slightly higher than the statewide criteria results. Once again, the closest similarity to the statewide criteria results werethose from the South Central and Southern Humid, Mixed Land Use Region. Streams in these ecoregions have a fauna most similar to that from which the IBI was originally developed.

Only two receiving water assessment stations were available from the Central Texas Plateau. As noted previously IBI scoring criteria developed for this ecoregion demonstrated some possible weaknesses (a greater than expected percentage of the least disturbed reference streams rated as intermediate or less). This ecoregion is one where the regional metrics should be used with caution, but appear to be more appropriate than the statewide criteria. The regional metrics developed for the Southern Deserts and Southern Texas Plains should mostly be used as a guide in developing site-specific criteria. Individuals performing stream fish assemblage analysis in these ecoregions would be well advised to develop site-specific criteria because of our limited sample size, the higher percentage of least disturbed reference streams rating as intermediate in the Southern Deserts, and the lack of clear similarity among fish collections in the Southern Texas Plains. Regional metrics for the other divisions of the state appear to be adequate and can be reliably used together with professional judgment to assess Texas stream fish assemblages.

Further validation of these proposed metrics and scoring criteria are planned on stream fish assemblage data collected from ninety-one streams sampled in ecoregions 32, 33, and 35. Extensive water quality and habitat data was collected in each of these streams (which were classified as either rural or urban) to serve as independent evaluators of the stream quality prior to applying the IBI metrics to the fish community. This exercise will not only provide additional validation but will also provide the means of distinguishing which metrics exhibit the greatest responsiveness to various disturbances (see Lyons et al. 2001 and McCormick et al. 2001). Variability of IBI scores among seasons and years and among longitudinally spaced sites on the same stream will also be tested using a number of existing data sets.

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APPENDIX A

Site Descriptions

Appendix A. Site descriptions of least disturbed reference streams used to develop a regionalized index of biotic integrity for Texas.

Ecoregion 24 - Southern Deserts

Live Oak Creek

Live Oak Creek lies within the Rio Grande Basin. The sample site was located at IH 10 northeast of Sheffield in west Crockett County ($30^0$44'32" N; $101^0$40'24" W).

Drainage Basin Size - 502 km^2

Soil Types - The creek follows a narrow band of Frio silty clay loam. This band is surrounded by Crawford stony clay (Kocher et al. 1915).

Flora - The watershed lies within the Mesquite-Juniper Brush association (Frye et al. 1984).

Land Use - Crockett County is a major sheep and Angora goat producing county (Kingston 1991).

Stream Characteristics - Base flow used to be provided by Live Oak Springs located 16 km northeast of Sheffield; however, this moderately large spring may no longer exist (Brune 1975). Some small springs were observed during the survey in the vicinity of IH 10. Local landowners indicated that the stream always flows at this site. Measured stream discharge was 2.0 ft^3/s. The creek had moderately long shallow pools interspersed with frequent riffles. Moderately deep pools occasionally occurred. The substrate was primarily comprised of gravel and rubble interspersed with sand and some areas of exposed bedrock.

Terlingua Creek

Terlingua Creek lies within the Rio Grande Basin. The sample site was located on the Big Bend National Park in southwest Brewster County ($29^0$11'00" N; $103^0$33'10" W).

Drainage Basin Size - 552 km^2

Soil Types - Soils at the sample site are of the Glendale-Anthony-Toyah association. These soils are deep, nearly level, calcareous, and located on the flood plains. The majority of the soils in the watershed, including the upper reach, are of the Badland-Vieja association. Bare clay, volcanic ash outcrop, and shallow, rolling calcareous soils on basins comprise this association (U.S. Department of Agriculture 1973).

Flora - The watershed lies within the Creosotebush-Lechuguilla Shrub association (Frye et al. 1984).

Land Use - Most of the watershed is used as rangeland and wildlife habitat (U.S. Department of Agriculture 1973). Nearly all of the county's annual agricultural income comes from cattle, sheep, and goats. Tourism and hunting also contribute to the economy (Kingston 1991).

Stream Characteristics - The stream characteristics were not described due to heavy rainfall the night prior to sampling which increased the discharge considerably above what typically passes through. The dominant substrate was a mixture of sand and small gravel.

Alamito Creek

Alamito Creek lies within the Rio Grande Basin. The sample site was located at FM 170 southeast of Presidio in south Presidio County ($29^0$31'15" N; $104^0$17'40" W).

Drainage Basin Size - 1041 km^2

Soil Types - Soils at the sample site are of the Glendale-Anthony-Toyah association. These soils are deep, nearly level, calcareous, and located on the flood plains. This association makes up a very minor part of the watershed. The creek begins in the Lozier association and traverses the Nickel-Canutio association before finally reaching the sample site. Soils in the Lozier association are very shallow, hilly, steep, calcareous, and located on limestone hills. Deep to shallow, undulating to rolling,

calcareous, gravelly soils on basins and valleys comprise the Nickel-Canutio association (U.S. Department of Agriculture 1972).

Flora - The sample site is located in the Tobosa-Black Grama Grassland association. The upper reach lies within the Creosotebush-Lechuguilla Shrub association (Frye et al. 1984).

Land Use - Most of the watershed is used as rangeland and wildlife habitat (U.S. Department of Agriculture 1972). Most of the county's annual agricultural income comes from cattle and goats. Income from tourism and hunting leases are major economic factors (Kingston 1991).

Stream Characteristics - The stream was comprised of shallow to moderately deep pools, shallow runs, and riffles. Measured stream discharge was 0.7 ft^3/s. Stream bend development was moderate. The substrate consisted of gravel and sand with some rubble and boulders.

Independence Creek

Independence Creek lies within the Rio Grande Basin. The sample site was located at SH 349 south of Sheffield in northeast Terrell County ($30^0$27'36" N; $101^0$49'28" W).

Drainage Basin Size - 1935 km^2

Soil Types - The creek follows a band of the Sanderson-Reagan association. These soils are nearly level to gently sloping, deep gravelly loams, gravelly clay loams, and silty clay loams. This band is surrounded by the Ector Rock Outcrop association. Moderately steep to steep, very shallow stony loams, stony clay loams, and rock outcrops comprise this association (Turner and Fox 1974).

Flora - The watershed lies within the Mesquite-Juniper Brush association (Frye et al. 1984).

Land Use - Much of the watershed is used for rangeland even though the hazard of water erosion is severe in the Ector Rock Outcrop association if the soil is not protected by a grass cover (Turner and Fox 1974). Terrell County is among the leading counties in the state in sheep and goat production (Kingston 1987).

Stream Characteristics - A moderately large (1 to 10 ft^3/s) spring is located a short distance downstream from the sampling site; however, no upstream springs are noted by Brune (1975). Measured stream discharge was 17.4 ft^3/s. The creek was mostly comprised of wide moderately shallow runs interspersed with riffles. Moderately deep glides were rarely encountered. Bend definition was poor. The dominant substrate was gravel with some rubble.

Devils River

The Devils River lies within the Rio Grande Basin. The sample site was located near Dolan Creek on the Devils River State Natural Area in east Val Verde County ($29^0$54'00" N; $100^0$59'52" W).

Drainage Basin Size - 9839 km^2

Soil Types - The River follows a narrow band of the Dev-Rio Diablo association upstream of the sample site. These soils are deep, loamy, clayey, gravelly, and are located on bottomlands and terraces. The predominant soil association of the watershed and the one in which the sample site is located is the Ector-Rock Outcrop. This association is comprised of very shallow-to-shallow, loamy, stony soils, and exposed limestone bedrock located in the uplands (Golden et al. 1982).

Flora - The watershed lies within the Mesquite-Juniper-Live Oak Brush association (Frye et al. 1984).

Land Use - The Devils River State Natural Area has been set aside to preserve the natural heritage of the region as well as protect the Devils River. The watershed is used almost exclusively for wildlife and range (Golden et al. 1982). Nearly all of the county's annual agricultural income comes from sheep, Angora goats, and cattle. Tourism contributes substantially to the economy (Kingston 1991).

Stream Characteristics - Several springs ranging in size from moderately large (1 to

10 ft^3/s) to large (10 to 100 ft^3/s), including Dolan Springs and Finegan Springs, exist along the river (Brune 1975). Measured stream discharge was 110 ft^3/s. The river was very wide with deep pools, shallow to moderately deep runs, and riffles. Channel sinuosity was moderate with two well developed bends in the study reach. The dominant substrate was bedrock with a small percentage of gravel or larger rocks. Instream cover was mainly provided by rock ledges although in some areas aquatic macrophytes were common.

Ecoregions 25 and 26 - Western High Plains and Southwestern Tablelands

Saddlers Creek

Saddlers Creek lies within the Red River Basin. The sample site was located on the Matthews Ranch north of Clarendon in northeast Donley County ($35^0$02'52" N; $100^0$47'04" W).

Drainage Basin Size -174 km^2

Soil Types - Soils at the sample site are of the Obaro-Aspermont-Quinlan association. These soils are deep to shallow, gently sloping to steep, moderately alkaline, loamy, and located on uplands. The upper reach traverses the Mobeetie-Veal-Potter association, and is comprised of deep to very shallow, gently sloping to steep, moderately alkaline, loamy soils on uplands (Williams and Crump 1980).

Flora - The sample site lies within a narrow band of the Cottonwood-Hackberry-Saltcedar Brush/Woods association which follows the creek. The majority of the watershed is the Sandsage-Mesquite Brush association (Frye et al. 1984).

Land Use - Most of the watershed is used as rangeland (Williams and Crump 1980). Beef cattle is the county's top agricultural revenue source. Where cultivated, the major crops include cotton, hay, wheat, peanuts, and grain sorghums (Kingston 1991).

Stream Characteristics - Measured stream discharge was 2.8 ft^3/s. The stream was comprised of shallow runs and riffles over a predominantly sandy substrate. Pools were absent and stream bend development was extremely poor.

Lelia Lake Creek

Lelia Lake Creek lies within the Red River Basin. The sample site was located at FM 2471 northeast of Lelia Lake in west Donley County ($34^0$56'07" N; $100^0$41'47" W).

Drainage Basin Size - 207 km^2

Soil Types - Soils at the sample site are of the Springer-Lincoln-Likes association. These soils are deep, nearly level to sloping, sandy, and located on uplands and bottomlands (Williams and Crump 1980).

Flora - The sample site lies within the Sandsage-Harvard Shin Oak Brush association. The upper reach traverses the Mesquite Scrub/Grassland association and areas dominated by crops (Frye et al. 1984).

Land Use - Most of the watershed is used as rangeland (Williams and Crump 1980). Beef cattle is the county's top agricultural revenue source. Where cultivated, the major crops include cotton, hay, wheat, peanuts, and grain sorghums (Kingston 1991).

Stream Characteristics - Measured stream discharge was 4.5 ft^3/s. Pools were absent and stream bend development was poor. The stream flowed as a uniformly wide shallow run with some riffles over a sand and gravel substrate.

Whitefish Creek

Whitefish Creek lies within the Red River Basin. The sample site was located at a private road off FM 2695 north of Hedley in northeast Donley County ($35^0$03'57" N; $100^0$36'35" W).

Drainage Basin Size - 306 km^2

Soil Types - Soils at the sample site are of the Mobeetie-Veal-Potter association. These soils are deep to very shallow, gently sloping to steep, moderately alkaline, loamy soils on uplands (Williams and Crump 1980).

Flora - The sample site lies within a narrow band of the Cottonwood-Hackberry-Saltcedar Brush/Woods association which follows the creek. The majority of the watershed is the Sandsage-Mesquite Brush association (Frye et al. 1984).

Land Use - Most of the watershed is used as rangeland (Williams and Crump 1980). Beef cattle is the county's top agricultural revenue source. Where cultivated, the major crops include cotton, hay, wheat, peanuts, and grain sorghums (Kingston 1991).

Stream Characteristics - Measured stream discharge was 1.2 ft^3/s. Pool and bend development were poor. The stream was comprised of shallow runs with numerous riffles over a predominantly sandy substrate.

McClellan Creek

McClellan Creek lies within the Red River Basin. The sample site was located at FM 273 north of McClean in south Gray County ($35^0$19'41" N; $100^0$36'31" W).

Drainage Basin Size - 534 km^2

Soil Types - Soils at the sample site are of the Likes-Springer-Tivoli association. Rolling sandy land and dunes comprise this association (Williams and Welker 1966).

Flora - The creek follows a narrow band of Cottonwood-Hackberry-Saltcedar Brush/Woods association. The dominant association of the watershed is the Mesquite Shrub/Grassland (Frye et al. 1984).

Land Use - Soils in the watershed are highly susceptible to wind erosion and are low in fertility (Williams and Welker 1966). Most of the county's annual agricultural income comes from fed cattle and stocker operations. Chief crops include wheat, grain sorghums, corn, hay, and forage (Kingston 1991).

Stream Characteristics - Measured stream discharge was 2.1 ft^3/s. Stream bend development was poor as the stream was essentially a uniformly wide shallow run. The substrate was comprised of fine sand with a small percentage of gravel.

Wolf Creek

Wolf Creek lies within the Canadian River Basin. The sample site was located at FM 1454 east of Lipscomb in east Lipscomb County ($36^0$15'09" N; $100^0$07'51" W).

Drainage Basin Size - 2124 km^2

Soil Types - Soils at the sample site are of the Devol-Tivoli-Likes association. These soils are deep, gently sloping to steep, and coarse (Williams 1975).

Flora - The creek flows between the Mesquite Shrub/Grassland and Sandsage-Harvard Shin Oak Brush associations (Frye et al. 1984).

Land Use - Soils of the watershed are susceptible to wind blowing and are mostly used for rangeland (Williams 1975). Cow-calf and stocker operations are the county's top agricultural revenue producers. Where cultivated, the major crops include wheat, milo, and forage sorghums (Kingston 1991).

Stream Characteristics - Wolf Creek was essentially a uniformly wide run over a homogeneous sand substrate. Pools were absent despite the presence of numerous poorly defined bends. Measured stream discharge was 2.3 ft^3/s.

Ecoregions 27, 29, and 32 - Subhumid Agricultural Plains

Geronimo Creek

Geronimo Creek lies within the Guadalupe River Basin. The sample site was located at Haberle Road north of Seguin in north Guadalupe County ($29^0$38'02" N; $097^0$56'38" W).

Drainage Basin Size - 62 km^2

Soil Types - Soils at the sample site are of the Branyon-Barbarosa-Lewisville association. These soils are deep, moderately well to well drained, nearly level to gently sloping, clayey, and located on stream terraces (Ramsey and Bade 1977).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Much of the watershed is used as cropland. Major crops include grain sorghums, corn, wheat, oats, cotton, peanuts, pecans, Christmas trees, peaches, and nursery plants (Kingston 1991).

Stream Characteristics - Geronimo Springs are located about 2.1 km upstream of the sampling site and are classified as medium sized (0.1 to 1 ft^3/s) by Brune (1975). Measured stream discharge was 8.6 ft^3/s. Stream bend development was moderate. The creek was comprised of long deep pools, shallow to moderately deep glides, and occasional riffles and runs. The predominant substrate was coarse gravel and rubble. Emergent and floating macrophytes were fairly common.

Willis Creek

Willis Creek lies within the Brazos River Basin. The sample site was located at FM 971 southwest of Granger in northeast Williamson County ($30^0$42'38" N; $097^0$27'30" W).

Drainage Basin Size -65 km^2

Soil Types - Soils at the sample site are of the Branyon-Houston Black-Burleson association. These soils are mildly to moderately alkaline, deep, calcareous and noncalcareous, clayey, formed in clayey alluvium and marine clays and shales, and located on ancient stream terraces and uplands. The upper reach traverses the Austin-Houston Black-Castephen association. Deep to shallow, calcareous clayey soils formed in marine chalk, marl, shale, and clays, located on uplands comprise this association (Werchan and Coker 1983).

Flora - The upper reach traverses the Silver Bluestem-Texas Wintergrass Grassland association before reaching the sample site, where the vegetation is dominated by crops (Frye et al. 1984).

Land Use - Chief crops include grain sorghum, cotton, wheat, corn, and oats (Kingston 1991).

Stream Characteristics - The creek was comprised of small shallow pools, glides, and riffles. Stream bend development was moderate. The substrate was primarily comprised of sand with some gravel. Measured stream discharge was less than 0.1 ft^3/s.

Bluff Creek

Bluff Creek lies within the Brazos River Basin. The sample site was located at an unmarked county road northwest of Crawford in west McLennan County ($31^0$33'15" N; $097^0$28'42" W).

Drainage Basin Size - 73 km^2

Soil Types - Prevailing soils are reddish-brown to black crumbly clays of the Denton, San Saba, Tarrant, and Crawford series. The soil lies over limestone and ranges in depth from shallow to deep (Templin et al. 1958).

Flora - The watershed lies within the Oak-Mesquite-Juniper Parks/Woods association (Frye et al. 1984).

Land Use - Much of the county's annual agricultural income comes from cattle, hogs, and milk. Principal crops include corn, grain sorghums, wheat, oats, cotton, and hay (Kingston 1991).

Stream Characteristics - The creek was comprised of shallow to moderately deep pools, riffles, and occasional shallow runs and glides. Gravel was the dominant substrate with occasional areas of exposed bedrock. Measured stream discharge was less than 0.1 ft^3/s. Stream bend development was moderate.

Ioni Creek

Ioni Creek lies within the Brazos River Basin. The sample site was located at U.S. Highway 180 north of Strawn in west Palo Pinto County ($32^0$44'07" N; $098^0$23'48" W).

Drainage Basin Size - 78 km^2

Soil Types - The creek follows a narrow band of the Bosque-Santo association. Soils in this association are located on flood plains and are deep, nearly level to gently sloping, and loamy. This narrow band is

surrounded by the Palopinto-Set-Hensley association, which is comprised of deep, nearly level to steep, loamy and clayey, stony soils located on uplands (Moore 1981).

Flora - The watershed lies within the Post Oak Parks/Woods association (Frye et al. 1984).

Land Use - Land in the Bosque-Santo association is mostly used for pasture. The Palopinto-Set-Hensley association is poorly suited for crops, pasture, and urban uses because of its slope, stoniness, and depth to rock. It is moderately well suited for range (Moore 1981). Livestock, mostly beef cattle, is the county's prime revenue producer. Chief crops include wheat, oats, grain sorghums, peanuts, and cotton (Kingston 1991).

Stream Characteristics - The stream was not flowing during sampling; however, a large deep permanent spring-fed pool was present. About 50% of the substrate was gravel size or larger.

Wilson Creek

Wilson Creek lies within the Trinity River Basin. The sample site was located at County Road 158 west of McKinney in southwest Collin County ($33^0$13'04" N; $096^0$41'37" W).
Drainage Basin Size - 83 km^2

Soil Types - The sample site was at a point where the creek enters the Trinity-Frio association. These soils are deep, nearly level, clayey and loamy, and located on flood plains. The upper reach traverses the Houston Black-Austin association, which is characterized by gently sloping to sloping, clayey soils that are deep over marl and chalk, and located on uplands (Hanson and Wheeler 1969).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Land in the lowlands protected from frequent flooding is mainly used for crops. These soils are subject to scouring where cover is lacking. Areas susceptible to flooding are either cut for hay or grazed. In the past about 70% of the upland soils were cultivated. Water erosion is moderate to severe on these soils where the slope is greater than one percent (Hanson and Wheeler 1969). Chief crops include sorghums, wheat, hay, and cotton (Kingston 1991).

Stream Characteristics - The stream was comprised of moderately large and deep pools, runs, and numerous riffles. The predominant substrate in the riffles and runs was gravel with some rubble; whereas, the pools had a higher percentage of clay although gravel was present in significant amounts. Measured stream discharge was 4.8 ft^3/s. Stream bends were well developed.

Bluff Creek

Bluff Creek lies within the Colorado River Basin. The sample site was located at FM 1606 west of Ira in southwest Scurry County ($32^0$35'29" N; $101^0$03'02" W).

Drainage Basin Size - 109 km^2

Soil Types - Soils at the stream sample site are of the Miles-Cobb association. They are deep to moderately deep, nearly level to gently sloping, well drained, moderately permeable, loamy soils. The majority of the upstream reach traverses through soils of the Rowena-Abilene-Olton association. These are deep, nearly level to gently sloping, well drained, moderately permeable, loamy soils (Dixon et al. 1973).

Flora - The watershed lies within the Mesquite-Lotebush Brush association (Frye et al. 1984).

Land Use - Scurry County is the nation's leading oil-producing county, and cotton is the major crop grown (Kingston 1987). Other chief crops include hay, grain sorghums, ensilage, wheat, and pecans (Kingston 1991). In the past cultivated crops have comprised 70-85% of the two soil associations found within the drainage basin, with range making up the rest (Dixon et al. 1973).

Stream Characteristics - The stream was comprised of moderately deep pools,

shallow glides, and numerous gravel riffles. Sand was the dominant substrate in the glides and pools. Discharge was measured at 0.2 ft^3/s. Stream bends were not well defined.

Auds Creek

Auds Creek lies within the Sulpher River Basin. The sample site was located at FM 1184 south of Paris in south Lamar County ($33^0$32'00" N; $095^0$34'30" W).

Drainage Basin Size - 117 km^2

Soil Types - Soils at the sample site are of the Trinity-Kaufman association. These soils are nearly level, very slowly permeable, clayey, and located on flood plains. The upper reach of the creek as well as a broad area surrounding the Trinity-Kaufman association is of the Houston Black-Leson-Heiden association. Nearly level to gently sloping, very slowly permeable, clayey soils on uplands comprise this association (Ressel 1979).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Land is mainly used for crops, pasture, and hay (Ressel 1979). Chief crops include hay, wheat, soybeans, and cotton (Kingston 1991).

Stream Characteristics - The stream was comprised of long, narrow shallow pools, glides, runs, and a few riffles. The predominant substrate was firm clay with a higher percentage of gravel in riffles. Measured stream discharge was 1.3 ft^3/s. Stream bends were poorly developed.

Deadman Creek

Deadman Creek lies within the Brazos River Basin. The sample site was located on the Stollins Ranch off FM 1082 north of Abilene in southeast Jones County ($32^0$35'03" N; $099^0$38'27" W).

Drainage Basin Size - 130 km^2

Soil Types - Soils are of the Tarrant-Valera association, which are shallow to moderately deep, well drained, nearly level to sloping, dark grayish-brown and dark-brown clays and silty clays over limestone (Rogers et al. 1972).

Flora - Vegetation in the watershed is predominantly crops (Frye et al. 1984).

Land Use - Much of the Tarrant-Valera association is used for range and crops (Rogers et al. 1972). Water erosion is a hazard (Rogers et al. 1972). Major crops include cotton, wheat, milo, hay, watermelons, and peanuts (Kingston 1991).

Stream Characteristics - Deadman Creek ceases to flow during normal dry weather conditions; however, moderately deep pools persist. Some of the perennial pools were quite extensive in length and moderately wide. At the time of sampling, stream discharge was measured at 0.1 ft^3/s. A few riffles were located between the pools; however mostly glides were present. Substrate in the pools was silt whereas gravel, rubble, and boulders made up the riffles. Substrate in the glides was a mixture of that found in the pools and riffles. Some areas had extensive stands of cattail *Typha* sp. Stream bends were not well defined.

Colony Creek

Colony Creek lies within the Brazos River Basin. The sample site was located at FM 570 south of Ranger in north Eastland County ($32^0$23'19" N; $098^0$40'05" W).

Drainage Basin Size - 140 km^2

Soil Types - Soils at the sample site are of the Truce-Thurber-Leeray association. They are nearly level to gently sloping, deep, loamy and clayey soils over limy clay or shale. The upper reach of the creek flows over about an equal amount of the Hensley-Lindy association. Soils in this association are gently sloping, shallow to moderately deep, loamy, and located over limestone (Moore et al. 1977).

Flora - The watershed lies within the Oak-Mesquite-Juniper Parks/Woods association (Frye et al. 1984).

Land Use - In the past the two soil associations over which Colony Creek run

have mostly been used for range. Erosion is a hazard in most cultivated areas (Moore et al. 1977). Top agricultural revenue producers for the county include fed beef, dairy cattle, and turkeys. Major crops include peanuts, hay, wheat, and grain sorghums (Kingston 1991).

Stream Characteristics - Measured stream discharge was 1.4 ft^3/s. Stream bend development was moderate. The stream consisted of shallow and deep pools, and riffles. The substrate was comprised of gravel, cobble, sand, and occasionally exposed bedrock.

Steele Creek

Steele Creek lies within the Brazos River Basin. The sample site was located at an unmarked private road west of Morgan in northeast Bosque County ($32^0$00'54" N; $097^0$37'53" W).

Drainage Basin Size - 140 km^2

Soil Types - Soils at the stream sample site are of the Denton-Purves association. They are moderately deep to shallow, gently sloping to sloping, clayey soils (Stringer 1980).

Flora - The watershed lies within the Silver Bluestem-Texas Wintergrass Grassland and Oak-Mesquite-Juniper Parks/Woods associations (Frye et al. 1984).

Land Use - Soils in the Denton-Purves association are mostly used for cropland (Stringer 1980); however, much of the agricultural income for Bosque County comes from cattle, Angora goats, sheep, and swine. Chief crops include wheat, grain sorghums, oats, hay, corn, and peaches (Kingston 1991).

Stream Characteristics - Stream discharge was measured at 0.7 ft^3/s. Stream bend development was moderate. The stream was comprised of moderately deep pools, occasional shallow runs, and frequent riffles. Bedrock dominated the substrate in the riffles and runs, while bedrock, gravel, and sand were found in the pools.

West Rocky Creek

West Rocky Creek lies within the Colorado River Basin. The sample site was located at FM 853 northeast of Mertzon in northeast Irion County ($31^0$26'37" N; $100^0$45'24" W).

Drainage Basin Size - 150 km^2

Soil Types - Soils at the sample site are of the Angelo-Nuvalde association. These soils are deep, nearly level to gently sloping, loamy, and located on uplands (Wiedenfeld 1986).

Flora - The watershed lies within the Mesquite-Juniper Brush association (Frye et al. 1984).

Land Use - Land within the watershed is mainly used as rangeland (Wiedenfeld 1986). Most of the county's annual agricultural income comes from Angora goats, sheep, and cattle (Kingston 1991).

Stream Characteristics - Measured stream discharge was 1.6 ft^3/s. Although stream bend development was absent, large deep pools were present. Only a few riffles were present. The substrate was mainly comprised of gravel, rubble, and boulders with some areas of bedrock with boulders.

Deer Creek

Deer Creek lies within the Brazos River Basin. The sample site was located at SH 320 west of Marlin in central Falls County ($31^0$16'46" N; $096^0$58'40" W).

Drainage Basin Size - 223 km^2

Soil Types - The creek follows a narrow band of the Ovan-Trinity association. These soils are nearly level, calcareous, very slowly permeable, and clayey. This band is surrounded in near equal amounts by soils in the Houston Black-Heiden and Crockett-Wilson associations. Soils in the Houston Black-Heiden association are nearly level to sloping, calcareous, very slowly permeable, and clayey. Crockett-Wilson association soils are nearly level to gently sloping, noncalcareous, very slowly permeable, and loamy (Wyrick 1978).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Land is mainly used for crops and pasture. Water erosion is a major hazard to the soils of the Houston Black-Heiden and Crockett-Wilson associations (Wyrick 1978). Major crops include corn, grain sorghums, cotton, and small grains (Kingston 1991).

Stream Characteristics - Deer Creek meandered with only moderately defined bends and flow alternated between pools, glides, runs, and riffles. Measured stream discharge was 1.6 ft^3/s. The substrate consisted of a complex of sand, mud, shale, gravel, and rubble (mostly in the riffles and runs).

Neils Creek

Neils Creek lies within the Brazos River Basin. The sample site was located at SH 6 south of Clifton in south Bosque County ($31^0$42'12" N; $097^0$32'07" W).

Drainage Basin Size - 352 km^2

Soil Types - The creek follows a narrow band of the Krum-Sunev association, surrounded by Eckrant-Brackett-Cranfill and Denton-Purves associations. Soils in the Krum-Sunev association are nearly level to gently sloping, clayey, and loamy. Eckrant-Brackett-Cranfill soils are very shallow to deep, gently sloping to steep, clayey, loamy, cobbly, and gravelly. Denton-Purves association soils are moderately deep to shallow, gently sloping to sloping, and clayey (Stringer 1980).

Flora - The watershed lies within the Oak-Mesquite-Juniper Parks/Woods association (Frye et al. 1984).

Land Use - Soils in the Krum-Sunev and Denton-Purves associations are mostly used for cropland, whereas those in the Eckrant-Brackett-Cranfill association are mainly used for rangeland (Stringer 1980). Chief crops include wheat, grain sorghums, oats, hay, corn, and peaches (Kingston 1991).

Stream Characteristics - Measured stream discharge was 7.9 ft^3/s. Stream bend development was moderate and flow was in moderately deep pools, shallow to moderately deep runs, and numerous riffles. Substrate was varied with bedrock and gravel in the riffles, gravel and coarse sand in the runs, and gravel, rubble, and firm mud in the pools.

Cottonwood Creek

Cottonwood Creek lies within the Brazos River Basin. The sample site was located at an unmarked county road southeast of Roby in southwest Fisher County ($32^0$44'11" N; $100^0$22'19" W).

Drainage Basin Size - 554 km^2

Soil Types - The creek follows a narrow band of the Spur-Yahola association. These soils are nearly level, deep, moderately fine to medium textured, moderately permeable, and located in the bottomland. This band is surrounded by the Carey-Woodward association. Gently sloping to moderately sloping, deep to moderately deep, loamy soils comprise this association (Schwartz 1966).

Flora - The upper reach traverses the Mesquite-Lotebush Shrub association before reaching the sample site, where the vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Chief crops include cotton, wheat, grain sorghums, and hay (Kingston 1991).

Stream Characteristics - Measured stream discharge was 0.35 ft^3/s. Stream bend development was poor. The creek was comprised of shallow to moderately deep pools, shallow glides and runs, and riffles. Substrate was predominantly mud/silt, except in the riffles where gravel was dominant.

Clear Creek

Clear Creek lies within the Trinity River Basin. The sample site was located at FM 455 west of Sanger in northwest Denton County ($33^0$21'33" N; $097^0$15'02" W).

Drainage Basin Size - 699 km^2

Soil Types - The creek follows a narrow band of the Frio-Ovan association. These soils are well to moderately well drained, moderately alkaline, nearly level, clayey, and moderately to very slowly permeable. This association is surrounded by the Aledo-Somervell association in the upper watershed, and by the Sanger-Somervell association at the sample site. Soils in the Aledo-Somervell association are well drained, moderately alkaline, gently sloping to sloping, loamy, and moderately permeable. Well drained, moderately alkaline, gently sloping to moderately steep, clayey, loamy, moderately to very slowly permeable soils comprise the Sanger-Somervell association (Ford and Pauls 1980).

Flora - The watershed lies within the Silver Bluestem-Texas Wintergrass Grassland association (Frye et al. 1984).

Land Use - Soils in the Aledo-Somervell association are mostly used as rangeland, whereas soils within the other two associations are used as cropland and rangeland (Ford and Pauls 1980). Beef cattle, horses, poultry, hay, and wheat are the county's top agricultural revenue sources. Nursery crops, grain sorghums, peanuts, cotton, and oats comprise other principal crops (Kingston 1991).

Stream Characteristics - Clear Creek was comprised of large deep pools, shallow to moderately deep runs, and riffles. Sand was the dominant substrate in the pools; whereas, gravel dominated the riffles. Substrate varied in the runs. Some runs were dominated by sand substrate, others by gravel. Stream bend development was moderate to high. Measured stream discharge was 22.7 ft^3/s.

Mill Creek

Mill Creek lies within the Brazos River Basin. The sample site was located at an unmarked county road southwest of Bellville in central Austin County ($29^0$55'43" N; $096^0$17'39" W).

Drainage Basin Size - 751 km^2

Soil Types - Soils at the sample site are of the Trinity association. These soils are nearly level, somewhat poorly drained, and clayey. In the upper reach, this band of Trinity soils is narrow and is surrounded by the Frelsburg-Latium-Crockett and Klump-Carbengle-Brenham associations. Soils in the Frelsburg-Latium-Crockett association are gently to strongly sloping, well to moderately well drained, clayey, and loamy. The Klump-Carbengle-Brenham association is comprised of gently sloping to sloping, well drained, loamy soils (Greenwade 1984).

Flora - The watershed lies within the Post Oak Woods/Forest association (Frye et al. 1984).

Land Use - Much of the watershed is used for rangeland and pastureland. Areas in the upper watershed are also used as cropland (Greenwade 1984). Most of the county's annual agricultural income comes from livestock and poultry. Sorghums, small grains, rice, corn, peanuts, and cotton are the chief crops grown (Kingston 1991).

Stream Characteristics - Mill Creek was comprised of large deep pools, moderately deep glides, shallow runs, and riffles. Stream bends were only moderately developed. The predominant substrate was fine sand with occasional areas of silt over hard clay. Some gravel occurred in the riffles and runs. Measured stream discharge was 3.4 ft^3/s.

Cummins Creek

Cummins Creek lies within the Colorado River Basin. The sample site was located at FM 109 north of Columbus in north central Colorado County ($29^0$44'50" N; $096^0$33'05" W).

Drainage Basin Size - 780 km^2

Soil Types - Soils are typically loamy with cracking, clayey subsoils (Texas State Historical Association 1996).

Flora - The watershed of the upper reach lies within the Post Oak Woods, Forest, and Grassland Mosaic association, whereas the sample site and its surrounding watershed

lies within the Post Oak Woods/Forest association (Frye et al. 1984).

Land Use - Agriculture is centered around rice, corn, and grain sorghums. Cow-calf operations are also important (Kingston 1991).

Stream Characteristics - Measured stream discharge was 0.8 ft^3/s. Stream bends were poorly defined and flow alternated between shallow to moderately deep pools, riffles, and occasional shallow runs. The predominant substrate was fine sand with higher percentages of gravel and rubble in the riffles and runs.

Spring Creek

Spring Creek lies within the Colorado River Basin. The sample site was located at Sherwood Cemetery Road northeast of Mertzon in east Irion County ($31^0$19'39" N; $100^0$44'44" W).

Drainage Basin Size - 782 km^2

Soil Types - The creek follows a narrow band of the Rioconcho-Angelo association. This band is encased within a slightly larger band of the Angelo-Nuvalde association. Soils within both associations are deep, nearly level to gently sloping, and loamy. Rioconcho-Angelo association soils are located on bottomlands and uplands, whereas Angelo-Nuvalde association soils are only found in the uplands (Wiedenfeld 1986).

Flora - The watershed lies within the Mesquite-Juniper Shrub association (Frye et al. 1984).

Land Use - Land within the watershed is mainly used as rangeland (Wiedenfeld 1986). Most of the county's annual agricultural income comes from Angora goats, sheep, and cattle (Kingston 1991).
Stream Characteristics - Stream flow is supported by Spring Creek Springs located about 13 km upstream of the sampling site. These moderately large springs provide annual average flows ranging from 5 to 13 ft^3/s (Brune 1975). Measured stream flow at the sampling site was 17.4 ft^3/s. Stream bend development was absent; however, large deep pools were present as well as several riffles. Runs occurred only rarely. The substrate was mainly comprised of bedrock with areas of gravel and rubble.

Elm Creek

Elm Creek lies within the Colorado River Basin. The sample site was located at an unmarked county road north of Ballinger in north Runnels County ($31^0$47'30" N; $099^0$56'34" W).

Drainage Basin Size - 1173 km^2

Soil Types - The creek follows a narrow band of the Spur-Colorado-Miles association, which is predominantly surrounded by the Portales-Potter-Mereta association. The Spur-Colorado-Miles association is comprised of nearly level to gently sloping, deep, loamy soils located mainly on flood plains but also on outwash plains and old stream terraces. Soils of the Portales-Potter-Mereta association are nearly level to undulating, loamy, moderately deep to very shallow and located over caliche on outwash plains (Wiedenfeld et al.1970).

Flora - The sample site lies within the Mesquite-Lotebush Shrub association. Vegetation in the upper reach of the watershed is dominated by crops (Frye et al. 1984).

Land Use - In the past most of the Spur-Colorado-Miles association has been cultivated, whereas the majority of the Portales-Potter-Mereta association was used as native range (Wiedenfeld et al. 1970). Major crops include cotton, sorghums, and wheat (Kingston 1991).

Stream Characteristics - Measured stream discharge was 0.1 ft^3/s. Stream bends were not well defined. Substrate varied from mud/silt in some of the deep pools, broken bedrock covered with a layer of silt in shallower pools and glides, to gravel and rubble in the riffles.

Ecoregion 30 - Central Texas Plateau

Little Barton Creek

Little Barton Creek lies within the Colorado River Basin. The sample site was located at a private road off SH 71 west of Austin in southwest Travis County ($30^0$17'51" N; $097^0$55'43" W).

Drainage Basin Size - 34 km^2

Soil Types - Soils at the sample site are of the Brackett association. These soils are shallow, gravelly, calcareous, loamy, and overlay interbedded limestone and marl (Werchan et al. 1974).

Flora - The watershed lies within the Live Oak-Ashe Juniper Woods association (Frye et al. 1984).

Land Use - The City of Austin is growing in the direction of Little Barton Creek. In the recent past, this area was used for rangeland with deer and turkey being plentiful (Werchan et al. 1974). Today, urban sprawl is making its way across the area.

Stream Characteristics - Measured stream discharge was 0.2 ft^3/s when sampled; however, flow ceased later in the year. The creek was mostly comprised of shallow to moderately deep pools. When the stream was flowing, the pools were frequently connected by riffles and occasionally by runs. Stream channel sinuosity was high. Substrate was predominantly gravel, rubble, and boulders. Some areas also had bedrock. Silt deposition occasionally occurred in the pools.

Oatmeal Creek

Oatmeal Creek lies within the Brazos River Basin. The sample site was located at FM 1174 south of Bertram in east Burnet County ($30^0$42'11" N; $098^0$03'50" W).

Drainage Basin Size - 41 km^2

Soil Types - Soils at the stream sample site are of the Brackett-Purves-Doss association. These soils are shallow, loamy and clayey (some are stony), undulating, hilly, and located on uplands. The upper reach traverses the Eckrant-Brackett association, which is comprised of very shallow to shallow, clayey and loamy (some are cobbly), undulating, hilly soils on uplands (Dittemore and Allison 1979).

Flora - The watershed lies within the Oak-Mesquite-Juniper Parks/Woods association (Frye et al. 1984).

Land Use - Burnet County is an especially scenic part of central Texas. A series of reservoirs on the Colorado River draw tourists into the county, as do the state parks, hunting facilities, and historic sites. About 95% of the agricultural income of the county comes from cattle, sheep, and goats (Kingston 1987).

Stream Characteristics - Measured stream discharge was less than 0.1 ft^3/s. Stream bend development was moderate. The stream was comprised of deep, long, relatively narrow pools interspersed with riffles and occasional long runs. Surface flow ceased at the downstream end of the lowermost pool included in the survey reach but reappeared about 18 m downstream as a riffle flowing into another long pool. The area of underflow was a thick deposit of gravel and rubble apparently overlying bedrock. Bedrock comprised the substrate in the long run immediately upstream of the lowermost pool. Overall, gravel, rubble, and boulders were the dominant substrate with bedrock and overlying silt providing the remainder.

Little Blanco River

The Little Blanco River lies within the Guadalupe River Basin. The sample site was located at Chick Ranch Road east of Twin Sisters in south Blanco County ($30^0$00'47" N; $098^0$21'12" W).

Drainage Basin Size - 109 km^2

Soil Types - The river follows a band of the Krum-Lewisville association. These soils are deep, clayey, loamy, nearly level to gently sloping, and located on foot slopes and stream terraces. This band is predominantly surrounded by the Brackett-Purves-Doss association, which is

comprised of shallow, loamy and clayey (some are stony), undulating, hilly soils, located on uplands (Dittemore and Allison 1979).

Flora - The watershed lies within the Live Oak-Ashe Juniper Parks association (Frye et al. 1984).

Land Use - Soils of the Krum-Lewisville association are mostly cultivated (Dittemore and Allison 1979). Principal crops include nursery plants, wheat, hay, peaches, and pecans (Kingston 1991).

Stream Characteristics - Pools in the Little Blanco River were long, deep, and moderately wide. Frequent riffles and occasional runs were also present. Limestone bedrock was the dominant substrate with significant amounts of gravel, rubble, and boulders also present. Measured stream discharge was 2.4 ft^3/s. Stream bend development was moderate.

Barton Creek

Barton Creek lies within the Colorado River Basin. The sample site was located at Creeks Edge Parkway in the Barton Creek West Subdivision in west Travis County ($30^0$17'12" N; $097^0$53'02" W).

Drainage Basin Size - 181 km^2

Soil Types - Soils at the sample site are of the Brackett association. These soils are shallow, gravelly, calcareous, loamy, and overlay interbedded limestone and marl (Werchan et al. 1974).

Flora - The watershed lies within the Live Oak-Ashe Juniper Woods association (Frye et al. 1984).

Land Use - The City of Austin is growing in the direction of Barton Creek. In the recent past, this area was used for rangeland with deer and turkey being plentiful (Werchan et al. 1974). Today, urban sprawl is making its way across the area.

Stream Characteristics - Barton Creek Springs are located more than 26 km upstream of the sample site and are classified as moderately large (1 to 10 ft^3/s) by Brune (1975). Measured stream discharge was 0.5 ft^3/s. Stream bend development was moderate. An artificial pool was created by a low water crossing/dam at the downstream end of the study reach. This pool was moderately deep, wide, and very long. Upstream, smaller shallow isolated pools existed. Frequent riffles were also present. More than 50% of the substrate was comprised of gravel, rubble, and boulders.

Rocky Creek

Rocky Creek lies within the Brazos River Basin. The sample site was located at FM 963 west of Oakalla in northeast Burnet County ($30^0$59'05" N; $097^0$55'35" W).

Drainage Basin Size - 243 km^2

Soil Types - Soils at the stream sample site are of the Brackett-Purves-Doss association. These soils are shallow, loamy and clayey (some are stony), undulating, hilly, and located on uplands (Dittemore and Allison 1979).

Flora - The sample site lies within the Oak-Mesquite-Juniper Parks/Woods association. The upper reach flows through the Live Oak-Mesquite-Ashe Juniper Parks associations (Frye et al. 1984).

Land Use - Burnet County is an especially scenic part of central Texas. A series of reservoirs on the Colorado River draw tourists into the county, as do the state parks, hunting facilities, and historic sites. About 95% of the agricultural income of the county comes from cattle, sheep, and goats (Kingston 1987).

Stream Characteristics - Rocky Creek was comprised of long, moderately wide and deep runs, short riffles, and occasional deep glides. Stream bends were poorly defined and pools were absent. Limestone bedrock was the dominant substrate; however, gravel and rubble deposits overlying bedrock created riffles and was also the dominant substrate in the glides. Measured stream discharge was 1.2 ft^3/s.

Onion Creek

Onion Creek lies within the Colorado River Basin. The sample site was located at the second low water crossing going north on FM 150 in northwest Hays County ($30^0$05'05" N; $098^0$00'47" W).

Drainage Basin Size - 316 km^2

Soil Types - Soils at the sample site are of the Brackett-Comfort-Real association. These soils are shallow, undulating to steep, over limestone or strongly cemented chalk, and located on uplands of the Edwards Plateau (Batte 1984).

Flora - The watershed lies within the Live Oak-Mesquite-Ashe Juniper Parks association (Frye et al. 1984).

Land Use - Much of the county's annual agricultural income comes from beef cattle, sheep, and goats. Crops include hay, cotton, grain sorghums, wheat, corn, and peaches (Kingston 1991).

Stream Characteristics - Dripping Springs are located more than 26 km upstream of the sample site and are classified as medium sized (0.2 to 1 ft^3/s) by Brune (1975). Measured stream discharge at the sample site was 1.8 ft^3/s. Stream bend development was moderate. The creek was primarily characterized by shallow to moderately deep, narrow pools and riffles (some of which were very long). Occasional large deep pools also occurred. Rubble, boulders, and gravel were the dominant substrate in the riffles. Limestone bedrock, large limestone slabs, rubble, gravel, and silt occurred in the pools.

South Llano River

The South Llano River lies within the Colorado River Basin. The sample site was located at US Highway 377 southwest of Junction in southwest Kimble County ($30^0$21'42" N; $099^0$53'21" W).

Drainage Basin Size - 492 km^2

Soil Types - The river follows a narrow band of the Nuvalde-Dev-Frio association. These soils are deep, nearly level to gently sloping, loamy, very gravelly, and located on both uplands and bottomlands. This narrow band is encased by a slightly wider band of the Tarrant-Real-Brackett association. This association is comprised of very shallow to shallow, undulating to steep, very cobbly, gravelly, loamy soils, located on uplands. The Tarrant association makes up the largest part of the watershed, with its very shallow to shallow, undulating, very cobbly soils, on the uplands (Blum 1982).

Flora - The watershed lies within the Live Oak-Mesquite-Ashe Juniper Parks association (Frye et al. 1984).

Land Use - Most of the watershed is used as rangeland and wildlife habitat (Blum 1982). Livestock production (Angora and Spanish goats, cattle, and sheep), wool, mohair, tourism, hunting, and fishing dominate the economy (Kingston 1991).

Stream Characteristics - Measured stream discharge was 73.5 ft^3/s. Seven Hundred Springs are located about 12 km upstream in Edwards County and are classified as large springs (10 to 100 ft^3/s) by Brune (1975). Tanner Springs, classified as moderately large (1 to 10 ft^3/s) are located further upstream (Brune 1975). The stream had moderately defined bends, large deep pools, long runs, and occasional riffles. The substrate was predominantly comprised of gravel and rubble with some boulders.

Medina River

The Medina River lies within the San Antonio River Basin. The sample site was located at SH 16 west of Bandera in northwest Bandera County ($29^0$44'09" N; $099^0$07'17" W).

Drainage Basin Size - 834 km^2

Soil Types - The river follows a band of the Frio-Krum-Nuvalde association. These soils are nearly level to gently sloping, clayey, deep, and located on bottomlands, terraces, and in valleys. Along this band are two other predominating soil associations. These are the Tarrant-Brackett and Anhalt-Denton. Soils in the Tarrant-Brackett association are undulating to steep, very cobbly clayey to loamy, shallow to very

shallow, and located on uplands. Anhalt-Denton association soils are nearly level to gently sloping, clayey, moderately deep, and located on uplands (Hensell et al. 1977).

Flora - The sample site lies within the Live Oak-Ashe Juniper Parks association. The upper reach flows through the Live Oak-Ashe Juniper Woods association (Frye et al. 1984).

Land Use - In the past about one-half of the Frio-Krum-Nuvalde and Anhalt-Denton associations were cultivated, whereas the Tarrant-Brackett association was used for range (Hensell et al. 1977). Beef cattle, sheep, and goats are the county's major agricultural revenue sources. Tourism, hunting, fishing, and forest products also contribute largely to the economy (Kingston 1991).

Stream Characteristics - The river had moderately defined bends, moderately large deep pools, occasional shallower glides and runs, and numerous riffles. Rubble and gravel were the dominant substrates in the riffles and pools; whereas, limestone bedrock was dominant in the runs and glides. Measured stream discharge was 19.6 ft^3/s.

Cowhouse Creek

Cowhouse Creek lies within the Brazos River Basin. The sample site was located at FM 116 southwest of Gatesville in south Coryell County($31^0$17'08" N; $097^0$53'01" W).

Drainage Basin Size - 1228 km^2

Soil Types - The creek follows a narrow band of the Bosque-Frio-Lewisville association. These soils are deep, nearly level to gently sloping, moderately alkaline, loamy, clayey, and located on bottomlands and terraces. This band is encased in a slightly broader band of the Doss-Real-Krum association, which in turn is within a large area of the Nuff-Cho association. Soils in the Doss-Real-Krum association are shallow to deep, gently sloping to sloping, moderately alkaline, loamy, gravelly, clayey, and located on uplands. Nuff-Cho association soils are deep to very shallow, gently sloping to sloping, moderately alkaline, very stony, loamy, and located on uplands (McCaleb 1985).

Flora - The watershed lies within the Silver Bluestem-Texas Wintergrass Grassland association (Frye et al. 1984).

Land Use - Land within the Bosque-Frio-Lewisville association is mostly used as cropland and pasture. The other two soil associations are mainly used as rangeland and pasture (McCaleb 1985). Much of the county's annual agricultural income comes from beef cattle, horses, sheep, goats, turkeys, and hogs. Chief crops include grains, hay, pecans, and soybeans (Kingston 1991).

Stream Characteristics - The creek meandered with an occasional well defined bend and was mostly characterized by large deep pools. Riffles occurred only occasionally. Gravel with some rubble was the dominant substrate with some areas of limestone bedrock. Measured stream discharge was 51.7 ft^3/s.

Ecoregion 31 - Southern Texas Plains

Pinto Creek

Pinto Creek lies within the Rio Grande Basin. The sample site was located at US Highway 90 in west Kinney County ($29^0$20'06" N; $100^0$32'01" W).

Drainage Basin Size - 88 km^2

Soil Types - Soils at the sample site are of the Uvalde-Montell association. These soils are deep, nearly level, loamy, clayey, and moderately to slowly permeable. The upper reach traverses the Kimbrough-Ector-Uvalde association. Very shallow, gravelly, stony, and loamy soils, located in nearly level to undulating areas comprise this association (Newman et al. 1967).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Much of the watershed is cultivated. Major crops include cotton, corn, and vegetables (Kingston 1991).

Stream Characteristics - Pinto Springs are located about 17.1 km upstream of the sampling site. These springs have been classified as moderately large (1 to 10 ft^3/s) by Brune (1975). Measured stream discharge at the sample site was 13.8 ft^3/s. The creek exhibited a diverse riffle - run - pool habitat with a few moderately defined bends. The dominant substrate in the riffles, runs, and shallow pools was rock, rubble, and gravel. Deep pools developed in areas with a clay/silt substrate.

Metate Creek

Metate Creek lies within the Nueces River Basin. The sample site was located at FM791 southwest of Campbellton in southeast Atascosa County ($28^0$43'14" N; $098^0$20'50" W).

Drainage Basin Size - 223 km^2

Soil Types - Soils at the sample site are of the Amphion-Floresville-Imogene association. These soils are deep, nearly level to gently sloping, loamy, moderately to very slowly permeable, and in some areas saline (Dittmar and Stevens 1980).

Flora - The watershed lies within the Mesquite-Blackbrush Brush association (Frye et al. 1984).

Land Use - Land within the watershed is mainly used as rangeland (Dittmar and Stevens 1980).

Stream Characteristics - The creek was intermittent with perennial pools. Measured stream discharge was less than 0.1 ft^3/s. Stream bend development was extremely poor. Riffles were rare. Water was basically confined to small, shallow to moderately deep pools with a clay/silt substrate.

Sycamore Creek

Sycamore Creek lies within the Rio Grande Basin. The sample site was located at US Highway 277 in southwest Kinney County ($29^0$15'14" N; $100^0$45'02" W).

Drainage Basin Size - 262 km^2

Soil Types - The predominant soils in the watershed are of the Kimbrough-Ector-Uvalde association. These soils are very shallow, gravelly, stony, loamy, and located in nearly level to undulating areas (Newman et al. 1967). A large proportion of the watershed is also comprised of the Olmos-Acuna-Coahuila association. Very shallow to deep, clayey, loamy, gravelly soils located on terraces and uplands comprise this association (Golden et al. 1982).

Flora - The watershed lies within the Mesquite-Blackbrush Brush association (Frye et al. 1984).

Land Use - Most of the watershed is used for rangeland (cattle, sheep, and goats) and wildlife habitat (Newman et al. 1967; Golden et al. 1982; Kingston 1991).

Stream Characteristics - Mud Creek joins Sycamore Creek about 2.4 km upstream of the sample site. In addition to Mud Springs (Brune 1975), located at the headwaters of Mud Creek, several unnamed springs are present in the lower reaches of Mud Creek and on an unnamed tributary to Sycamore Creek just above the confluence of Mud Creek, according to the U.S. Geological Survey topographic map of that area. A small spring was also observed in the sample reach. Measured stream discharge was 2.4 ft^3/s. The creek had a braided channel with moderately developed bends. Riffles and runs were common with only rare occurrences of moderately deep pools. Submerged aquatic macrophytes were common but unevenly distributed throughout the sample reach. The dominant substrate was gravel and rubble.

San Miguel Creek

San Miguel Creek lies within the Nueces River Basin. The sample site was located at SH 97 southwest of Charlotte in southwest Atascosa County ($28^0$42'50" N; $098^0$47'44" W).

Drainage Basin Size - 2028 km^2

Soil Types - Soils at the sample site are of the Amphion-Floresville-Imogene association. These soils are deep, nearly level to gently sloping, loamy, moderately to

very slowly permeable, and in some areas saline (Dittmar and Stevens 1980).

Flora - The watershed of the upper reach lies within the Mesquite-Granjeno Parks association, whereas the vegetation at the sample site and its surrounding watershed is dominated by crops (Frye et al. 1984).

Land Use - Much of the county's annual agricultural income comes from beef and dairy cattle. Major crops include peanuts, hay, corn, grain sorghums, and strawberries (Kingston 1991).

Stream Characteristics - San Miguel Creek had only moderately defined bends and flow was generally confined to runs and glides with the rare occurrence of riffles and moderately deep pools. Measured stream discharge was 3.9 ft^3/s. Substrate composition was diverse with some areas having a predominance of gravel and rubble whereas other areas had a predominance of either sand or clay/silt.

Ecoregions 33 and 35 - South Central and Southern Humid, Mixed Land Use Region

Ponds Creek

Ponds Creek lies within the Brazos River Basin. The sample site was located at an unmarked county road off FM 1098 north of Prairie View in northeast Waller County ($30^0$06'09" N; $095^0$59'13" W).

Drainage Basin Size - 18 km^2

Soil Types - Soils at the sample site are of the Kenney-Tabor-Chazos association. These soils are gently sloping to sloping, well to moderately well drained, sandy, and loamy. The upper reach traverses the Hockley-Wockley-Monaville association, which is comprised of nearly level to gently sloping, moderately well to somewhat poorly drained, loamy, sandy soils (Greenwade 1984).

Flora - The watershed lies within the Native and/or Introduced Grasses association (Frye et al. 1984).

Land Use - Much of the land is used for pastures and crops (Greenwade 1984). Agriculture enterprises are mostly based on beef cattle, hogs, goats, rice, hay, and corn (Kingston 1991).

Stream Characteristics - Measured stream discharge was less than 0.1 ft^3/s. Stream bends were poorly defined. The creek was comprised of very shallow pools, riffles, and occasional shallow glides. The predominant substrate was fine sand with some areas having higher percentages of gravel.

Wheelock Creek

Wheelock Creek lies within the Trinity River Basin. The sample site was located at an unmarked county road off FM 831 southeast of Buffalo in northwest Leon County ($31^0$25'41"N; $095^0$56'05" W).

Drainage Basin Size - 41 km^2

Soil Types - The creek follows a narrow band of the Hatliff-Nahatche association. These soils are nearly level, deep, loamy, slightly acid to neutral, and moderately well to somewhat poorly drained. This band is surrounded by soils of the Wolfpen-Pickton-Cuthbert association, which are gently sloping to moderately steep, deep, sandy, loamy, well drained, and located in woodlands (Neitsch et al. 1989).

Flora - The watershed lies within the Post Oak Woods/Forest association (Frye et al. 1984).

Land Use - Leon County is the top cow-calf producer in the state (Kingston 1991). Much of the area is used for pasture, hayland, rangeland, and woodland. Most of the pasture and hay is improved bermudagrass and bahiagrass. Dominant commercial trees are loblolly pine *Pinus taeda*, shortleaf pine *Pinus echinata*, and southern red oak *Quercus falcata* (Neitsch et al. 1989).

Stream Characteristics - Stream bends were well defined and flow alternated between shallow pools, glides, runs, and riffles. Measured stream discharge was 0.8 ft^3/s. The substrate was comprised of fine sand with higher percentages of gravel in the runs and riffles.

Black Cypress Creek

Black Cypress Creek lies within the Cypress Creek Basin. The sample site was located at FM 250 northeast of Hughes Spring in southwest Cass County ($33^0$02'58" N; $094^0$36'11" W).

Drainage Basin Size - 75 km^2

Soil Types - The creek traverses the Bibb fine sandy loam soil type. This is a very wet soil during most of the year (Beck et al. 1937).

Flora - The watershed lies within the Native and/or Introduced Grasses and Pine-Hardwood Forest associations (Frye et al. 1984).

Land Use - Much of the county's annual agricultural income comes from timber. Beef cattle, broilers, forages, fruit, vegetables, and Christmas trees also contribute significantly (Kingston 1991).

Stream Characteristics - Black Cypress Creek was mostly characterized by long shallow, occasionally moderately deep, pools and shallow runs. The substrate was primarily comprised of clay and decaying organic material with some areas having a predominance of fine sand. Measured stream discharge was 0.9 ft^3/s. The creek meanders extensively; however, only one bend was well defined within the study reach. Instream cover was provided by woody debris, undercut banks, and overhanging vegetation.

Beech Creek

Beech Creek lies within the Neches River Basin. The sample site was located at FM 1013 west of Spurger in southeast Tyler County ($30^0$41'39" N; $094^0$11'25" W).

Drainage Basin Size - 98 km^2

Soil Types - The creek follows a narrow band of the Mantachie-luka association. These soils are nearly level, loamy and clayey, moderately permeable, and located on flood plains. This band is surrounded by a broader band of the Otanya-Kirbyville-Waller association. These soils are nearly level to gently sloping, loamy, moderately to moderately slowly permeable, and located in the flatwoods (U.S. Department of Agriculture 1983a).

Flora - The watershed lies within the Young Forest/Grassland association (Frye et al. 1984).

Land Use - Timber sales is the county's major agricultural income source. Additional farming income comes from cattle, hogs, poultry, horses, and fruit (Kingston 1991).

Stream Characteristics - The Beech Creek channel braided through an extensive wooded swamp. No discernible stream bends were noted. Measured stream discharge was 2.2 ft^3/s, and primarily flowed through narrow shallow runs and wider moderately deep glides. The substrate was comprised of silt and sand with decaying organic matter. Instream cover was provided by woody debris, root wads, and overhanging vegetation.

White Oak Creek

White Oak Creek lies within the Sabine River Basin. The sample site was located at FM 363 east of Bleakwood in central Newton County ($30^0$41'46" N; $093^0$48'43" W).

Drainage Basin Size - 119 km^2

Soil Types - The creek begins in the Pinetucky-Shankler-Doucette association, then briefly traverses the Malbis association before entering the Iuka-Mantachie association. Soils in the Pinetucky-Shankler-Doucette association are gently undulating to hilly, deep, loamy, sandy, and moderately well to somewhat excessively drained. Malbis association soils are gently undulating, deep, loamy, and moderately well drained. Soils at the sample site are of the Iuka-Mantachie association. These soils are nearly level, deep, loamy, and moderately well to somewhat poorly drained. This association is surrounded by the Kirbyville-Malbis association, which is comprised of gently undulating, deep, loamy, and somewhat poorly to moderately well drained soils (Neitsch 1982).

Flora - The watershed lies within the Pine-Hardwood Forest association (Frye et al. 1984).

Land Use - Timber production and woodland grazing comprise the major activities in the watershed (Neitsch 1982).

Stream Characteristics - Measured stream discharge was 26.0 ft^3/s. The creek meanders with some well developed bends and flow is primarily in deep pools and runs. The substrate was comprised of silty sand. Abundant instream cover was provided by fallen logs, undercut banks, root snags, bald cypress *Taxodium distichum* knees, and overhanging vegetation.

Frazier Creek

Frazier Creek lies within the Cypress Creek Basin. The sample site was located at US Highway 59 northeast of Linden in central Cass County ($33^0$03'15" N; $094^0$17'25" W).

Drainage Basin Size - 137 km^2

Soil Types - The creek traverses the Bibb fine sandy loam soil type. This is a very wet soil during most of the year (Beck et al. 1937).

Flora - The watershed lies within the Pine-Hardwood Forest association (Frye et al. 1984).

Land Use - Much of the county's annual agricultural income comes from timber. Beef cattle, broilers, forages, fruit, vegetables, and Christmas trees also contribute significantly (Kingston 1991).

Stream Characteristics - Measured stream discharge was 3.2 ft^3/s. The U.S. Geological Survey gage at this site has recorded periods of no flow at times for most years (Buckner and Shelby 1991). The creek meanders with an occasional well defined bend and is primarily comprised of moderately deep pools with occasional riffles, runs, and glides. The substrate is mostly fine sand with some areas of silt and clay. A moderate amount of instream cover is provided by woody debris, root snags, undercut banks, and overhanging vegetation.

Irons Bayou

Irons Bayou lies within the Sabine River Basin. The sample site was located at SH 149 southeast of Beckville in northwest Panola County ($32^0$12'52" N; $094^0$25'58" W).

Drainage Basin Size - 181 km^2

Soil Types - The bayou follows a band of the Nahatche-Mantachie-Urbo association. These soils are nearly level, slightly to strongly acidic, loamy to clayey, and located on bottomlands. This band is surrounded by the Sacul-Bowie association, which is comprised of gently sloping to moderately steep, slightly to medium acidic, loamy soils located on uplands (Dolezel 1975).

Flora - The watershed lies within the Pine-Hardwood Forest association (Frye et al. 1984).

Land Use - Most of the watershed is used for timber and pasture. A few small areas are used as cropland. At one time all of the soils in the Sacul-Bowie association, except the steep areas, were cleared for crops. They have now either reverted back to forest or were converted to improved pasture (Dolezel 1975). Much of the annual agricultural income comes from poultry, cattle, and hogs, with Panola County being among the leading broiler counties in Texas. Timber sales are also significant (Kingston 1991).

Stream Characteristics - Measured stream discharge was 1.6 ft^3/s. The bayou had large meanders but bend definition was poor. The bayou was comprised of long moderately deep pools, occasional shallow glides, and less occasional short riffles created by bald cypress knees. Clay was the dominant substrate. Instream cover was provided by woody debris, old bald cypress stumps and knees, roots, and fallen and cut timber.

Piney Creek

Piney Creek lies within the Neches River Basin. The sample site was located at FM

2262 east of Groveton in east Trinity County ($31^0$03'56" N; $095^0$03'20" W).

Drainage Basin Size - 264 km^2

Soil Types - The creek follows a narrow band of the Koury-Pophers association. These soils are nearly level, loamy and clayey, moderately slowly to slowly permeable, and located in the bottomlands. This band is surrounded by a broader band of the Diboll-Keltys-Rosenwall association, which is made up of nearly level to gently sloping, loamy, slowly to very slowly permeable soils located on the uplands (U.S. Department of Agriculture 1983b).

Flora - The watershed lies within the Young Forest/Grassland association (Frye et al. 1984).

Land Use - Timber sales is the county's major agricultural income source. Other farm income comes from beef cattle, poultry, hogs, hay, vegetables, peaches, and pecans (Kingston 1991).

Stream Characteristics - Piney Creek meandered in well defined bends and flowed in shallow to moderately deep pools, glides, runs, and occasional riffles. The predominant substate was silt and sand; however, the runs and riffles had higher percentages of gravel. A moderate amount of instream cover was provided by woody debris, overhanging vegetation, and aquatic macrophytes. Measured stream discharge was 1.2 ft^3/s.

Keechi Creek

Keechi Creek lies within the Trinity River Basin. The sample site was located at SH 7 east of Centerville in central Leon County ($31^0$16'03" N; $095^0$56'12" W).

Drainage Basin Size - 293 km^2

Soil Types - The creek follows a narrow band of the Hatliff-Nahatche association. These soils are nearly level, deep, loamy, slightly acid to neutral, and moderately well to somewhat poorly drained. This band is predominantly surrounded by soils of the Wolfpen-Pickton-Cuthbert and Padina-Silstid-Hearne associations. Soils in the Wolfpen-Pickton-Cuthbert association are gently sloping to moderately steep, deep, sandy, loamy, well drained, and located in woodlands. Padina-Silstid-Hearne association soils are gently sloping to moderately steep, deep, sandy, loamy, moderately well to well drained, and located on savannahs (Neitsch et al. 1989).

Flora - The watershed lies within the Post Oak Woods/Forest association (Frye et al. 1984).

Land Use - Leon County is the top cow-calf producer in the state (Kingston 1991). Much of the area is used for pasture, hayland, rangeland, and woodland. Most of the pasture and hay is improved bermudagrass and bahiagrass. Dominant commercial trees are loblolly pine, shortleaf pine, and southern red oak (Neitsch et al. 1989).

Stream Characteristics - Keechi Creek was mostly comprised of pools, ranging in depth from shallow to deep. Occasional glides, runs, and riffles also occurred. The substrate was predominantly fine sand mixed with small amounts of gravel. Measured stream discharge was 0.9 ft^3/s. Stream bend development was high.

East Fork of the San Jacinto River

The East Fork of the San Jacinto River lies within the San Jacinto River Basin. The sample site was located at FM 945 north of Cleveland in south San Jacinto County ($30^0$25'30" N; $095^0$07'26" W).

Drainage Basin Size - 306 km^2

Soil Types - The river follows a narrow band of the Hatliff-Pluck-Kian association. These soils are nearly level to gently sloping, moderately well to poorly drained, moderately rapidly to moderately permeable, and loamy. This band is surrounded nearly equally by the Pinetucky-Doucette and Woodville-Pinetucky associations. Soils in the Pinetucky-Doucette association are gently sloping, moderately well to well drained, moderately slowly to moderately permeable, medium to very strongly acid, loamy, and sandy. The Woodville-Pinetucky association is comprised of gently to strongly sloping, somewhat poorly to

moderately well drained, very slowly to moderately slowly permeable, loamy soils (McEwen et al. 1988).

Flora - The watershed lies within the Pine-Hardwood Forest association (Frye et al. 1984).

Land Use - Land in the watershed is used as woodland and is a part of the Sam Houston National Forest (McEwen et al. 1988).

Stream Characteristics - Measured stream discharge was 7.8 ft^3/s. The river meandered with well defined bends. The river had long runs, deep pools and glides, and occasional riffles. The substrate was primarily comprised of fine sand with some gravel occurring in the runs and riffles. Occasional instream cover was provided by woody debris and undercut banks.

Big Cypress Creek

Big Cypress Creek lies within the Sabine River Basin. The sample site was located at SH 87 northwest of Deweyville in south Newton County ($30^0$20'40" N; $093^0$48'17" W).

Drainage Basin Size - 368 km^2

Soil Types - The creek follows a narrow band of the Iuka-Mantachie association. These soils are nearly level, deep, loamy, and moderately well to somewhat poorly drained. This association is surrounded by the Kirbyville-Malbis association in the upper watershed, and by the Evadale-Gist association at the sample site. Soils in these associations are identical to those of the Iuka-Mantachie association except that they are gently undulating, and nearly level to gently undulating respectively (Neitsch 1982).

Flora - The watershed lies within the Pine-Hardwood Forest association (Frye et al. 1984).

Land Use - Timber production and woodland grazing comprise the major activities in the watershed (Neitsch 1982).

Stream Characteristics - Measured stream discharge was 0.2 ft^3/s. The channel was braided within a large swamp complex. Canopy cover was nearly complete. Stream bend development was poor and flow was in an essentially long, shallow to moderately deep pool. The substrate was comprised of silt/clay and decaying organic material. Abundant instream cover was provided by bald cypress, roots, woody debris, and overhanging vegetation.

Catfish Creek

Catfish Creek lies within the Trinity River Basin. The sample site was located on the Engling Wildlife Management Area located in west Anderson County ($31^0$55'12" N; $095^0$52'51" W).

Drainage Basin Size - 554 km^2

Soil Types - Soils are of the Fuquay-Kirvin-Darco association, and are deep, sandy, loamy, nearly level to moderately steep, and located on uplands (Coffee 1975).

Flora - The sample site lies within the Post Oak Woods, Forest, and Grassland Mosaic association. The upper reach flows through the Post Oak Woods/Forest association (Frye et al. 1984).

Land Use - The Engling Wildlife Management Area is a 10,941 acre state owned refuge. It provides a protective buffer to Catfish Creek. Most of the land within the Fuquay-Kirvin-Darco association is wooded and grazed. The hazard of erosion is moderate to severe (Coffee 1975).

Stream Characteristics - Numerous stream bends were only moderately defined and flow alternated between moderately deep pools, glides, riffles, and runs. Measured stream discharge was 4.7 ft^3/s. The substrate was almost entirely silt with some organic material. Instream cover was provided by woody debris, fallen logs, and overhanging vegetation. The stream had a closed canopy except for small openings provided by fallen trees.

Little Cypress Creek

Little Cypress Creek lies within the Cypress Creek Basin. The sample site was located at SH 155 northeast of Gilmer in

northeast Upshur County (32^{0}46'05" N; 094^{0}54'55" W).

Drainage Basin Size - 616 km^2

Soil Types - The creek follows a narrow band of the Mantachie-luka association. These soils are nearly level, somewhat poorly to moderately well drained, very strongly acidic, loamy, and located on flood plains. This band is encased within the Bowie-Cuthbert-Kirvin association, which is comprised of gently sloping to steep, well to moderately well drained, slightly to very strongly acidic, loamy, and gravelly soils, located on uplands (Roberts 1983).

Flora - The watershed predominantly lies within the Pine-Hardwood Forest association. The upper watershed is also a part of the Native and/or Introduced Grasses association (Frye et al. 1984).

Land Use - Most of the watershed is used for woodland and pasture. A few areas in the upper watershed are also used for crops (Roberts 1983). Upshur County is among the leading broiler and dairy producing counties in Texas. Timber is also a major product. Chief crops include vegetables, hay, and peaches (Kingston 1987).

Stream Characteristics - Measured stream discharge was 5.6 ft^3/s. The stream channel meandered with moderately defined bends. The bayou was mostly comprised of long moderately deep pools and occasional moderately deep glides, runs, and riffles. The substrate was comprised of clay often overlain by a thin layer of silt or decaying organic matter. A moderate amount of instream cover was primarily provided by woody debris with some areas of overhanging vegetation.

Lake Creek

Lake Creek lies within the San Jacinto River Basin. The sample site was located at a private road off FM 1488 southeast of Conroe in west Montgomery County (30^{0}16'27" N; 095^{0}31'04" W).

Drainage Basin Size - 865 km^2

Soil Types - The creek follows a band of the Tuscumbia association. These soils are poorly drained, very firm, clayey, and located on flood plains. Other dominant soil associations outside of this band include the Wicksburg-Susquehanna and Conroe. Soils in the Wicksburg-Susquehanna association are deep, gently sloping, well to somewhat poorly drained, sandy, loamy, and have clayey lower layers. Conroe association soils are deep, gently sloping to rolling, moderately well to well drained, sandy, and contain clayey lower layers (McClintock et al. 1972).

Flora - The watershed lies within the Pine-Hardwood Forest association (Frye et al. 1984).

Land Use - Much of the land is used for timber. Large acreages have also been cleared for pasture (McClintock et al. 1972).

Stream Characteristics - Lake Creek meandered with highly developed bends and flow alternated between runs, pools, and some well developed riffles. Measured stream discharge was 7.2 ft^3/s. The substrate was primarily comprised of fine sand, with some gravel in the riffles. Occasional instream cover was provided by woody debris and overhanging vegetation.

Ecoregion 34 - Western Gulf Coastal Plain

Placedo Creek

Placedo Creek lies within the Lavaca-Guadalupe River Basin. The sample site was located at FM 616 east of Placedo in southeast Victoria County (28^{0}44'19" N; 096^{0}46'06" W).
Drainage Basin Size - 130 km^2

Soil Types - Soils at the sample site are of the Lake Charles-Dacosta association. These soils are somewhat poorly drained, very slowly permeable, clayey, and loamy (Miller 1982).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Most of the land is used as cropland for sorghum and corn (Miller 1982).

Stream Characteristics - Placedo Creek was not flowing at the time of sampling. Water was confined to moderately wide shallow to deep pools. The substrate was mostly silt with some fine sand. Instream cover was provided by woody debris and undercut banks.

West Carancahua Creek

West Carancahua Creek lies within the Colorado-Lavaca River Basin. The sample site was located at an unmarked county road southeast of LaWard in southeast Jackson County ($28^0$50'43" N; $096^0$24'41" W).

Drainage Basin Size - 132 km^2

Soil Types - The creek flows over soils of the Dacosta-Laewest association. These soils are moderately well drained, very slowly permeable, loamy and clayey. A band of soils in the Edna-Telferner association follows the eastern bank of the creek at the sample site. These soils are somewhat poorly drained and moderately well drained, very slowly permeable, and loamy (Miller 1997).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Rice is the county's top agricultural revenue source. Corn, grain sorghums, and cotton are also raised (Kingston 1991).

Stream Characteristics - The creek was mostly characterized by long shallow runs and glides. Riffles and moderately deep pools occasionally occurred. The substrate was predominantly fine sand, with rare occurrences of gravel. Instream cover was provided by woody debris, overhanging vegetation, and undercut banks. Stream bends were poorly defined. Measured stream discharge was 0.6 ft^3/s.

Big Creek

Big Creek lies within the Brazos River Basin. The sample site was located at Geiss-Big Creek Road south of Thompsons in southeast Fort Bend County ($29^0$27'10" N; $095^0$43'36" W).

Drainage Basin Size - 145 km^2

Soil Types - Soils at the sample site are of the Edna-Bernard-Waller association. These soils are level to nearly level, sandy loam to clay loam, poorly drained, and located on uplands (Mowery et al. 1960).

Flora - Vegetation in the watershed was dominated by crops (Frye et al. 1984).

Land Use - Rice and cotton are the county's top crops. Sorghums, soybeans, corn, and vegetables are also grown (Kingston 1991).

Stream Characteristics - Measured stream discharge was 0.6 ft^3/s. The creek had been channelized and the banks cleared of shrubs and trees. Flow was confined to long, moderately wide, shallow pools, and rarely riffles. The substrate was comprised of a mixture of sand, silt, and some gravel. The only instream cover was provided by overhanging grasses and weeds.

Arenosa Creek

Arenosa Creek lies within the Lavaca-Guadalupe River Basin. The sample site was located at County Road 103 east of Victoria, in southwest Jackson County ($28^0$56'55" N; $096^0$48'13" W).

Drainage Basin Size - 236 km^2

Soil Types - Soils at the sample site are of the Inez association. These soils are somewhat poorly drained, very slowly permeable, and loamy (Miller 1982).

Flora - The watershed lies within the Bluestem Grassland association (Frye et al. 1984).

Land Use - Most of the area is in rangeland. Some areas are used as cropland, principally for rice and sorghum (Miller 1982).

Stream Characteristics - The stream was comprised of long moderately deep pools, shallow glides, long shallow runs, and short riffles. The stream had moderately developed bends with some point bars. The substrate was fine sand except in the riffles where gravel was common. Instream cover

was provided by woody debris. Measured stream discharge was 1.4 ft^3/s.

West Mustang Creek

West Mustang Creek lies within the Lavaca River Basin. The sample site was located at County Road 328 northwest of Louise in west Wharton County ($29^0$07'36" N; $096^0$27'43" W).

Drainage Basin Size - 357 km^2

Soil Types - Soils at the sample site are of the Edna-Bernard association. These soils are poorly to somewhat poorly drained, have a surface layer of fine sandy loam and clay loam and lower layers that are dominantly clay, and are located on uplands. Much of the upper reach traverses the Lake Charles association. Somewhat poorly drained soils located on the uplands, and containing layers of clay from the surface to the lower layers comprise this association (McEwen and Crout 1974).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Wharton County is the leading rice-producing county in the state. Other crops include sorghums, cotton, and corn (Kingston 1991).

Stream Characteristics - Measured stream discharge was 0.2 ft^3/s. The stream had numerous moderately defined bends and exposed sand banks and bars. Flow was in long, narrow, moderately deep pools with occasional riffles, runs, and glides. The substrate was uniformly comprised of fine sand. Instream cover was provided by woody debris, root snags, and occasional undercut banks.

West Bernard Creek

West Bernard Creek lies within the Brazos-Colorado River Basin. The sample site was located at SH 60 north of Hungerford in north Wharton County ($29^0$24'54" N; $096^0$04'41" W).

Drainage Basin Size - 386 km^2

Soil Types - Soils at the sample site are of the Crowley association. These soils are somewhat poorly drained, have a surface layer of fine sandy loam and lower layers of clay and sandy clay, and are located on uplands (McEwen and Crout 1974).

Flora - Vegetation in the watershed is dominated by crops (Frye et al. 1984).

Land Use - Wharton County is the leading rice-producing county in the state. Other crops include sorghums, cotton, and corn (Kingston 1991).

Stream Characteristics - Measured stream discharge was 9.3 ft^3/s. Stream bends were poorly defined and flow was primarily in long, narrow, moderately deep pools and long shallow runs. Glides and riffles occasionally occurred. The substrate was uniformly comprised of fine sand. Instream cover was provided by woody debris, undercut banks, and overhanging vegetation.

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APPENDIX B

Guidelines for Applying the Index of Biotic Integrity Metrics

Appendix B. Guidelines for applying the index of biotic integrity metrics developed for Texas streams.

Values for metrics requiring the calculation of percentages or number per unit sampling effort should be rounded to the number of digits listed under the respective criteria before assigning a score.

Total Number of Fish Species

To use this metric, one will need to know the drainage basin size of the sample location. If not available from a past study or a United States Geological Survey gaging station, this can be calculated using a planimeter and a scaled map. Scoring criteria are based on the relationship between species richness and the log of the drainage basin size. The score is determined from the intersection of a vertical line drawn from the calculated drainage basin size located on the x-axis and a horizontal line extended from the species richness value located on the y-axis. Species that are observed but not collected should be included in the species count if the observer can be positive about the identification. Hybrids are not included if either or both of the progenitor species are collected.

Number of Native Cyprinid Species

Use the total number of cyprinid species native to Texas. Introduced species are identified in Appendix K, according to Hubbs et al. (1991). This list should be considered subject to revision as new introductions are possible at any time.

Number of Benthic Invertivore Species

Benthic invertivore species are those species within the Catostomidae, Ictaluridae, and Percidae families that are identified as invertebrate feeders in Appendix J (Linam and Kleinsasser 1998).

Number of Benthic Species

Benthic species are all species within the Catostomidae, Ictaluridae, and Percidae families.

Number of Sunfish Species

For this metric, sunfish species are identified as all members of the family Centrarchidae, exclusive of black basses *Micropterus* sp.

Number of Intolerant Species

Intolerant species are identified in Appendix J, according to Linam and Kleinsasser (1998).

Percentage of Individuals as Tolerant Species (excluding western mosquitofish)

Tolerant species are identified in Appendix J, according to Linam and Kleinsasser (1998). Even though western mosquitofish are identifed as a tolerant species by Linam and Kleinsasser (1998), they are treated otherwise in calculating this metric. Western mosquitofish are included as part of the total number of individuals collected, but are just not included as a tolerant species.

Percentage of Individuals as Omnivores, Invertivores, and Piscivores

Omnivores, invertivores, and piscivores are identified in Appendix J, according to Linam and Kleinsasser (1998).

Number of Individuals in Sample

Scoring criteria for this metric are based on a combination of seine and electrofishing data (except for ecoregions 25 and 26 where only seining criteria were established). Seining effort (number of effective seine hauls) and electrofishing effort (number of minutes electrofished) must be recorded. In order for a seine haul to be considered effective, the sampler must judge whether the seine haul was affected negatively in any way. Getting the seine hung on woody debris or lifting the net in a manner that allows escape are two examples of ineffective seine hauls. Capturing no fish would not constitute an ineffective seine haul if the seine hauls were performed adequately.

Using the recommended scoring criteria, a score should be assigned for both sampling techniques. These two scores are averaged for the final score. For example, if the seining effort yielded a score of 5 while the electrofishing effort only yielded a 1, then the final score would be 3. If either sampling technique was not used, then the score is based solely on the one technique employed.

Percentage of Individuals as Non-Native Species

Non-native species are those species that have been introduced into Texas. These species are identified in Appendix K, according to Hubbs et al. (1991). This list should be considered subject to revision as new introductions are possible at any time.

Percentage of Individuals with Disease or Other Anomaly

This metric includes individuals with disease, tumors, hemorrhaging, deformities, and other similar abnormalities, but does not include parasite infestation or fin damage attributed to spawning activity or other normal behavior.

APPENDIX C

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregion 24 (Southern Deserts)

Fish species collected from Live Oak Creek, Crockett County (8/30/90).

Species	Common Name	Seine (7 hauls)
Cyprinella proserpina	Proserpine shiner	16
Dionda episcopa	Roundnose minnow	1158
Astyanax mexicanus	Mexican tetra	6
Ictalurus punctatus	Channel catfish	26
Cyprinodon pecosensis x variegatus	Pecos pupfish x sheepshead minnow	4
Fundulus zebrinus	Plains killifish	9
Gambusia affinis	Western mosquitofish	20
Lepomis megalotis	Longear sunfish	62
Cichlasoma cyanoguttatum	Rio Grande cichlid	21

Fish species collected from Terlingua Creek, Brewster County (7/12/89).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (4.9 min)
Campostoma ornatum	Mexican stoneroller	21	6
Cyprinella lutrensis	Red shiner	117	
Cyprinus carpio	Common carp	1	
Macrhybopsis aestivalis	Speckled chub	3	
Notropis braytoni	Tamaulipas shiner	2	
Notropis chihuahua	Chihuahua shiner	30	1
Pimephales promelas	Fathead minnow	4	
Carpiodes carpio	River carpsucker	8	1
Ictalurus furcatus	Blue catfish	6	
Fundulus zebrinus	Plains killifish	174	

Fish species collected from Alamito Creek, Presidio County (7/11/89).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (10 min)
Campostoma ornatum	Mexican stoneroller	241	102
Cyprinella lutrensis	Red shiner	70	3
Notropis braytoni	Tamaulipas shiner		1
Notropis chihuahua	Chihuahua shiner	50	17
Carpiodes carpio	River carpsucker	8	6
Astyanax mexicanus	Mexican tetra	1	
Cyprinodon eximius	Conchos pupfish	12	84
Gambusia affinis	Western mosquitofish	819	184
Lepomis cyanellus	Green sunfish	2	1

Fish species collected from Independence Creek, Terrell County (8/28/90).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (13.9 min)
Cyprinella proserpina	Proserpine shiner		10
Dionda episcopa	Roundnose minnow	37	11
Moxostoma congestum	Gray redhorse	3	
Astyanax mexicanus	Mexican tetra	3	7
Ictalurus punctatus	Channel catfish	22	3
Pylodictis olivaris	Flathead catfish	1	
Gambusia geiseri	Largespring gambusia	104	247
Lepomis auritus	Redbreast sunfish	8	4
Lepomis megalotis	Longear sunfish	8	3
Micropterus salmoides	Largemouth bass	1	
Etheostoma grahami	Rio Grande darter	3	1
Cichlasoma cyanoguttatum	Rio Grande cichlid	4	

Fish species collected from the Devils River, Val Verde County (7/10/89).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (11.8 min)
Cyprinella proserpina	Proserpine shiner	31	7
Cyprinella venusta	Blacktail shiner	30	25
Cyprinus carpio	Common carp	*	
Dionda episcopa	Roundnose minnow	25	53
Notropis amabilis	Texas shiner	819	8
Notropis stramineus	Sand shiner	1	
Moxostoma congestum	Gray redhorse	*	
Astyanax mexicanus	Mexican tetra	**	
Ictalurus lupus	Headwater catfish	**	
Pylodictis olivaris	Flathead catfish		1
Gambusia affinis	Western mosquitofish	19	12
Lepomis auritus	Redbreast sunfish	1	4
Lepomis megalotis	Longear sunfish		18
Micropterus dolomieu	Smallmouth bass	1	1
Micropterus salmoides	Largemouth bass	**	
Etheostoma grahami	Rio Grande darter	**	
Cichlasoma cyanoguttatum	Rio Grande cichlid	14	7
Tilapia aurea	Blue tilapia		1

* Observed but not collected

** Collected with substantial additional effort

APPENDIX D

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregions 25 and 26 (Western High Plains and Southwestern Tablelands)

Fish species collected from Saddlers Creek, Donley County (8/17/89).

Species	Common Name	Seine (7 hauls)
Cyprinella lutrensis	Red shiner	2
Hybognathus placitus	Plains minnow	1
Notropis bairdi	Red River shiner	42
Cyprinodon rubrofluviatilis	Red River pupfish	57
Fundulus zebrinus	Plains killifish	128
Gambusia affinis	Western mosquitofish	3
Lepomis cyanellus	Green sunfish	2

Fish species collected from Lelia Lake Creek, Donley County (8/16/89).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (10.5 min)
Cyprinella lutrensis	Red shiner	104	11
Pimephales promelas	Fathead minnow		2
Ameiurus melas	Black bullhead		1
Ameiurus natalis	Yellow bullhead		2
Fundulus zebrinus	Plains killifish	97	38
Lepomis cyanellus	Green sunfish		10

Fish species collected from Whitefish Creek, Donley County (8/16/89).

Species	Common Name	Seine (7 hauls)
Cyprinella lutrensis	Red shiner	2
Cyprinodon rubrofluviatilis	Red River pupfish	64
Fundulus zebrinus	Plains killifish	354
Gambusia affinis	Western mosquitofish	15
Lepomis cyanellus	Green sunfish	2
Lepomis macrochirus	Bluegill	1

Fish species collected from McClellan Creek, Gray County (7/17/90).

Species	Common Name	Seine (10 hauls)
Cyprinella lutrensis	Red shiner	132
Pimephales promelas	Fathead minnow	3
Cyprinodon rubrofluviatilis	Red River pupfish	7
Fundulus zebrinus	Plains killifish	111
Gambusia affinis	Western mosquitofish	9
Lepomis cyanellus	Green sunfish	5
Lepomis megalotis	Longear sunfish	2
Micropterus salmoides	Largemouth bass	4

Fish species collected from Wolf Creek, Lipscomb County (7/17/90).

Species	Common Name	Seine (14 hauls)
Cyprinella lutrensis	Red shiner	32
Notropis stramineus	Sand shiner	18
Phenacobius mirabilis	Suckermouth minnow	3
Fundulus zebrinus	Plains killifish	10
Gambusia affinis	Western mosquitofish	27
Lepomis cyanellus	Green sunfish	1
Lepomis megalotis	Longear sunfish	1
Micropterus salmoides	Largemouth bass	3

APPENDIX E

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregions 27, 29, and 32 (Subhumid Agricultural Plains)

Fish species collected from Geronimo Creek, Guadalupe County (6/29/88).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (0.1 min)	Boat Shocker (10 min)
Cyprinella lutrensis	Red shiner	34		
Notropis amabilis	Texas shiner	44		1
Notropis volucellus	Mimic shiner	5		
Moxostoma congestum	Gray redhorse	1		6
Astyanx mexicanus	Mexican tetra	3		
Lepomis megalotis	Longear sunfish	3	6	
Lepomis punctatus	Spotted sunfish			1
Micropterus treculi	Guadalupe bass	3		3
Etheostoma spectabile	Orangethroat darter	1		
Percina carbonaria	Texas logperch	2		

Fish species collected from Willis Creek, Williamson County (7/18/89).

Species	Common Name	Seine (8 hauls)	Backpack Shocker (5.7 min)
Campostoma anomalum	Central stoneroller	18	1
Cyprinella lutrensis	Red shiner	2	
Cyprinella venusta	Blacktail shiner	21	1
Pimephales vigilax	Bullhead minnow	1	
Ameiurus natalis	Yellow bullhead	2	10
Gambusia affinis	Western mosquitofish	250	
Lepomis cyanellus	Green sunfish		1
Lepomis megalotis	Longear sunfish	2	6
Etheostoma spectabile	Orangethroat darter	6	

Fish species collected from Bluff Creek, McLennan County (7/12/88).

Species	Common Name	Seine (9 hauls)	Backpack Shocker (9.1 min)
Campostoma anomalum	Central stoneroller	18	12
Ameiurus natalis	Yellow bullhead	2	8
Gambusia affinis	Western mosquitofish	99	
Lepomis cyanellus	Green sunfish		3
Lepomis megalotis	Longear sunfish		4
Micropterus salmoides	Largemouth bass	7	1
Etheostoma spectabile	Orangethroat darter	3	2

Fish species collected from Ioni Creek, Palo Pinto County (7/14/88).

Species	Common Name	Seine (6 hauls)	Boat Shocker (6 min)
Dorosoma petenense	Threadfin shad	1	
Cyprinella venusta	Blacktail shiner	136	37
Pimephales vigilax	Bullhead minnow	10	
Moxostoma congestum	Gray redhorse	1	15
Fundulus notatus	Blackstripe topminnow	41	
Gambusia affinis	Western mosquitofish	13	
Lepomis cyanellus	Green sunfish	1	2
Lepomis macrochirus	Bluegill	36	3
Lepomis megalotis	Longear sunfish	8	3
Lepomis sp. (juvenile)	Sunfish species	284	
Micropterus salmoides	Largemouth bass	41	4

Fish species collected from Wilson Creek, Collin County (8/1/89).

Species	Common Name	Seine (11 hauls)	Backpack Shocker (12.8 min)
Campostoma anomalum	Central stoneroller	1	2
Cyprinella lutrensis	Red shiner	27	
Notropis stramineus	Sand shiner	1	
Pimephales vigilax	Bullhead minnow	9	
Ameiurus natalis	Yellow bullhead	1	32
Ictalurus punctatus	Channel catfish	2	
Fundulus notatus	Blackstripe topminnow	1	
Gambusia affinis	Western mosquitofish	1	
Lepomis cyanellus	Green sunfish	9	4
Lepomis humilis	Orangespotted sunfish	3	
Lepomis macrochirus	Bluegill	2	1
Lepomis megalotis	Longear sunfish	2	1
Micropterus salmoides	Largemouth bass	3	

Fish species collected from Bluff Creek, Scurry County (8/25/88).

Species	Common Name	Seine (8 hauls)
Cyprinella lutrensis	Red shiner	61
Notemigonus crysoleucas	Golden shiner	1
Pimephales promelas	Fathead minnow	25
Pimephales vigilax	Bullhead minnow	2
Gambusia affinis	Western mosquitofish	57
Lepomis cyanellus	Green sunfish	8
Lepomis macrochirus	Bluegill	18
Lepomis megalotis	Longear sunfish	31
Micropterus salmoides	Largemouth bass	2

Fish species collected from Auds Creek, Lamar County (8/2/89).

Species	Common Name	Seine (10 hauls)	Backpack Shocker (18.1 min)
Cyprinella lutrensis	Red shiner	269	13
Phenacobius mirabilis	Suckermouth minnow	8	11
Pimephales vigilax	Bullhead minnow	7	1
Ameiurus melas	Black bullhead		1
Ameiurus natalis	Yellow bullhead		8
Ictalurus punctatus	Channel catfish		12
Gambusia affinis	Western mosquitofish	6	
Lepomis cyanellus	Green sunfish		21
Lepomis humilus	Orangespotted sunfish	1	
Lepomis megalotis	Longear sunfish		4
Micropterus salmoides	Largemouth bass		1

Fish species collected from Deadman Creek, Jones County (8/24/88).

Species	Common Name	Seine (4 hauls)
Dorosoma cepedianum	Gizzard shad	18
Cyprinella lutrensis	Red shiner	46
Pimephales vigilax	Bullhead minnow	4
Carpiodes carpio	River carpsucker	1
Ictalurus punctatus	Channel catfish	*
Gambusia affinis	Western mosquitofish	169
Lepomis cyanellus	Green sunfish	1
Lepomis gulosus	Warmouth	19
Lepomis macrochirus	Bluegill	16
Lepomis megalotis	Longear sunfish	3
Micropterus salmoides	Largemouth bass	2
Pomoxis annularis	White crappie	7

* Observed but not collected

Fish species collected from Colony Creek, Eastland County (7/13/88).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (15.3 min)
Dorosoma petenense	Threadfin shad	33	
Campostoma anomalum	Central stoneroller	1	2
Cyprinella lutrensis	Red shiner	202	
Cyprinella venusta	Blacktail shiner	179	2
Pimephales vigilax	Bullhead minnow	67	
Ameiurus natalis	Yellow bullhead		3
Ictalurus punctatus	Channel catfish	1	
Fundulus notatus	Blackstripe topminnow	19	
Gambusia affinis	Western mosquitofish	77	1
Lepomis cyanellus	Green sunfish	26	21
Lepomis macrochirus	Bluegill	3	4
Lepomis megalotis	Longear sunfish	5	8
Micropterus salmoides	Largemouth bass	1	

Fish species collected from Steele Creek, Bosque County (7/13/88).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (11.8 min)
Campostoma anomalum	Central stoneroller	2	
Cyprinella venusta	Blacktail shiner	273	2
Ameiurus melas	Black bullhead		5
Ameiurus natalis	Yellow bullhead		7
Ictalurus punctatus	Channel catfish		3
Fundulus notatus	Blackstripe topminnow	14	
Gambusia affinis	Western mosquitofish	21	
Lepomis cyanellus	Green sunfish	18	17
Lepomis macrochirus	Bluegill	2	3
Lepomis megalotis	Longear sunfish	17	6
Lepomis microlophus	Redear sunfish	2	
Micropterus salmoides	Largemouth bass	1	3
Etheostoma spectabile	Orangethroat darter	14	4

Fish species collected from West Rocky Creek, Irion County (8/27/90).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (10.7 min)
Campostoma anomalum	Central stoneroller	1	15
Cyprinella venusta	Blacktail shiner	43	6
Moxostoma congestum	Gray redhorse		*
Ictalurus punctatus	Channel catfish		1
Gambusia affinis	Western mosquitofish	24	13
Lepomis cyanellus	Green sunfish		7
Lepomis macrochirus	Bluegill	3	17
Lepomis megalotis	Longear sunfish	5	48
Lepomis punctatus	Spotted sunfish	6	3
Micropterus salmoides	Largemouth bass	2	2
Etheostoma spectabile	Orangethroat darter	3	1

* Observed but not collected

Fish species collected from Deer Creek, Falls County (7/18/89).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (13.1 min)
Lepisosteus osseus	Longnose gar	2	
Dorosoma cepedianum	Gizzard shad	32	
Cyprinella lutrensis	Red shiner	132	50
Cyprinella venusta	Blacktail shiner	1	4
Pimephales vigilax	Bullhead minnow	3	2
Ictiobus bubalus	Smallmouth buffalo	1	
Ameiurus natalis	Yellow bullhead		5
Ictalurus punctatus	Channel catfish	3	41
Gambusia affinis	Western mosquitofish	3	
Lepomis cyanellus	Green sunfish		7
Lepomis macrochirus	Bluegill	2	5
Lepomis megalotis	Longear sunfish		32
Micropterus punctulatus	Spotted bass		1
Micropterus salmoides	Largemouth bass	2	

Fish species collected from Neils Creek, Bosque County (7/19/89).

Species	Common Name	Seine (8 hauls)	Backpack Shocker (17.3 min)
Cyprinella lutrensis	Red shiner	2	
Cyprinella venusta	Blacktail shiner	187	2
Pimephales vigilax	Bullhead minnow	1	
Ameiurus natalis	Yellow bullhead		3
Ictalurus punctatus	Channel catfish		3
Fundulus notatus	Blackstripe topminnow	4	1
Gambusia affinis	Western mosquitofish	20	1
Lepomis cyanellus	Green sunfish		9
Lepomis macrochirus	Bluegill	5	7
Lepomis megalotis	Longear sunfish	5	21
Lepomis microlophus	Redear sunfish		1
Lepomis hybrid	Sunfish hybrid		1
Micropterus punctulatus	Spotted bass	1	1
Micropterus salmoides	Largemouth bass	3	1
Etheostoma spectabile	Orangethroat darter	4	1

Fish species collected from Cottonwood Creek, Fisher County (8/24/88).

Species	Common Name	Seine (8 hauls)
Dorosoma cepedianum	Gizzard shad	12
Campostoma anomalum	Central stoneroller	19
Cyprinella lutrensis	Red shiner	1930
Hybognathus sp.		1
Pimephales vigilax	Bullhead minnow	9
Ictalurus punctatus	Channel catfish	11
Gambusia affinis	Western mosquitofish	1032
Lepomis cyanellus	Green sunfish	17
Lepomis gulosus	Warmouth	3
Lepomis humilus	Orangespotted sunfish	15
Lepomis macrochirus	Bluegill	2
Lepomis megalotis	Longear sunfish	127
Micropterus salmoides	Largemouth bass	1

Fish species collected from Clear Creek, Denton County (8/2/89).

Species	Common Name	Seine (12 hauls)	Backpack Shocker (17.8 min)
Campostoma anomalum	Central stoneroller	2	
Cyprinella lutrensis	Red shiner	82	3
Pimephales vigilax	Bullhead minnow	18	
Carpiodes carpio	River carpsucker	1	
Ameiurus natalis	Yellow bullhead		5
Ictalurus punctatus	Channel catfish	1	
Noturus nocturnus	Freckled madtom		5
Pylodictis olivaris	Flathead catfish		3
Fundulus notatus	Blackstripe topminnow	3	
Gambusia affinis	Western mosquitofish	9	
Lepomis cyanellus	Green sunfish	6	14
Lepomis macrochirus	Bluegill	1	1
Lepomis megalotis	Longear sunfish	1	2
Lepomis sp. (juvenile)	Sunfish species	1	
Micropterus salmoides	Largemouth bass	2	
Etheostoma spectabile	Orangethroat darter		1
Percina macrolepida	Bigscale logperch	1	

Fish species collected from Mill Creek, Austin County (7/19/88).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (14.7 min)
Cyprinella lutrensis	Red shiner	33	
Cyprinella venusta	Blacktail shiner	390	2
Cyprinid sp.	Cyprinid species	10	
Cyprinus carpio	Common carp		1
Notropis amabilis	Texas shiner	1	
Notropis volucellus	Mimic shiner	40	
Pimephales vigilax	Bullhead minnow	158	14
Minytrema melanops	Spotted sucker	13	
Ictalurus punctatus	Channel catfish		1
Pylodictus olivarus	Flathead catfish		1
Gambusia affinis	Western mosquitofish	93	
Fundulus notatus	Blackstripe topminnow	14	
Lepomis cyanellus	Green sunfish	4	3
Lepomis macrochirus	Bluegill	28	
Lepomis megalotis	Longear sunfish	55	6
Micropterus punctulatus	Spotted bass	17	
Micropterus salmoides	Largemouth bass	4	1
Etheostoma gracile	Slough darter	2	
Percina sciera	Dusky darter	1	1

Fish species collected from Cummins Creek, Colorado County (6/25/90).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (7.6 min)
Campostoma anomalum	Central stoneroller	1	
Cyprinella lutrensis	Red shiner	4	
Cyprinella venusta	Blacktail shiner	138	2
Notropis stramineus	Sand shiner	1	
Notropis texanus	Weed shiner	13	
Notropis volucellus	Mimic shiner	1	
Pimephales vigilax	Bullhead minnow		1
Moxostoma congestum	Gray redhorse		1
Ameiurus natalis	Yellow bullhead	1	
Ictalurus punctatus	Channel catfish		1
Noturus gyrinus	Tadpole madtom		1
Fundulus notatus	Blackstripe topminnow	8	1
Gambusia affinis	Western mosquitofish	329	
Lepomis cyanellus	Green sunfish		12
Lepomis gulosus	Warmouth		1
Lepomis macrochirus	Bluegill		3
Lepomis megalotis	Longear sunfish	4	25
Lepomis gulosus	Warmouth		1
Lepomis punctatus	Spotted sunfish	6	3
Micropterus salmoides	Largemouth bass	1	1
Micropterus treculi	Guadalupe bass		2
Percina sciera	Dusky darter	3	3

Fish species collected from Spring Creek, Irion County (8/28/90).

Species	Common Name	Seine (10 hauls)	Backpack Shocker (13.1 min)
Campostoma anomalum	Central stoneroller		2
Cyprinella venusta	Blacktail shiner	127	78
Notropis amabilis	Texas shiner	4	
Notropis stramineus	Sand shiner	5	
Ictalurus punctatus	Channel catfish		1
Gambusia affinis	Western mosquitofish	2	5
Lepomis auritus	Redbreast sunfish		8
Lepomis gulosus	Warmouth		1
Lepomis macrochirus	Bluegill	7	24
Lepomis megalotis	Longear sunfish	3	16
Micropterus salmoides	Largemouth bass	15	18
Cichlasoma cyanoguttatum	Rio Grande cichlid		1

Fish species collected from Elm Creek, Runnels County (8/23/88).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (16.1 min)	Boat Shocker (4 min)
Lepisosteus osseus	Longnose gar	1		
Dorosoma cepedianum	Gizzard shad			1
Cyprinella lutrensis	Red shiner	646		11
Cyprinus carpio	Common carp		1	*
Pimephales vigilax	Bullhead minnow	341	1	1
Carpiodes carpio	River carpsucker	1		
Ictalurus punctatus	Channel catfish	8	1	1
Gambusia affinis	Western mosquitofish	227		
Lepomis cyanellus	Green sunfish	1	5	
Lepomis macrochirus	Bluegill	14	3	2
Lepomis megalotis	Longear sunfish	19	1	
Micropterus salmoides	Largemouth bass	3		
Etheostoma spectabile	Orangethroat darter	3		

* Observed but not collected

APPENDIX F

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregion 30 (Central Texas Plateau)

Fish species collected from Little Barton Creek, Travis County (7/7/88).

Species	Common Name	Seine (11 hauls)	Backpack Shocker (15.7 min)
Campostoma anomalum	Central stoneroller	54	31
Cyprinella venusta	Blacktail shiner	248	18
Ameiurus natalis	Yellow bullhead		3
Ictalurus punctatus	Channel catfish		1
Gambusia affinis	Western mosquitofish	131	2
Lepomis auritus	Redbreast sunfish		34
Lepomis cyanellus	Green sunfish		2
Lepomis macrochirus	Bluegill		4
Lepomis megalotis	Longear sunfish	6	18
Micropterus salmoides	Largemouth bass	2	
Micropterus treculi	Guadalupe bass	1	5

Fish species collected from Oatmeal Creek, Burnet County (6/30/88).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (unrecorded)
Campostoma anomalum	Central stoneroller	144	
Cyprinella venusta	Blacktail shiner	62	4
Ameiurus natalis	Yellow bullhead		1
Ictalurus punctatus	Channel catfish		*
Lepomis cyanellus	Green sunfish	2	8
Lepomis megalotis	Longear sunfish	32	10
Micropterus salmoides	Largemouth bass	10	
Etheostoma lepidum	Greenthroat darter	10	

* Observed but not collected

Fish species collected from the Little Blanco River, Blanco County (6/29/88).

Species	Common Name	Seine (9 hauls)	Backpack Shocker (7.8 min)
Campostoma anomalum	Central stoneroller	5	
Cyprinella lutrensis	Red shiner	87	2
Cyprinella venusta	Blacktail shiner	4	
Notropis stramineus	Sand shiner	6	
Ictalurus punctatus	Channel catfish		1
Gambusia affinis	Western mosquitofish	46	2
Lepomis auritus	Redbreast sunfish	31	7
Lepomis cyanellus	Green sunfish		4
Lepomis gulosus	Warmouth		1
Lepomis hybrid	Sunfish hybrid		2
Lepomis macrochirus	Bluegill		2
Lepomis megalotis	Longear sunfish	12	7
Micropterus salmoides	Largemouth bass	2	1

Fish species collected from Barton Creek, Travis County (7/7/88).

Species	Common Name	Seine (10 hauls)	Backpack Shocker (15	Boat Shocker minutes)
Campostoma anomalum	Central stoneroller	60		
Cyprinella venusta	Blacktail shiner	58		1
Ictalurus punctatus	Channel catfish			9
Gambusia affinis	Western mosquitofish	56		
Lepomis auritus	Redbreast sunfish	16		13
Lepomis macrochirus	Bluegill	5		3
Lepomis megalotis	Longear sunfish	4		
Lepomis microlophus	Redear sunfish	1	2	
Micropterus salmoides	Largemouth bass	1	2	
Micropterus treculi	Guadalupe bass	3	4	

Fish species collected from Rocky Creek, Burnet County (6/30/88).

Species	Common Name	Seine (6 hauls)
Campostoma anomalum	Central stoneroller	364
Cyprinella lutrensis	Red shiner	4
Cyprinella venusta	Blacktail shiner	251
Notemigonus crysoleucas	Golden shiner	1
Notropis volucellus	Mimic shiner	1
Pimephales vigilax	Bullhead minnow	2
Gambusia affinis	Western mosquitofish	74
Lepomis cyanellus	Green sunfish	8
Lepomis humilis	Orangespotted sunfish	1
Lepomis macrochirus	Bluegill	21
Lepomis megalotis	Longear sunfish	40
Lepomis sp. (juvenile)	Sunfish species	43
Micropterus salmoides	Largemouth bass	25
Etheostoma spectabile	Orangethroat darter	8

Fish species collected from Onion Creek, Hays County (7/6/88).

Species	Common Name	Seine (8 hauls)	Backpack Shocker (8.9 min)
Campostoma anomalum	Central stoneroller	31	32
Cyprinella venusta	Blacktail shiner	74	12
Notemigonus crysoleucas	Golden shiner	1	
Ameiurus natalis	Yellow bullhead		1
Ictalurus punctatus	Channel catfish		4
Gambusia affinis	Western mosquitofish	21	
Lepomis auritus	Redbreast sunfish	5	4
Lepomis cyanellus	Green sunfish	2	6
Lepomis macrochirus	Bluegill	1	
Lepomis megalotis	Longear sunfish	7	3
Lepomis sp. (juvenile)	Sunfish species	2	
Micropterus salmoides	Largemouth bass	17	1

Fish species collected from the South Llano River, Kimble County (6/21/89).

Species	Common Name	Seine (8 hauls)	Boat Shocker (13.2 min)
Cyprinella venusta	Blacktail shiner	63	1
Dionda episcopa	Roundnose minnow	8	
Notropis amabilis	Texas shiner	221	20
Notropis volucellus	Mimic shiner	423	2
Moxostoma congestum	Gray redhorse		2
Lepomis auritus	Redbreast sunfish	2	12
Lepomis cyanellus	Green sunfish		2
Lepomis gulosus	Warmouth		1
Lepomis megalotis	Longear sunfish		11
Micropterus salmoides	Largemouth bass		2
Micropterus treculi	Guadalupe bass	1	16
Etheostoma spectabile	Orangethroat darter	1	
Percina carbonaria	Texas logperch		9
Cichlasoma cyanoguttatum	Rio Grande cichlid	4	1

Fish species collected from the Medina River, Bandera County (6/20/89).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (20.2 min)
Campostoma anomalum	Central stoneroller	3	2
Cyprinella venusta	Blacktail shiner	50	
Notropis amabilis	Texas shiner	198	
Notropis stramineus	Sand shiner	1	1
Notropis volucellus	Mimic shiner	59	
Moxostoma congestum	Gray redhorse	*	
Ictalurus punctatus	Channel catfish		2
Gambusia affinis	Western mosquitofish	27	1
Lepomis auritus	Redbreast sunfish	1	3
Lepomis cyanellus	Green sunfish		9
Lepomis gulosus	Warmouth		3
Lepomis hybrid	Sunfish hybrid		1
Lepomis macrochirus	Bluegill		5
Lepomis megalotis	Longear sunfish	2	11
Micropterus treculi	Guadalupe bass		3
Cichlasoma cyanoguttatum	Rio Grande cichlid		1

* Observed but not collected

Fish species collected from Cowhouse Creek, Coryell County (6/21/89).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (13.9 min)
Campostoma anomalum	Central stoneroller	7	
Cyprinella lutrensis	Red shiner	41	
Cyprinella venusta	Blacktail shiner	101	
Pimephales vigilax	Bullhead minnow	5	1
Ictalurus punctatus	Channel catfish	1	1
Lepomis cyanellus	Green sunfish		18
Lepomis humilus	Orangespotted sunfish	1	9
Lepomis macrochirus	Bluegill		2
Lepomis megalotis	Longear sunfish	6	12
Micropterus punctulatus	Spotted bass	2	
Etheostoma spectabile	Orangethroat darter	17	1

APPENDIX G

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregion 31 (Southern Texas Plains)

Fish species collected from Pinto Creek, Kinney County (6/13/90).

Species	Common Name	Seine (8 hauls)	Backpack Shocker (12 min)
Cyprinella lutrensis	Red shiner	134	5
Cyprinella venusta	Blacktail shiner	1	
Notropis amabilis	Texas shiner	7	
Ictalurus punctatus	Channel catfish	2	13
Gambusia affinis	Western mosquitofish	12	
Poecilia latipinna	Sailfin molly	1	
Lepomis auritus	Redbreast sunfish		5
Lepomis cyanellus	Green sunfish		1
Lepomis gulosus	Warmouth		7
Lepomis macrochirus	Bluegill	7	10
Lepomis megalotis	Longear sunfish		11
Lepomis microlophus	Redear sunfish	1	1
Micropterus salmoides	Largemouth bass	15	12
Cichlasoma cyanoguttatum	Rio Grande cichlid	3	1

Fish species collected from Metate Creek, Atascosa County (7/30/90).

Species	Common Name	Seine (10 hauls)	Backpack Shocker (13 min)
Cyprinella lutrensis	Red shiner	11	
Pimephales vigilax	Bullhead minnow	2	1
Ictiobus bubalus	Smallmouth buffalo		1
Ameiurus melas	Black bullhead		4
Gambusia affinis	Western mosquitofish	150	60
Poecilia latipinna	Sailfin molly	12	1
Lepomis gulosus	Warmouth	1	
Lepomis macrochirus	Bluegill	24	1
Lepomis sp. (juvenile)	Sunfish species		1

Fish species collected from Sycamore Creek, Kinney County (6/12/90).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (10.4 min)
Campostoma anomalum	Central stoneroller	18	6
Cyprinella lutrensis	Red shiner	13	3
Cyprinella proserpina	Proserpine shiner	19	1
Cyprinella venusta	Blacktail shiner	10	7
Cyprinus carpio	Common carp	2	14
Dionda episcopa	Roundnose minnow	150	44
Notropis amabilis	Texas shiner	39	2
Notropis stramineus	Sand shiner	1	
Pimephales vigilax	Bullhead minnow	6	4
Astyanax mexicanus	Mexican tetra	53	6
Ameiurus natalis	Yellow bullhead		1
Ictalurus lupus	Headwater catfish	20	1
Gambusia affinis	Western mosquitofish	9	2
Lepomis auritus	Redbreast sunfish		3
Lepomis cyanellus	Green sunfish		1
Lepomis macrochirus	Bluegill	1	4
Lepomis megalotis	Longear sunfish		14
Micropterus salmoides	Largemouth bass	10	9
Etheostoma grahami	Rio Grande darter	3	10
Cichlasoma cyanoguttatum	Rio Grande cichlid	1	5
Tilapia aurea	Blue tilapia		1

Fish species collected from San Miguel Creek, Atascosa County (7/31/90).

Species	Common Name	Seine (11 hauls)	Backpack Shocker (16.7 min)
Lepisosteus oculatus	Spotted gar		2
Dorosoma cepedianum	Gizzard shad	2	
Cyprinella lutrensis	Red shiner	23	3
Pimephales vigilax	Bullhead minnow	1	
Ameriurus melas	Black bullhead	1	1
Gambusia affinis	Western mosquitofish	105	56
Lepomis cyanellus	Green sunfish	6	12
Lepomis gulosus	Warmouth		2
Lepomis humilis	Orangespotted sunfish		1
Lepomis hybrid	Hybrid sunfish	1	
Lepomis macrochirus	Bluegill	3	2
Lepomis megalotis	Longear sunfish	3	1
Micropterus salmoides	Largemouth bass	1	
Pomoxis annularis	White crappie	1	

APPENDIX H

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregions 33 and 35 (South Central and Southern Humid, Mixed Land Use Region)

Fish species collected from Ponds Creek, Waller County (7/19/88).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (6.6 min)
Cyprinella venusta	Blacktail shiner	3	7
Cyprinid sp.	Cyprinid species	1	
Lythrurus fumeus	Ribbon shiner	32	
Notropis atrocaudalis	Blackspot shiner	6	6
Ameiurus melas	Black bullhead		1
Ameiurus natalis	Yellow bullhead		2
Noturus gyrinus	Tadpole madtom		2
Esox americanus vermiculatus	Grass pickerel		1
Aphredoderus sayanus	Pirate perch	1	14
Gambusia affinis	Western mosquitofish	682	17
Elassoma zonatum	Banded pygmy sunfish		1
Lepomis gulosus	Warmouth		2
Lepomis macrochirus	Bluegill		5
Lepomis megalotis	Longear sunfish	21	14
Lepomis sp.	Sunfish species	23	
Etheostoma sp.	Darter species		*

* Observed but not collected

Fish species collected from Wheelock Creek, Leon County (8/17/88).

Species	Common Name	Seine (9 hauls)	Backpack Shocker (18.9 min)
Cyprinella venusta	Blacktail shiner	50	22
Lythrurus fumeus	Ribbon shiner	10	3
Notropis atrocaudalis	Blackspot shiner	2	4
Notropis texanus	Weed shiner		3
Pimephales vigilax	Bullhead minnow		10
Erimyzon sucetta	Lake chubsucker		3
Ameiurus natalis	Yellow bullhead	2	12
Noturus nocturnus	Freckled madtom	2	10
Fundulus notatus	Blackstripe topminnow		1
Fundulus olivaceus	Blackspotted topminnow	36	9
Lepomis cyanellus	Green sunfish		2
Lepomis macrochirus	Bluegill		17
Lepomis megalotis	Longear sunfish		10
Micropterus salmoides	Largemouth bass		2
Etheostoma parvipinne	Goldstripe darter		4
Percina sciera	Dusky darter	2	3

Fish species collected from Black Cypress Creek, Cass County (8/30/89).

Species	Common Name	Seine (12 hauls)	Backpack Shocker (18.9 min)
Cyprinidae sp.	Shiner species	1	
Luxilus chrysocephalus	Striped shiner	8	
Lythrurus fumeus	Ribbon shiner	37	2
Lythrurus umbratilis	Redfin shiner	10	
Notemigonus crysoleucas	Golden shiner	1	
Notropis texanus	Weed shiner		1
Opsopoeodus emiliae	Pugnose minnow	1	1
Pimephales vigilax	Bullhead minnow		1
Noturus gyrinus	Tadpole madtom		2
Aphredoderus sayanus	Pirate perch		15
Fundulus notatus	Blackstripe topminnow	3	1
Gambusia affinis	Western mosquitofish	93	
Centrarchus macropterus	Flier		1
Lepomis cyanellus	Green sunfish		1
Lepomis gulosus	Warmouth		4
Lepomis macrochirus	Bluegill	1	21
Lepomis megalotis	Longear sunfish	1	1
Lepomis punctatus	Spotted sunfish		3
Micropterus salmoides	Largemouth bass		2
Etheostoma gracile	Slough darter	5	7
Etheostoma proeliare	Cypress darter	4	3
Etheostoma whipplei	Redfin darter	1	
Percina sciera	Dusky darter		1

Fish species collected from Beech Creek, Tyler County (9/12/89).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (16.8 min)
Cyprinella venusta	Blacktail shiner	1	
Lythrurus umbratilis	Redfin shiner	3	
Notropis chalybaeus	Ironcolor shiner	3	
Ameiurus natalis	Yellow bullhead		3
Noturus gyrinus	Tadpole madtom		2
Noturus nocturnus	Freckled madtom		5
Esox americanus vermiculatus	Grass pickerel		2
Aphredoderus sayanus	Pirate perch		22
Fundulus notatus	Blackstripe topminnow	10	6
Fundulus olivaceus	Blackspotted topminnow		4
Gambusia affinis	Western mosquitofish	1	1
Labidesthes sicculus	Brook silverside	9	
Elassoma zonatum	Banded pygmy sunfish		3
Lepomis cyanellus	Green sunfish		2
Lepomis gulosus	Warmouth		3
Lepomis macrochirus	Bluegill		8
Lepomis marginatus	Dollar sunfish		2
Lepomis megalotis	Longear sunfish		15
Lepomis punctatus	Spotted sunfish		4
Lepomis sp. (juvenile)	Sunfish species		1
Micropterus salmoides	Largemouth bass		1
Etheostoma chlorosomum	Bluntnose darter	6	2
Etheostoma gracile	Slough darter		1
Etheostoma proeliare	Cypress darter		2
Percina sciera	Dusky darter	1	2

Fish species collected from White Oak Creek, Newton County (9/12/89).

Species	Common Name	Seine (12 hauls)	Backpack Shocker (13.4 min)
Cyprinella venusta	Blacktail shiner	18	17
Hybognathus nuchalis	Mississippi silvery minnow	2	
Lythrurus fumeus	Ribbon shiner	19	
Notropis texanus	Weed shiner	35	8
Notropis volucellus	Mimic shiner	5	
Ameiurus natalis	Yellow bullhead		1
Aphredoderus sayanus	Pirate perch		13
Fundulus olivaceus	Blackspotted topminnow	7	4
Gambusia affinis	Western mosquitofish	1	
Elassoma zonatum	Banded pygmy sunfish		1
Lepomis macrochirus	Bluegill	1	
Lepomis megalotis	Longear sunfish		6
Lepomis microlophus	Redear sunfish	1	
Micropterus punctulatus	Spotted bass	1	
Micropterus salmoides	Largemouth bass	2	
Ammocrypta vivax	Scaly sand darter	7	
Etheostoma chlorosomum	Bluntnose darter	3	
Etheostoma gracile	Slough darter	1	
Etheostoma parvipinne	Goldstripe darter	1	1
Percina sciera	Dusky darter	1	1

Fish species collected from Frazier Creek, Cass County (8/29/89).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (15 min)
Luxilus chrysocephalus	Striped shiner	12	
Lythrurus fumeus	Ribbon shiner	82	
Lythrurus umbratilis	Redfin shiner	38	
Notemigonus crysoleucas	Golden shiner		3
Opsopoeodus emiliae	Pugnose minnow	1	
Pimephales vigilax	Bullhead minnow	2	
Ameiurus natalis	Yellow bullhead		3
Esox americanus vermiculatus	Grass pickerel	1	
Aphredoderus sayanus	Pirate perch		12
Fundulus notatus	Blackstripe topminnow	8	4
Gambusia affinis	Western mosquitofish	21	
Labidesthes sicculus	Brook silverside	12	
Lepomis cyanellus	Green sunfish		2
Lepomis macrochirus	Bluegill		13
Lepomis megalotis	Longear sunfish		21
Lepomis microlophus	Redear sunfish	5	1
Lepomis punctatus	Spotted sunfish		1
Micropterus salmoides	Largemouth bass	1	1
Etheostoma gracile	Slough darter	5	
Etheostoma proeliare	Cypress darter	3	2
Percina carbonaria	Texas logperch		2

Fish species collected from Irons Bayou, Panola County (8/30/89).

Species	Common Name	Seine (8 hauls)	Backpack Shocker (15.9 min)
Cyprinella lutrensis	Red shiner	1	
Cyprinella venusta	Blacktail shiner		1
Lythrurus fumeus	Ribbon shiner	33	
Notropis texanus	Weed shiner	1	1
Opsopoeodus emiliae	Pugnose minnow	21	2
Pimephales vigilax	Bullhead minnow	4	3
Ameiurus natalis	Yellow bullhead		1
Noturus gyrinus	Tadpole madtom		1
Aphredoderus sayanus	Pirate perch		11
Fundulus olivaceus	Blackspotted topminnow	2	
Lepomis cyanellus	Green sunfish		10
Lepomis gulosus	Warmouth		2
Lepomis macrochirus	Bluegill	3	3
Lepomis megalotis	Longear sunfish	1	11
Lepomis microlophus	Redear sunfish	8	4
Lepomis punctatus	Spotted sunfish		6
Lepomis sp. (juvenile)	Sunfish species	2	
Micropterus salmoides	Largemouth bass		2
Etheostoma chlorosomum	Bluntnose darter	21	
Etheostoma gracile	Slough darter	3	2
Etheostoma radiosum	Orangebelly darter		4
Percina sciera	Dusky darter		2

Fish species collected from Piney Creek, Trinity County (9/14/89).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (17.9 min)
Cyprinella venusta	Blacktail shiner	6	3
Hybognathus nuchalis	Mississippi silvery minnow		2
Lythrurus fumeus	Ribbon shiner	20	6
Notemigonus crysoleucas	Golden shiner	1	
Notropis atrocaudalis	Blackspot shiner	4	3
Notropis texanus	Weed shiner	3	1
Pimephales vigilax	Bullhead minnow	3	2
Erimyzon oblongus	Creek chubsucker		1
Minytrema melanops	Spotted sucker	1	1
Ameiurus natalis	Yellow bullhead		1
Esox americanus vermiculatus	Grass pickerel	1	
Aphredoderus sayanus	Pirate perch		6
Fundulus notatus	Blackstripe topminnow	8	
Gambusia affinis	Western mosquitofish	116	4
Lepomis cyanellus	Green sunfish	1	8
Lepomis macrochirus	Bluegill		4
Lepomis marginatus	Dollar sunfish		1
Lepomis megalotis	Longear sunfish		2
Micropterus salmoides	Largemouth bass	1	2
Etheostoma chlorosomum	Bluntnose darter	4	
Etheostoma gracile	Slough darter	6	1
Percina sciera	Dusky darter		1

Fish species collected from Keechi Creek, Leon County (8/17/88).

Species	Common Name	Seine (8 hauls)	Backpack Shocker (13.7 min)
Dorosoma cepedianum	Gizzard shad	5	
Cyprinella venusta	Blacktail shiner	20	4
Lythrurus fumeus	Ribbon shiner	28	
Pimephales vigilax	Bullhead minnow	3	
Moxostoma poecilurum	Blacktail redhorse	2	
Noturus nocturnus	Freckled madtom		5
Esox americanus vermiculatus	Grass pickerel		1
Aphredoderus sayanus	Pirate perch		1
Fundulus notatus	Blackstripe topminnow	18	
Gambusia affinis	Western mosquitofish	5	1
Lepomis cyanellus	Green sunfish		2
Lepomis gulosus	Warmouth	1	1
Lepomis megalotis	Longear sunfish	4	7
Micropterus punctulatus	Spotted bass		4
Micropterus salmoides	Largemouth bass	1	
Etheostoma gracile	Slough darter	1	
Percina sciera	Dusky darter	1	4

Fish species collected from the East Fork of the San Jacinto River, San Jacinto County (7/20/88).

Species	Common Name	Seine (9 hauls)	Backpack Shocker (12.5 min)
Cyprinella venusta	Blacktail shiner	48	2
Lythrurus fumeus	Ribbon shiner	4	
Notropis sabinae	Sabine shiner	1	
Notropis volucellus	Mimic shiner	26	1
Pimephales vigilax	Bullhead minnow	3	
Minytrema melanops	Spotted sucker		1
Moxostoma poecilurum	Blacktail redhorse	4	4
Ictalurus punctatus	Channel catfish		2
Noturus gyrinus	Tadpole madtom		1
Aphredoderus sayanus	Pirate perch		4
Fundulus notatus	Blackstripe topminnow	14	2
Gambusia affinis	Western mosquitofish	11	
Lepomis gulosus	Warmouth		1
Lepomis macrochirus	Bluegill		2
Lepomis megalotis	Longear sunfish	12	23
Lepomis punctatus	Spotted sunfish		1
Micropterus punctulatus	Spotted bass	3	2
Pomoxis nigromaculatus	Black crappie		1
Ammocrypta vivax	Scaly sand darter	3	
Percina macrolepida	Bigscale logperch	1	
Percina sciera	Dusky darter	1	1
Aplodinotus grunniens	Freshwater drum		1

Fish species collected from Big Cypress Creek, Newton County (9/12/89).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (13.4 min)
Lepisosteus oculatus	Spotted gar		1
Hybognathus hayi	Cypress minnow	1	
Lythrurus fumeus	Ribbon shiner	16	
Notemigonus crysoleucas	Golden shiner	6	
Notropis texanus	Weed shiner	101	4
Opsopoeodus emiliae	Pugnose minnow	3	
Ameiurus natalis	Yellow bullhead		2
Noturus gyrinus	Tadpole madtom		17
Aphredoderus sayanus	Pirate perch	1	71
Fundulus notatus	Blackstripe topminnow	4	
Gambusia affinis	Western mosquitofish	124	11
Labidesthes sicculus	Brook silverside	6	
Elassoma zonatum	Banded pygmy sunfish	3	6
Lepomis cyanellus	Green sunfish		1
Lepomis gulosus	Warmouth	2	31
Lepomis macrochirus	Bluegill	4	3
Lepomis marginatus	Dollar sunfish		4
Lepomis megalotis	Longear sunfish	6	
Lepomis punctatus	Spotted sunfish		8
Lepomis symmetricus	Bantam sunfish	3	7
Micropterus salmoides	Largemouth bass	6	
Pomoxis nigromaculatus	Black crappie	2	
Etheostoma asprigene	Mud darter		1
Etheostoma chlorosomum	Bluntnose darter	1	
Etheostoma gracile	Slough darter	2	

Fish species collected from Catfish Creek, Anderson County (8/16/88).

Species	Common Name	Seine (9 hauls)	Backpack Shocker (15.6 min)
Cyprinella venusta	Blacktail shiner	11	4
Lythrurus fumeus	Ribbon shiner	34	6
Notropis texanus	Weed shiner	29	3
Opsopoeodus emiliae	Pugnose minnow		1
Pimephales vigilax	Bullhead minnow	15	
Minytrema melanops	Spotted sucker	6	
Ameiurus natalis	Yellow bullhead	1	2
Ictalurus punctatus	Channel catfish		1
Noturus nocturnus	Freckled madtom	3	3
Pylodictus olivarus	Flathead catfish		1
Esox americanus vermiculatus	Grass pickeral	1	2
Aphredoderus sayanus	Pirate perch		1
Gambusia affinis	Western mosquitofish	2	
Fundulus notatus	Blackstripe topminnow	5	
Lepomis cyanellus	Green sunfish		4
Lepomis gulosus	Warmouth	2	3
Lepomis macrochirus	Bluegill	4	
Lepomis megalotis	Longear sunfish	5	15
Lepomis punctatus	Spotted sunfish		9
Lepomis sp. (juvenile)	Sunfish species		1
Micropterus sp.	Black bass	*	
Pomoxis nigromaculatus	Black crappie	2	1
Etheostoma chlorosomum	Bluntnose darter	6	
Etheostoma gracile	Slough darter	1	
Percina sciera	Dusky darter		3

* Observed but not collected

Fish species collected from Little Cypress Creek, Upshur County (8/31/89).

Species	Common Name	Seine (10 hauls)	Backpack Shocker (14 min)
Cyprinella venusta	Blacktail shiner	1	2
Luxilus chrysocephalus	Striped shiner	1	
Lythrurus fumeus	Ribbon shiner	96	8
Lythrurus umbratilis	Redfin shiner		1
Notropis texanus	Weed shiner	7	4
Opsopoeodus emiliae	Pugnose minnow	2	
Pimephales vigilax	Bullhead minnow	1	
Ameiurus natalis	Yellow bullhead		4
Noturus gyrinus	Tadpole madtom		2
Aphredoderus sayanus	Pirate perch		10
Fundulus notatus	Blackstripe topminnow	4	2
Gambusia affinis	Western mosquitofish	34	1
Centrarchus macropterus	Flier		1
Lepomis cyanellus	Green sunfish		4
Lepomis gulosus	Warmouth		2
Lepomis macrochirus	Bluegill	3	1
Lepomis megalotis	Longear sunfish	4	4
Lepomis microlophus	Redear sunfish		1
Micropterus salmoides	Largemouth bass		1
Etheostoma asprigene	Mud darter		2
Etheostoma chlorosomum	Bluntnose darter	5	
Etheostoma gracile	Slough darter	6	4
Etheostoma proeliare	Cypress darter	1	
Etheostoma whipplei	Redfin darter	1	1
Percina sciera	Dusky darter		4

Fish species collected from Lake Creek, Montgomery County (7/21/88).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (21.3 min)
Lepisosteus oculatus	Spotted gar		2
Lepisosteus spatula	Alligator gar		1
Cyprinella lutrensis	Red shiner	1	4
Cyprinella venusta	Blacktail shiner	247	34
Lythrurus fumeus	Ribbon shiner	2	
Lythrurus umbratilis	Redfin shiner	1	
Notropis sabinae	Sabine shiner	139	
Notropis volucellus	Mimic shiner	20	12
Pimephales vigilax	Bullhead minnow	84	13
Moxostoma poecilurum	Blacktail redhorse	8	1
Noturus nocturnus	Freckled madtom		1
Pylodictis olivaris	Flathead catfish		1
Aphredoderus sayanus	Pirate perch		3
Fundulus notatus	Blackstripe topminnow	13	5
Gambusia affinis	Western mosquitofish	9	
Labidesthes sicculus	Brook silverside	7	
Lepomis gulosus	Warmouth		1
Lepomis macrochirus	Bluegill		10
Lepomis megalotis	Longear sunfish	15	33
Lepomis punctatus	Spotted sunfish		1
Lepomis sp. (juvenile)	Sunfish species	1	
Micropterus punctulatus	Spotted bass	19	9
Micropterus salmoides	Largemouth bass		2
Percina sciera	Dusky darter		4

APPENDIX I

Fish Species and Abundance in Selected Least Disturbed Reference Streams within Ecoregion 34 (Western Gulf Coastal Plain)

Fish species collected from Placedo Creek, Victoria County (9/7/88).

Species	Common Name	Seine (5 hauls)	Backpack Shocker (12.2 min)
Anguilla rostrata	American eel		4
Cyprinella lutrensis	Red shiner	61	5
Ameiurus natalis	Yellow bullhead		2
Ictalurus punctatus	Channel catfish	1	
Gambusia affinis	Western mosquitofish	637	7
Lepomis cyanellus	Green sunfish	1	
Lepomis gulosus	Warmouth		4
Lepomis macrochirus	Bluegill	1	5
Lepomis megalotis	Longear sunfish	5	16

Fish species collected from West Carancahua Creek, Jackson County (9/7/88).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (10.3 min)
Anguilla rostrata	American eel		1
Cyprinella lutrensis	Red shiner	1360	3
Opsopoeodus emiliae	Pugnose minnow	9	1
Pimephales vigilax	Bullhead minnow		1
Ameiurus natalis	Yellow bullhead		1
Ictalurus punctatus	Channel catfish	32	16
Noturus gyrinus	Tadpole madtom	1	
Gambusia affinis	Western mosquitofish	430	2
Lepomis cyanellus	Green sunfish	3	9
Lepomis gulosus	Warmouth		5
Lepomis macrochirus	Bluegill		2
Lepomis megalotis	Longear sunfish		1

Fish species collected from Big Creek, Fort Bend County (6/20/90).

Species	Common Name	Seine (7 hauls)	Backpack Shocker (6.6 min)
Lepisosteus oculatus	Spotted gar	1	
Dorosoma cepedianum	Gizzard shad	84	
Cyprinella lutrensis	Red shiner	90	
Pimephales vigilax	Bullhead minnow	52	4
Ameiurus natalis	Yellow bullhead		1
Ictalurus punctatus	Channel catfish		1
Pylodictis olivaris	Flathead catfish	1	*
Gambusia affinis	Western mosquitofish	158	9
Lepomis cyanellus	Green sunfish		2
Lepomis gulosus	Warmouth	1	2
Lepomis macrochirus	Bluegill		3
Lepomis megalotis	Longear sunfish	2	4
Micropterus salmoides	Largemouth bass	1	
Pomoxis annularis	White crappie	3	
Etheostoma gracile	Slough darter		2

* Observed but not collected

Fish species collected from Arenosa Creek, Jackson County (9/8/88).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (19.5 min)
Lepisosteus oculatus	Spotted gar		4
Anguilla rostrata	American eel		1
Cyprinella lutrensis	Red shiner	9	
Opsopoeodus emiliae	Pugnose minnow	4	
Gambusia affinis	Western mosquitofish	1056	4
Lepomis cyanellus	Green sunfish		11
Lepomis macrochirus	Bluegill	30	3
Lepomis megalotis	Longear sunfish	29	6
Micropterus salmoides	Largemouth bass	2	

Fish species collected from West Mustang Creek, Wharton County (6/21/90).

Species	Common Name	Seine (9 hauls)
Lepisosteus oculatus	Spotted gar	1
Lepisosteus osseus	Longnose gar	1
Cyprinella lutrensis	Red shiner	201
Cyprinella venusta	Blacktail shiner	35
Opsopoeodus emiliae	Pugnose minnow	5
Pimephales vigilax	Bullhead minnow	13
Ameiurus natalis	Yellow bullhead	2
Ictalurus punctatus	Channel catfish	5
Noturus gyrinus	Tadpole madtom	4
Pylodictis olivaris	Flathead catfish	1
Gambusia affinis	Western mosquitofish	329
Lepomis megalotis	Longear sunfish	4

Fish species collected from West Bernard Creek, Wharton County (6/20/90).

Species	Common Name	Seine (6 hauls)	Backpack Shocker (2.1 min)
Lepisosteus oculatus	Spotted gar		2
Cyprinella lutrensis	Red shiner	3	1
Cyprinus carpio	Common carp		4
Opsopoeodus emiliae	Pugnose minnow	3	
Pimephales vigilax	Bullhead minnow	2	
Ictalurus punctatus	Channel catfish	2	
Noturus gyrinus	Tadpole madtom		1
Aphredoderus sayanus	Pirate perch		7
Gambusia affinis	Western mosquitofish	102	146
Lepomis cyanellus	Green sunfish	7	17
Lepomis gulosus	Warmouth		3
Lepomis humilus	Orangespotted sunfish	2	4
Lepomis macrochirus	Bluegill		1
Lepomis megalotis	Longear sunfish	1	4
Pomoxis annularis	White crappie	3	
Etheostoma gracile	Slough darter	1	3

APPENDIX J

Classification of Texas Freshwater Fishes into Trophic and Tolerance Groups

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Classification of Texas Freshwater Fishes into Trophic and Tolerance Groups

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The Index of Biotic Integrity (IBI) as proposed by Karr (1981) and modified by others (Miller *et al*. 1988) provides a means of assessing the health of a stream through attributes of its fish community. IBI is an EPA approved technique for conducting biological monitoring (Plafkin *et al*. 1989). It is comprised of biological metrics, which fall into three broad categories: species composition, trophic composition, and fish abundance and condition. Data are obtained for each of these metrics at a given site and evaluated in light of what might be expected at an unimpacted site located in a similar geographical region and on a stream of comparable size. Designation of fish into feeding guilds is an essential part of IBI. Trophic composition metrics offer a means of evaluating the shift toward more generalized foraging that typically occurs with increased degradation of the physical and chemical habitat. Identification of the most tolerant and intolerant fish species is also a vital part of IBI. Intolerant species are typically the first species to disappear following a disturbance and therefore provide a means for distinguishing high and moderate quality sites. Tolerant species typically show increasd distribution or abundance despite the historical degradation of surface water and shift from incidental to dominant in disturbed sites. This metric therefore helps distinguish low from moderate quality waters. The absence of comprehensive lists for Texas species prompted this endeavor.

Methods

Individuals with an expertise in Texas freshwater fishes were sent a survey requesting that a feeding guild (herbivore, invertivore, piscivore, or omnivore) be assigned to adult members of each fish species for which they had knowledge. The list of fishes included on the survey was modified from Hubbs (1982). The final species list included in this manuscript relies upon Hubbs *et al*. (1991). Scientific and common names follow Robins *et al*. (1991). Feeding guilds for the study were defined as:

herbivore (H) - diet of adult consists entirely of plant material;

invertivore (IF) - diet of adult consists primarily of insects, but may also occasionally include small crustacea and fish (or eggs and larvae);

piscivore (P) - diet of adult is predominantly fish, but may also include frogs, crustacea, and insects (Karr et al. 1986);

omnivore (O) - diet of adult consists of significant quantities of both plant and animal materials (at least 25% plant and 25% animal)(Schlosser 1982).

In addition, survey participants were requested to designate the species which are especially tolerant or intolerant of organic enrichment and low dissolved oxygen concentrations. Literature was also reviewed to supplement the returned surveys.

Results and Discussion

Texas' freshwater fishes (Hubbs et al. 1991) were classified into trophic and tolerance groups (Table 1) using returned surveys from fishery professionals familiar with Texas fishes, and with information gathered from a comprehensive literature review. Survey responders are listed in Appendix A and literature relied upon for trophic and tolerance information is provided in Appendix B.

When conflicting responses occurred in trophic classifications that trophic group receiving the most positive responses was selected. In the event of ties, survey responses were given more weight than the literature since the literature represented information from a large geographical area.

Since the tolerance classification was to determine the most tolerant and intolerant species, conflicting responses were treated differently than those for trophic classification. Those few species with conflicting classifications were therefore not classified but were left within the intermediate range, except for gizzard shad

Table 1. Trophic and tolerance classification of Texas freshwater fish species. Trophic group designations are as follows: IF-invertivore; P-piscivore; O-omnivore; and H-herbivore. Tolerance designations are: T-tolerant; I-intolerant. Those species without a tolerance designation are considered intermediate.

Scientific name	Common name	Trophic Group	Tolerance
Ichthyomyzon castaneus	Chesnut lamprey	P	I
Ichthyomyzon gagei	Southern brook lamprey	NONE	I
Carcharhinus isodon	Fine tooth shark	P	
Carcharhinus leucas	Bull shark	P	
Pristis pectinata	Smalltooth sawfish	P	
Dasyatis sabina	Atlantic stingray	IF	
Scaphirynchus platorynchus	Shovelnose sturgeon	IF	
Polyodon spathula	Paddlefish	O	I
Lepisosteus oculatus	Spotted gar	P	T
Lepisosteus osseus	Longnose gar	P	T
Lepisosteus platostomus	Shortnose gar	P	T
Lepisosteus spatula	Alligator gar	P	T
Amia calva	Bowfin	P	T
Hiodon alosoides	Goldeye	IF	
Elops saurus	Ladyfish	P	
Megalops atlanticus	Tarpon	P	T
Anguilla rostrata	American eel	P	
Myrophis punctatus	Speckled worm eel	P	
Alosa chrysochloris	Skipjack herring	P	
Brevoortia gunteri	Finescale menhaden	O	
Dorosoma cepedianum	Gizzard shad	O	T
Dorosoma petenense	Threadfin shad	O	
Harengula jaguana	Scaled sardine	IF	
Anchoa hepsetus	Striped anchovy	IF	
Anchoa mitchilli	Bay anchovy	IF	
Campostoma anomalum	Central stoneroller	H	
Campostoma ornatum	Mexican stoneroller	H	
Carassius auratus	Goldfish	O	T
Ctenopharyngodon idella	Grass carp	H	T
Cyprinella lutrensis	Red shiner	IF	T
Cyprinella proserpina	Proserpine shiner	IF	
Cyprinella venusta	Blacktail shiner	IF	
Cyprinus carpio	Common carp	O	T
Dionda diaboli	Devils River minnow	IF	I
Dionda episcopa	Roundnose minnow	O	I
Gila pandora	Rio Grande chub	IF	I
Hybognathus hayi	Cypress minnow	O	

Table 1. continued.

Scientific name	Common name	Trophic Group	Tolerance
Hybognathus nuchalis	Mississippi silvery minnow	O	T
Hybognathus placitus	Plains minnow	O	T
Luxilus chrysocephalus	Striped shiner	IF	
Lythrurus fumeus	Ribbon shiner	IF	
Lythrurus umbratilis	Redfin shiner	IF	
Macrhybopsis aestivalis	Speckled chub	IF	
Macrhybopsis storeriana	Silver chub	IF	
Notemigonus crysoleucas	Golden shiner	IF	T
Notropis amabilis	Texas shiner	IF	
Notropis amnis	Pallid shiner	IF	
Notropis atherinoides	Emerald shiner	IF	
Notropis atrocaudalis	Blackspot shiner	IF	
Notropis bairdi	Red River shiner	IF	
Notropis blennius	River shiner	IF	
Notropis braytoni	Tamaulipas shiner	IF	
Notropis buccula	Smalleye shiner	IF	
Notropis buchanani	Ghost shiner	IF	
Notropis chalybaeus	Ironcolor shiner	IF	I
Notropis chihuahua	Chihuahua shiner	IF	
Notropis girardi	Arkansas River shiner	IF	
Notropis hubbsi	Bluehead shiner	IF	
Notropis jemezanus	Rio Grande shiner	IF	
Notropis maculatus	Taillight shiner	IF	
Notropis oxyrhynchus	Sharpnose shiner	IF	
Notropis potteri	Chub shiner	IF	
Notropis sabinae	Sabine shiner	IF	
Notropis shumardi	Silverband shiner	IF	
Notropis stramineus	Sand shiner	IF	
Notropis texanus	Weed shiner	IF	
Notropis volucellus	Mimic shiner	IF	I
Opsopoeodus emiliae	Pugnose minnow	IF	
Phenacobius mirabilis	Suckermouth minnow	IF	
Pimephales promelas	Fathead minnow	O	T
Pimephales vigilax	Bullhead minnow	IF	
Platygobio gracilis	Flathead chub	IF	
Rhinichthys cataractae	Longnose dace	IF	
Scardinius erythrophthalmus	Rudd	O	T
Semotilus atromaculatus	Creek chub	P	
Carpiodes carpio	River carpsucker	O	T
Cycleptus elongatus	Blue sucker	IF	I
Erimyzon oblongus	Creek chub sucker	O	

Table 1. continued.

Scientific name	Common name	Trophic Group	Tolerance
Erimyzon sucetta	Lake chubsucker	O	
Ictiobus bubalus	Smallmouth buffalo	O	
Ictiobus cyprinellus	Bigmouth buffalo	IF	T
Ictiobus niger	Black buffalo	O	
Minytrema melanops	Spotted sucker	IF	
Moxostoma austrinum	West Mexican redhorse	IF	
Moxostoma congestum	Gray redhorse	IF	
Moxostoma erythrurum	Golden redhorse	IF	
Moxostoma poecilurum	Blacktail redhorse	IF	
Astyanax mexicanus	Mexican tetra	IF	
Ameiurus melas	Black bullhead	O	T
Ameiurus natalis	Yellow bullhead	O	
Ictalurus furcatus	Blue catfish	P	
Ictalurus lupus	Headwater catfish	O	
Ictalurus punctatus	Channel catfish	O	T
Noturus gyrinus	Tadpole madtom	IF	I
Noturus nocturnus	Freckled madtom	IF	I
Pylodictis olivaris	Flathead catfish	P	
Satan eurystomus	Widemouth blindcat	IF	
Trogloglanis pattersoni	Toothless blindcat	O	
Arius felis	Hardhead catfish	IF	T
Bagre marinus	Gafftopsail catfish	P	T
Hypostomus plecostomus	Suckermouth catfish	H	
Esox americanus vermiculatus	Grass pickerel	P	
Esox lucius	Northern pike	P	I
Esox niger	Chain pickerel	P	
Oncorhynchus mykiss	Rainbow trout	IF - LOTIC P - LENTIC	I
Aphredoderus sayanus	Pirate perch	IF	
Strongylura marina	Atlantic needlefish	P	
Adinia xenica	Diamond killifish	O	T
Cyprinodon bovinus	Leon Springs pupfish	O	
Cyprinodon elegans	Comanche Springs pupfish	O	
Cyprinodon eximius	Conchos pupfish	O	
Cyprinodon pecosensis	Pecos River pupfish	O	T
Cyprinodon rubrofluviatilis	Red River pupfish	O	T
Cyprinodon variegatus	Sheepshead minnow	O	T
Fundulus chrysotus	Golden topminnow	IF	
Fundulus dispar	Starhead topminnow	IF	
Fundulus grandis	Gulf killifish	O	
Fundulus jenkinsi	Saltmarsh topminnow	IF	

Table 1. continued.

Scientific name	Common name	Trophic Group	Tolerance
Fundulus notatus	Blackstripe topminnow	IF	
Fundulus olivaceus	Blackspotted topminnow	IF	I
Fundulus pulvereus	Bayou killifish	IF	
Fundulus similis	Longnose killifish	O	I
Fundulus zebrinus	Plains killifish	IF	T
Lucania parva	Rainwater killifish	IF	
Gambusia affinis	Western mosquitofish	IF	T
Gambusia gaigei	Big Bend gambusia	IF	
Gambusia geiseri	Largespring gambusia	IF	
Gambusia heterochir	Clear Creek gambusia	IF	
Gambusia nobilis	Pecos gambusia	IF	
Heterandria formosa	Least killifish	IF	
Poecilia formosa	Amazon molly	O	
Poecilia latipinna	Sailfin molly	O	T
Poecilia reticulata	Guppy	IF	T
Labidesthes sicculus	Brook silverside	IF	I
Membras martinica	Rough silverside	IF	
Menidia beryllina	Inland silverside	IF	
Menidia clarkhubbsi	Texas silverside	IF	
Menidia peninsulae	Tidewater silverside	IF	
Microphis brachyurus	Opposum pipefish	IF	
Syngnathus louisianae	Chain pipefish	IF	
Syngnathus scovelli	Gulf pipefish	IF	
Centropomus parallelus	Fat snook	P	
Centropomus undecimalis	Common snook	P	I
Morone chrysops	White bass	P	
Morone mississippiensis	Yellow bass	P	
Morone saxatilis	Striped bass	P	
Ambloplites rupestris	Rock bass	P	I
Centrarchus macropterus	Flier	IF	
Elassoma zonatum	Banded pygmy sunfish	IF	
Lepomis auritus	Redbreast sunfish	IF	
Lepomis cyanellus	Green sunfish	P	T
Lepomis gulosus	Warmouth	P	T
Lepomis humilus	Orangespotted sunfish	IF	
Lepomis macrochirus	Bluegill	IF	T
Lepomis marginatus	Dollar sunfish	IF	
Lepomis megalotis	Longear sunfish	IF	
Lepomis microlophus	Redear sunfish	IF	
Lepomis punctatus	Spotted sunfish	IF	
Lepomis symmetricus	Bantam sunfish	IF	

Table 1. continued.

Scientific name	Common name	Trophic Group	Tolerance
Micropterus dolomieu	Smallmouth bass	P	I
Micropterus punctulatus	Spotted bass	P	
Micropterus salmoides	Largemouth bass	P	
Micropterus treculi	Guadalupe bass	P	I
Pomoxis annularis	White crappie	P	
Pomoxis nigromaculatus	Black crappie	P	
Ammocrypta clara	Western sand darter	IF	
Ammocrypta vivax	Scaly sand darter	IF	
Etheostoma asprigene	Mud darter	IF	
Etheostoma chlorosomum	Bluntnose darter	IF	
Etheostoma fonticola	Fountain darter	IF	I
Etheostoma fusiforme	Swamp darter	IF	
Etheostoma gracile	Slough darter	IF	
Etheostoma grahami	Rio Grande darter	IF	
Etheostoma histrio	Harlequin darter	IF	
Etheostoma lepidum	Greenthroat darter	IF	I
Etheostoma parvipinne	Goldstripe darter	IF	I
Etheostoma proeliare	Cypress darter	IF	I
Etheostoma radiosum	Orangebelly darter	IF	I
Etheostoma spectabile	Orangethroat darter	IF	
Etheostoma whipplei	Redfin darter	IF	
Perca flavescens	Yellow perch	P	
Percina caprodes	Logperch	IF	I
Percina carbonaria	Texas logperch	IF	I
Percina macrolepida	Bigscale logperch	IF	I
Percina maculata	Blackside darter	IF	I
Percina sciera	Dusky darter	IF	I
Percina shumardi	River darter	IF	
Stizostedion canadense	Sauger	P	I
Stizostedion vitreum	Walleye	P	
Caranx hippos	Crevalle jack	P	I
Diapterus auratus	Irish pompano	IF	
Eucinostomus argenteus	Spotfin mojarra	IF	
Eucinostomus melanopterus	Flagfin mojarra	IF	
Conodon nobilis	Barred grunt	IF	
Pomodasys crocro	Burro grunt	IF	
Archosargus probatocephalus	Sheepshead	O	
Lagodon rhomboides	Pinfish	O	
Aplodinotus grunniens	Freshwater drum	IF	T
Bairdiella chrysoura	Silver perch	IF	
Cynoscion arenarius	Sand seatrout	P	I

Table 1. continued.

Scientific name	Common name	Trophic Group	Tolerance
Cynoscion nebulosus	Spotted seatrout	P	I
Leiostomus xanthurus	Spot	O	
Micropogonias undulatus	Atlantic croaker	IF	I
Pogonias cromis	Black drum	IF	
Sciaenops ocellatus	Red drum	P	
Cichlasoma cyanoguttatum	Rio Grande cichlid	IF	
Tilapia aurea	Blue tilapia	O	T
Tilapia mossambica	Mozambique tilapia	O	
Tilapia zilli	Redbelly tilapia	O	
Agonostomus monticola	Mountain mullet	O	
Mugil cephalus	Striped mullet	O	
Mugil curema	White mullet	O	
Polydactylus octonemus	Atlantic threadfin	IF	
Dormitator maculatus	Fat sleeper	O	
Eleotris pisonis	Spinycheek sleeper	O	
Erotelis smaragdus	Emerald sleeper	IF	
Gobiomorus dormitor	Bigmouth sleeper	IF	
Awaous tajasica	River goby	O	
Bathygobius soporator	Frillfin goby	IF	T
Evorthodus lyricus	Lyre goby	H	
Gobioides broussonneti	Violet goby	O	
Gobionellus atripinnis	Blackfin goby	O	
Gobionellus boleosoma	Darter goby	O	
Gobionellus oceanicus	Highfin goby	O	
Gobionellus shufeldti	Freshwater goby	IF	
Gobionellus stigmaticus	Marked goby	O	
Gobiosoma bosc	Naked goby	IF	T
Gobiosoma robustum	Code goby	IF	
Microgobius gulosus	Clown goby	IF	
Citharichthys spilopterus	Bay whiff	IF	
Etropus crossotus	Fringed flounder	IF	
Paralichthys lethostigma	Southern flounder	P	
Achirus lineatus	Lined sole	IF	
Trinectes maculatus	Hogchoker	IF	
Sphoeroides parvus	Least puffer	IF	

(*Dorosoma cepedianum*) which was classified as tolerant due to the overwhelming number of tolerant responses and only one intolerant response.

Of the 235 fish species listed 2% were designated as herbivores, 21% as omnivores, 57% as invertivores, and 19% as piscivores. Rainbow trout (*Oncorhynchus mykiss*) were split into two trophic groups (one for lotic and one for lentic), while brook lamprey (*Ichthyomyzon gagei*) were not given a designation since they do not feed as adults. Trophic classifications recommended in this paper do not differ substantially from those published by USEPA (1983) and Plafkin et al. (1989); however, many of the species found in Texas were not on these lists and USEPA (1983) did not identify invertebrate feeding species, but only listed top carnivores and omnivores. While classification differences do exist between our list and each of the other two lists, only one species common to all three lists was classified differently in this paper than in the other two lists. Golden shiner (*Notemigonus crysoleucas*) was classified as an omnivore by USEPA (1983) and Plafkin (1989) whereas it was identified as an invertivore in this report.

In regards to tolerance classification, 15% of the fish species were identified as especially intolerant to low dissolved oxygen concentrations; whereas, 16% rated as especially tolerant. USEPA (1983) provides a list of intolerant species (but not tolerant species) which designates a number of species as intolerant that our list classifies as intermediate. These discrepancies are attributed to the USEPA (1983) list covering a very broad geographical area (the list is considered a national list) and lumping all darters as intolerant. Differences also exists between our list and that of Plafkin et al. (1989); however, of the species present on all three lists, only one was classified differently in this paper than in the other two lists. Western sand darter (*Ammocrypta clara*) was classified as intermediate in our paper, but was designated as intolerant by USEPA (1983) and Plafkin (1989).

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APPENDIX A

Survey Responders

Appendix A. Responders to trophic and tolerance classification survey.

Cross, F.B. Museum of Natural History, University of Kansas, Lawrence, Kansas.

Echelle, A.A. Department of Zoology, Oklahoma State University, Stillwater, Oklahoma.

Hubbs, C. Department of Zoology, University of Texas, Austin, Texas.

Janssen, H.J., Jr. Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State, Mississippi.

Whiteside, B.G. Department of Biology, Southwest Texas State University, San Marcos, Texas.

APPENDIX B

Referenced Literature

Appendix B. Sources referenced for designating trophic and tolerance classification.

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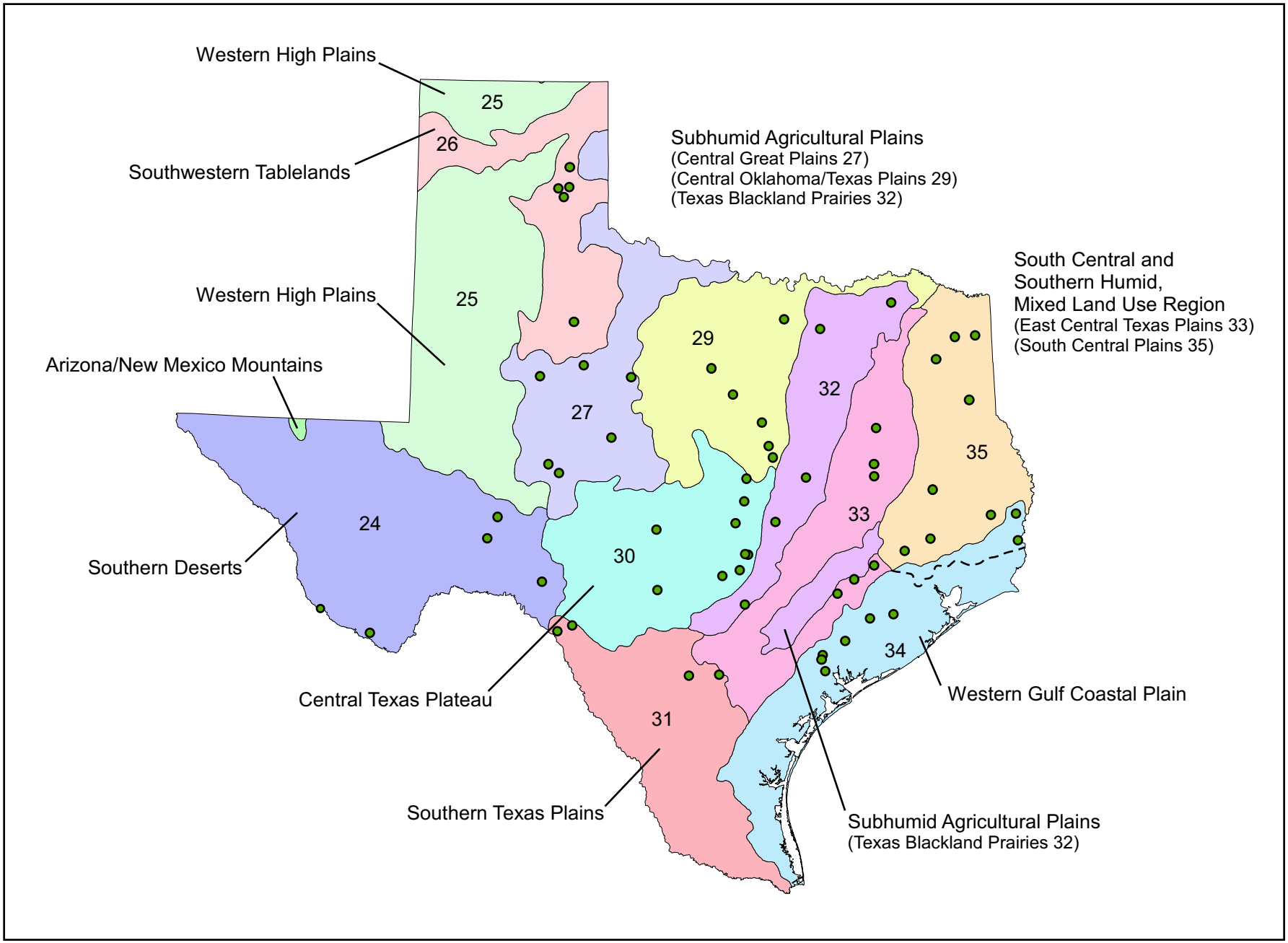
APPENDIX K

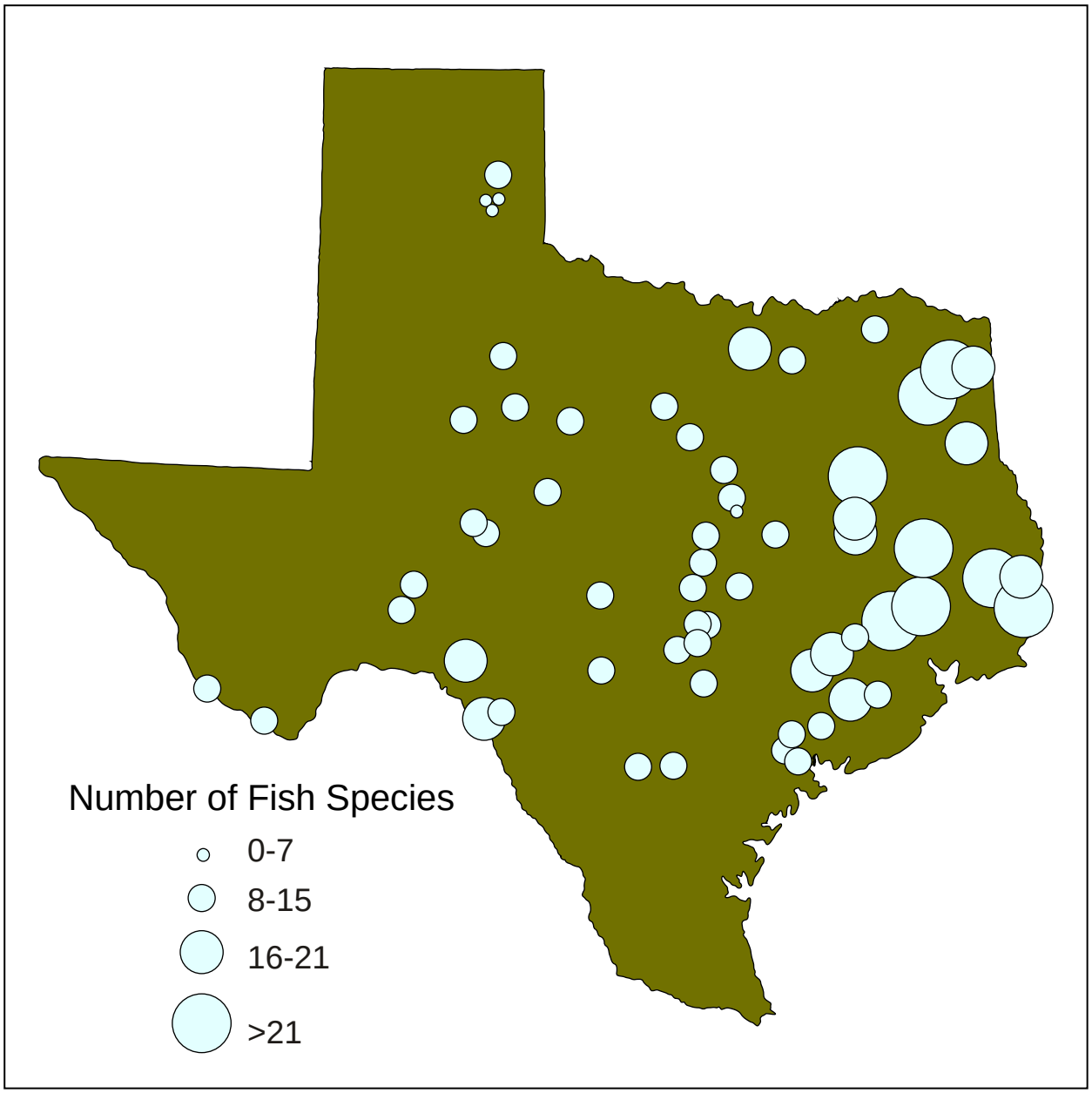
List of Introduced Fish Species in Texas Waters

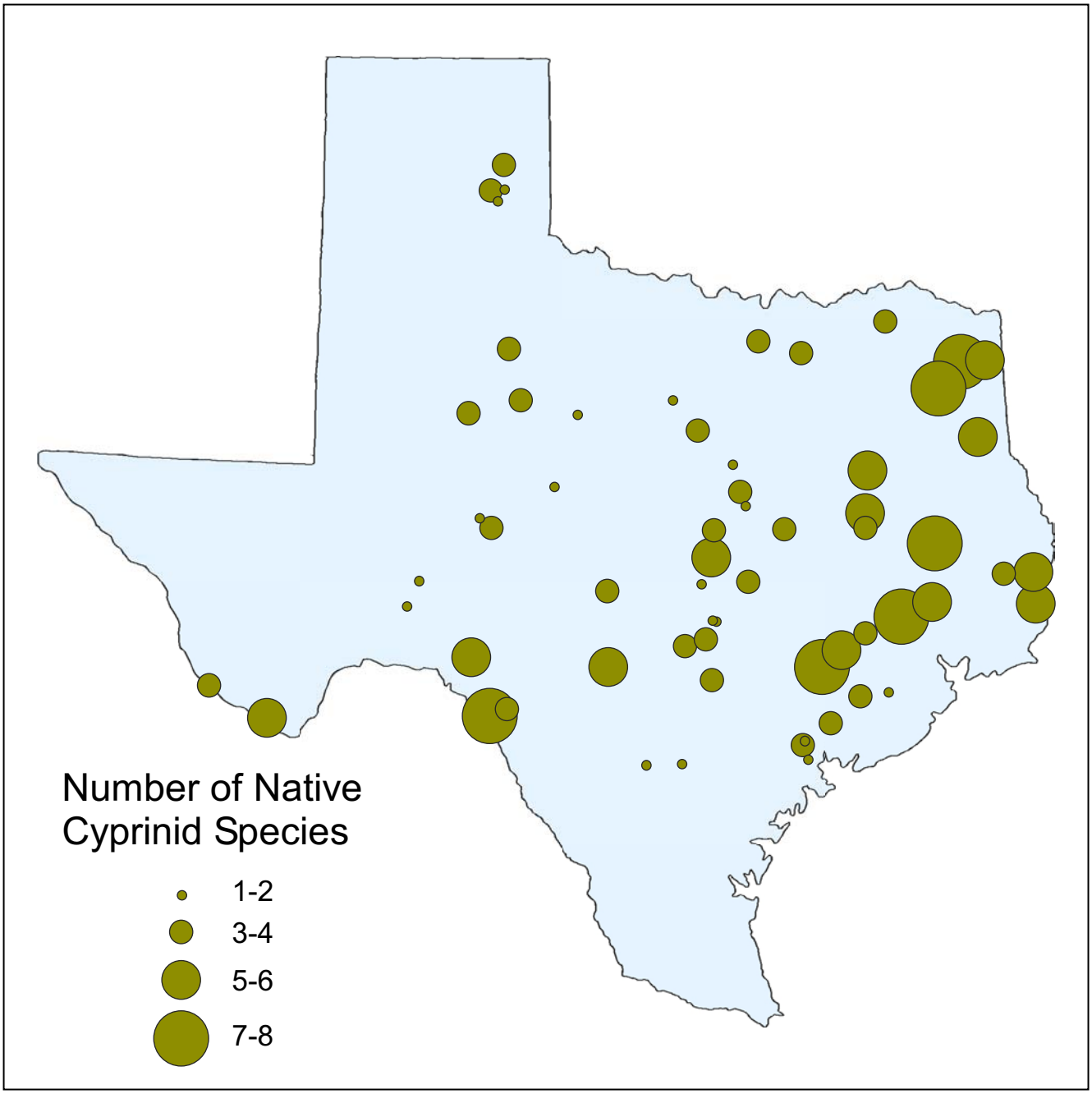
Appendix K. List of introduced fish species in Texas waters according to Hubbs et al. (1991)*

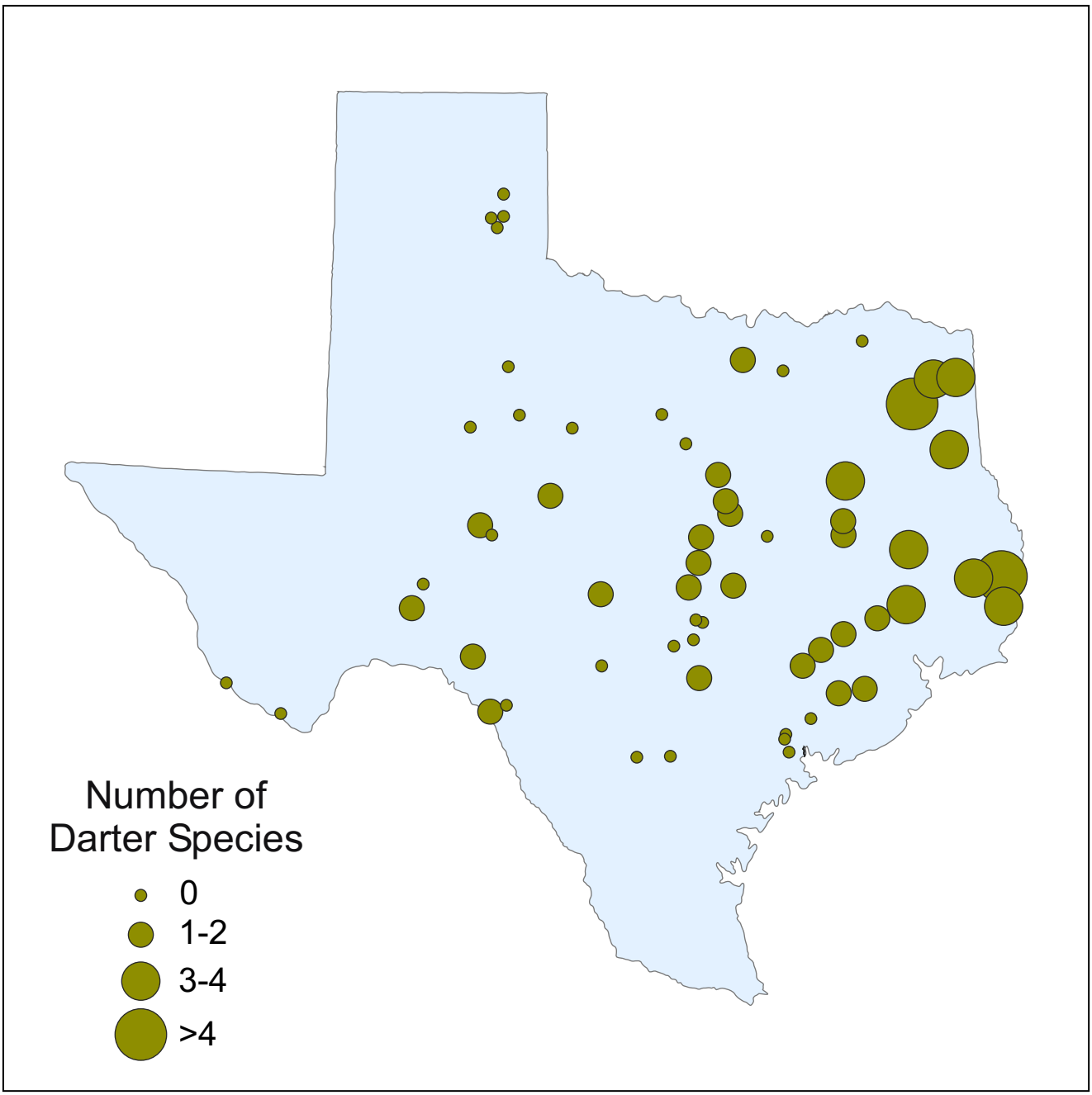
Species	Common Name
Carassius auratus	Goldfish
Ctenopharyngodon idella	Grass carp
Cyprinus carpio	Common carp
Scardinius erythrophthalmus	Rudd
Hypostomus sp.	Armadillo del rio
Esox lucius	Northern pike
Oncorhynchus mykiss	Rainbow trout
Poecilia reticulata	Guppy
Morone saxatilis	Striped bass
Ambloplites rupestris	Rock bass
Lepomis auritus	Redbreast sunfish
Micropterus dolomieu	Smallmouth bass
Perca flavescens	Yellow perch
Stizostedion canadense	Sauger
Stizostedion vitreum	Walleye
Tilapia aurea	Blue tilapia
Tilapia mossambica	Mozambique tilapia
Tilapia zilli	Redbelly tilapia

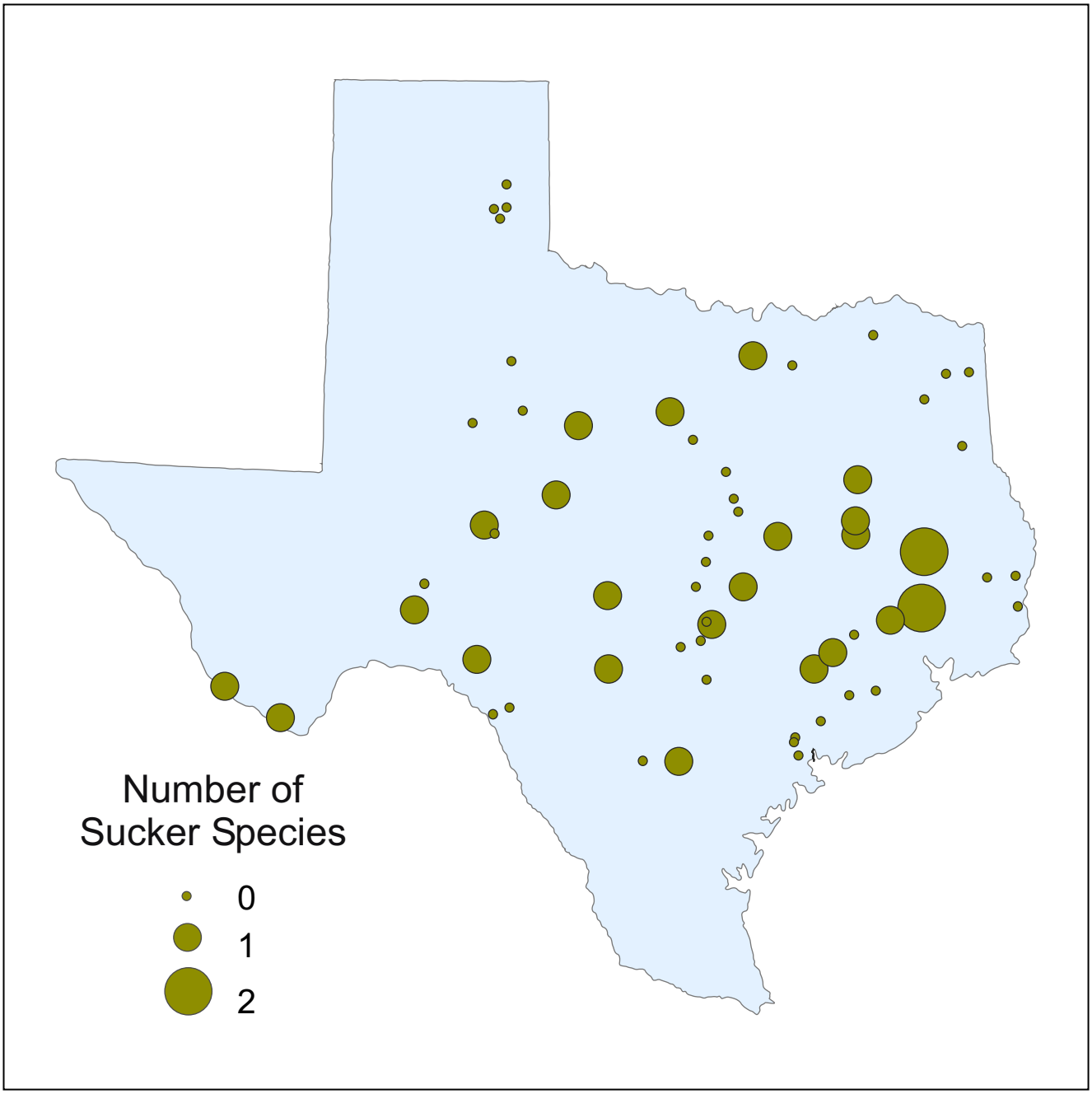
*Hubbs, C., R.J. Edwards, and G.P. Garrett. 1991. An annotated checklist of the freshwater fishes of Texas, with keys to identification of species. Texas Journal of Science 43(4): supplement.

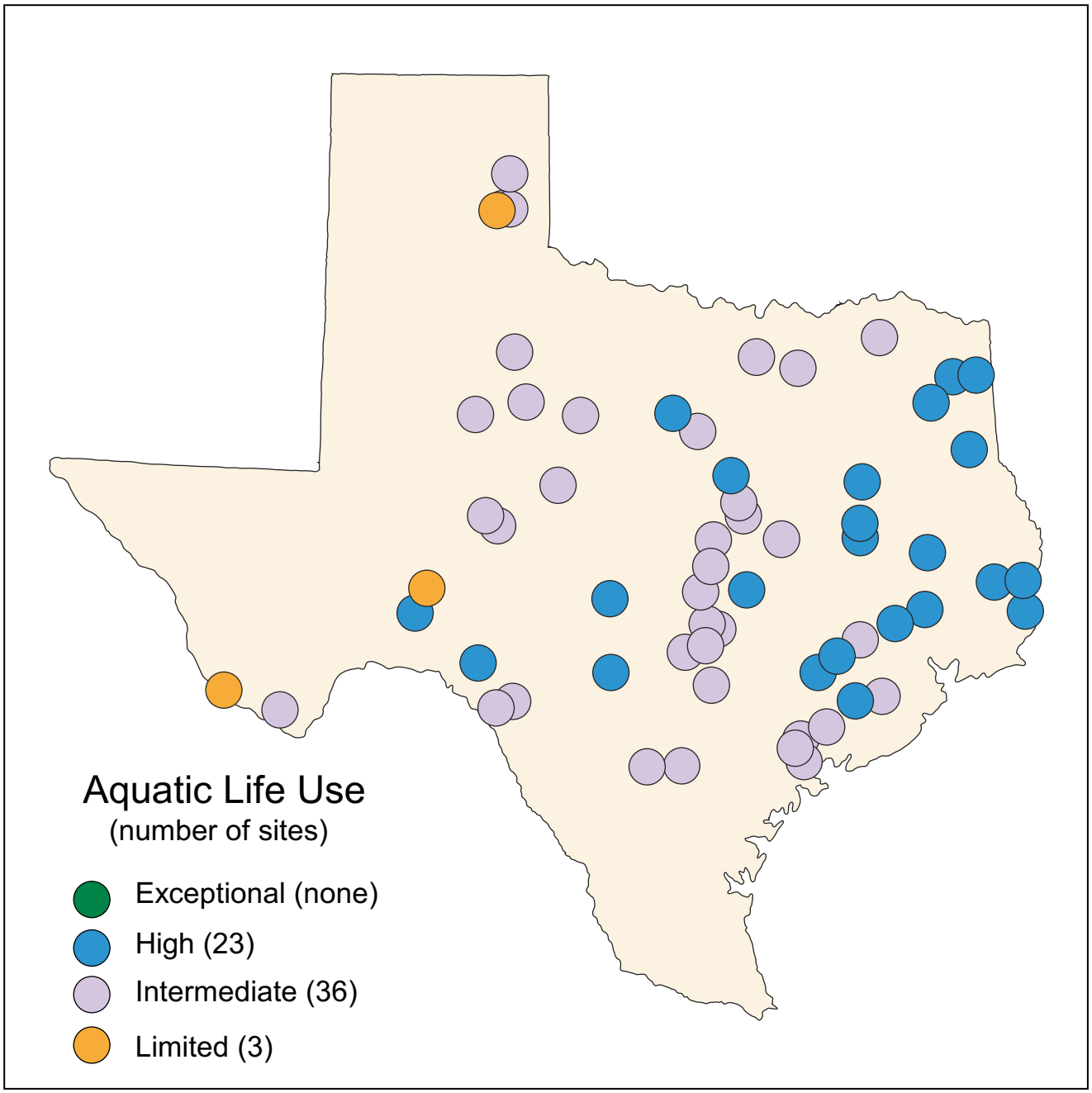

Western High Plains
25
26
Southwestern Tablelands
Subhumid Agricultural Plains
(Central Great Plains 27)
(Central Oklahoma/Texas Plains 29)
(Texas Blackland Prairies 32)
South Central and
Southern Humid,
Mixed Land Use Region
(East Central Texas Plains 33)
(South Central Plains 35)
Western High Plains
25
Arizona/New Mexico Mountains
27
29
32
35
24
Southern Deserts
30
33
34
Western Gulf Coastal Plain
Central Texas Plateau
31
Southern Texas Plains
Subhumid Agricultural Plains
(Texas Blackland Prairies 32)


Number of Fish Species
0-7
8-15
16-21
>21


Number of Native
Cyprinid Species
1-2
3-4
5-6
7-8


Number of
Darter Species
0
1-2
3-4
>4


Number of
Sucker Species
0
1
2


Aquatic Life Use
(number of sites)
Exceptional (none)
High (23)
Intermediate (36)
Limited (3)