MESOHABITAT USE AND COMMUNITY STRUCTURE OF BRAZOS RIVER FISHES IN THE VICINITY OF THE PROPOSED ALLENS CREEK RESERVOIR

Submitted to:
Texas Water Development Board
P.O. Box 13231, Capitol Station
1700 N. Congress Avenue
Austin, Texas 78711-3231

Submitted by:
Frances P. Gelwick
Raymond Y. Li
Department of Wildlife and Fisheries Sciences
210 Nagle Hall
Texas A&M University
College Station, Texas 77843-2258

December 19, 2002

Texas Water Development Board Contract No. 2001-483-376

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This is the report of a study under Texas Water Development Board contract number 2001-483-376. Many people contributed to the effort represented by this report. Fellow Texas A&M University students Christine Burgess, Mike Kjelland, Michael Miller, Virginia Shervette, and Adam Cohen of the Texas Council on Environmental Quality assisted with field collections. Ray Matthews (Texas Water Development Board), Barney Austin (TWDB), Doyle Mosier (TCEQ), Kevin Mayes (Texas Parks and Wildlife Department) and Bill Colbert (Army Corps of Engineers, Dallas-Fort Worth) assisted with the selection of our study reach. Doyle Mosier further provided guidance with mesohabitat delineation. Mark Wentzel (TWDB) calculated target discharge rates. Ray Matthews and Barney Austin also provided guidance for the overall completion of the project. A very special thanks to Jeff Coleman of "Big Nuts Tree Farm" of Houston, Texas for providing and maintaining access to the Brazos River.

1.0 INTRODUCTION

To accommodate projected increases in the demand for water, the Texas Water Development Board (TWDB) adopted the Texas Water Plan in 1997. The Texas Water Plan identifies Allens Creek as a potential reservoir site to supply water for the growing populations of Fort Bend and Brazoria counties and central Texas. Water from the lower Brazos River will be diverted to the proposed 142,982 acre-feet reservoir. This project was designed to provide information concerning Brazos River fish communities. To assist in modeling reduced instream flows 15th, 30th, and 50th percentile discharges of the summer and winter seasons were targeted for fish collections. Previous studies documenting fishes occurring near our study reach can be found in Linam et al. (1994) and Winemiller et al. (2000). Studies reporting fish communities of tidal portions and upper reaches of the Brazos River can be found in Johnson (1977), Wilde and Ostrand (1999), Winemiller and Gelwick (1999), and Ostrand and Wilde (2002). McEachran and Fechhelm (1998) lists documented species occurrences in the Brazos River watershed.

This report provides information on habitat characteristics and fish assemblages across 15th, 30th, and 50th percentile discharges in summer and winter. The objectives of this project were to: (1) delineate and photodocument riffle, run, and pool mesohabitats within our study reach; (2) characterize and quantify the fishes occurring in identified mesohabitats; (3) determine indicator species of mesohabitats based on fish distributions; and (4) calculate an Index of Biotic Integrity for the reach.

2.0 STUDY AREA

2.1 Allens Creek

Allens Creek is a third-order intermittent tributary of the lower Brazos River in southern Austin County, Texas. From its headwaters in Sealy, Allens Creek flows south-southeast and enters the Brazos River 10 km downstream. Year round water flow to the lower portions of Allens Creek is maintained by effluent discharge from the City of Wallis wastewater treatment facility. The proposed reservoir site is located immediately upstream of the FM 1458 road crossing, approximately 900 m above the Allens Creek confluence with the Brazos River.

2.2 Brazos River

The headwaters of the Brazos River originate in New Mexico. The river meander eastward across Texas then southeast into the Gulf of Mexico. Several flood control dams and water supply reservoirs are located along the upper reaches of the watershed partially regulating the natural discharge regime. Situated between Austin and Fort Bend counties (29º40'N and 96º01'W) our study reach is located in the Western Gulf Coastal Plain physiographic region and drains approximately 72,000 km^2. Characteristic of its sinuous pattern (Sinuosity Index of 2.16), lateral point bars and deep-water pools dominate the shoreline of our study reach. Rangeland and crop production dominates the land use of the lower Brazos River watershed. A gallery forest dominated by black willow (*Salix nigra*), sugarberry (*Celtis laevigata*), elm (*Ulmus sp.*)

and pecan (*Carya sp.*) extends along both banks for most of the reach. The study area is described in further detail by McKone et al. 1996.

3.0 MATERIALS AND METHODS

3.1 Study Reach Delineation

On June 26, 2001 a 10 km study reach was identified during a site visit by representatives from the Texas Water Development Board, Texas Parks and Wildlife, Texas Commission of Environmental Quality (formerly Texas Natural Resources Conservation Commission), U.S. Army Corps of Engineers-Dallas/Fort Worth District, and Texas A&M University. The study reach was selected as representative habitats in the lower Brazos River downstream of the proposed Allens Creek reservoir. During baseflow conditions on July 11, 2001, representatives from Texas A&M University and the Texas Commission of Environmental Quality identified sampling sites based on the presence of riffle, run and pool mesohabitats. These mesohabitat-sites were characterized by current velocity, water depth, planform river morphology and the dominant particle size of substrate.

3.2 Sampling Schedule

Six collections were completed over a range of river discharges. Collections targeted the 15^{th}, 30^{th}, and 50^{th} percentile discharge of the summer (April through October) and winter (November through March) seasons from September 2001 through August 2002. Target discharges were calculated by the Texas Water Development Board from 60 years of record compiled through the USGS Brazos River at the Richmond, Texas gaging station (#08114000). Sampling dates and actual discharges during collections are reported in Table 1.

Table 1. Dates and daily discharge of collection periods calculated from USGS Brazos River at Richmond, Texas gaging station (#08114000).

Season	Collection Dates	Target Discharge (cfs)	Actual Discharge (avg.)
Summer 50th	20 – 23 Sept 2001	2,630	4,043
Summer 30th	27 – 30 Aug 2002	1,410	1,477
Summer 15th	13 – 16 May 2002	924	886
Winter 50th	29 Mar – 01 Apr 2002	3,460	4,185
Winter 30th	02 – 05 Feb 2002	1,710	2,623
Winter 15th	08 – 11 Mar 2002	1,000	2,228

3.3 Fish Collections

Seines and gillnets were the primary effective methods used to capture fishes. Nearshore shallow-water areas of each mesohabitat-site were sampled with a 5 x 1.25 x 1.25 m bag seine of 5 mm bar mesh. Midpoint along each mesohabitat, seines were hauled along at least three contiguous 15 m longitudinal transects until no additional species were captured in two consecutive hauls. The total number of seine hauls was recorded to standardize abundance per m^2. Experimental monofilament gillnets measuring 38.1 m long by 1.8 m deep and consisting of five equal sized panels (2.5, 3.8, 5.1, 6.3 and 7.6 cm mesh) were used to collect fishes in deep-water habitats. Three to five gillnets were set overnight for a total of 9-15 sets per collection period. Gillnets were set with one end anchored into a riverbank or large woody debris and set at a 45º or 315º angle with the shoreline. Backwaters support the vast proportion of fishes in large rivers (Stalnaker et al. 1989), so gillnets were typically set to target backwater areas within mesohabitat-sites. Gillnet captures were standardized as abundance per m^2 of net.

Deep-water areas, large aggregations of woody debris, and mesohabitat-sites dominated by large woody debris were sampled with a boat-mounted electrofisher. We used a Coffelt model VVP-2C electrofisher powered by a 5000 watt Honda generator mounted onto a 4.3-m aluminum jon boat powered by a 15-horsepower Mercury outboard. Fishes were captured only in areas of large aggregations of woody debris and mesohabitat-sites dominated by large woody debris during the winter 30th and summer 15th percentile discharge collections. Due to technical difficulties with electrofishing equipment, samples were not collected in the woody debris field near the downstream end of our study reach (mesohabitat-site H) during the winter 30th percentile collections. Electrofishing catch was standardized as abundance per m^2 sampled.

Three baited funnel-type minnow traps of 7.62 mm mesh and 2.54 cm funnel openings were also used to collect fishes during the winter 50th, 30th, 15th and summer 15th percentile discharge rates. Minnow traps were deployed in large aggregations of woody debris across the study reach and allowed to fish for approximately 72 hours. Additionally, during the summer 15th and 30th percentile discharge collections, two 61 cm diameter hoopnets of 2.54 cm mesh and two 91.44 cm diameter hoopnets of 2.54 cm mesh were set. Hoopnets were baited with a can of catfood, positioned with the openings facing downstream and allowed to fish for 72 hours. Hoopnet and minnow trap captures were standardized as abundance per m^2 sampled by their openings.

Captured individuals that were rare, threatened, or endangered and large common fishes were identified and immediately returned to the river. All other fishes were euthanized in tricane (MS-222), fixed in 10% formalin, and returned to the lab for enumeration. With the exception of bowfin (*Amia calva*) and spotted gar (*Lepidosteus oculatus)*, several individuals of each species captured was catalogued as voucher specimen into the Texas Cooperative Wildlife Collections located on the campus of Texas A&M University.

3.4 Habitat Assessments

Physicochemical parameters were measured immediately following fish collections. Temperature (ºC), conductivity (µS/cm), dissolved oxygen concentration (mg/L) and saturation (%) were measured in the center of each sampling area with a YSI-85 (Yellow Springs Instrument) multimeter. Water depth and velocity were measured at 3 equidistant points along a diagonal bisecting each area seined or electrofished. Single values for water depth and current velocity of gillnet, hoopnet or minnow trap sites were measured in the center of the sampled area. Water depths less than 150 cm were measured using a graduated wading rod. Depths greater than 150 cm were measured using a Speedtech® sonar depth meter. Flow was measured at 0.6 times the water depth using a Marsh-McBirney Flowmate 2000 electromagnetic flow meter. At large woody debris habitats, flows were measured several feet upstream of the structure. Areas sampled were photodocumented during the winter 30th or summer 30th percentile discharge collections.

3.5 Index of Biotic Integrity (IBI)

The Index of Biotic Integrity (IBI) assesses attributes of the fish assemblage to determine water quality and condition of aquatic ecosystems (Karr 1981). We calculated an IBI for our study reach using metrics developed by Winemiller and Gelwick (1999) for the Brazos-Navasota River watershed (Tables 2-5). Since reference data for large, undisturbed rivers in Texas were unavailable (Bayer et al. 1992), we compared our IBI scores to scores calculated for sites sampled in autumn along the mainstem of the lower Brazos River by Winemiller and Gelwick (1999). We calculated four scores of our study reach: (1) seine captures during autumn collections; (2) captures in all gears during autumn collections; (3) seine captures across the six rates of discharge; and (4) captures in all gears across the six rates of discharge.

Table 2. Outline of the IBI metrics and scoring criteria as adapted for the Brazos River in central Texas (from Winemiller and Gelwick 1999).

	Scoring Criteria				
	10	7	5	2	0
Species Richness and Composition Metrics:					
# native species	21+	16-20	10-15	5-9	0-4
# darter species	4+	3	2	1	0
# sunfish species	4+	3	2	1	0
# sucker species	1+	-	-	-	0
# intolerant species	8+	6-7	3-5	1-2	0
% tolerant species	0-49	50-79	80-89	90-94	95-100
% mosquitofish	0-1	2-9	10-19	20-29	30-100
Trophic Function Metrics:					
% omnivores	0-75	76-79	80-89	90-94	95-100
% invertivores	25-100	20-24	11-19	6-10	0-5
% carnivores	7-100	4-6	2-3	0.1-1	0

Table 3. Assignment of fish species for the species richness and composition metrics of the IBI (adopted from Winemiller and Gelwick 1999).

Non-native species	*Cyprinus carpio*
Darters	*Etheostoma gracile, Noturus gyrinus*
Suckers	*Carpoides carpio, Ictiobus bubalus*
Sunfish	*Lepomis cynaellus, L. gulosus, L. humilis, L. macrochirus, L. marginatus, L. megalotis, L. microlophus, L. punctatus, Pomoxis annularis*
Intolerant species	*Cyprinus carpio, Etheostoma gracile, Labidesthes sicculus, Lepomis megalotis, Lythrurus fumeus, Menidia beryllina, Notropis buchanani, Notropis shumardi, Noturus gyrinus, Opsopeoedus emiliae*
Tolerant species	*Amia calva, Aplodinotus grunniens, Cyprinella lutrensis, Carpoides carpio, Dorosoma petenense, Gambusia affinis, Ictalurus punctatus, Lepisosteus oculatus, L. osseus, Lepomis cyanellus, L. gulosus, L. macrochirus, Pimephales vigilax*

Table 4. Assignment of fish species from trophic structure metrics of IBI (adopted from Winemiller and Gelwick 1999).

Omnivores	*Carpoides carpio, Cyprinus carpio, Cyprinella lutrensis, Dorosoma cepedianum, Mugil cephalus, Pimephales vigilax*
Invertivores	*Aphredodreus sayanus, Aplodinotus grunniens, Cyprinella venusta, Dorosoma petenense, Etheostoma gracile, Ictiobus bubalus, Macrhybopsis aestivalis, M. storeriana, Fundulus notatus, Gambusia affinis, Ictiobus bubalus, Labidesthes sicculus, Lepomis cyanellus, L. humilis, L. macrochirus, L. marginatus, L. megalotis, L. microlophus, L. punctatus, Lythrurus fumeus, Menidia beryllina, Notropis buchanani, N. oxyrhynchus, N. shumardi, Noturus gyrinus, Opsopeoedus emiliae*
Top carnivores	*Amia calva, Ictalurus furcatus, Ictalurus punctatus, Lepisosteus osseus, L. oculatus, Lepomis gulosus, Micropterus puntulatus, Micropterus salmoides, Pomoxis annularis, Pyliodictus olivaris*

Table 5. Interpretation of IBI scores (from Winemiller and Gelwick 1999).

IBI Score	Assessment	Fish Community and Stream Attributes
65-100	Excellent	Comparable to the best situations with minimal human disturbance; most of the regionally expected species for habitat and stream size, including the most intolerant forms, are present with a balanced trophic structure.
50-64	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species, especially top carnivores, are present with less than optimal abundances; trophic structure may show signs of imbalance.
30-49	Fair	Signs of additional deterioration include decreased species richness, loss of intolerant forms, increased abundance of tolerant species, and/or highly skewed trophic structure (e.g., greater frequency of omnivores and lower frequency of invertebrate feeders and carnivores.
20-29	Poor	Relatively few species; dominated by omnivores, tolerant forms, and habitat generalists; few or no top carnivores.
0-19	Very Poor	Very few species present, mostly exotics or tolerant forms; few large or old fish; diseased fish may be common.

3.6 Indicator Species Analysis

We performed an indicator species analysis (Dufrêne and Legendre 1997) based on percent abundances in collections and percent occurrence among collections to test the probability that species were indicators of pool, run, riffle, and tributary confluence mesohabitats. We calculated species abundance per m^2 sampled in each mesohabitat-type for each of our six collection periods. Two separate analyses were performed with PC-ORD (McCune and Mefford 1997): (1) using only those species exceeding 1% of total collections; and (2) including all species regardless of abundance.

4.0 RESULTS AND CONCLUSIONS

4.1 Mesohabitat-Site Delineation

Eleven sites were identified based upon mesohabitat delineations. Five runs, 4 pools, 1 riffle and a tributary confluence were each designated by a unique mesohabitat-site code (Figure 1). The presence of pool, run, or riffle mesohabitats did not vary across our six collection discharges (886-4185 cfs). However, slight reductions in mesohabitat volume (water surface area and depth) were observed with decreasing discharge. The lower reaches of Allens Creek was hydrologically connected to waters of the Brazos River during collections at all targeted discharges. However, during our summer 15th percentile collections, fish movement between the Brazos River and Allens Creek was likely impeded by the combined effects of a low river stage and high sediment aggradation which acted as a low-water dam across the mouth of Allens Creek. Additionally, the large woody debris aggregation at the FM 1093 bridge crossing was elevated above the water on a sediment bar and did not provide woody habitat for fish during the summer 15th percentile discharge.

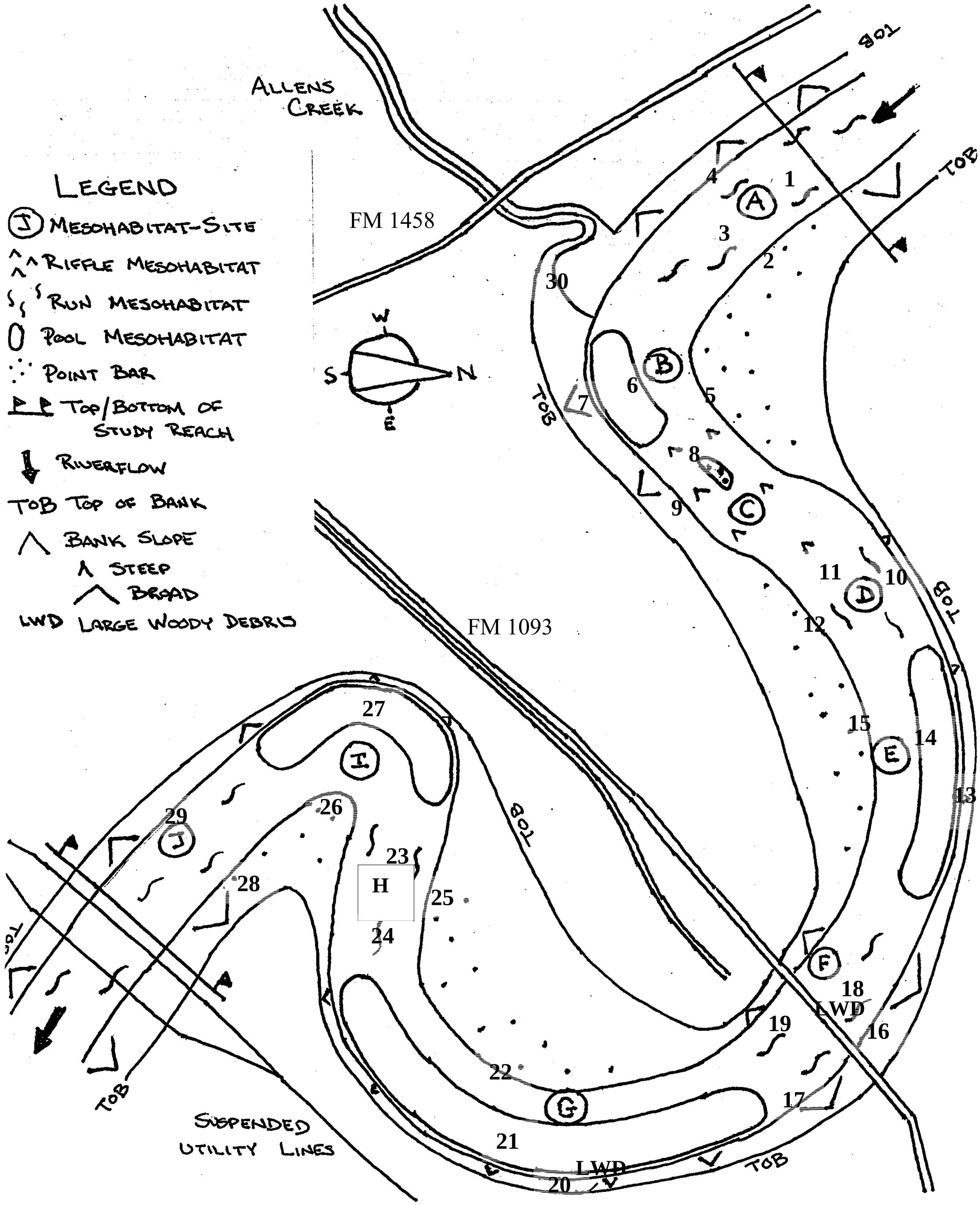

Figure 1. Sketch map of Brazos River study reach with mesohabitat-sites indicated by a letter code and sampling locations by a numeric code.

4.2 Physicochemical Parameters

Mean daily discharge ranged from 1,792 to 17,300 cfs (from 82 years of record), compared to a range of 886 to 4,185 cfs during our collection periods (Figure 2). Averaged across all sites, water temperature ranged from 13.8 to 31.4°C, conductivity ranged 467.5 to 1059.0 µS/cm, dissolved oxygen concentration from 6.72 to 13.67 and saturation from 76.2 to 117.5% for each collection period (Table 6).

Water depths and current velocities of each sampling location are reported for each collection period in Tables 7 and 8. Mean depth and current velocity measurements of mesohabitat within each collection period are reported in Table 9. Because gillnets were generally deployed in deep backwaters and not areas representative of their respective mesohabitat-site, we did not include gillnet depths and velocities in our overall calculations of the mean. Mean current velocities were related to mesohabitat types. Pool mesohabitat-sites were generally characterized by minimal velocities (mean 14.2; range 7.7 to 20.7 cm/s). Runs were characterized by moderate velocities (21.3; 15.4 to 27.9 cm/s) and riffles by the highest velocities (34.1; 20.0 to 66.0 cm/s). Velocities of the Allens Creek confluence site were negligible due to a backwater effect by riverflow of the Brazos River. Mean water depths of areas seined were 38.6, 50.6, 50.8, and 38.6 cm in pool, run, riffle and tributary confluence mesohabitats, respectively.

4.3 Fish Species and Mesohabitat Use

A total of 44,122 individuals representing 43 species from 14 families were collected across our 6 collection periods (Table 10). Red shiners (*Cyprinella lutrensis*) and bullhead minnows (*Pimephales vigilax*) accounted for 67.4% and 16.9% of our collections, respectively. Other common species (abundances exceeding 1% of overall collections) were ghost shiner (*Notropis buchanani*), silverband shiner (*N. shumardi*), striped mullet (*Mugil cephalus*), and mosquitofish (G*ambusia affinis*). Three individuals of sharpnose shiner (*Notropis oxyrhynchus*) were collected in the confluence of Allens Creek (mesohabitat-site AC) during our summer 50th percentile discharge collections. The sharpnose shiner was recently proposed as a candidate species for federal listing by the U.S. Fish and Wildlife Service (2002). Bubble graphs of fish species collections per sampled location for each of the targeted discharge rates are provided in Figures 3-8. Species and sampling location codes used in the bubble graphs are listed in Table 11. Photos of representative habitats sampled are provided in Figures 9-40. All photos are looking upriver. A list of species documented to occur in the Brazos River near our study reach is provided in Table 12 (Linam et. al 1994, Winemiller et. al. 2000).

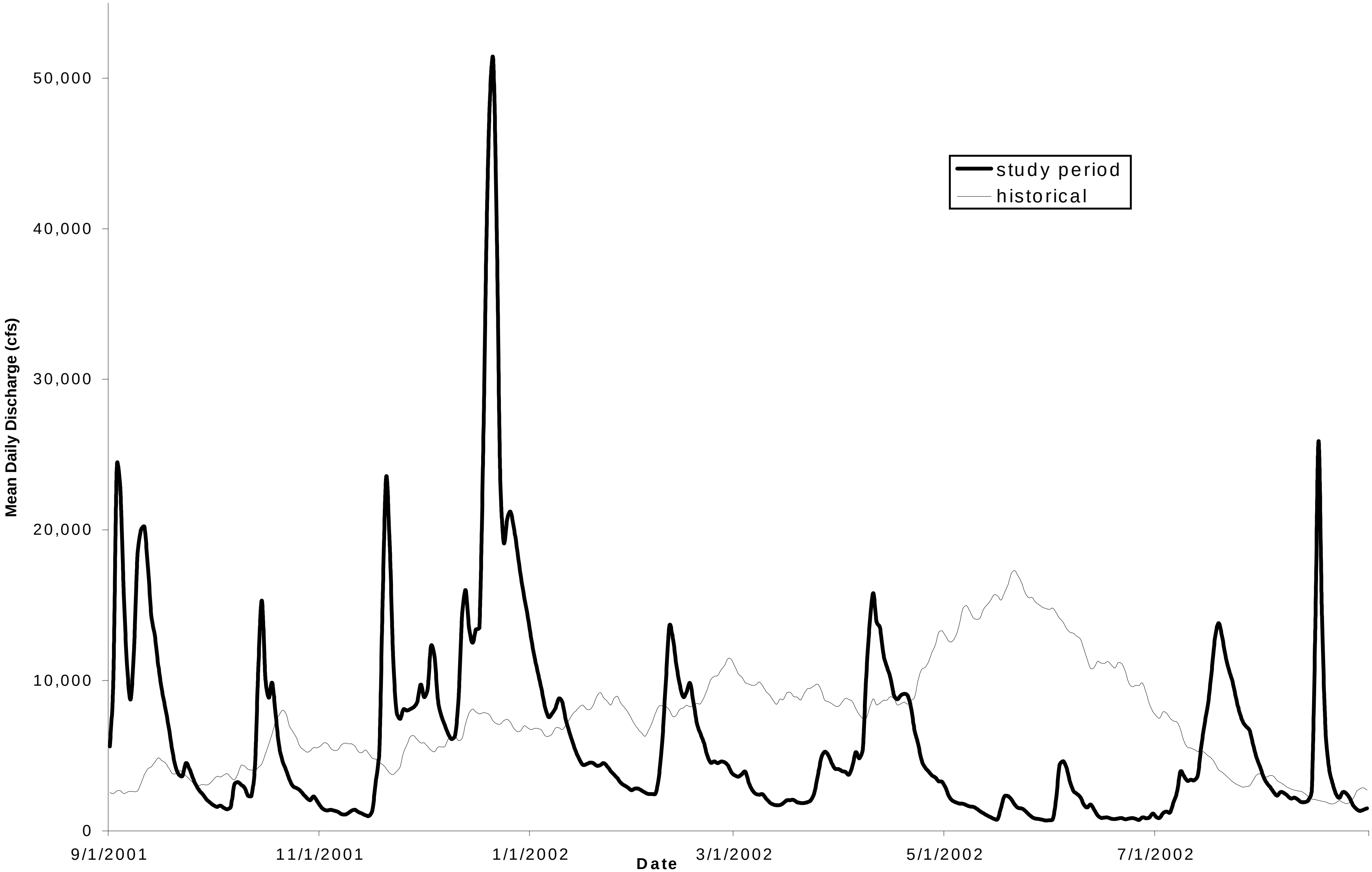

Figure 2. Historical (based on 82 years of record) and mean daily discharge recorded during the study period (September 01, 2001 – August 31, 2002) at the USGS Brazos River at Richmond, Texas gage (station #08114000).

Table 6. Physicochemical parameters for each collection period (reported as the mean of all sampling locations).

Season	Sampling Dates	Mean Daily Discharge (cfs)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen	
					Concentration (mg/L)	Saturation (%)
Summer 50th	September 20-23, 2001	4043	28.9	492.2	8.79	76.2
Summer 30th	August 27-30, 2002	1477	31.4	1059.0	6.72	91.6
Summer 15th	May 13-16, 2002	886	26.2	856.3	8.20	107.7
Winter 50th	March 29-April 1, 2002	4185	20.9	467.5	8.18	91.8
Winter 30th	February 2-5, 2002	2533	13.8	589.4	13.67	110.2
Winter 15th	March 8-11, 2002	2228	17.5	569.4	11.23	117.5

Table 7. Depth and current velocities of sampling locations during summer collection periods. Habitat codes correspond with bubble graph and are described in Table 11.

Habitat-Code	50th Percentile		30th Percentile		15th Percentile	
	Depth (cm)	Velocity (cm/s)	Depth (cm)	Velocity (cm/s)	Depth (cm)	Velocity (cm/s)
1	165.4	19.5				
2	53.7	45.3	51.3	29.3	40.7	23.3
3						
4	280.0	4.0	200.0	55.0	93.0	21.0
5	67.7	9.0	73.7	17.3	77.0	16.3
6	230.0	30	120.0	49.0	98.0	37.0
7	161.3	26.3	250.0	10.0		
8	33.3	31.7	93.0	66.0	39.0	23.7
9					25.3	0.0
10			150.0	45.0		
11						
12	17.7	7.7	40.3	33.7	15.7	19.3
13			335.0	9.0		
14			120.0	52.8	101.0	47.0
15	15.0	-0.3	91.2	16.5	22.0	15.7
16	88.3	-0.7	62.3	3.0	38.7	1.0
17	400.0	-34.0	78.3	14.0	84.3	13.7
18	190.0	8.0				
19			221.5	0.0	128.2	2.1
20 (LWD)	156	62.0	230.0	0.0	208.4	-1.5
20			210.0	45.0	130.0	71.0
21					123.0	33.0
22	44.2	12.7	23.3	13.3	34.0	12.3
23					123.7	46.3
24			140.0	89.0	125.0	58.0
25	71.7	29.7	18.0	22.7	34.7	16.7
26	33.7	16.3	48.0	20.0	48.7	14.7
27	270.0	-6.0	441.0	-5.5	160.0	-4.0
28	310.0	30.0	116.9	25.5	56.2	10.9
29	38.0	25.7	65.7	-5.0	53.7	-1.7
30	64.7	19.1	105.2	13.1	40	8.0

Table 8. Depth and current velocities of sampling locations during winter collection periods. Habitat codes correspond with bubble graph and are described in Table 11.

Habitat-Site	50th Percentile Depth (cm)	50th Percentile Velocity (cm/s)	30th Percentile Depth (cm)	30th Percentile Velocity (cm/s)	15th Percentile Depth (cm)	15th Percentile Velocity (cm/s)
1			153.2	39.0		
2	45.7	22.3	43.7	23.7	35.7	20.3
3			216.7	52.3		
4					230.7	31.0
5	44.7	10.7	40.3	8.0	27.3	7.7
6	190.0	49.0	210.0	27.0	131.0	60.0
7	35.0	21.0	185.3	30.0	145.0	-17.0
8	64.0	35.0	36.3	28.3	39.3	20.0
9			22.7	31.7	32.3	30.7
10			142.7	40.3		
11			150.0	35.0		
12	15.0	15.7	53.3	43.7	28.3	22.0
13	202.0	10.5	146.7	50.7	122.0	22.0
14						
15	31.0	15.0	13.7	2.0	34.0	39.7
16	45.5	21.0	58.2	-0.3	32.2	20.2
17	73.0	8.7	101.0	-1.0	56.7	16.7
18						
19	355.0	-7.0	290.0	-5.5	255.0	-9.5
20 (LWD)	300.0	-2.0	105.0	-1.0	190.0	0.0
20					190.0	0.0
21			122.0	56.0		
22	26.7	14.5	47.5	17.5	26.0	8.7
23						
24	80.0	42.0	121.0	26.0	62.0	33.0
25	186.2	26.5	45.0	22.3	58.0	13.7
26	23.0	16.0	51.3	11.0	39.0	5.7
27	180.0	-4.0	159.0	-1.0	200.0	1.0
28	66.0	16.2	81.7	14.0	113.0	26.4
29	97.9	23.5	74.5	0.0	54.4	-3.0
30	106.0	8.9	39.2	14.7	70.4	1.9

Table 9. Mean water depth and current velocity measurements of mesohabitats during collections. (Note: because gillnets targeted backwaters and not areas representative of mesohbabitats, depth and velocity measurements of gillnetted areas were not included in these calculations.)

Season	Water Depth (cm)				Current Velocity (cm/s)			
	Pool	Run	Riffle	Tributary Confluence	Pool	Run	Riffle	Tributary Confluence
Summer 50th	42.5	45.9	33.3	64.2	16.7	27.9	31.7	14.8
Summer 30th	44.3	53.9	93.0	105.2	20.7	23.7	66.0	13.2
Summer 15th	45.4	44.7	39.0	40.0	14.8	18.5	23.7	4.0
Winter 50th	30.4	63.9	64.0	106.0	14.1	19.2	35.0	7.5
Winter 30th	38.7	49.1	36.3	64.2	7.7	23.2	28.3	14.7
Winter 15th	30.2	45.9	39.3	70.4	11.0	15.4	20.0	1.9

Table 10. Total species abundance across collection periods.

Species	Summer 15th	Summer 30th	Summer 50th	Winter 15th	Winter 30th	Winter 50th	Total
Amiidae							
Amia calva (bowfin)	0	0	0	1	0	0	1
Aphredoderidae							
Aphredodreus sayanus (pirate perch)	0	0	1	0	0	0	1
Atherinidae							
Labidesthes sicculus (brook silverside)	0	0	4	0	0	0	4
Menidia beryllina (inland silverside)	6	3	22	1	0	1	33
Catostomidae							
Carpoides carpio (river carpsucker)	8	6	16	5	3	2	40
Ictiobus bubalus (smallmouth buffalo)	3	6	0	3	3	1	16
Centrarchidae							
Lepomis cyanellus (green sunfish)	1	0	0	7	5	0	13
Lepomis gulosus (warmouth)	0	0	1	0	2	0	3
Lepomis humilis (orangespotted sunfish)	0	5	4	2	2	0	13
Lepomis macrochirus (bluegill sunfish)	2	2	2	6	1	1	14
Lepomis megalotis (longear sunfish)	2	2	3	1	11	3	22
Lepomis microlophus (redear sunfish)	0	4	4	0	0	0	8
Lepomis punctatus (spotted sunfish)	0	0	0	0	2	0	2
Lepomis hybrid (hybrid sunfish)	0	0	0	1	1	0	2
Lepomis sp. (juvenile sunfish)	0	3	11	0	0	1	15
Micropterus punctulatus (spotted bass)	1	0	0	0	0	2	3
Micropterus salmoides (largemouth bass)	0	1	0	0	0	0	1
Pomoxis annularis (white crappies)	0	1	4	0	0	0	5
Clupeidae							
Alosa crysochloris (skipjack herring)	0	3	0	0	0	0	3
Dorosoma cepedianum (gizzard shad)	2	2	41	7	10	12	74
Dorosoma petenense (threadfin shad)	2	70	60	3	10	3	148

Table 10. Species abundance across collection periods (continued).

Cyprinidae							
Cyprinella lutrensis (red shiner)	5006	1611	2558	9664	4712	6172	29723
Cyprinella venusta (blacktail shiner)	2	2	0	1	0	1	6
Cyprinus carpio (common carp)	0	1	0	0	0	0	1
Lythrurus fumeus (ribbon shiner)	0	0	2	0	1	0	3
Macrhybopsis aestivalis (speckled chub)	0	10	52	11	27	45	145
Machrybopsis storeriana (silver chub)	2	1	39	0	3	0	45
Notropis buchanani (ghost shiner)	62	0	75	316	64	446	963
Notropis oxyrhynchus (sharpnose shiner)	0	0	3	0	0	0	3
Notropis shumardi (silverband shiner)	134	11	311	659	83	934	2132
Opsopoeodus emiliae (pugnose minnow)	1	0	1	0	0	0	2
Pimephales vigilax (bullhead minnow)	156	266	867	1660	1039	3448	7436
Fundulidae							
Fundulus notatus (blackstripe topminnow)	1	0	0	1	0	0	2
Ictaluridae							
Ictalurus furcatus (blue catfish)	3	6	8	4	6	1	28
Ictalurus punctatus (channel catfish)	7	2	17	4	20	12	62
Noturus gyrinus (tadpole madtom)	0	0	0	0	1	1	2
Pylodictis olivaris (flathead catfish)	3	1	2	0	7	1	14
Lepisosteidae							
Lepidosteus oculatus (spotted gar)	4	8	3	11	4	29	59
Lepidosteus osseus (longnose gar)	111	9	4	34	8	42	208
Mugilidae							
Mugil cephalus (striped mullet)	15	0	0	2	25	1079	1121
Percidae							
Etheostoma gracile (slough darter)	0	0	0	1	0	0	1
Poeciliidae							
Gambusia affinis (mosquitofish)	833	181	465	41	147	74	1741
Sciaenidae							
Aplodinotus grunniens (freshwater drum)	2	2	0	0	0	1	5
Totals	6369	2219	4580	12445	6197	12312	44122

Table 11. Species and sampling location codes reported in bubble graphs.

Code	Species	Habitat
1	*Amia calva* (bowfin)	A – run; all
2	*Aphredodreus sayanus* (pirate perch)	A – run; left margin
3	*Labidesthes sicculus* (brook silverside)	A – run; mid channel
4	*Menidia beryllina* (inland silverside)	A – run; right margin
5	*Carpoides carpio* (river carpsucker)	B – pool; left margin
6	*Ictiobus bubalus* (smallmouth buffalo)	B – pool; mid channel
7	*Lepomis cyanellus* (green sunfish)	B – pool; right margin
8	*Lepomis gulosus* (warmouth)	C – riffle; mid channel
9	*Lepomis humilis* (orangespotted sunfish)	C – riffle; right margin
10	*Lepomis macrochirus* (bluegill sunfish)	D – run; left margin
11	*Lepomis megalotis* (longear sunfish)	D – run; mid channel
12	*Lepomis microlophus* (redear sunfish)	D – run; right margin
13	*Lepomis punctatus* (spotted sunfish)	E – pool; left margin
14	*Lepomis* hybrid (hybrid sunfish)	E – pool; mid channel
15	*Lepomis* sp. (juvenile sunfish TL < 20mm)	E – pool; right margin
16	*Micropterus punctulatus* (spotted bass)	F – backwater; left bank
17	*Micropterus salmoides* (largemouth bass)	F – run; left margin
18	*Pomoxis annularis* (white crappie)	F – run; mid channel
19	*Alosa crysochloris* (skipjack herring)	F – run; right margin
20	*Dorosoma cepedianum* (gizzard shad)	G – pool; left margin/LWD
21	*Dorosoma petenense* (threadfin shad)	G – pool; mid channel

Table 11. Species and sampling location codes reported in bubble graphs (continued).

22	*Cyprinella lutrensis* (red shiner)	G – pool; right channel
23	*Cyprinella venusta* (blacktail shiner)	H – LWD field/run; all
24	*Cyprinus carpio* (common carp)	H – LWD field/run; mid channel
25	*Lythrurus fumeus* (ribbon shiner)	H – LWD field/run; right margin
26	*Macrhybopsis aestivalis* (speckled chub)	I – pool; left margin
27	*Machrybopsis storeriana* (silver chub)	I – pool; right margin
28	*Notropis buchanani* (ghost shiner)	J – run; left margin
29	*Notropis oxyrhynchus* (sharpnose shiner)	J – run; right margin
30	*Notropis shumardi* (silverband shiner)	AC – Allens Creek; tributary confluence
31	*Opsopoeodus emiliae* (pugnose minnow)	
32	*Pimephales vigilax* (bullhead minnow)	
33	*Fundulus notatus* (blackstripe topminnow)	
34	*Ictalurus furcatus* (blue catfish)	
35	*Ictalurus punctatus* (channel catfish)	
36	*Noturus gyrinus* (tadpole madtom)	
37	*Pylodictis olivaris* (flathead catfish)	
38	*Lepidosteus oculatus* (spotted gar)	
39	*Lepidosteus osseus* (longnose gar)	
40	*Mugil cephalus* (striped mullet)	
41	*Etheostoma gracile* (slough darter)	
42	*Gambusia affinis* (mosquitofish)	
43	*Aplodinotus grunniens* (freshwater drum)	

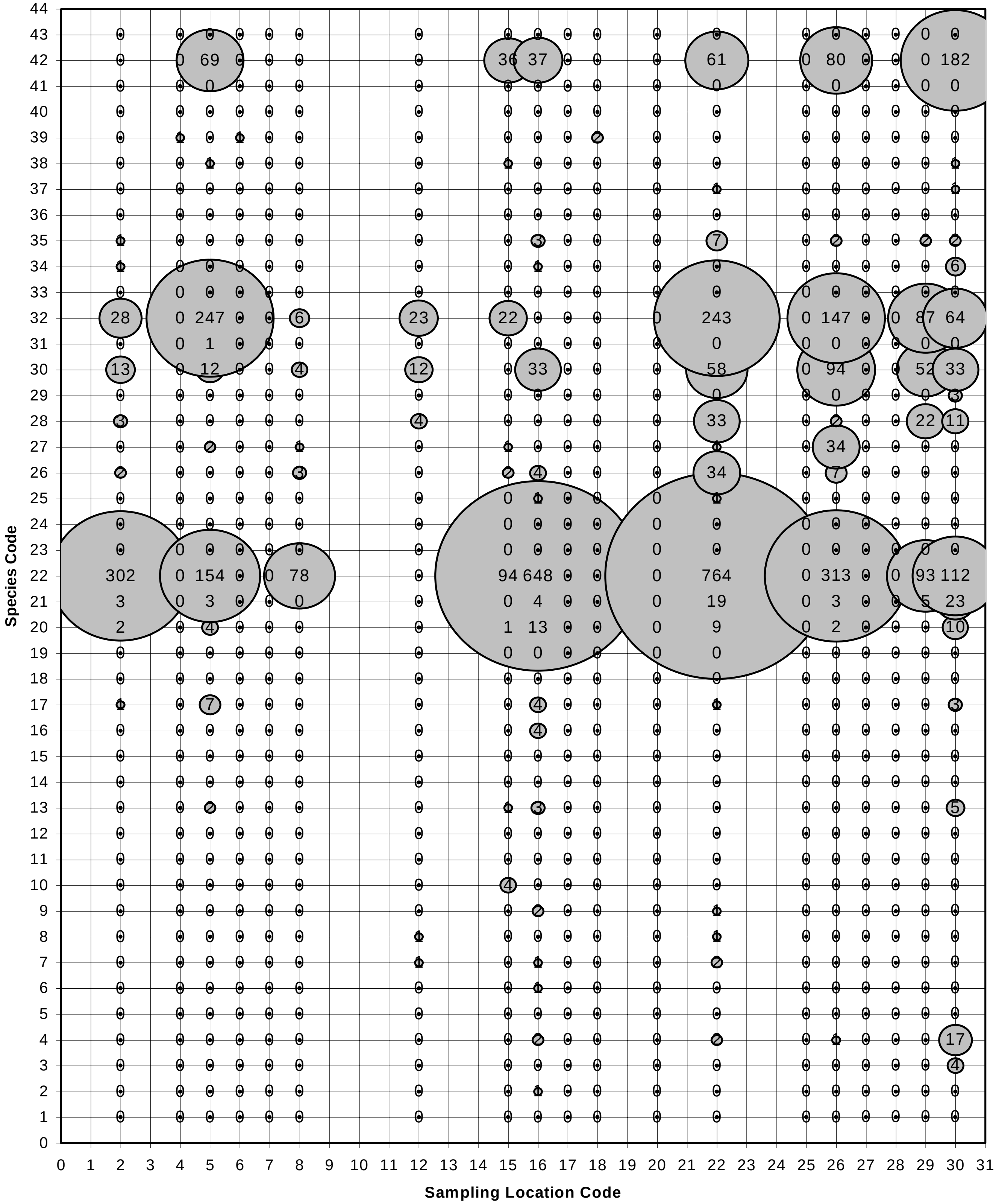

Figure 3. Total number of fishes collected in the Brazos River during summer 50th percentile discharge collections. Number of fishes is indicated at the intersections of species and sampling location codes and also by the relative size of bubbles centered at intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was not sampled. Species and sampling location codes are in Table 9.

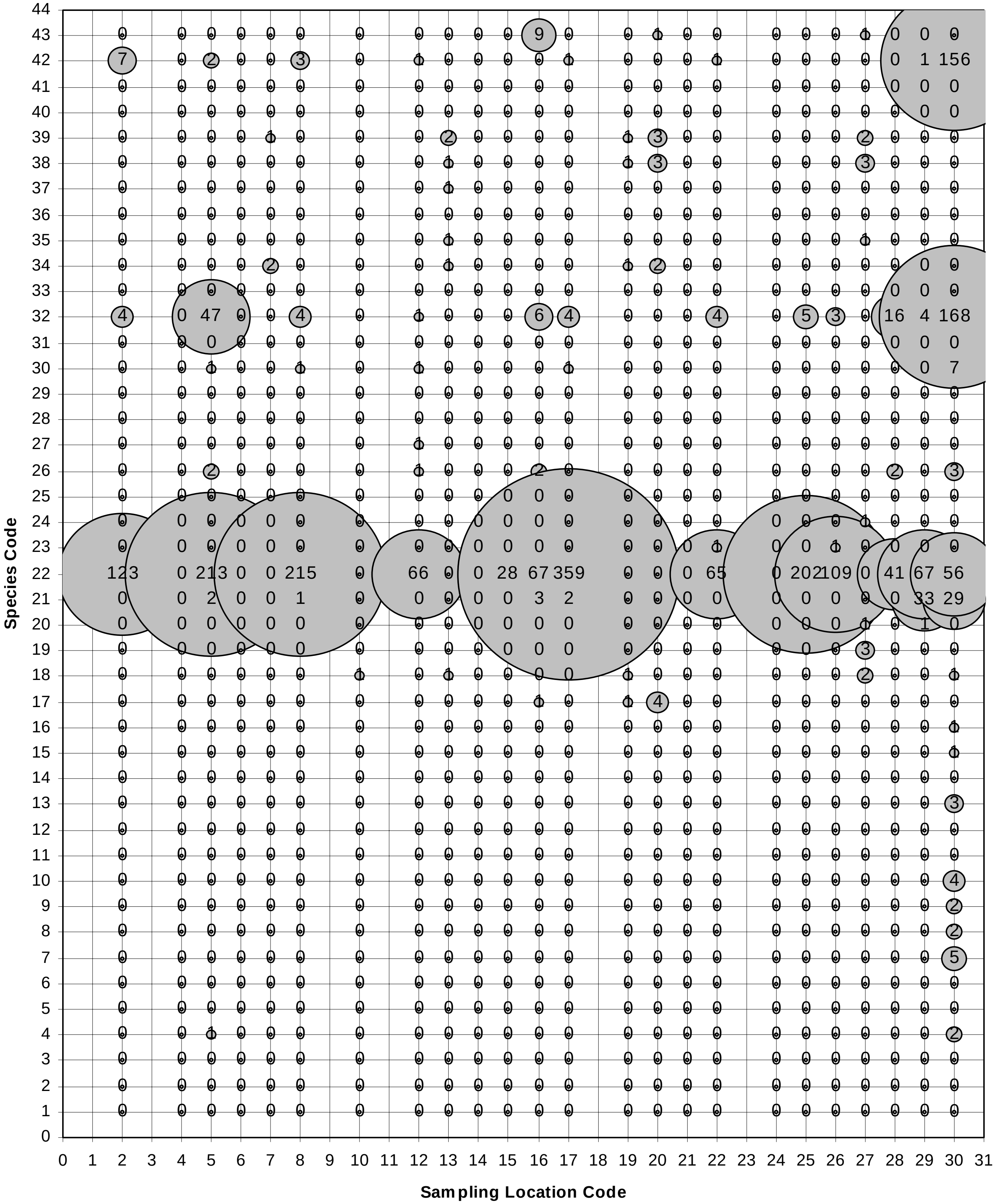

Figure 4. Total number of fishes collected in the Brazos River during summer 30th percentile discharge collections. Number of fishes is indicated at the intersections of species and sampling location codes and also by the relative size of bubbles centered at intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was not sampled. Species and sampling location codes are in Table 9.

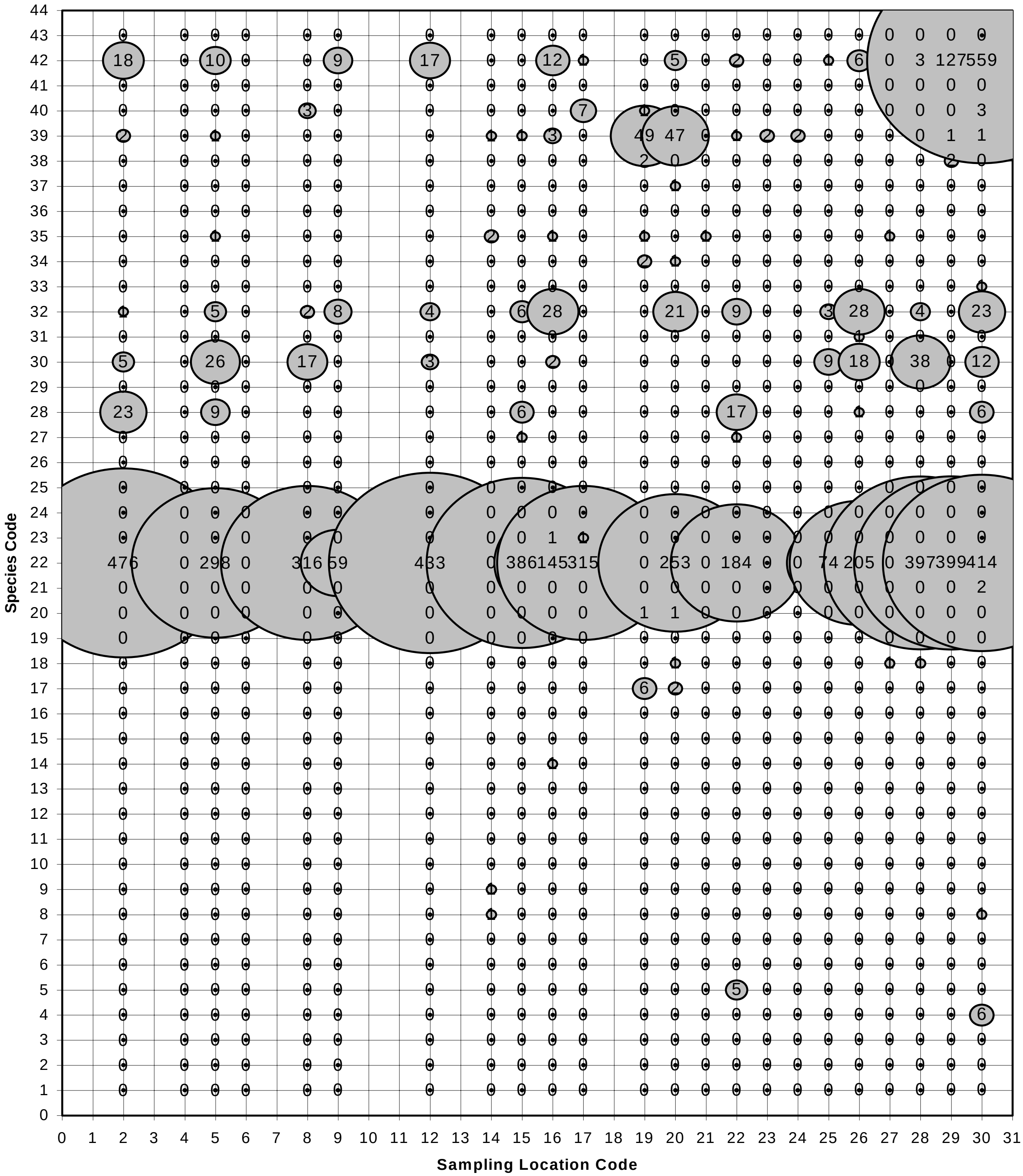

Figure 5. Total number of fishes collected in the Brazos River during summer 15th percentile discharge collections. Number of fishes is indicated at the intersections of species and sampling location codes and also by the relative size of bubbles centered at intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was not sampled. Species and sampling location codes are in Table 9.

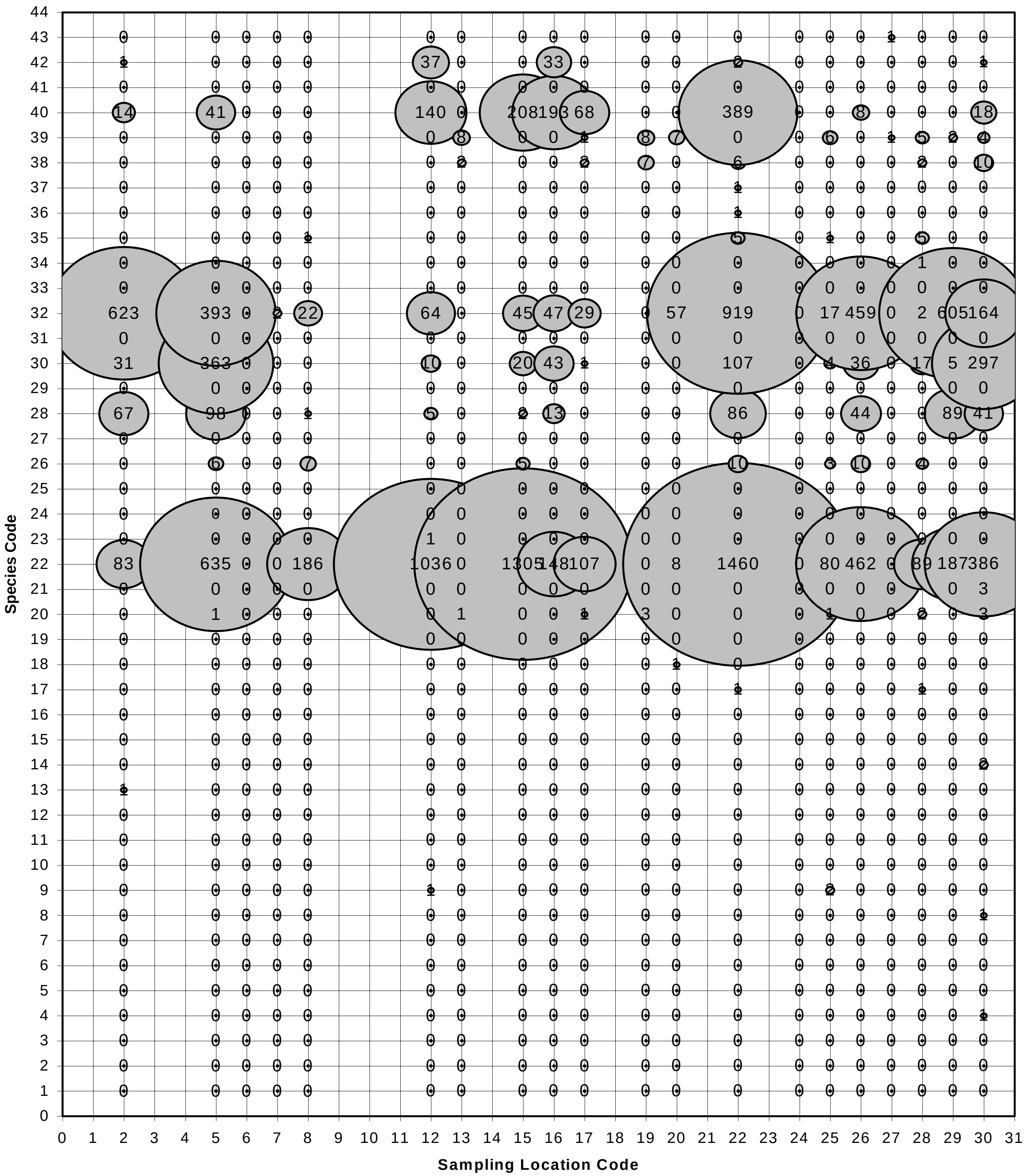

Figure 6. Total number of fishes collected in the Brazos River during winter 50th percentile discharge collections. Number of fishes is indicated at the intersections of species and sampling location codes and also by the relative size of bubbles centered at intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was not sampled. Species and sampling location codes are in Table 9.

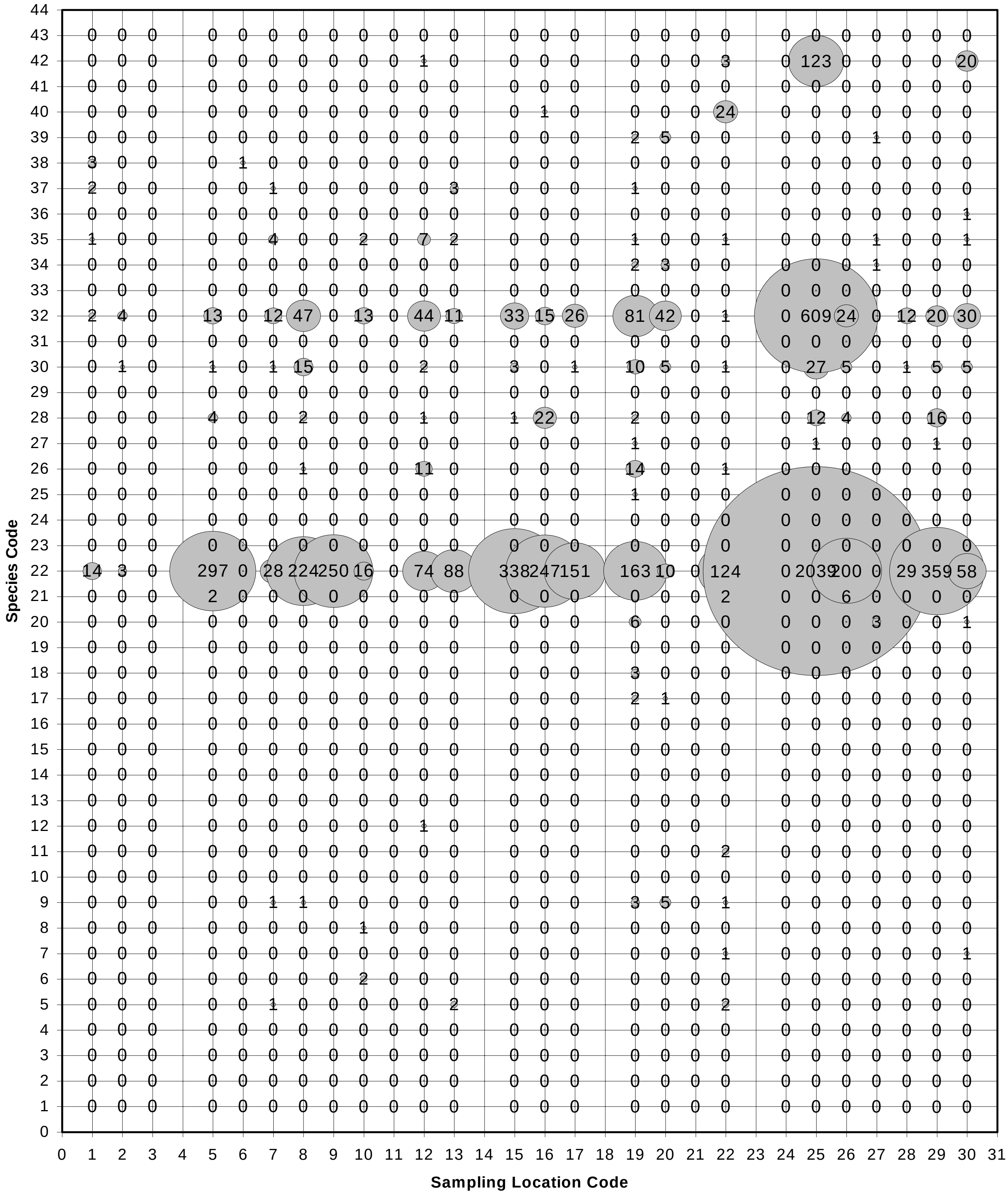

Figure 7. Total number of fishes collected in the Brazos River during winter 30th percentile discharge collections. Number of fishes is indicated at the intersections of species and sampling location codes and also by the relative size of bubbles centered at intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was not sampled. Species and sampling location codes are in Table 9.

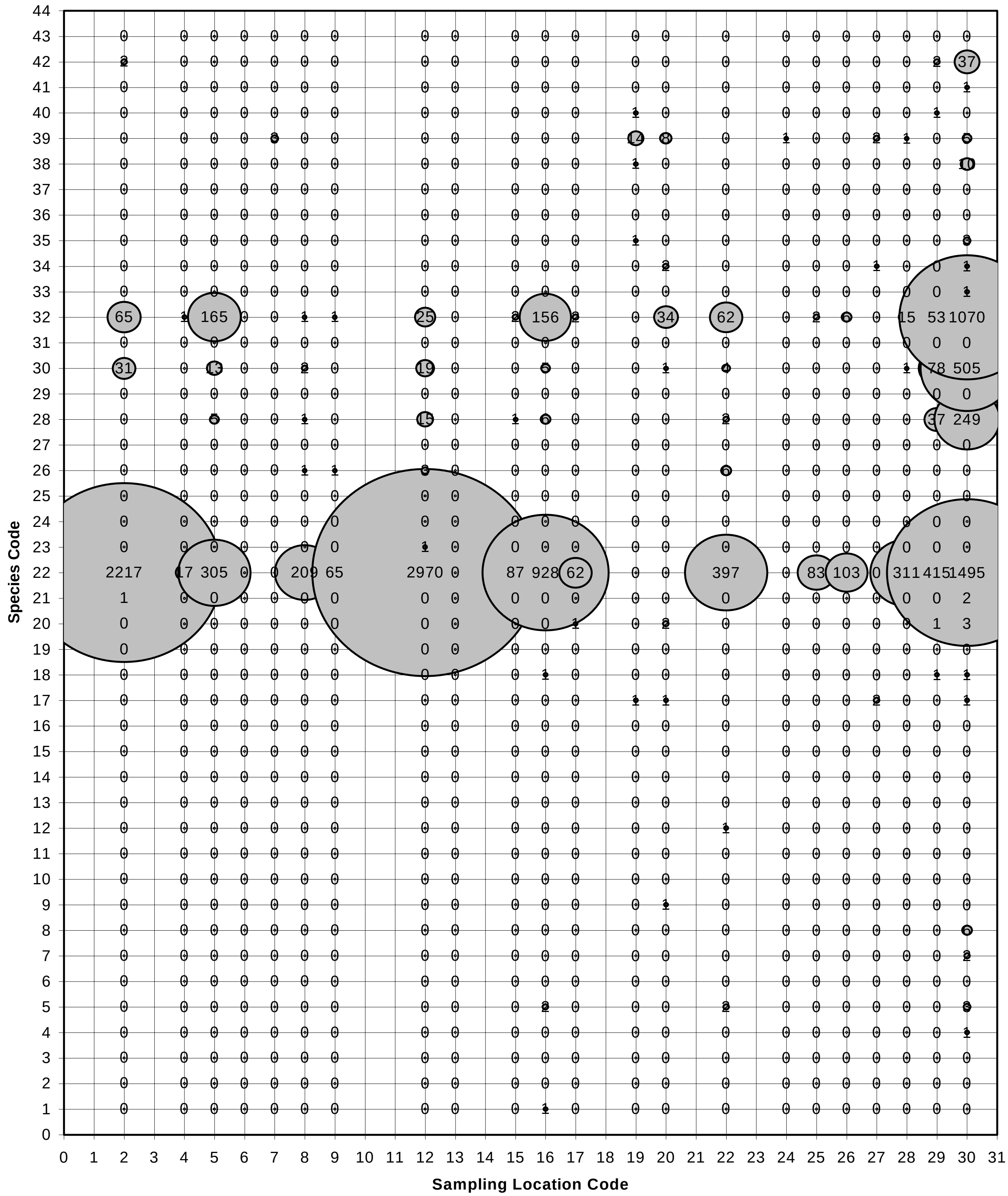

Figure 8. Total number of fishes collected in the Brazos River during winter 15th percentile discharge collections. Number of fishes is indicated at the intersections of species and sampling location codes and also by the relative size of bubbles centered at intersections. Zeros indicate the species was not collected from the habitat. No number at an intersection indicates the habitat was not sampled. Species and sampling location codes are in Table 9.

Figure 9. Mesohabitat A – left margin (sampling location code – 2; all photos looking upriver);
Aug 27-30, 2002; Depth (D) = 51.3cm, Velocity (V) = 29.3cm.

Figure 10. Mesohabitat A – midchannel (code – 1);
Feb 2-5, 2002; D = 216.7cm, V = 52.3cm.


Figure 11. Mesohabitat A – right margin (code – 4);
Aug 27-30, 2002; D = 140cm, V = 30cm.


Figure 12. Mesohabitat B – left margin (code – 5);
Aug 27-30, 2002; D = 73.7cm, V = 17.3cm.

Figure 13. Mesohabitat B – midchannel (code – 6);
Aug 27-30, 2002; D = 120cm, V = 49cm.

Figure 14. Mesohabitat B – right margin (code – 7);
Aug 27-30, 2002; D = 250cm, V = 10cm.

Figure 15. Mesohabitat C – midchannel (code – 8);
Aug 27-30, 2002; D = 93.0cm, V = 66.0cm.

Figure 16. Mesohabitat C – right margin (code – 9);
Feb 2-5, 2002; D = 22.7cm, V = 31.7cm.

Figure 17. Mesohabitat D – left margin (code – 10);
Aug 27-30, 2002; D = 150cm, V = 45cm.

Figure 18. Mesohabitat D – midchannel (code – 11 in background and code – 14 in foreground);
Aug 27-30, 2002; code – 11: D = n/a, V = n/a; code – 14: D = 110cm, V = 70cm.

Figure 19. Mesohabitat D – right margin (code – 12);
Feb 2-5, 2002; D = 53.3cm, V = 43.7cm.

Figure 20. Mesohabitat E – left margin (code – 13);
Aug 27-30, 2002; D = 160cm, V = 15cm.

Figure 21. Mesohabitat E – midchannel and right margin (codes – 14 and 15);
Aug 27-30, 2002; code – 14: D = 110cm, V = 70cm; code – 15: D = 32.3cm, V = 32.0cm.

Figure 22. Mesohabitat F – left margin (code – 16; backwater);
Aug 27-30, 2002; D = 62.3cm, V = 3.0cm.

Figure 23. Mesohabitat F – left margin (code – 17);
Aug 27-30, 2002; D = n/a, V = n/a.

Figure 24 Mesohabitat F – LWD (code – 17; in background) and midchannel (code – 18; in foreground);
Aug 27-30, 2002; code – 17: D = 78.3cm, V = 14.0cm; code – 18: D = n/a, V = n/a.

Figure 25. Mesohabitat F – right margin (code – 19; upstream);
Aug 27-30, 2002; D = 280cm, V = -2cm.

Figure 26. Mesohabitat F – right margin (code – 19; downstream);
Aug 27-30, 2002; D = 163cm, V = 2cm.

Figure 27. Mesohabitat F – right margin (code – 19; LWD);
Aug 27-30, 2002; D = n/a, V = n/a.

Figure 28. Mesohabitat G – left margin (code – 20);
Aug 27-30, 2002; D = 210cm, V = 45cm.

Figure 29. Mesohabitat G – left margin (code – 20; LWD);
Aug 27-30, 2002; D = 230cm, V = 0cm.

Figure 30. Mesohabitat G – midchannel (code – 21);
Aug 27-30, 2002; D = 110cm, V = 49cm.

Figure 31. Mesohabitat G – right margin (code – 22);
Aug 27-30, 2002; D = 23.3cm, V = 13.3cm.

Figure 32. Mesohabitat H – midchannel (code – 23);
Aug 27-30, 2002; D = 140cm, V = 89cm.

Figure 33. Mesohabitat H – right margin (code – 25);
Aug 27-30, 2002; D = 18.0cm, V = 22.7cm.

Figure 34. Mesohabitat I – left margin (code – 26);
Aug 27-30, 2002; D = 48.0cm, V = 20.0cm.

Figure 35. Mesohabitat I – right margin (code – 27);
Aug 27-30, 2002; D = 132cm, V = -8cm.

Figure 36. Mesohabitat J – left margin (code – 28);
Aug 27-30, 2002; D = 81.7cm, V = 19.0cm.


Figure 37. Mesohabitat J – midchannel;
Feb 2-5, 2002; D = n/a, V = n/a.


Figure 38. Mesohabitat J – right margin (code – 29);
Aug 27-30, 2002; D = 65.7cm, V = -5.0 cm.

Figure 39. Allens Creek confluence (code – 30);
Aug 27-30, 2002; D = 38.3cm, V = 7.3cm.

Figure 40. Allens Creek (code – 30);
Aug 27-30, 2002; D = 38.3cm, V = 7.3cm.

Table 12. Documented occurrences of fish species near our Brazos River study reach (from Linam et. al 1994 and Winemiller et. al. 2000). * indicates species not collected during our study.

Family	Species	Common Name
Amiidae	Amia calva	bowfin
Aphredoderidae	Aphredodreus sayanus	pirate perch
Atherinidae	Labidesthes sicculus	brook silverside
	Menidia beryllina	inland silverside
Catostomidae	Carpoides carpio	river carpsucker
	Cycleptus elongatus *	blue sucker
	Ictiobus bubalus	smallmouth buffalo
	Minytrema melanops *	spotted sucker
Centrarchidae	Elassoma zonatum *	banded pygmy sunfish
	Lepomis cyanellus	green sunfish
	Lepomis gulosus	warmouth
	Lepomis humilis	orangespotted sunfish
	Lepomis macrochirus	bluegill sunfish
	Lepomis megalotis	longear sunfish
	Lepomis microlophus	redear sunfish
	Lepomis punctatus	spotted sunfish
	Micropterus punctulatus	spotted bass
	Micropterus salmoides	largemouth bass
	Pomoxis annularis	white crappie
	Pomoxis nigromaculatus *	black crappie
Cichlidae	Oreochromis aureus *	blue tilapia
Clupeidae	Alosa crysochloris	skipjack herring
	Dorosoma cepedianum	gizzard shad
	Dorosoma petenense	threadfin shad
Cyprinidae	Cyprinella lutrensis	red shiner
	Cyprinella venusta	blacktail shiner
	Cyprinus carpio	common carp
	Hybognathus nuchalis *	Mississippi silvery minnow
	Lythrurus fumeus	ribbon shiner
	Macrhybopsis aestivalis	speckled chub
	Machrybopsis storeriana	silver chub
	Notemigonus crysoleucas *	golden shiner
	Notropis buchanani	ghost shiner
	Notropis buccula *	smalleye shiner
	Notropis oxyrhynchus	sharpnose shiner
	Notropis shumardi	silverband shiner
	Opsopoeodus emiliae	pugnose minnow
	Pimephales vigilax	bullhead minnow

Table 12. Documented occurrences of fish species near our Brazos River study reach (from Linam et. al 1994 and Winemiller et. al. 2000). * indicates species not collected during our study. (continued)

Fundulidae	Fundulus notatus	blackstripe topminnow
Ictaluridae	Ameiurus melas *	black bullhead
	Ameiurus natalis *	yellow bullhead
	Ictalurus furcatus	blue catfish
	Ictalurus punctatus	channel catfish
	Noturus gyrinus	tadpole madtom
	Pylodictis olivaris	flathead catfish
Lepisosteidae	Lepidosteus oculatus	spotted gar
	Lepidosteus osseus	longnose gar
Mugilidae	Mugil cephalus	striped mullet
	Mugil curema *	white mullet
Percidae	Etheostoma chlorosomum *	bluntnose darter
	Etheostoma gracile	slough darter
	Percina caprodes *	logperch
	Percina macrolepida *	bigscale logperch
	Percina sciera *	dusky darter
Poeciliidae	Gambusia affinis	mosquitofish
Sciaenidae	Aplodinotus grunniens	freshwater drum

4.4 Index of Biological Integrity

Scores for the 10 IBI metrics of the seined collections are reported in Table 13. Our study reach rated good (score: 63) for September 2001 and excellent (score: 69) across our six collections. When considering all sampling gears our study reach rated excellent (score: 71) in both September and overall collections (Table 14). Our study reach scored consistently higher than the scores for seined collections at six sites (22 to 63), and seine and electrofish collections at three of six sites (44 to 53) calculated by Winemiller and Gelwick (1999). Differences in scores and categorical rankings between the two studies may be attributed to differences in the total area sampled. Winemiller and Gelwick (1999) sampled between 25-200 m of river length per site whereas our site encompassed over 4950 m, increasing the likelihood of capturing species of low densities or abundances.

Table 13. IBI ranks and scores of seine captures during September 2001 and overall collections.

	Scoring Criteria			
	September 2001 Collections		Overall Collections	
	Value	Score	Value	Score
Species Richness and Composition Metrics:				
# of native species	26	10	38	10
# of darter species	0	0	2	5
# of sunfish species	5	10	6	10
# of sucker species	1	10	2	10
# of intolerant species	7	7	9	10
% tolerant species	87.15	5	89.27	5
% mosquitofish	10.23	5	4.12	7
Trophic Function Metrics:				
% omnivores	76.03	7	87.35	5
% invertivores	23.02	7	12.44	5
% carnivores	0.70	2	0.18	2
Totals:		63 (good)		69 (excellent)

Table 14. IBI ranks and scores of total captures during September 2001 and overall collections.

	Scoring Criteria			
	September 2001 Collections		Overall Collections	
	Value	Score	Value	Score
Species Richness and Composition Metrics:				
# of native species	27	10	43	10
# of darter species	0	0	1	2
# of sunfish species	6	10	8	10
# of sucker species	1	10	2	10
# of intolerant species	7	7	10	10
% tolerant species	87.18	5	29.55	10
% mosquitofish	10.15	5	3.95	7
Trophic Function Metrics:				
% omnivores	76.03	7	87.02	5
% invertivores	22.88	7	12.07	5
% carnivores	8.52	10	0.90	2
Totals:		71 (excellent)		71 (excellent)

Table 15. Comparison of IBI scores for mainstem reaches of the lower Brazos River.

Source	Scoring	Rating
Winemiller and Gelwick (seine only): September-October 1998	Range: 22-63	Poor – Good
Winemiller and Gelwick (seine and electrofish): September-October 1998	Range: 44-53	Fair – Good
TWDB (seine only):		
September 2001	63	Good
Overall	69	Excellent
TWDB (total collections):		
September 2001	71	Excellent
Overall	71	Excellent

4.5 Fish Species Indicators

Of the common species, bullhead minnow had the highest indicator value of pools but was not-significant ($P > 0.05$; Table 16). Red shiner and striped mullet had the highest values for runs, but were also not significant. Riffles were poorly differentiated by fishes of any species. Ghost shiner, silverband shiner, and mosquitofish had the highest indicator values of the tributary confluence habitat, with mosquitofish being the only significant indicator species. Results of an indicator species analysis conducted for all captured species is reported in Table 17.

Table 16. Indicator values for common fishes (abundance > 1%) based on relative abundance and frequency of occurrence in Brazos River mesohabitats. *P* is the proportion of Monte Carlo randomized trials (1000) with indicator values equal to or exceeding the observed indicator value. Bold numbers indicate the value that is highest for each species.

		Mesohabitat			
Species	*P*	Pool	Run	Riffle	Tributary Confluence
Red shiner	0.412	16	**51**	14	19
Ghost shiner	0.612	14	12	0	**45**
Silverband shiner	0.179	28	14	3	**55**
Bullhead minnow	0.064	**59**	17	1	23
Striped mullet	0.686	20	**22**	0	2
Mosquitofish	0.003	5	6	0	**87**

Table 17. Indicator values for all fishes based on relative abundance and frequency of occurrence in Brazos River mesohabitats. *P* is the proportion of Monte Carlo randomized trials (1000) with indicator values equal to or exceeding the observed indicator value. Bold numbers indicate the value that is highest for each species.

		Mesohabitat			
Species	*P*	Pool	Run	Riffle	Tributary Confluence
Bowfin	0.999	0	**17**	0	0
Pirate perch	0.999	0	**17**	0	0
Brook silverside	0.999	0	0	0	**17**
Inland silverside	0.002	1	0	0	**80**
River carpsucker	0.164	29	**37**	0	10
Smallmouth buffalo	0.707	**19**	**19**	0	11
Green sunfish	0.999	1	0	0	**16**
Warmouth	0.207	0	**33**	0	0
Orangespotted sunfish	0.067	1	1	0	**46**
Bluegill sunfish	0.006	0	1	0	**64**
Longear sunfish	0.871	2	**20**	0	10
Redear sunfish	0.999	2	0	0	**15**
Spotted sunfish	0.999	**17**	0	0	0
Hybrid sunfish	0.999	0	**17**	0	0
Juvenile sunfish	0.294	0	4	0	**29**
Spotted bass	0.999	0	1	0	**15**
Largemouth bass	0.999	0	0	0	**17**
White crappie	0.999	0	7	0	**9**
Skipjack herring	0.999	**17**	0	0	0
Gizzard shad	0.222	12	25	0	**40**
Threadfin shad	0.041	3	8	0	**66**
Red shiner	0.828	21	**30**	22	27
Blacktail shiner	0.122	7	**30**	0	0
Common carp	0.999	**17**	0	0	0
Ribbon shiner	0.388	5	**23**	0	0
Speckled chub	0.483	**31**	13	26	1
Silver chub	0.589	**22**	5	4	0
Ghost shiner	0.492	12	12	0	**44**
Sharpnose shiner	0.999	0	0	0	**17**
Silverband shiner	0.059	17	8	3	**71**
Pugnose minnow	0.999	**8**	**8**	0	0
Bullhead minnow	0.259	24	19	3	**54**
Blackstripe topminnow	0.177	0	0	0	**33**
Blue catfish	0.861	**17**	12	0	**17**
Channel catfish	0.766	**24**	19	1	21
Tadpole madtom	0.999	3	0	0	**14**
Flathead catfish	0.046	**49**	0	0	7
Spotted gar	0.327	7	13	0	**36**
Longnose gar	0.215	**38**	35	0	10
Striped mullet	0.897	**21**	19	0	3
Slough darter	0.999	0	0	0	**17**
Mosquitofish	0.005	2	7	0	**89**
Freshwater drum	0.048	**50**	0	0	0

REFERENCES

Bayer, C. W., J. R. Davis, S. R. Twidwell, R. Kleinsasser, G. Linam, K. Mayes, and E. Hornig. 1992. Texas aquatic ecoregion project: an assessment of least disturbed streams (draft). Texas Water Commission.

Dufrene, M., and P. Legendre. 1997. Species assemblage and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Karr, J., F. D. Fausch, P. L., Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing the biological integrity in running waters: a method and its rationale. Illinois Natural History Survey. Champaign, Illinois. Special Publication 5.

Johnson, R. B. 1977. Fishery survey of Cedar Lakes and the Brazos and San Bernard River estuaries. Texas Parks and Wildlife Department. Austin, Texas. Technical Series No. 23.

Linam, G. W., J. C. Henson, and M. A. Webb. 1994. A fisheries inventory and assessment of Allens Creek and the Brazos River, Austin County, Texas. Texas Parks and Wildlife Department. Austin, Texas. River Studies Report No. 12.

McEachran, J. D. and J. D. Fechhelm. 1998. Fishes of the Gulf of Mexico. University of Texas Press, Austin, Texas.

McCune, B., and M.J. Mefford. 1997. PC-ORD. Multivariate analysis of ecological data, Version 3.0. MjM Software Design, Gleneden Beach, Oregon.

McKone, P. D., M. A. Shelton, and S. J. Basham. 1996. Status of environmental issues for Allens Creek reservoir. Trans-Texas Water Program Southeast Area, Draft Memorandum. Freese and Nichols, Inc.

Ostrand, K. G., and G. R. Wilde. 2002. Seasonal and spatial variation in a prairie stream-fish assemblage. Ecology of Freshwater Fish 11:137-149.

Stalnaker, C. B., R. T. Milhous, and K. D. Bovee. 1989. Hydrology and hydraulics applied to fishery management in large rivers. Pages 13-30 *in* D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Journal of Fisheries and Aquatic Sciences 106.

U.S. Fish and Wildlife Service. June 13, 2002. Notice of Review. Federal Register. Vol. 67, No. 114:40657-40679.

Wilde, G. R. and K. G. Ostrand. 1999. Changes in the fish assemblage of an intermittent prairie stream upstream from a Texas impoundment. Texas Journal of Science 51:203-210

Winemiller, K. O., and F. P. Gelwick. 1999. Assessment of ecological integrity of streams in the Brazos-Navasota watershed based on biotic indicators. Texas Agriculture Experiment Station, College Station, Texas.

Winemiller, K. O., S. Tarim, D. Shormann, and J. B. Cotner. 2000. Fish assemblage structure in relation to environmental variation among Brazos River oxbow lakes. Transactions of the American Fisheries Society 129:451-468.