Fisheries Use Attainability Study for the Bosque River

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The Bosque River, located within the Brazos River Basin, was sampled by Texas Parks and Wildlife Department (TPWD) Resource Protection Division staff as part of a use attainability analysis being prepared by the Texas Water Commission (TWC). The role of TPWD was to provide the TWC with a characterization of the fishery in the river.

Study Site

The Bosque River (Segments 1226 and 1246) consists of the north, middle, and south forks from the headwaters of each fork to Lake Waco. Eight stations were sampled (Table 1; Figure 1). The South Bosque River differed greatly from the other two. The substrate was comprised of silt and patches of gravel, whereas the north and middle forks had limestone bases. The South Bosque River was the narrowest and shortest of the three forks. The Middle Bosque River was shallowest and had the lowest discharge (Table 2). The North Bosque River boasted the greatest discharge, depth, length, and width of the three forks (Table 2).

Examination of flow data from United States Geological Survey gaging stations at Hico, Clifton, and Valley Mills indicated that "no flow" conditions have occurred at times in the North Bosque River (Buckner *et al*. 1987). However, deep, enduring pools that could maintain aquatic life during dry periods were observed in the North Bosque River.

South Bosque River

Large amounts of submerged aquatic vegetation, filamentous green algae, and floating blue-green algae were observed at the upper station on the South Bosque River. Periphyton and filamentous algae were noted only along the perimeter and extending out about one meter into the channel at the lower South Bosque River station. Canopy cover increased downstream, from less than 1% to 40%, mostly due to the increase in willows (*Salix*). Substrate at the upper station was silt with patches of gravel. The lower station had a hard bottom with an overlying layer of silt, accompanied by cobble in slow moving back water areas. Two municipal wastewater treatment plants were discharging into tributaries of the South Bosque River at the time of sampling (Figure 1).

Middle Bosque River

Hard limestone and patches of cobble composed the substrate in the Middle Bosque River. Silty substrate was also present in back water areas at the lower station. Periphyton and submerged aquatic vegetation were noted. Filamentous algae were especially prevalent in pools at the upper station, whereas small amounts of blue-green algae were located along the bank at the lower station. Riparian vegetation bordered the channel, contributing 15% and 10% canopy cover at the upper and lower stations, respectively. One municipal wastewater treatment plant was discharging into a tributary of the Middle Bosque River at the time of sampling (Figure 1).

North Bosque River

Substrate varied in the North Bosque River from silt and gravel at the upper station; to smooth limestone, boulder, sand, and gravel in the middle stations; and changed to silt and cobble at the lowest station. The proportion of riffle to pool habitat increased downstream. Canopy cover was greatest at the upper and lower stations (40-50%), but was less than 5% at the middle stations. Centrachid spawning beds were noted at the upper station. A phytoplankton bloom was observed at the Highway 6 station. Six municipal wastewater plants were discharging into the river or its tributaries at the time of sampling (Figure 1).

Methods

Fish were collected July 8-10, 1987. Representative habitats were sampled by a seine measuring 4.5 m in length, 1.2 m in depth, and composed of 3.1 mm ace weave mesh.

Each station was seined for at least 15 minutes.

Table 1. List of municipal discharges and survey stations on the Bosque River.

	Dischargers and Survey Stations	1985 Flow (MGD)	River km*
NORTH BOSQUE			
A.	Stephenville Wastewater Treatment Plant	1.50	189.9
1.	County Road between Hwy. 281 and 914		187.9
B.	Hico Wastewater Treatment Plant	0.18	149.2 (0.3)
2.	Highway 6 at Iredell		128.0
C.	Iredell Wastewater Treatment Plant	0.02	123.0
D.	Meridian Wastewater Treatment Plant	0.14	90.5
3.	Old Iron Bridge at Clifton		66.2
E.	Clifton Wastewater Treatment Plant	0.28	65.9
F.	Valley Mills Wastewater Treatment Plant	0.44	43.3 (0.2)
4.	C. O. Tolbert Farm		26.7
MIDDLE BOSQUE			
5.	County Road near Prairie Chapel		37.8
6.	Highway 185		19.5
G.	Crawford Wastewater Treatment Plant	0.03	10.1 (21.8)
SOUTH BOSQUE			
H.	McGregor Wastwater Treatment Plant	0.31	30.9 (2.6)
7.	Highway 2416		23.5
I.	McGregor Wastewater Treatment Plant	0.31	15.7 (14.8)
8.	Highway 84		11.0

*Entries in parenthesis refer to the distance a discharge travels in a tributary before emptying into the Bosque River.

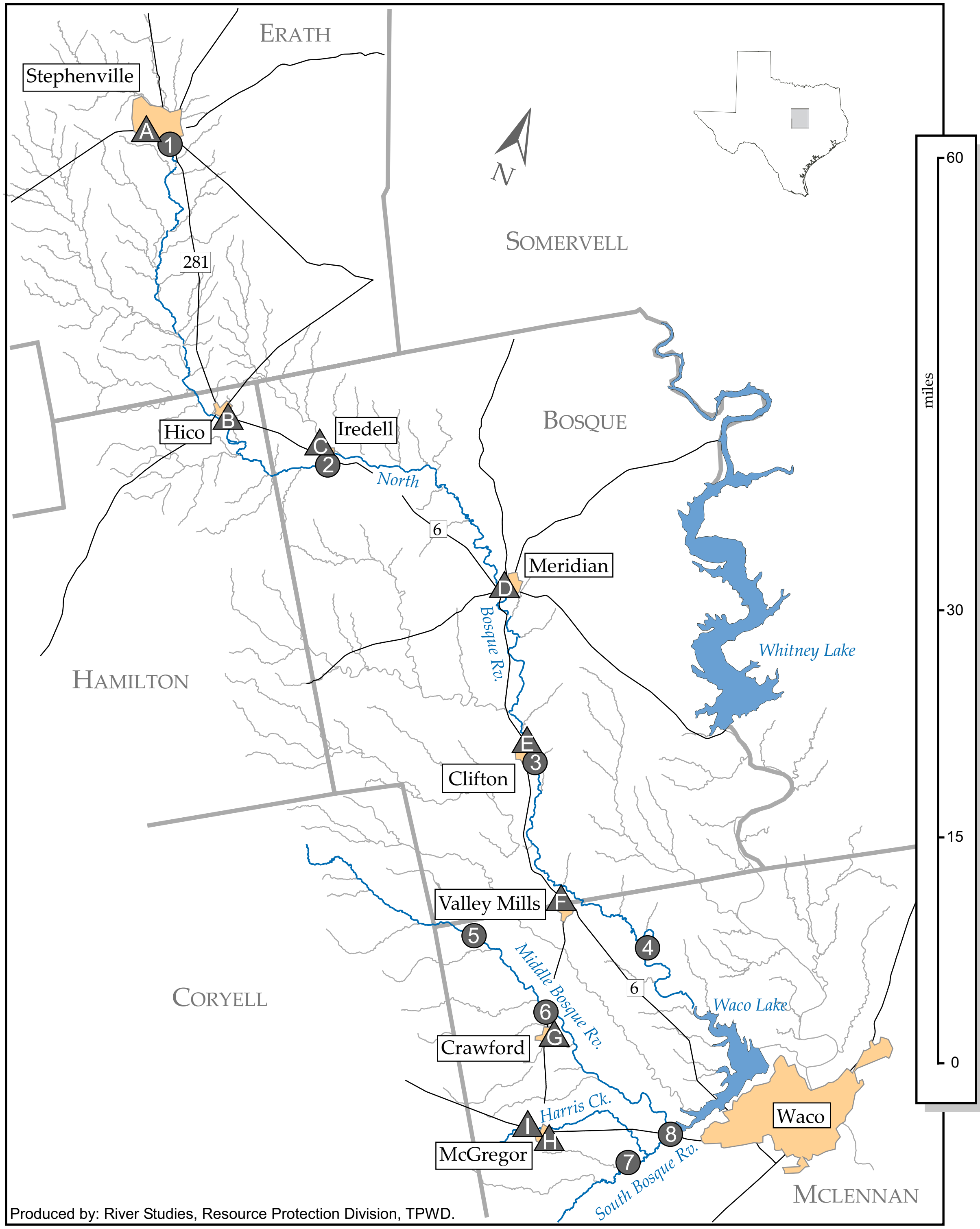

FIGURE 1.— Map of sampling area. See table 1 for site descriptions.

Table 2. Physiochemical measurements taken on the Bosque River (July 1987).

Station	Date	Time	Channel Width (m)	Mean Depth (m)	Discharge (m^3/s)	DO (mg/L)	pH	Temp. (°C)	Cond. (*u*mhos)	Trans- parency (m)	Canopy Cover (%)
NORTH BOSQUE											
County Road between HWY 281 & 914	7/8/87	1830	14.4	0.45	0.04	8.67	8.04	26.86	1163	0.86	40
HWY 6 at Iredell	7/8/87	1550	14.3	0.45	-	12.37	8.14	30.00	724	0.33	<5
Old Iron Bridge in Clifton	7/8/87	1400	20.0	0.45	-	9.50	8.08	29.44	564	0.38	<5
C.O. Tolbert Farm	7/9/87	0945	18.6	0.29	5.87	7.22	7.72	27.28	532	0.03	45
MIDDLE BOSQUE											
County Road near Prairie Chapel	7/9/87	1215	5.1	0.12	0.07	8.70	7.68	27.02	502	>0.61	15
HWY 185	7/9/87	1445	11.2	0.23	0.23	8.85	7.89	30.14	441	>0.61	<10
SOUTH BOSQUE											
HWY 2416	7/9/87	1730	3.4	0.27	0.03	9.55	7.66	28.72	543	>0.30	<1
HWY 84	7/10/87	0913	10.4	0.22	0.32	6.28	7.70	26.19	555	0.15	40

Weight (g) and total length (mm) were recorded from larger individuals. Seventy-five fish from each sample were examined for disease and other abnormalities. All fish were preserved in 10% formalin and transported to the laboratory for identification. Taxonomic references include Eddy and Underhill (1978), Hubbs (1970, University of Texas unpublished manuscript), and Pflieger (1975). Common and scientific names follow Robins *et al.* (1980).

Dissolved oxygen, pH, temperature, and conductivity were sampled in situ at each station using a Hydrolab Surveyor II. Flow was measured with a flow velocity meter (Montedoro-Whitney, Model PVM-2A).

Discharge (m^3/sec) was calculated according to Orth (1983). Water transparency was measured with a secchi disk. Stream width, average depth, and canopy cover were estimated by visual observation.

Species diversity was calculated according to the equation presented in Wilhm (1970):

$$\overline{H} = -\sum_{i-1}^{s} (n_i/n) \log_2 (n_i/n),$$

where $\overline{H}$ = species diversity, n_i = number of individuals in the i^{th} species, n = number of individuals in the sample, and s = number of species. Generally, values less than 1 indicate severely degraded conditions, 1-3 indicate moderately polluted streams, and greater than 3 indicate clean water streams (Wilhm and Dorris 1968).

Index of similarity, a measure of the degree of resemblance in species composition between two sites, was calculated according to the equation presented in Odum (1971):

$$S = 2C/A + B,$$

where S = index of similarity, A = number of species in sample A, B = number of species in sample B, and C = number of species common to both samples. Values can range from 0, meaning the sites are entirely dissimilar, to 1.0, indicating the two sites are identical in terms of species present.

Condition factors, a measure of the well-being or plumpness of a fish, were calculated according to the equation presented in Carlander (1969, 1977):

$$K = W10^5/L^3,$$

where K = condition factor, W = weight in grams, L = length in millimeters, and 10^5 is a factor to bring the value of K near unity. K-factors were calculated only for species for which Carlander (1969, 1979) presents comparative data. In selecting values for comparisons, an effort was made to find data in Carlander (1969, 1977) for fish from a similar geographical area and of a similar size to that collected in this study. K-factors vary with species and size, but generally, larger values are indicative of better fish condition.

Index of biotic integrity (IBI) was calculated according to Karr *et al.* (1986), though the scoring criteria were modified to rate the Bosque River (Table 3). Scoring criteria for total number of fish species was based on work performed by Fausch *et al.* (1984) on midwestern streams. However, the values for that study, in which stream order was plotted against total number of species, are comparable to work on the Plum Creek drainage basin of south-central Texas and the Otter Creek drainage of north-central Oklahoma. In Plum Creek, a maximum number of 12 fish species were found in third through fifth order streams (Whiteside and McNatt 1972). Harrel *et al.* (1967) found that the maximum number of species collected from third, fourth, and fifth order streams in the Otter Creek drainage were five, 11, and 13, respectively. The Middle Bosque at the County Road near Prairie Chapel and the South Bosque at Hwy. 2416 were both estimated to be third order streams; whereas, the North Bosque at Old Iron Bridge in Clifton and at the C.O. Tolbert Farm were estimated to be fifth order streams. The remaining stations were estimated to be fourth order streams.

The IBI metric for number of sucker species was eliminated because few species of catostomids were in historical seine collections. Hubbs and Strawn (unpublished data), who sampled the north and south forks of the Bosque River in 1953, collected only one species of sucker, gray redhorse (*Moxostoma congestum*). Other common sucker species, smallmouth buffalo (*Ictiobus bubalus*) and river carpsucker (*Carpiodes carpio*), are not especially vulnerable to seine capture once they reach maturity and are not notable for their sensitivity to declines in water quality. When it is not practical to use the target groups originally employed in IBI, Karr *et al.* (1986) suggest substituting other species-rich groups. The target groups should represent one benthic- and one non-benthic oriented taxon, whereas the third can be either (Karr *et al.* 1986). Since darters (benthic oriented) and sunfish (water-

Table 3. Scoring criteria used for rating the index of biotic integrity of the Bosque River.

Category		Metric	Scoring criteria 5	3	1
Species richness and composition	1.	Total number of fish species	a	a	a
	2.	Total number of darter species	≥2	1	0
	3.	Total number of sunfish species	>2	1-2	0
	4.	Total number of cyprinid species other than common carp	>3	2-3	0-1
	5.	Total number of intolerant species	≥2	1	0
	6.	Proportion of individuals as tolerants	<5%	5-20%	>20%
Trophic composition	7.	Proportion of individuals as omnivores	<20%	20-45%	>45%
	8.	Proportion of individuals as invertebrate feeders	>80%	>40-80%	≤40%
	9.	Proportion of individuals as piscivores	>5%	1-5%	<1%
Fish abundance and condition	10.	Number of individuals in sample	>200	>50-200	≤50
	11.	Proportion of individuals as hybrids	0%	>0-1%	>1%
	12.	Proportion of individuals with disease other anomaly	≤2%	>2-5%	>5%

a Third order streams: ≥9(5), 4-8(3), ≤3(1)
Fourth order streams: ≥12(5), 6-11(3), ≤5(1)
Fifth order streams: ≥14(5), 7-13(3), ≤6(1)

column oriented) were retained, the primary criterion for selecting a third target group was one sensitive to water quality degradation.

The number of cyprinid species other than common carp was substituted for the sucker metric. 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; Moyse 1976). Ramsey (1986) 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 suffer few distributional limitations and were common at a nearby, minimally impacted reference site (Steele Creek). Kleinsasser and Linam (1989) found that cyprinid species declined in number at impacted sites on the Trinity River. Carp were omitted because they are tolerant of environmental perturbations. Numerical criteria for the metric were the same used by Kleinsasser and Linam (1989).

Other modifications to the IBI included substituting the proportion of individuals as tolerants for occurrences of green sunfish (*Lepomis cyanellus*) to make the index less susceptible to the presence or absence of a single species. The proportion of individuals as invertebrate feeders was substituted for insectivorous cyprinids. Trophic and tolerance classifications were established based upon a survey of ichthyologists familiar with Texas freshwater fishes and a comprehensive literature review (Appendix A; Linam and Kleinsasser unpublished). IBI integrity class scores and attributes are listed in Appendix B. Proportions mentioned in the text refer to IBI metrics listed in Table 3.

Species richness and IBI were emphasized in characterizing the fishery. A gauge of system health is the number and types of species present, with a greater number of species typically suggesting a more stable and healthy system. This reasoning must be used with care, but as Young *et al*. (1973) point out, the presence of some fish species upstream of an entry point of waste and their absence downstream of that point suggests the waste is limiting their occurrence. In addition, IBI provides a means of assigning a score to a collection by integrating a variety of fisheries information. The index has gained acceptance by a number of states as a tool for evaluating fish communities for water quality standards purposes. The United States Environmental Protection Agency (USEPA) has increasingly recommended its use for biological assessments of fish communities (Plafkin *et al*. 1988; USEPA 1983). Together, IBI and species richness, provide a sound characterization of the fishery.

Less emphasis was placed on species diversity, similarity indices, and condition factors. They are not reliable indicators in themselves, but when used in conjunction with other methods can provide additional information for characterizing the system.

Results and Discussion

Water Quality Parameters

Physiochemical data presented in Table 2 reflect nonlimiting conditions for aquatic life. The incidence of periphyton, a plankton bloom at Highway 6, and supersaturated dissolved oxygen levels at all stations except the C.O. Tolbert Farm and Highway 84 stations suggested possible nutrient enrichment in the Bosque River at the time of the study. Readings at the C.O. Tolbert Farm and Highway 84 stations may have been below the saturation level because the measurements were taken at 0945 and 0913 hours when the levels of photosynthesis are still low. Shading by riparian vegetation at those sites could have also decreased primary production. If nutrient enrichment is occurring from point or nonpoint sources, it could become detrimental to aquatic life, particularly during low flow periods. Conductivity was highest in the North Bosque River and lowest in the Middle Bosque River. Conductivity was especially high at the upper North Bosque River station, possibly due to effluent from the Stephenville Waste Water Treatment Plant. Conductivity decreased downstream in the North and Middle Bosque rivers, whereas it increased downstream in the South Bosque River. Water transparency was typically greatest in the Middle Bosque River where sunlight penetrated to the stream bottom at both stations. Overall, the South Bosque River had the lowest water transparency. This may be a result of its substrate character and effluent influences from the City of McGregor. Water transparency tended to decrease downstream. No great differences in water temperature among stations were observed.

Fisheries Parameters

Fish species collected from the three forks of the Bosque River are presented in Tables 4, 5, and 6.

Table 4. Fishes collected by seine from the North Bosque River (July 1987).

Taxa	Common Name	County Road between HWY 281 & 914	HWY 6 at Iredell	Old Iron Bridge in Clifton	C.O. Tolbert Farm
Dorosoma cepedianum	Gizzard shad	26			
Notropis venustus	Blacktail shiner	5	4	29	3
Notropis lutrensis	Red shiner	248	37	470	264
Notropis volucellus	Mimic shiner			9	
Pimephales vigilax	Bullhead minnow		5	5	2
Campostoma anomalum	Common stoneroller				1
Ictalurus punctatus	Channel catfish	1			
Gambusia affinis	Mosquitofish	7	5	3	86
Menidia beryllina	Inland silverside			1	
Micropterus punctulatus	Spotted bass				2
Micropterus salmoides	Largemouth bass	3	1	1	13
Lepomis cyanellus	Green sunfish		15	1	
Lepomis microlophus	Redear sunfish			1	4
Lepomis macrochirus	Bluegill	10	7	3	11
Lepomis humilis	Orangespotted sunfish			4	
Lepomis megalotis	Longear sunfish	3	11		3
Lepomis marginatus	Dollar sunfish	7	1		
Pomoxis annularis	White crappie	1			
Percina macrolepida	Bigscale logperch		1		
Etheostoma spectabile	Orangethroat darter			2	7
		311	87	529	396

Table 5. Fishes collected by seine from the Middle Bosque River (July 1987).

Taxa	Common Name	County Road near Prairie Chapel	HWY 185
Notropis venustus	Blacktail shiner	63	272
Notropis lutrensis	Red shiner	7	5
Campostoma anomalum	Common stoneroller	13	3
Moxostoma congestum	Gray redhorse		1
Ictalurus natalis	Yellow bullhead		2
Gambusia affinis	Mosquitofish	80	2
Micropterus punctulatus	Spotted bass		3
Micropterus salmoides	Largemouth bass	7	6
Lepomis macrochirus	Bluegill	13	5
Lepomis megalotis	Longear sunfish	1	3
Etheostoma spectabile	Orangethroat darter	10	4
		194	306

Table 6. Fishes collected by seine from the South Bosque River (July 1987).

Taxa	Common Name	HWY 2416	HWY 84
Dorosoma petenense	Threadfin shad		1
Dorosoma cepedianum	Gizzard shad		39
Notropis emiliae	Pugnose minnow		13
Notropis venustus	Blacktail shiner		15
Notropis lutrensis	Red shiner		147
Pimephales vigilax	Bullhead minnow		13
Campostoma anomalum	Common stoneroller		1
Moxostoma congestum	Gray redhorse		6
Ictalurus natalis	Yellow bullhead	4	
Fundulus notatus	Blackstripe topminnow		15
Gambusia affinis	Mosquitofish	22	70
Menidia beryllina	Inland silverside		28
Micropterus punctulatus	Spotted bass		3
Micropterus salmoides	Largemouth bass	25	10
Lepomis gulosus	Warmouth		2
Lepomis cyanellus	Green sunfish	17	
Lepomis macrochirus	Bluegill	1	10
Lepomis megalotis	Longear sunfish	49	9
Percina macrolepida	Bigscale logperch		1
Etheostoma spectabile	Orangethroat darter	11	
		129	383

A total of 26 different species were identified, including three which are considered pollution intolerant. These include longear sunfish (*Lepomis megalotis*), bigscale logperch (*Percina macrolepida*), and mimic shiner (*Notropis volucellus*).

Twenty species were collected in both the North and South Bosque rivers, whereas only 11 were collected in the Middle Bosque River. All three pollution intolerant species were collected in the North Bosque River. Two pollution intolerant species were collected in the South (longear sunfish and bigscale logperch) and one in the Middle Bosque River (longear sunfish).

Early collections in the Bosque River by Hubbs and Strawn in 1953 (unpublished; University of Texas Natural History Collection) totalled 20 species (Appendix C). Their species list was very similar to that found in this study. Species that were identified in this study but did not appear in the earlier study included: threadfin shad (*Dorosoma petenese*), gizzard shad (*Dorosoma cepedianum*), pugnose minnow (*Notropis emiliae*), mimic shiner, inland silverside (*Menidia beryllina*), redear sunfish (*Lepomis microlophus*), orangespotted sunfish (*Lepomis humilis*), dollar sunfish (*Lepomis marginatus*), warmouth (*Lepomis gulosus*), and white crappie (*Pomoxis annularis*). Four species were collected in the earlier study that were not found in this study. These included: fathead minnow (*Pimephales promelas*), golden shiner (*Notemigonus crysoleucas*), dusky darter (*Percina sciera*), and flathead catfish (*Pylodictus olivaris*).

County Road between HWY 281 & 914 Station (North Bosque River)

Ten fish species were collected at this station (Table 4), including one pollution intolerant species (longear sunfish). This station was the only location where no darter species were collected.

The species diversity value (Table 7) was in the range considered indicative of moderate pollution ($\overline{H}$ of 1 - 3; Wilhm and Dorris 1968). The index of similarity (Table 8) indicated that the fish community from this station was most like that at the HWY 6 Station (North Bosque River), and least like that at the Old Iron Bridge Station (North Bosque River).

Condition factors calculated for bluegill (*Lepomis macrochirus*) and white crappie collected at this station (Table 9) were similar to values found in Carlander (1977), whereas low values were derived for largemouth bass (*Micropterus salmoides*) and longear sunfish. Because few fish were used in the analysis, it is difficult to draw conclusions about overall fish condition at this station.

This station was assigned a rating of fair (Table 10) based on the index of biotic integrity (Appendix B; Karr *et al*. 1986). Major reasons for this less than excellent rating include reduced species richness; the absence of darter species, which are particularly sensitive to degradation of benthic habitat due to their specificity for reproducing and feeding there (Page 1983); the reduced number of cyprinid and intolerant species; the high proportion of tolerant individuals; and the low proportion of piscivores.

HWY 6 Station (North Bosque River)

Ten fish species were collected at this station (Table 4), including two pollution intolerant species (longear sunfish and bigscale logperch). The highest proportion of diseased fish in the study was found here (Table 10).

The species diversity value was the highest of the North Bosque River stations, and the second highest of the study (Table 6), but was still in the range considered indicative of moderate pollution ($\overline{H}$ of 1 - 3; Wilhm and Dorris 1968). The index of similarity (Table 8) indicated that the fish community from this station was most like that at the County Road between HWY 281 and 914 Station (North Bosque River) and least like that at the HWY 185 Station (Middle Bosque River).

Condition factors calculated for fish species collected at this station (Table 9) were slightly low or similar to values found in Carlander (1977).

This station was assigned a rating of fair (Table 10) based on the index of biotic integrity (Appendix A; Karr *et al*. 1986). Major reasons for this rating include reduced species richness; reduced numbers of darter, cyprinid, and intolerant species; the high proportion of tolerant species; the low proportion of invertebrate feeders; the high proportion of diseased individuals; and low numbers of individuals.

Old Iron Bridge in Clifton Station (North Bosque River)

This station boasted the highest species richness (12) of the North Bosque River stations (Table 7), and second highest of the study. The species diversity value was lowest of the study (Table 7) and in the range considered indicative of heavy pollution ($\overline{H}$ < 1; Wilhm and Dorris 1968). The species

Table 7. Fish community indices calculated for each station on the Bosque River (July 1987).

Station	Species Richness	Species Diversity
NORTH BOSQUE		
County Road between HWY 281 & 914	10	1.24
HWY 6 at Iredell	10	2.54
Old Iron Bridge in Clifton	12	0.78
C.O. Tolbert Farm	11	1.55
MIDDLE BOSQUE		
County Road near Prairie Chapel	8	2.18
HWY 185	11	0.86
SOUTH BOSQUE		
HWY 2416	7	2.32
HWY 84	17	2.94

Table 8. Index of similarity results on fish species composition among each possible combination of stations on the Bosque River (July 1987).

	County Road between HWY 281 & 914	HWY 6 at Iredell	Old Iron Bridge in Clifton	C.O Tolbert Farm	County Road near Prairie Chapel	HWY 185	HWY 2416	HWY 84
NORTH BOSQUE								
County Road between HWY 281 & 914	-	-	-	-	-	-	-	-
HWY 6 at Iredell	0.70	-	-	-	-	-	-	-
Old Iron Bridge in Clifton	0.45	0.64	-	-	-	-	-	-
C.O. Tolbert Farm	0.57	0.67	0.70	-	-	-	-	-
MIDDLE BOSQUE								
County Road near Prairie Chapel	0.67	0.67	0.60	0.84	-	-	-	-
HWY 185	0.57	0.57	0.52	0.73	0.84	-	-	-
SOUTH BOSQUE								
HWY 2416	0.47	0.59	0.53	0.56	0.67	0.67	-	-
HWY 84	0.52	0.59	0.48	0.64	0.56	0.64	0.33	-

Table 9. Mean condition factors calculated for fishes collected in the North Bosque River (July 1987). Values from Carlander (1977) are included for comparison. Values in parentheses indicate the number of fish used. Standard deviations for each species are listed when condition factors for at least three specimens were calculated.

	County Road between HWY 281 & 914	HWY 6 at Iredell	Old Iron Bridge in Clifton	C.O Tolbert Farm	Carlander
Micropterus salmoides	0.80 (1)			1.07 (1)	1.00
Lepomis cyanellus		1.42 (9) ±0.49			1.87
Lepomis microlophus			1.46 (1)	1.25 (2)	1.72
Lepomis macrochirus	1.35 (6) ±0.30	1.31 (6) ±0.19	1.53 (1)	1.30 (2)	1.49
Lepomis humilis			1.08 (3) ±0.17		1.24
Lepomis megalotis	1.64 (2)	1.68 (12) ±0.39		1.68 (2)	1.93
Pomoxis annularis	1.49 (1)				1.44

Table 10. Summary table for calculating the index of biotic integrity (IBI) for the stations on the North Bosque River (July 1987). The metric ratings are given in parenthesis for each station and summed to generate the final index value.

Species	County Road between HWY 218 & 914		HWY 6 at Iredell		Old Iron Bridge in Clifton		C.O. Tolbert Farm	
Number of species of: (metrics 1-5)								
Total	10	(3)	10	(3)	12	(3)	11	(3)
Darters	0	(1)	1	(3)	1	(3)	1	(3)
Sunfishes	3	(5)	4	(5)	4	(5)	3	(5)
Cyprinids	2	(3)	3	(3)	4	(5)	4	(5)
Intolerants	1	(3)	2	(3)	1	(3)	1	(3)
Proportion of individuals as: (metrics 6-9, 11-12)								
Tolerants	81.9%	(1)	65.4%	(1)	89.6%	(1)	88.4%	(1)
Omnivores	8.7%	(5)	5.7%	(5)	0.9%	(5)	0.5%	(5)
Invertebrate feeders	89.9%	(5)	75.6%	(3)	98.8%	(5)	95.6%	(5)
Piscivores	1.3%	(3)	18%	(5)	0.4%	(1)	3.8%	(3)
Hybrids	0%	(5)	0%	(5)	0%	(5)	0%	(5)
Diseased	1%	(5)	2.3%	(3)	0%	(5)	0%	(5)
Total number of individuals in the`sample (metric 10)	311	(5)	87	(3)	529	(5)	396	(5)
IBI total score		44		42		46		48
Integrity class (Appendix B)	Fair		Fair		Fair to Good		Good	

diversity value was depressed by the disproportionally large numbers of red shiners (*Notropis lutrensis*) collected. The index of similarity (Table 8) indicated that the fish community from this station was most like that at the C.O. Tolbert Farm Station (North Bosque River) and least like that at the HWY 84 Station (South Bosque River).

Condition factors calculated for bluegill collected at this station (Table 9) were similar to values found in Carlander (1977), whereas low values were derived for redear sunfish and orangespotted sunfish. Because of the low number of fish used in the analysis, it is difficult to draw conclusions about overall fish condition at this station.

This station was assigned a rating of fair to good (Table 10) based on the index of biotic integrity (Appendix B; Karr *et al*. 1986). Major reasons for this rating, instead of an excellent rating, include: reduced species richness; reduced numbers of darters and intolerant species; the high proportion of tolerant individuals; and the low proportion of piscivores.

C.O. Tolbert Farm Station (North Bosque River)

Eleven fish species were collected at this station (Table 4), including one pollution intolerant species (longear sunfish).

The species diversity value (Table 7) was in the range considered indicative of moderate pollution ($\overline{H}$ of 1 - 3; Wilhm and Dorris 1968). The index of similarity between this station and the County Road near Prairie Chapel Station (Middle Bosque River) was tied for the highest of the study (Table 8). This station was least similar (Table 8) to the HWY 2416 Station (South Bosque River).

Condition factors calculated for largemouth bass collected at this station (Table 9) were similar to values found in Carlander (1977), whereas low values were derived for redear sunfish, longear sunfish, and bluegill. The condition factor for largemouth bass suggests an adequate prey base for the limited numbers of piscivores; however, the below average condition factors for the insectivorous sunfishes suggest potential probelms with the invertebrate food base. These values should be reviewed with caution, however, due to the low number of fish analyzed.

This station was assigned a rating of good (Table 10) based on the index of biotic integrity (Appendix B; Karr *et al*. 1986). Major reasons for a less than excellent rating include low species richness; reduced numbers of darter and intolerant species; the high proportion of tolerant individuals; and the low proportion of piscivores.

County Road near Prairie Chapel Station (Middle Bosque River)

Eight fish species, the second lowest species richness of the study, were collected at this station (Table 5). One pollution intolerant species (longear sunfish) was collected at this station.

The species diversity value (Table 7) was in the range considered indicative of moderate pollution ($\overline{H}$ of 1 - 3; Wilhm and Dorris 1968). The index of similarity between this station and the C.O. Tolbert Farm (North Bosque River) and HWY 185 stations (Middle Bosque River) were the highest in the study (Table 8). This station was least similar (Table 8) to the HWY 84 Station (South Bosque).

Comparison of condition factors calculated for this station (Table 11) with expected values from Carlander (1977) indicated a low value for longear sunfish and high values for bluegill and largemouth bass. The condition factors for bluegill and largemouth bass suggest adequate prey. The low condition factor for longear sunfish may be a sampling artifact since only one fish was collected.

This station was assigned a rating of fair (Table 12) based on the index of biotic integrity (Appendix B; Karr *et al*. 1986). Major reasons for this less than excellent rating include reduced scoring on all species richness metrics; a high proportion of tolerant individuals; a low proportion of piscivores; and low number of individuals in sample.

HWY 185 Station (Middle Bosque River)

Eleven fish species were collected at this station (Table 4), including one pollution intolerant species (longear sunfish). The species diversity value was the second lowest of the study (Table 5) and in the range considered indicative of heavy pollution ($\overline{H} < 1$; Wilhm and Dorris 1968). The species diversity value was depressed by the disproportionally large numbers of blacktail shiners (*Notropis venustus*) collected. The index of similarity between this station and the County Road near Prairie Chapel Station (Middle Bosque River) was tied for the highest value of the study (Table 8). This station was least similar (Table 8) to the Old Iron Bridge in Clifton Station (North Bosque River).

Condition factors calculated for longear sunfish and

Table 11. Mean condition factors calculated for fishes collected in the Middle and South Bosque rivers (July 1987). Values from Carlander (1969, 1977) are included for comparison. Values in parentheses indicate the number of fish used. Standard deviations for each species are listed when condition factors for at least three specimens were calculated.

Species	County Road near Prairie Chapel	HWY 185	HWY 2416	HWY 84	Carlander
Dorosoma cepedianum				1.04 (28) ±0.24	0.96
Ictalurus natalis		1.46 (1)			1.21
Micropterus salmoides	1.28 (5) ±0.17	0.99 (3) ±0.04	1.10 (10) ±0.28	1.29 (5) ±0.28	1.00
Lepomis macrochirus	1.82 (13) ±0.24	1.79 (2)	1.40 (1)		1.49
Lepomis megalotis	1.42 (1)	1.83 (2)	1.85 (2)	1.81 (3) ±0.08	1.93

Table 12. Summary table for calculating the index of biotic integrity (IBI) for the stations on the Middle and South Bosque rivers (July 1987). The metric ratings are given in parenthesis for each station and summed to generate the final index value.

Species	County Road near Prairie Chapel		HWY 185		HWY 2416		HWY 84	
Number of species of: (metrics 1-5)								
Total	8	(3)	11	(3)	7	(3)	17	(5)
Darters	1	(3)	1	(3)	1	(3)	1	(3)
Sunfishes	2	(3)	2	(3)	3	(5)	3	(5)
Cyprinids	3	(3)	3	(3)	0	(1)	5	(5)
Intolerants	1	(3)	1	(3)	1	(3)	2	(5)
Proportion of individuals as: (metrics 6-9, 11-12)								
Tolerants	44.8%	(1)	2.2%	(5)	30.2%	(1)	57.2%	(1)
Omnivores	0%	(5)	0.6%	(5)	3.1%	(5)	13.8%	(5)
Invertebrate feeders	89.7%	(5)	95.4%	(5)	64.3%	(3)	82.0%	(5)
Piscivores	3.6%	(3)	2.9%	(3)	32.5%	(5)	3.9%	(3)
Hybrids	0%	(5)	0%	(5)	0%	(5)	0%	(5)
Diseased	0%	(5)	0%	(5)	1%	(5)	1%	(5)
Total number of individuals in the sample (metric 10)	194	(3)	306	(5)	129	(3)	383	(5)
IBI total score		42		48		42		52
Integrity class (Appendix B)	Fair		Good		Fair		Good	

largemouth bass collected at this station (Table 11) were similar to values found in Carlander (1969, 1977), whereas high values were derived for yellow bullhead (*Ictalurus natalis*) and bluegill. Condition factors suggest adequate food bases for both piscivorous and insectivorous fishes.

This station was assigned a rating of good (Table 12) based on the index of biotic integrity (Appendix B; Karr *et al*. 1986). The major reason for this less than excellent rating were the reduced values for species richness metrics and the low proportion of piscivores.

HWY 2416 Station (South Bosque River)

Seven fish species, the lowest species richness of the study, were collected at this station (Table 6), including one pollution intolerant species (longear sunfish). The species diversity value (Table 7) was in the range considered indicative of moderate pollution ($\overline{H}$ of 1 - 3; Wilhm and Dorris 1968). The index of similarity indicated that the fish community from this station was most like those at the two Middle Bosque River stations (Table 8). The index of similarity between this station and HWY 84 Station (South Bosque River) was the lowest of the study (Table 8).

Condition factors calculated for longear sunfish, bluegill, and largemouth bass collected at this station (Table 11) were similar to values found in Carlander (1977). Condition factors suggest adequate food bases for both insectivorous and piscivorous fishes.

This station was assigned a rating of fair (Table 12) based on the index of biotic integrity (Appendix A; Karr *et al*. 1986). Major reasons for this less than excellent rating include low species richness; the absence of cyprinid species; low numbers of darter and intolerant species; the high proportion of tolerant individuals; the low proportion of invertebrate feeders; and low number of individuals in sample.

HWY 84 Station (South Bosque River)

This station boasted the greatest species richness of the study (17; Table 7), including two pollution intolerant species.

The species diversity value was the highest of the study (Table 7), but in the range considered indicative of moderate pollution ($\overline{H}$ of 1 - 3: Wilhm and Dorris 1968). The index of similarity (Table 8) indicated that the fish community from this station was most like that at the C.O. Tolbert Farm Station (North Bosque River) and HWY 185 Station (Middle Bosque River). The index of similarity between this station and the HWY 2416 Station (South Bosque River) was the lowest of the study (Table 8).

Condition factors calculated for gizzard shad, longear sunfish, and largemouth bass collected at this station (Table 11) were similar to values found in Carlander (1969, 1977). Condition factors suggest adequate food bases for all trophic levels.

This station was assigned a rating of good (Table 12) based on the index of biotic integrity (Appendix B; Karr *et al*. 1986). The major reasons this rating was less than excellent were the reduced number of darter species, the high proportion of tolerant individuals, and the low proportion of piscivores.

Conclusion

Physiochemical conditions throughout the Bosque River were adequate to support a variety of aquatic life. Abundant habitat existed in the river for spawning and reproduction to occur. Overall, data indicated the potential for a diverse and healthy fish community. In the upstream areas, however, the biota appeared to be somewhat limited, as evidenced by the lower index of biotic integrity ratings and the slightly lower than optimal species richness. A lack of flow contributed by sources other than treated wastewater may be a problem, as might nutrient loading into the system. The impacts of that loading would be most detrimental during low flow, when stretches of the North Bosque are effluent dominated. Other factors not addressed by this survey could also explain trends in the fish community. Potential for recovery is good, given the occurrence of pools and the proximity of Lake Waco. Those areas undoubtedly serve as refugia during low flow periods and as subsequent sources for recruitment.

The Bosque River does have some importance as a recreational fishery. Simmons (1986) wrote that fishing in the river can be excellent, although often restricted to deeper holes. In addition, he added that good runs of white bass occur in the North Bosque River above Lake Waco.

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APPENDIX A. Trophic feeding group and tolerance classifications for fishes collected from the Bosque River. Linam and Kleinsasser (TPWD).

Species	Common Name	Trophic Group*	Tolerance**
Dorosoma cepedianum	Gizzard shad	O	
Dorosoma petenense	Threadfin shad	O	
Notropis emiliae	Pugnose minnow	IF	
Notropis lutrensis	Red shiner	IF	T
Notropis venustus	Blacktail shiner	IF	
Notropis volucellus	Mimic shiner	IF	I
Pimephales vigilax	Bullhead minnow	O	
Campostoma anomalum	Common stoneroller	H	
Moxostoma congestum	Gray redhorse	IF	
Ictalurus natalis	Yellow bullhead	O	
Ictalurus punctatus	Channel catfish	O	
Fundulus notatus	Blackstripe topminnow	IF	
Gambusia affinis	Mosquitofish	IF	T
Menidia beryllina	Inland silverside	IF	
Micropterus punctulatus	Spotted bass	P	
Micropterus salmoides	Largemouth bass	P	
Lepomis cyanellus	Green sunfish	P	T
Lepomis gulosus	Warmouth	P	T
Lepomis humilis	Orangespotted sunfish	IF	
Lepomis macrochirus	Bluegill	IF	
Lepomis marginatus	Dollar sunfish	IF	
Lepomis megalotis	Longear sunfish	IF	I
Lepomis microlophus	Redear sunfish	IF	
Lepomis punctatus	Spotted sunfish	IF	
Pomoxis annularis	White crappie	P	
Percina macrolepida	Bigscale log perch	IF	I
Etheostoma spectabile	Orangethroat darter	IF	

*Trophic Group Designations:
- IF - Invertebrate Feeder
- P - Piscivore
- O - Omnivore
- H - Herbivore

**Tolerance Designations:
- T - Tolerant
- I - Intolerant

APPENDIX B. Total Index of Biotic Integrity (IBI) scores, the designated integrity class, and the attributes of those classes as modified from Karr et al. (1986).

Total IBI score (sum of the 12 metric ratings)	Integrity class	Attributes
58-60	Excellent	Comparable to the best situations without human disturbance; all regional expected species for the habitat and stream size, including the most intolerant forms, are present with a full array of age (size) classes; balanced trophic structure.
48-52	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species are present with less than optimal abundances or size distributions; trophic structure shows some signs of stress.
40-44	Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, highly skewed trophic structure (e.g., increasing frequency of omnivores and green sunfish or other tolerant species); older age classes of top predators may be rare.
28-34	Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
12-22	Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.
	No fish	Repeated sampling finds no fish.

APPENDIX C. Fishes collected by Hubbs and Strawn in their 1953 survey of the Bosque River.

Taxa	Common Name
Notemigonus crysoleucas	Golden shiner
Notropis venustus	Blacktail shiner
Notropis lutrensis	Red shiner
Pimephales vigilax	Bullhead minnow
Pimephales promelas	Fathead minnow
Campostoma anomalum	Common stoneroller
Moxostoma congestum	Gray redhorse
Ictalurus punctatus	Channel catfish
Ictalurus natalis	Yellow bullhead
Pylodictus olivaris	Flathead catfish
Fundulus notatus	Blackstripe topminnow
Gambusia affinis	Mosquito fish
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Lepomis cyanellus	Green sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Percina sciera	Dusky darter
Percina macrolepida	Bigscale logperch
Etheostoma spectabile	Orangethroat darter