U. S. Fish and Wildlife Service
Region 2

A FISHERY SURVEY OF THE MIDDLE BRAZOS RIVER BASIN IN NORTH-CENTRAL TEXAS

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Introduction

The Brazos River Authority of Texas and local water districts have recently expressed concern about potential water quality impacts of dairy farms, concentrated animal feeding operations (CAFO's), and intensive agricultural activities within the Middle Brazos River Basin on public water supplies. The Middle Brazos River Basin, especially the Bosque and Leon River watersheds, contain the highest concentration of dairy farms and/or CAFO's in the State of Texas. A tremendous amount of animal wastes that often reach the areas' rivers and streams are produced by these agricultural enterprises. Many watersheds within the basin have been extensively developed with small flood control reservoirs by the Natural Resources Conservation Service (NRCS), and these structures often contain high concentrations of sediments from agricultural runoff. Catastrophic failure or over-flow from these structures could introduce large amounts of contaminants into streams, and therefore, area water supply reservoirs.

Water pollution sources are characteristically divided into two general categories: point source and nonpoint source. Point source pollution refers to specific locations where pollutants are discharged, such as municipal and industrial wastewater treatment facility outfalls, gas and oil production areas, and sewage bypasses. Whereas nonpoint source pollution is attributed to contamination which does not originate from single discharge points or specific outfalls. Examples of nonpoint source pollution include pollutants contained in stormwater runoff from agricultural (cropland, feedlots, and pastures) and urban (roadways, construction sites, and landfills) areas.

Pollution can have acute or chronic effects on the aquatic environment. Acute impacts usually cause immediate death or danger and are catastrophic to the aquatic environment, while chronic impacts represent long-term effects to the aquatic environment. However, chronic impacts can be just as destructive to aquatic organisms by altering behavior, growth, reproduction, and development. Indicator organisms such as fish and macro-invertebrates are often utilized to determine whether water pollution sources are having an acute, chronic, or no effect on the ecological integrity of watersheds.

Monitoring of physical and chemical characteristics of water is relatively common, but biological monitoring founded on a broadly based concept of biological integrity is rare (Karr and Dudley 1981). This primary dependence on physical and chemical criteria has numerous shortcomings (Thurston et al. 1979; Gosz 1980), and a more valid approach for assessing a system's ecological integrity is to examine properties of the biotic communities that live there (Weber 1981). Movement towards a more comprehensive approach to assessment of water quality was aided by the introduction of an index of biotic integrity (IBI) by Karr (1981). The IBI can be an important tool for assessing the biological integrity of stream resources and along with information on physical and chemical conditions, should provide a sound basis for management decisions.

The IBI has the potential to aid resource managers because it is based on attributes of stream fish communities that are relatively easy to measure. As Karr (1981) suggested, fish have numerous advantages as indicator organisms for biological monitoring. These advantages include:

1. Life-history information is extensive for most fish species.
2. Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and include foods of both aquatic and terrestrial origin. Their position at the top of the aquatic food chain in relation to other aquatic organisms also helps to provide an integrative view of the watershed environment.
3. Fish are relatively easy to identify, with most samples being sorted, identified at the sample site, and released after processing.
4. The general public can relate to statements about conditions of the fish community much easier than those about the diatom or invertebrate community.
5. Both acute toxicity (missing taxa) and chronic toxicity (depressed growth and reproductive success) can be evaluated.
6. Fish are typically present, even in the smallest streams and in all but the most polluted waters.
7. Finally, the results of studies using fish can be directly related to the fishable waters mandate of Congress.

A number of disadvantages of monitoring fish can also be cited. These include the selective nature of sampling, fish mobility on diel and seasonal time scales, and manpower needs for field sampling. But these disadvantages are associated with any major taxa.

The U. S. Fish and Wildlife Service conducted a fishery survey throughout the Middle Brazos River Basin watersheds to evaluate potential influences of water quality on fish populations and communities. The FWS's goal for fish sampling in the Middle Brazos River Basin Reconnaissance study was to collect representative samples of the species present to determine their relative abundances. This assessment had to be completed in a cost-effective manner, while remaining capable of distinguishing the various impacts on the aquatic ecosystem and being scientifically sound. The index of biotic integrity (IBI) utilized statewide by the Texas Parks and Wildlife Department (TPWD) was selected as the best means to complete this task.

Study Area

The Middle Brazos River Basin in north-central Texas covers approximately 29,000 square miles (75,110 km^2). Stream fish communities were analyzed at 12 sample sites within the Bosque, Leon, and Lampasas River watersheds. All three watersheds drain southeasterly and empty into the Brazos River.

The Bosque River watershed encompasses 1,660 square miles (4,299 km^2) in north-central Texas and drains into Lake Waco. Lake Waco provides flood control and supplies water for an estimated 140,000 people (McFarland and Hauck 1998). Major tributaries of the Bosque River include the North Bosque River, Hog Creek, Middle Bosque River, and South Bosque River. Of these tributaries, the North Bosque River basin encompasses approximately 74 percent of the total drainage area of the watershed. Statewide attention has focused on the Bosque River largely because of the prominence of the dairy industry in the northern portion of the watershed. In the State of Texas 1998 Clean Water Act §303(d) listing, the North Bosque River was designated as impaired due to increased bacteria levels exceeding the limits for safe contact recreation and excessive nutrient levels entering the river from tributaries (TNRCC 1998). The state nonpoint source pollution assessment conducted in 1990 identified the North Bosque River as a "known" problem watershed as the result of dairy waste (TWC & TSSWCB, 1991). Erath County, located in the headwaters of the North Bosque River, is the number one milk producing county in the state (USDA, 1997). While most attention has focused on the North Bosque River, elevated nitrogen levels associated with nonpoint source pollution from agricultural operations are suggested to be "the most serious threat to maintaining stream water quality" in the Middle and South Bosque Rivers (TNRCC, 1996).

The Leon River watershed, as measured above Belton Lake Dam, has a drainage area of 3,533 square miles (9,151 km^2). Major tributaries of the Leon River include Cowhouse Creek and Nolan Creek, while the primary impoundments in the watershed consist of Leon Lake, Proctor Lake, and Belton Lake. These three reservoirs supply drinking water to a combined population of 250,000 people (Hauck and Easterling 1997). The Leon River watershed is predominately rural. Major agricultural interests in the watershed include dairies; beef cattle on rangeland; and hay, wheat, oats, sorghum, corn, cotton, peanut, and pecan operations. In the State of Texas 1998 Clean Water Act §303(d) listing, the Leon River below Proctor Lake and Nolan Creek were designated as impaired due to bacteria levels that exceeded the criterion established to assure the safety of contact recreation (TNRCC 1998). In the 1990 nonpoint source assessment for the state, the Texas Water Commission (TWC), now the Texas Natural Resource Conservation Commission (TNRCC), and the Texas State Soil and Water Conservation Board (TSSWCB) identified water quality concerns attributed to runoff from animal waste and animal confinement facilities in the upper portion of the watershed and from irrigated farmland and agricultural runoff in the lower portion of the watershed (TWC & TSSWCB, 1991).

The Lampasas River watershed, as measured approximately eight miles (21 km) upstream from its confluence with the Little River, has a drainage area of approximately 1,321 square miles (3,421 km^2). The watershed includes Stillhouse Hollow Lake, which was constructed for flood control and water conservation, and many small diversions upstream of the reservoir which are used for irrigation, municipal water supply, and oil field operations. The Lampasas River watershed is predominately rural. Major agricultural interests in the watershed include beef cattle on rangeland; and hay, wheat, oats, sorghum, corn, cotton, peanut, and pecan operations.

Methods

Twelve sites were sampled within the Middle Brazos River Basin during the summer of 1998. Sample sites were selected using the following criteria: (1) sites were downstream of the confluences of lower-ranking tributaries; (2) riparian habitat was intact; and (3) convenient access for the sampling crew was available. All available varieties of habitats were sampled in this study, including riffles, runs, and pools. Five sites were sampled in the Bosque River watershed, five sites in the Leon River watershed, and two sites in the Lampasas River watershed.

The Bosque River watershed sampling sites included one site on the South Fork of the North Bosque River north of Stephenville in Erath County (Texas Brazos River segment 1255); a site on the North Bosque River just south of the Stephenville waste water treatment plant (WWTP) in Erath County (Texas Brazos River segment 1226); a site on Green Creek, which is a tributary of the North Bosque River in Erath County (Texas Brazos River segment 1226); a site on the North Bosque River east of the town of Iredell in Bosque County (Texas Brazos River segment 1226); and a site on the North Bosque River just north of the town of Valley Mills in Bosque County (Texas Brazos River segment 1226).

The Leon River watershed sampling sites included one site just east of the town of Eastland in Eastland County (Texas Brazos River segment 1224); a site downstream from Proctor Lake in Comanche County (Texas Brazos River segment 1221); a site north of the City of Hamilton in Hamilton County (Texas Brazos River segment 1221); a site on Nolan Creek, which is a tributary of the Leon River, south of the Killeen WWTP in Bell County (Texas Brazos River segment 1218); and a site in the tailrace of Belton Lake Dam in Bell County (Texas Brazos River segment 1219).

The Lampasas River watershed sampling sites included one site west of the town of Kempner in Lampasas County (Texas Brazos River segment 1217) and one site downstream from Stillhouse Hollow Lake in Bell County (Texas Brazos River segment 1215).

Fish were collected from June 11 through September 29, 1998. Collections were made using a combination of backpack electrofishing and seines. The collector carrying the backpack shocker (Smith-Root type VII Electrofisher) would wade in an upstream direction so that the effects of turbidity caused by disturbed bottom sediment would be eliminated. Two people would follow the shocker with dip nets attempting to net all fish that were stunned, while a fourth person would handle the buckets where the fish were placed. When sampling riffles in strong current, a block seine was set downstream of the persons electrofishing in an attempt to catch additional fish stunned and swept downstream without surfacing. Electrofishing was completed in two riffle and two pool sample runs at each site. The duration of each sampling run was 900 seconds.

Seining was used as a complementary technique to electrofishing in habitats where shocking was not effective. Those habitats included deep pools where wading with a backpack shocker would be difficult, shallow riffles where kick-seining would effectively capture organisms living in and around the substrate, and streams where specific water conductivity was greater than that feasible for effective electrofishing. Several different seines were used at each sample site, depending on habitat conditions. A 30' x 6' x 1/4" mesh straight seine or a 50' x 6' x 3/8" mesh bag seine was used for large deep pools and wide slow-moving channels with minimal obstructions present to cause snagging. A 20' x 4' x 1/8" mesh seine was used in small streams with snags, and for kick seining in small riffles. A 10' x 4' x 1/8" mesh seine was used in shallow, small streams that had several obstructions present. Where possible, an attempt was made to sample at least four riffles and four pools at each site. However, due to the lack of riffle and pool habitat and the large number of obstructions at some sites, seine samples varied from 2-10 samples per site. Only successful seine hauls were recorded. Runs where fish could escape the net by out swimming it or when a major snag was encountered were deemed unsuccessful.

Once fish were collected, they were identified to species, enumerated, and released some distance downstream from the sampling area (Lee et al. 1980; Robison and Buchanan 1988; Hubbs et al. 1991; Pflieger 1991; Robins et al. 1991; Etnier and Starnes 1993). The utmost care was taken to release fish unharmed. If the identification of a fish collected was questionable, it was preserved in 10% formalin solution and returned to the laboratory for identification and preservation. All fish were examined for external deformities, lesions, or tumors. When an anomaly was found on a fish, it was preserved in 10% formalin solution and returned to the lab for documentation.

The index of biotic integrity (IBI) proposed by Karr (1981) was designed to evaluate the quality or condition of an aquatic resource based on the attributes of the fish assemblage that can be easily derived from a representative sample. The IBI applied in this study was initially developed for statewide use by the Texas Parks and Wildlife Department (TPWD). Their statewide IBI consisted of 12 attributes in three categories: species composition, trophic composition, and health and abundance of fish (Table 1). Species composition attributes focus on the overall species richness and richness within major taxonomic groups as well as the occurrences of notably tolerant and intolerant species. Food habits of the fish assemblage, as categorized by trophic composition, are products of the diversity and productivity of the lower trophic levels in the community. The preliminary designation of Texas fishes into trophic and tolerance classifications was designed by Linam and Kleinsasser (1991). Fish abundance and fish health reflect system productivity and habitat stability. A fish sample is assigned one, three, or five points for each attribute by comparison to expectations for a pristine stream of similar size in the same region. Total scores define stream health in four classes ranging from exceptional (pristine) to limited (degraded).

Effective use of the IBI requires a knowledge of the structure and function of regional stream fish communities and of species' tolerances. Species' composition attributes will vary as functions of stream size and region (Fausch et al. 1984). While some attributes were adjusted by stream order, no adjustments were made for region since all sample sites were located within the same zoogeographic area. Stream order adjustments were made following the criterion established by the TPWD from past IBI analyses of the Bosque River watershed in which the smallest tributaries shown on 1:24,000 (7.5-minute) United States Geological Survey topographic maps, whether intermittent or not, were designated as third-order streams. A fourth-order stream is formed where two third-order streams join. When two fourth-order streams join, a fifth-order stream is formed and so on. Where a stream of low order enters a higher order stream, but is not a part of the hierarchy of streams used in the classification, the order number of the larger stream is not changed.

Table 1. Index of Biotic Integrity Scoring and Evaluation Criteria (TPWD-statewide).

Category	Metric	Scoring		
		5	3	1
Species Richness and Composition	1. Total number of fish species			
	2. Total number of darter species	3	1-2	0
	3. Total number of sunfish species (excluding bass)	2	1	0
	4. Total number of sucker species	2	1	0
	5. Total number of intolerant species	3	1-2	0
	6. Percentage of individuals as tolerants	<5	5-20	>20
Trophic composition	7. Percentage of individuals as omnivores	<20	20-45	>45
	8. Percentage of individuals as insectivores	>80	>40-80	40
	9. Percentage of individuals as piscivores	>5	1-5	<1
Fish abundance and condition	10. Number of individuals in sample	>200	>50-200	50
	11. Percentage of individuals as hybrids	0	>0-1	>1
	12. Percentage of individuals with disease or other anomaly	2	>2-5	>5

First-second order streams: 7(5), 4-6(3), 3(1)
Third-fourth order streams: 10(5), 5-9(3), 4(1)
Fifth-sixth order streams: 16(5), 8-15(3), 7(1)
Seventh-eighth order streams: 22(5), 11-21(3), 10(1)

Total Score for Aquatic Life Use Subcategories:

58 - 60 Exceptional
48 - 52 High
40 - 44 Intermediate
34 Limited

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General observations of the number of fish species observed but not caught, the surrounding stream and riparian habitat, and the aquatic and terrestrial wildlife were also made for each sample site (Kolbe and Luedke 1993).

Results

A total of 11,470 individuals comprising 12 families and 35 species were represented in the combined samples from seining and electrofishing (Table 2). The highest number of species collected at a sampling site was 23 while the lowest number captured was 6. The average number of fish species captured per site for the study area was 14.92 (s = 4.54, n = 12). The families most often represented in this study were the minnow (Cyprinidae) and sunfish (Centrarchidae) families with eight and ten species captured, respectively. Other families collected during this study were the gar (Lepisosteidae), herrings (Clupeidae), suckers (Catostomidae), characins (Characidae), bullhead catfishes (Ictaluridae), killifishes (Cyprinodontidae), livebearers (Poeciliidae), silversides (Atherinidae), temperate basses (Percichthyidae), and perches (Percidae). The most common species collected during the sampling efforts was the red shiner (*Notropis lutrensis*). Other species collected regularly were the blacktail shiner (*N. venustis*), mosquitofish (*Gambusia affinis*), green sunfish (*Lepomis cyanellis*), bluegill (*L. macrochirus*), channel catfish (*Ictalurus punctatus*), and largemouth bass (*Micropterus salmoides*).

Table 2. Fishes collected from the Bosque (Bq), Leon (Ln), and Lampasas (Lp) River watersheds within the Middle Brazos River Basin.

Family	Taxa	Common Name	Watershed
Lepisosteidae			
	Lepisosteus oculatus	Spotted gar	Ln
	Lepisosteus osseus	Longnose gar	Bq, Ln, & Lp
Clupeidae			
	Dorosoma cepedianum	Gizzard shad	Bq & Ln
Cyprinidae			
	Campostoma anomalum	Central stoneroller	Bq, Ln, & Lp

Family	Taxa	Common Name	Watershed
	Cyprinus carpio	Common carp	Bq
	Notropis amabilis	Texas shiner	Ln & Lp
	Notropis lutrensis	Red shiner	Bq, Ln, & Lp
	Notropis stramineus	Sand shiner	Bq & Lp
	Notropis texanus	Weed shiner	Bq & Lp
	Notropis venustis	Blacktail shiner	Bq, Ln, & Lp
	Pimephales vigilax	Bullhead minnow	Bq, Ln, & Lp
Catostomidae			
	Carpiodes carpio	River carpsucker	Bq
	Moxostoma congestum	Gray redhorse	Bq, Ln, & Lp
Characidae			
	Astyanax mexicanus	Mexican tetra	Lp
Ictaluridae			
	Ameiurus melas	Black bullhead	Bq
	Ameiurus natalis	Yellow bullhead	Bq & Ln
	Ictalurus punctatus	Channel catfish	Bq, Ln, & Lp
	Pylodictus olivaris	Flathead catfish	Bq, Ln, & Lp
Cyprinodontidae			
	Fundulus notatus	Blackstripe topminnow	Bq & Lp
Poecillidae			
	Gambusia affinis	Western mosquitofish	Bq, Ln, & Lp
Atherinidae			
	Menidia beryllina	Inland silverside	Bq & Ln
Percichthyidae			
	Morone chrysops	White bass	Bq
Centrarchidae			

Family	Taxa	Common Name	Watershed
	Lepomis auritus	Redbreast sunfish	Bq
	Lepomis cyanellus	Green sunfish	Bq, Ln, & Lp
	Lepomis gulosus	Warmouth	Bq & Lp
	Lepomis humilis	Orangespotted sunfish	Bq
	Lepomis macrochirus	Bluegill	Bq, Ln, & Lp
	Lepomis megalotis	Longear sunfish	Bq, Ln, & Lp
	Lepomis microlophus	Redear sunfish	Bq & Lp
	Micropterus punctulatus	Spotted bass	Bq & Lp
	Micropterus salmoides	Largemouth bass	Bq & Ln
	Pomoxis annularis	White crappie	Bq
Percidae			
	Etheostoma spectabile	Orangethroat darter	Bq, Ln, & Lp
	Percina carbonaria	Texas logperch	Bq & Ln
	Percina sciera	Dusky darter	Ln & Lp

The consolidation of sampling methodology (i.e., seining with electrofishing) and stream habitat types (i.e., riffles and pools) resulted in an increased diversity of fish species per unit effort. If only one sampling method had been employed at any of the sites, or all habitat types had not been sampled, species diversity would have been underestimated. On average, electrofishing and pool habitat samples produced higher numbers of species than seining and riffle habitat samples. However, sampling with both methods in all habitats was found to provide the most reliable data for this study.

An IBI score, representing the entire fish community, was tabulated for each sample site within the Middle Brazos River Basin. Results from the 12 sample sites examined within the Bosque, Leon, and Lampasas River watersheds are summarized below. Sample sites from all three watersheds are discussed beginning with the site farthest upstream and working downstream.

<u>Bosque River Watershed</u>

The first Bosque River site was northwest of the City of Stephenville on CR 393. This site on the South Fork of the North Bosque River was given a stream order of three. An IBI evaluation score of 30 was calculated and this site's aquatic life use class was designated as limited. The following factors contributed to this low overall score: only six species of fish were collected from the site; five of the species collected were designated as tolerant to environmental changes; no darter, sucker, or intolerant species were collected; and significant percentages of hybrid sunfish (4.6%) and individuals with disease or other anomalies (6.1%) were observed. A few green sunfish (*Lepomis cyanellus*) were preserved and brought to the lab for examination due to abscesses present around the fish's mouth and operculum. Overall, the quality of stream habitat was poor due to high turbidity, strong sewage odor, excessive algal growth, and surface film noticed by the sampling crew. The riparian zone was intact and the only aquatic invertebrate observed was the fairy shrimp of the order Anostraca.

The next sample site downstream in the Bosque River watershed was just south of the City of Stephenville at CR 246. This site, also on the North Bosque River, was given a stream order designation of four. An IBI evaluation score of 42 was calculated for this site, and its aquatic life use class was designated as intermediate. The score was relatively low because no darter, intolerant, or sucker species were present and there was a relatively high percentage of tolerant individuals (~62%) in the sample. Scoring for this site was positively influenced by the low percentage of hybrid sunfish collected (0.63%) and the absence of individual fish with disease or other anomalies. Stream quality had improved to some extent with a slight decrease in turbidity and no noticeable odor. While algal blooms were still present, the sludge deposits had dissipated. Severe bank erosion has reduced the riparian zone in some areas. An increase in aquatic invertebrates was observed, including Ephemeroptera, Odonata, and Trichoptera.

The third sample site in the Bosque River watershed was near the town of Clairette at CR 266. This site on Green Creek is a fourth order tributary of the North Bosque River. An IBI evaluation score of 42 was calculated for Green Creek resulting in an intermediate aquatic life use classification. The IBI score was lowered by the absence of intolerant species and the comparably high percentage of tolerant (60%) and hybrid (2.26%) individuals in the fish community. Three metrics that had a positive influence on the scoring were the presence of both a darter and sucker species in the sampling effort and the absence of individuals within the sample with disease or other anomaly. The water quality of Green Creek was similar to the previous site with moderate turbidity levels, no noticeable odor or surface film, and algal blooms with some floating aquatic vegetation present in backwater areas. The riparian zone was intact but low numbers of aquatic invertebrates were observed.

Another site sampled in the Bosque River watershed was at CR 2385 east of the town of Iredell. This site on the North Bosque River was defined as a fifth order stream. It received an IBI evaluation score of 48. It was designated as a high aquatic life use class due to the presence of darter (2) and sucker (2) species, the presence of the intolerant Texas logperch (*Percina carbonaria*), and the absence of individuals with disease or other anomalies. The only metrics receiving low scores were the percentage of tolerant (~82%) and hybrid (1.5%) individuals. Water quality improved with low-moderate turbidity levels, no noticeable odor or surface film, algal growth, and aquatic vegetation thick in shallow areas. The riparian zone was intact with mature overstory trees. Aquatic invertebrates observed included Ephemeroptera, Odonata, Trichoptera, Dipterans, and

Gastropoda.

The final sample site in the Bosque River watershed was on the North Bosque River just north of the town of Valley Mills at FM 56. It was designated as a fifth order stream. A high aquatic life use rating of 48 was calculated for this site. The two low scoring metrics were the absence of intolerant species and the high percentage of tolerant individuals (~46%). The presence of darter (1) and sucker (2) species, the absence of hybrid and individual fish with disease or anomalies, and the overall high number of individuals collected at the site (1,526) were metrics that positively influenced the overall site score. Water quality was affected by the large amount of erosion that has occurred from agricultural runoff and bank sloughing, therefore increasing turbidity levels. The riparian zone has been heavily impacted by clearing, grazing, and farming practices. Aquatic invertebrates observed included Megaloptera, Diptera, Coleoptera, and Odonata.

Leon River Watershed

The site farthest upstream in the Leon River watershed was just east of the city of Eastland at Interstate Highway 20. This site on the North Fork of the Leon River was designated a third order stream. It received an IBI evaluation score of 40 and an aquatic life use class of intermediate due to the following low scoring metrics: (1) the absence of sucker species; (2) the high percentage of tolerant (90.7%) and omnivorous (73.4%) individuals; and (3) the low percentage of insectivorous individuals (19.3%). The percentage of omnivorous individuals was greatly affected by the collection of a large number of gizzard shad (*Dorosoma cepedianum*) at the sample site. The presence of the pollution intolerant Texas logperch (*Percina carbonaria*) and the fact that no hybrids or individuals with disease or other anomalies were collected warranted higher scores for these three metrics. Water quality appeared to be good at this site with moderate turbidity levels, no odors or surface film, and emergent aquatic vegetation present. The riparian zone was intact and aquatic invertebrates observed included Ephemeroptera, Coleoptera, Megaloptera, and Odonata.

The second site on the Leon River was downstream from Proctor Lake at FM 1476. The Leon River at this site was classified as a fifth order stream. This site received an IBI evaluation score of 42 and an intermediate aquatic life use class due to (1) the absence of sucker species; (2) the percentage of tolerant individuals, although lower than other sites, was high enough to receive a low score of 26.3%; and (3) the comparably high percentage of hybrid sunfish present in the fish community. Two positively influenced metrics were the presence of the pollution intolerant dusky darter (*Percina sciera*) and the absence of individuals with disease or other anomalies. Water quality appeared to be impaired in comparison to the upstream site due to its high turbidity level and the lack of aquatic vegetation. The riparian zone was heavily impacted by grazing along portions of the site. Aquatic invertebrates observed included Ephemeroptera, Homoptera, and Odonata.

The third Leon River site was north of the City of Hamilton at CR 203. This fifth order stream received an IBI evaluation score of 40 and an intermediate aquatic life use classification. Scoring for this site was negatively influenced by the high percentage of tolerant (49.7%) and hybrid (7%) individuals and positively influenced by the number of darter (2) and sucker (1) species, as well as the lack of individuals with disease or other anomalies present in the fish community.

Impact to the riparian zone due to uncontrolled livestock grazing may have resulted in elevated turbidity levels in the stream which were observed during the sampling. The aquatic invertebrates observed included Megaloptera and Odonata.

The fourth sample site in the watershed was on Nolan Creek, a fourth order tributary of the Leon River. This site was located northwest of Belton, Bell County, at FM 93. Nolan Creek received an IBI evaluation score of 36 which falls between the limited and intermediate aquatic life use classes. This comparably low score was negatively affected by the lack of pollution intolerant species present, the high percentage of hybrid sunfish (3.4%), and individuals with disease or anomalies (6.1%). Metrics that positively affected this evaluation score were the presence of the orangethroat darter (*Etheostoma spectible*) and the gray redhorse sucker (*Moxostoma congestum*). A few green sunfish specimens were preserved due to observations of "bleaching" of scales along the belly. The water quality in Nolan Creek was considered poor due to the turbidity, a bleach odor, white surface film, and excessive algal growth observed during sampling. The riparian zone was intact and a diversity of aquatic invertebrates including Odonata, Diptera, and Gastropoda were collected.

The final sample site on the Leon River was just downstream of the tailrace of Belton Lake and was designated a sixth order stream. An IBI evaluation score of 40 was calculated for this site, resulting in an intermediate aquatic life use classification. This intermediate score was negatively affected due to the absence of sucker and intolerant species and was positively affected by the large number of individuals collected (1,350) and the low percentage of tolerant individuals present (5.3%). Several inland silversides (*Menidia berrylina*) collected from this site were examined and preserved due to the occurrence of black spots on the scales. Turbidity below the tailrace of Belton Lake was low to moderate. An unusually cool water temperature of 18°C, for the 11th of August, was observed during sampling. Algae and floating aquatic vegetation were present in shallow backwater areas. The riparian zone was intact, except for an area around a boat ramp. Few aquatic invertebrates were observed at this site.

<u>Lampasas River Watershed</u>

The upstream sample site for the Lampasas River watershed was west of the town of Kempner at U. S. Highway 190. This fifth order stream received an IBI score of 48, resulting in a high aquatic life use classification. The only metric negatively influencing this otherwise high score was the high percentage of tolerant species present (47.6%) in the fish community. All other metrics scored average to high with some more significant being the total number of species present (20); number of intolerant (1), darter (2) and sucker (1) species; the low percentage of omnivorous individuals (0.17%); and the lack of hybrid and diseased individuals. Water quality appeared to be good with low turbidity and several species of emergent aquatic vegetation were present. The riparian zone at this site was intact, and the diversity of aquatic invertebrates included Megaloptera, Ephemeroptera, Hemiptera, and Coleoptera.

The other sample site on the Lampasas River was downstream of Stillhouse Hollow Lake at U.S. Highway 35. This site was given a stream order designation of five. An IBI evaluation score of 44 resulted in the classification this stream segment as an intermediate aquatic life use class. The only low scoring metric was due to the absence of a sucker species in the sample. Some more significant high scoring metrics were the total number of darter (2) and sunfish (5) species present; the absence of omnivores; and the relatively low percentage of tolerant species present when compared to other sites. Water quality was considered good with low turbidity and a large diversity of aquatic vegetation growing within its banks. The water temperature at this site was also considered cooler, ~ 20°C, than normal for a central Texas stream in the middle of August. The riparian zone was intact with several mature trees preventing erosion. A diverse group of aquatic invertebrates were observed, including Trichoptera, Ephemeroptera, Megaloptera, Coleoptera, Odonata, Diptera, Chironomidae, and Gastropoda.

Discussion

In summary, the Index of Biotic Integrity (IBI) successfully demonstrated the positive relationships that exist between relevant water quality information provided by the TNRCC and the IBI scores calculated during this study. For example, based on our IBI scoring it is evident that at least two river segments should be considered impacted by point and/or nonpoint water pollution sources. The upper North Bosque River (Texas river segment 1255) received a Limited IBI score of 30, while Nolan Creek (Texas river segment 1218) had a Limited-Intermediate IBI score of 36. The TNRCC draft 1999 303(d) list, distributed on November 4, 1998, designated both of these segments, along with several others in the Middle Brazos River Basin, as impaired waterbodies. According to their draft, the upper North Bosque River, which includes the upper segment boundary downstream to the city of Stephenville WWTP, contains bacteria levels that intermittently exceed the criterion established to assure the safety of contact recreation and occasionally has dissolved oxygen concentrations lower than the standard established to assure optimum conditions for aquatic life. The impacts to the Upper North Bosque River stem from nonpoint source runoff from the large number of concentrated animal feeding operations (CAFO's) in Erath County. The draft 303(d) list also states that in Nolan Creek, bacteria levels exceed the criterion established to assure safety during contact recreation. Two fish-kills on Nolan Creek were reported to the Region 9 office of TNRCC during September 1997. Investigations led to the discovery that both fish-kills were the result of discharges of treated/chlorinated drinking water by Bell County WCID No. 1. A total estimate of six million gallons of treated/chlorinated water were discharged directly into the creek during these incidents (Snyder, personal communication). Although the fish-kills occurred eleven months before sampling took place, it is feasible that these incidents may have biased the resulting IBI score. Nolan Creek is known to have both point and nonpoint source pollution from WWTP's in the City of Killeen and surrounding small towns and agricultural runoff.

Three additional river segments listed as impaired in TNRCC's draft 303(d) list include: the North Bosque River (Texas river segment 1226), Proctor Lake (Texas river segment 1222), and the Leon River below Proctor Lake (Texas river segment 1221). The North Bosque River (Texas river segment 1226) is listed due to periodic high bacteria levels that exceed criterion established for safe contact recreation in 75 miles of the segment from the upper segment boundary downstream through the City of Clifton. While point source pollution from the Stephenville WWTP is established, the TNRCC indicates that nonpoint source loading, most likely from concentrated animal feeding operations (CAFO's), is the most serious threat to the segment. Proctor Lake (Texas river segment 1222) is proposed to be listed for the first time in 1999 due to excessive levels of total dissolved solids and chlorides that pose a risk to the protection of aquatic life and other water quality uses. Possible impacts to this segment of the watershed are attributed to nonpoint sources such as the large concentration of peanut operations, CAFO's located upstream of the reservoir, and former oil producing sites in Eastland County which have caused saltwater contamination of the groundwater. The Market Administrator's Report (1996) designated Erath, Comanche, and Hamilton Counties as the number 1, 3, and 7 milk producing counties in Texas, respectively, and the portion of Erath County which is in the Leon River watershed and drains into Proctor lake has a high density of dairies. The Leon River below Proctor Lake (Texas river segment 1221) is listed due to occasional high bacteria levels that exceed the criterion established to assure the safety of contact recreation in 125 miles of the segment downstream of the South Fork Leon River and total dissolved oxygen levels that exceed criterion to protect aquatic life and other water quality uses. Impact to this segment is mostly considered to be from nonpoint agricultural runoff.

Two sample sites within Texas river segment 1226 and one in Texas river segment 1221 did not produce limited or low IBI scores. However, this does not imply that they are not impaired as described above. Sites sampled within the 303(d) listed areas of these two segments scored an intermediate 42, a high 48, and an intermediate 40. The possibility that the higher rated site was inflated does exist due to the ease with which it was sampled when compared to the other two sites. The sampling effort remained equal throughout this study, but the effectiveness of the sampling techniques and equipment did vary at each site. Another factor sometimes overlooked is that the farther downstream in a watershed samples are taken, the more likely pollutants may have been diluted to less harmful levels. For example, the highly rated site mentioned above and another site even farther downstream both had an IBI score of 48.

Upon completion of this survey, the FWS suggests several restoration measures that could contribute to a significant improvement in the fishery of the Middle Brazos River Basin. The FWS believes that by taking steps to improve the water quality of the Basin, the fishery will recover on its own. As distinguished by this study, the fishery is substantially impacted by nonpoint source pollution from agricultural practices, point source pollution from WWTP's, and seasonal temperature and dissolved oxygen manipulations in tailraces below dams.

Agricultural practices are acknowledged as a major contributor of nonpoint source pollution in surface waters. The FWS recommend using a combination of offstream constructed wetlands and riparian buffer zones as measures of control. We also suggest using best management practices in agricultural activities like following the contouring method when tilling fields and eliminating livestock access to streambanks by fencing management areas. Stock watering areas could be used to limit access and should be stabilized by stone or railroad ties which can withstand trampling.

Wetlands constructed offstream of small permanent or ephemeral streams could provide nonpoint source pollution control for agricultural watersheds. In this role, wetlands would provide several benefits which contribute to water quality improvements. First, the wetlands provide water quality function through solids settling, nutrient transformation, and biological uptake. Second, because they provide a fairly large surface area, wetlands provide flood water storage and serve to collect peak flood flows known to carry most of the polluted runoff from nonpoint sources. Finally, wetlands provide diversity in the landscape and supply a unique habitat for many plants and animal species.

Where wetlands are not feasible, riparian buffer zones of at least 25 feet on each side could be used to enhance and protect aquatic resources from adverse impacts of agricultural practices. Riparian buffer zones provide several benefits for aquatic resources. First, riparian zones stabilize eroding banks by absorbing the erosive force of flowing water while roots hold soil in place. Second, riparian zones filter sediment, nutrients, pesticides, and animal waste from agricultural runoff. Finally, riparian zones provide shade, shelter, and food for fish and other aquatic organisms.

WWTP's are one of the most common point source pollution in surface waters of the United States. Recent improvements in design have corrected many of the inherent problems with these facilities. However, when several unauthorized discharges from outdated valves, rusted bolts and transfer lines cause repeated fish kills in the same watershed, it can have a detrimental and irrecoverable affect on the aquatic environment. The FWS recommends more stringent enforcement of the Texas Water Code, §26.121 (a)(3) to assure that any case of accidental release or bypass by a WWTP facility is reported within 24 hours so that adequate response measures can be taken.

Dams have an enormous effect on streams by interrupting daily and seasonal streamflows, altering seasonal temperature patterns, reducing movement of sediment, and disrupting the natural processing and flow of organic materials and nutrients through the aquatic ecosystem. Coarse and fine particulate organic matter, the energy source of streams on which the aquatic food web relies, is trapped in reservoirs (Edwin 1998). Furthermore, as organic materials settle out in reservoirs and decompose, oxygen is removed from the water, degrading the quality of the water that is eventually released to tailwaters. The FWS recommends that reservoirs lacking a multilevel discharge system consider upgrading their systems.

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