# CYPRINID ASSEMBLAGE STRUCTURE ALONG PHYSICAL, LONGITUDINAL, AND SEASONAL GRADIENTS AND LIFE HISTORY AND REPRODUCTIVE ECOLOGY OF THE SABINE SHINER

# THESIS

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By

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## **CHAPTER I**

# CYPRINID ASSEMBLAGE STRUCTURE ALONG PHYSICAL, LONGITUDINAL, AND SEASONAL GRADIENTS IN EAST TEXAS AND WEST-CENTRAL LOUISIANA UPLAND STREAMS

# ABSTRACT

Cyprinid fish assemblages were sampled monthly from three sites on Kisatchie Bayou, west-central Louisiana, and four sites on Banita Creek and Lanana Bayou in east Texas for one year. Species and richness were similar between drainages but differed in abundance; Kisatchie Bayou assemblage was dominated by Cyprinella venusta (74%) while species abundances were more evenly distributed in Banita Creek. Canonical correspondence analysis was used to examine cyprinid species-environment relationships and effects of physical parameters, site, and season on spatial and temporal variation of assemblage structure. Physical parameters, site, and season explained 78% of the cyprinid assemblage in Kisatchie Bayou and 72% in Banita Creek and Lanana Bayou (72%). Pure effects of physical parameters explained a significant (P<0.05) proportion (35%) of assemblage structure variability in the Kisatchie Bayou assemblage, followed by season (9%) and site (6%). However, only the pure effect of site was significant (<0.05) in Banito Creek and Lanana Bayou. Differences in pure "habitat" effects among drainages accentuated differences in life history traits in dominant species of the assemblage.

#### INTRODUCTION

Numerous factors contribute to the structure and persistence of stream fish assemblages through time and space. From a historical perspective, assemblages are the results of large-scale processes (e.g., plate tectonics and glaciation) that have influenced speciation, extinction, and movement of fishes to form assemblages through geological time (Gilbert 1980, Lawton 1990, Brown 1995, Moyle and Cech 2000). From a recent perspective, abiotic and biotic processes of the aquatic and terrestrial environment maintain assemblage structure (Matthews 1998). In many temperate streams, fish composition, abundance, and distribution are regulated by a variety of physical and chemical characteristics of the aquatic environment, including water depth, current velocity, substrate type, cover, dissolved oxygen concentration, temperature, and turbidity (Gorman and Karr 1978, Baker and Ross 1981, Angermeier 1987, Felley and Felley 1987, Matthews 1987, Rutherford et al. 1987, Taylor et al. 1993, Bonner and Wilde 2002).

Physical and chemical characteristics, however, are not homogeneous throughout a stream but differ longitudinally (spatial effects) and through time (seasonal effects, Baker and Ross 1981, Meador and Matthews 1992, Matthews et al. 1994). Thus, spatial and seasonal effects are often correlated with assemblage structure (Schlosser 1982, Felley and Hill 1983, Meador and Matthews 1992). Spatial and seasonal differences in fish distribution also occur independently of the physical and chemical characteristics of the stream due to differing life history traits of species (Ross and Baker 1983, Cross et al. 1985, Minckley and Mefee 1987, Schlosser 1987, Meffe and Sheldon 1988, Schlosser

1991, Schlosser 1995, Bonner 2000). For example, Bonner (2000) found that two broadcast-spawning cyprinids move a substantial distance upstream (>100 km) to spawn so that their eggs can develop as they float downstream. Thus, assemblage composition and abundance at any particular location on the stream was regulated in part by physical and chemical characteristics and innate biotic effects, the latter being correlated with seasonal and longitudinal parameters.

Anthropogenic modifications of the aquatic and terrestrial environments alter natural processes that structure fish assemblages. Instream dams, dewatering, non-point and point-source pollution, and alterations to riparian zones often disrupt assemblage structure by reducing the number of some species and increasing the numbers of more generalist species (Li et al. 1987, Winston and Taylor 1991, Rabeni and Smale 1995, Richter et al. 1997, Harding et al. 1998, Wilde and Ostrand 1999, Jones et al. 1999, Bonner and Wild 2000, Scott and Helfman 2001). Overall effects of anthropogenic modifications vary among streams (Anderson et al. 1995) but may have detrimental impacts on assemblages comprised of species with narrow distributions (Warren and Burr 1994). Currently, 28% of native freshwater fishes in the southeastern United States are considered extinct, endangered, threatened, or vulnerable (Warren et al. 2000). Many of these southern fish species are geographically restricted or isolated endemics (Burr and Mayden 1992), with 28% of southern fishes endemic to one drainage basin (Warren et al. 2000).

Among cyprinids alone, 30% of species in Texas and 10% of species in Louisiana are considered of conservation concern (Hubbs et al. 1991, Warren et al. 2000). With few exceptions, these listed species are endemic to flowing streams and creeks and

limited to one to a few drainage basins. For example, the sabine shiner *Notropis sabinae* is an inhabitant of clear, sandy streams in two disjunct populations, one in Texas and Louisiana, the other in Arkansas and Missouri (Robison and Buchanan 1988, Hubbs et al. 1991). Due to apparent declines in population abundance and distribution in Texas, the sabine shiner is listed as a species of concern by the US Forest Service, Region 8 (D. Peterson, US Forest Service, pers. comm.) and U.S. Fish and Wildlife Service (USFWS), Region 2 (USFWS 2000).

The purpose of this study was to assess the structuring effects of physical parameters, site, and season on cyprinid assemblages of two clear, sandy streams of east Texas and west-central Louisiana. Cyprinidae assemblages were selected for this assessment because of their dominance of fish assemblages in this region (Hancock 1951, Evans and Noble 1979). The identification of significant factors that affect cyprinid assemblage structure will aid in understanding habitat needs of narrowly-distributed cyprinid species of this region (e.g., sabine shiner, blackspot shiner *Notropis atrocaudalis*) and allow for prediction of the effects of anthropogenic modification to fish assemblages of these streams.

#### MATERIALS AND METHODS

Kisatchie Bayou (Natchitoches, Sabine, and Vernon Parishes) is a tributary of the Red River drainage of west-central Louisiana and listed as a State Natural and Scenic Stream. Portions of Kisatchie Bayou main stem are privately owned, however, most of this stream is located within Kisatchie National Forest (Kisatchie Ranger District). The stream is generally shallow throughout much of its course with moderate current velocities and sand substrate. Dense stands of various hardwood trees (e.g., beech, magnolia, and red maple) dominate the riparian vegetation (Martin et al. 1990).

Banita Creek and Lanana Bayou (Nacogdoches County) are tributaries of the Angelina River drainage in east-central Texas. Both streams originate north of the city of Nacogdoches, Texas and flow southerly and through the city, where they merge and continue to flow south. These streams are generally shallow with moderate current velocities and gravel, sand, and bedrock substrates. Due to its urban nature, concrete debris is very common in some areas. Riparian areas and watersheds are used primarily for urban or agriculture purposes.

Three sites on Kisatchie Bayou were sampled monthly from October 2001 through September 2002. Three sites on Banita Creek and one site on Lanana Bayou (downstream from Banita Creek and Lanana Bayou confluence) were sampled from November 2001 through October 2002. Collection sites were established in upstream (Site 1), middle (Site 2), and downstream (Site 3) reaches on Kisatchie Bayou, and upstream (Site 1), middle (sites 2 and 3), and downstream (Lanana Bayou; henceforth referred to as Site 4 of Banita Creek) reaches on Banita Creek. Sites were selected to

represent headwater, middle, and downstream reaches within each stream and not according to a pre-defined distance between collection sites. Thus, upstream, middle, and downstream sites on Banita Creek were within closer linear distance from each other than corresponding sites on Kisatchie Bayou.

At each site, fish were collected from all habitat types (i.e., riffles, run, chutes, backwaters, and pools; Arend 1999) with a Smith-Root Model 12-B POW backpack electrofisher and/or seines of various mesh sizes ( $\geq 5$  mm). Mean monthly total length of stream sampled was 140 m for Kisatchie Bayou and 485 m for Banita Creek. When necessary, block nets (mesh size: 4 mm) were placed upstream and downstream of collection sites to prevent escapement of fishes. Within each habitat type, fish were collected until all were presumably collected or until no new species were detected (in larger stream reaches). Fish were identified to species, enumerated, measured for total length (up to 30 individuals for each species), and released. Voucher specimens were retained for all species, anesthetized in tricaine methane sulphonate, and preserved in 10% formalin.

Length, width, percent substrate type (sand, silt, bedrock, gravel, or cobble from 10 random points), percent detritus, percent woody cover, percent vegetation, mean current velocity (Marsh-McBirney Flowmate current meter), mean depth, and maximum depth were obtained from each habitat type. Physical parameters (i.e., percent substrate, percent woody cover, percent vegetation, current velocity, and depth) were weighted by habitat length and summed to obtain a site estimate for each physical parameter. Water temperature (°C), dissolved oxygen (mg/l), pH, and conductivity ( $\mu$ S/cm) were measured with YSI-Model 85 and YSI-Model 60 water quality meters at each collection site.

Patterns in daily stream discharge for the period of stream surveys were estimated from local rainfall data.

Canonical correspondence analysis (CCA; Canoco 4.5; ter Braak 1986) and resulting ordination plots were used to describe the fish species-environment relationships within these streams. Pure effects of physical parameters, site, and season were partitioned from assemblage variability following the methods described by Borcard et al. (1992). For each variable (effect), a separate CCA model was constructed with one variable used as the main effect and the two remaining variables used as covariates. This was repeated for each variable. Monte Carlo tests (1000 permutations) were used to determine the significance of each pure effect (ter Braak and Smilauer 2002). Additional variation was explained by a shared effect of the three variables, but due to possible two and three-way effects, this shared portion of variation could not be partitioned into individual effects. Species richness, Shannon-Wiener diversity indices (SWI), and evenness were calculated for each site per each month. Mean values for species richness, species diversity (Shannon-Wiener diversity indices), and evenness within each stream were calculated from these monthly values.

#### RESULTS

#### Stream characteristics

Kisatchie Bayou and Banita Creek were generally clear, shallow streams with slightly acidic to slightly basic pH, highly oxygenated, low conductivity, and moderate flowing water (Appendix 1.1). Aquatic macrophytes and woody debris were uncommon (< 10%) within collection sites. Kisatchie Bayou was more variable in depth throughout the year and wider with predominately sand substrate whereas Banita Creek contained greater amounts of detritus and gravel, cobble, and bedrock substrates. Rainfall patterns were similar between streams, with monthly averages of 113.03 mm (45.72 - 291.34 mm) for Kisatchie Bayou and 94.511 mm (36.32 - 230.38 mm) for Banita Creek. Peak rainfall occurred in late fall or early winter in both areas.

# Fish abundance and structure

Eight families, 29 species and 5,578 individuals were collected from Kisatchie Bayou from October 2001 through September 2002 (Appendix 1.2). Cyprinidae were most abundant (94%), followed by Cyprinodontidae (3%), Percidae (2%), Centrarchidae, Catostomidae, Poecilidae, Ictaluridae, and Esocidae (<1% each in relative abundance). *Cyprinella venusta* (74%) *Lythrurus umbratilis* (14%), *Notropis sabinae* (4%), *Luxilus chrysocephalus* (4%), *Lythrurus fumeus* (2%), and *Pimephales vigilax* (1%) comprised 99% of the cyprinid assemblage in Kisatchie Bayou. Four other species (*C. lutrensis, Notemigonus crysoleucas, N. atrocaudalis,* and *N. texanus*) were rare (<1% in relative abundance). Eight families, 35 species and 12,173 individuals were collected from Banita Creek from November 2001 through October 2002. Cyprinidae were most abundant (70%), followed by Centrarchidae (11%), Poecilidae (10%), Cyprinodontidae (7%), Percidae (2%), Ictaluridae, Catostomidae, and Aphrododeridae (<1% each in relative abundance). Notropis atrocaudalis (33%), C. lutrensis (15%), N. sabinae (15%), P. vigilax (11%), S. atromaculatus (11%), C. venusta (10%), and N. texanus (3%) comprised 98% of the cyprinid assemblage in Banita Creek. Three other cyprinids (L. umbratilis, L. fumeus, and N. crysoleucas) were rare in abundance.

Nine of 11 cyprinid fishes inhabited both Kisatchie Bayou and Banita Creek (Percent similarity index = 81%). However, cyprinid assemblage structures differed substantially between streams. Kisatchie Bayou was dominated by *C. venusta* whereas species abundance was more evenly distributed in Banita Creek. Among sites, mean species richness for cyprinids was 4.11, mean diversity was 0.59, and mean evenness was 0.48 for Kisatchie Bayou. In contrast, Banita Creek had higher mean species richness (5.2), diversity (1.13), and evenness (0.66) among sites.

## Canonical correspondence analysis

Physical parameters, site, and season explained 78% (P<0.01) of the Kisatchie Bayou cyprinid assemblage variability (Appendix 1.3). Pure effects of the physical parameters explained 35.6% (P<0.01), season explained 9.4% (P<0.01), and site explained 6.1% (P<0.02) of assemblage variation. Shared effects (two- and three-way effects among habitat, site, and season) explained 27% of assemblage variation. Physical parameters with positive centroids on the first environmental axis of CCA were silt substrate and depth (Appendix 1.1a). Physical parameters with the highest negative centroids on the first environmental axis of CCA were sand substrate, current velocity (cv), stream width, woody debris, and vegetation. Site 1 was positively associated whereas sites 2 and 3 were negatively associated with the first environmental axis (Appendix 1.4b). Thus, the first environmental axis described an upstream to downstream gradient with upstream areas generally consisting of greater silt substrate, slower current velocities, narrower stream width, less woody debris and vegetation. Downstream sites generally consisted of sand substrate, swifter current velocities, wider stream width, and greater amounts of woody debris. Season was strongly associated with the second environmental axis of CCA (Appendix 1.4c). Spring, summer, and winter generally consisted of swifter current velocities, higher conductivities, and woody debris, reflecting higher amounts of seasonal precipitation. In contrast, the fall season generally consisted of slower current velocities with silt and gravel substrates, higher pH, and more detritus associated with lesser amounts of precipitation.

Physical parameters, site, and season explained 72% of the Banita Creek cyprinid assemblage variability (Appendix 1.3). Pure effects of physical parameters explained 19.3% (P>0.05), season explained 4.7% (P>0.05), and site explained 9.5% (P <0.01) of assemblage variation. Shared effects (two- and three-way effects among habitat, site, and season) explained 39% of assemblage variation. Physical parameters with positive centroids on the first environmental axis of CCA were bedrock and cobble substrates, detritus, and woody debris (Appendix 1.5a). Physical parameters with the highest negative centroids on the first environmental axis of CCA were sand and silt substrates, current velocity, depth, and stream width, and silt substrate. Site 1 and 2 were positively associated whereas sites 3 and 4 were negatively associated with the first environmental axis (Appendix 1.5b). Thus, the first environmental axis described an upstream to downstream gradient with upstream areas generally consisting of cobble and bedrock substrates, greater amounts of detritus and woody debris, and slower current velocity, and downstream areas consisting of sand and silt substrates, swifter current velocities, and greater stream widths and depths.

### Effects of physical parameters, site, and season on Kisatchie Bayou cyprinid assemblage

Kisatchie Bayou cyprinids positively associated with the first environmental axis were *N. atrocaudalis, L. umbratilis*, and *L. chrysocephalus* (Appendix 1.4a.). Cyprinids negatively associated with the first environmental axis were *N. texanus, P. vigilax, N. sabinae, L. fumeus, N. crysoleucas, C. lutrensis*, and *C. venusta*. Among physical parameters (explained 36% of assemblage variation), *N. atrocaudalis* (N = 6), *L. umbratilis* (N = 737), and *L. chrysocephalus* (N = 200) were associated with slower current velocities, narrow stream width, and silt substrate. Silt substrate was most abundant at Site 1, however, this substrate type was uncommon and comprised <13% of the total substrate. *Pumephales vigilax* (N = 52) and *L. fumeus* (N = 112) were associated with intermediate flows, gravel, cobble, and bedrock substrate, vegetation and detritus. *Notropis sabinae* (N = 22) and *C. venusta* (N = 3,915) were associated with intermediate flows and weakly associated with sand substrate and woody debris. *Notropis texanus* (N = 2), *N. crysoleucas* (N = 6), and *C. lutrensis* (N = 2) were associated with swifter current velocities, gravel redepths, and sand substrate.

Significant seasonal effects (explained 9.4% of assemblage variation) were attributed to the reduction of *C. venusta* during the winter following a large storm event (Appendix 1.6). Catch per unit effort for *C. venusta* decreased from 6.37 to 0.544 individuals per meter and relative abundance decreased from 85.2% to 42.5% between November and December 2001. This decrease was associated with high flows from a 274 mm rainfall of three days between November and December 2001 collection dates.

Among sites (explained 6.1% of assemblage variation), species with strong site affinities were *N. atrocaudalis* (upstream) and *C. venusta*, *N. sabinae*, *L. fumeus*, and *P. vigilax* (middle and downstream, Appendix 1.7). *Lythrurus umbratilis* were most abundant at Site 1 and *L. chrysocephalus* at Site 2, but also common to rare in abundance at the other two sites.

#### Effects of physical parameters, site, and season on Banita Creek cyprinid assemblage

Banita Creek cyprinids positively associated with the first environmental axis were *S. atromaculatus*, *N. crysoleucas*, and *N. atrocaudalis* (Appendix 1.5a). Cyprinids negatively associated with the first environmental axis were *N. texanus*, *L. fumeus*, *C. venusta*, *L. umbratilis*, *P. vigilax*, *N. sabinae*, and *C. lutrensis*. Pure physical parameters and season effects did not explain a significant portion of the cyprinid assemblage structure although components of physical parameters and season are expressed in shared effects with site.

Among physical parameters, *N. atrocaudalis* (N = 2,787), *S. atromaculatus* (N = 961), and *N. crysoleucas* (N = 19) were associated with slower current velocities, narrow stream width, and cobble and bedrock substrates. *Cyprinella lutrensis* (N = 1,262) and *N.* 

sabinae (N = 1,246) were associated with intermediate current velocity, sand substrate, and vegetation. *Pimephales vigilax* (N = 968) were associated with swifter current velocity and sand substrate. *Cyprinella venusta* (N = 845), *L. umbratilis* (N = 71), *L. fumeus* (N = 61), and *N. texanus* (N = 235) were associated with swifter current velocity, greater depths, and wider stream width.

Although season effects were not significant, seasonal trends in fish abundance were observed for *C. lutrensis, C. venusta, Notropis sabinae, P. vigilax,* and *S. atromaculatus. Cyprinella lutrensis* and *C. venusta* catch per unit effort and relative abundance decreased in January following a similar rain event that led to the reduction of *C. venusta* in Kisatchie Bayou (Appendix 1.8). Seasonal increases in abundance were found for *Notropis sabinae* and *S. atromaculatus* and attributed to spawning, but no increases in other species spawning during the same season were noted.

Among sites (explained 9.5% of assemblage structure), species with strong site affinities were *S. atromaculatus* (upstream), *C. venusta* (downstream), *P. vigilax* (downstream), and *N. texanus* (downstream) in Banita Creek across time (Appendix 1.7). Species with weak longitudinal affinities were *N. atrocaudalis* (upstream), *N. sabinae* (downstream), and *C. lutrensus* (downstream). For these three species, distributions among habitats and sites were assessed by month to fully explore their lack of longitudinal affinity.

*Notropis atrocaudalis* was most abundant in the upstream reaches from November 2001 until May 2002 (Appendix 1.9). During June and July, highest abundances were observed in downstream reaches. At the downstream sites however, 80% of individuals at Site 3 and 100% at Site 4 were age-0 fish. Thus, this abundance shift was attributed to reproductive behavior rather than influenced by habitat or site effects. *Notropis* sp. are typically broadcast spawners (Johnston and Page 1992) with adults moving or residing upstream to spawn and eggs and juveniles floating downstream to hatch and develop (Cross et al. 1985). Based on length frequency histograms (not shown), adults reside upstream and age-0 fish are collected downstream during the summer because of downstream transport during hatching and development.

*Notropis sabinae* had a similar pattern of distribution except adults were most abundant at sites 2 and 3 and uncommon (<6% in relative abundance) at Site 4 from November through April. From June to October, monthly relative abundance of the sabine shiner ranged from 10 to 52% with the population composed of 31-89% age-0 fish.

*Cyprinella lutrensis* steadily increased in abundance upstream after the reduction in occurrence of high flows in December 2001. Thus, weak longitudinal affinity was attributed to displacement and subsequent upstream recolonization of Banita Creek.

*Notropis atrocaudalis*, *N. sabinae*, and *C. lutrensis* moved among sites and habitat conditions because of innate biotic factors instead of specific habitat associations or site affinities. This feasibly accounts for the inability to detect pure habitat effects on Banita Creek cyprinid assemblage structure since species without strong habitat or site affinities comprised (i.e., *N. atrocaudalis*, *N. sabinae*, and *C. lutrensis*) 66% of the assemblage.

#### DISCUSSION

On a large scale, the influence of environmental factors on Kisatchie Bayou and Banita Creek cyprinid assemblages are similar. Species most abundant in these streams (*N. sabinae*, *N. atrocaudalis*, and *C. venusta*) typically inhabit clear, swiftly flowing, shallow streams (Miller and Robison 1973, Heins 1981, Robison and Buchanan 1988) whereas species in lower abundance (*L. umbratilis* and *L. fumeus*) typically inhabit streams that are deeper and slower moving (Trautman 1957, Miller and Robison 1973, Pflieger 1975, Becker 1983). However, on a smaller scale, the influence of physical parameters, site, and season varied in their effects on species within these streams.

Physical parameters explained a significant portion of cyprinid assemblage variation for Kisatchie Bayou but not for Banita Creek. Significance levels in Kisatchie Bayou reflect the structuring effects of physical parameters on *C. venusta*, the dominant species. In contrast, cyprinid species abundances of Banita Creek were more evenly distributed and contained a greater percentage of broadcast spawning species. Broadcast spawning strategies include periods of upstream migration and downstream drift of juvenile or larval stages, and thus longitudinal occurrence is independent of physical parameters (Platania and Altenbach 1998, Bonner 2000). Correspondingly, effects of physical parameters on the cyprinid assemblage of Banita Creek were dampened and found to be insignificant.

Site effects explained a significant portion of cyprinid assemblage variation within these streams, with substantial differences in site effects found among species. Species such as *N. texanus* and *S. atromaculatus* demonstrated very high site affinities and resulted in the greater site influence on assemblage variation of Banita Creek.

Longitudinal distribution patterns of species demonstrating such high site affinities are persistent and predictable through time (Felley and Hill 1983), suggesting these species are well adapted for existence within these specific stream reaches (Meador and Matthews 1992). For example, Semotilus atromaculatus is a widespread species throughout the eastern United States and, independent of physical parameters, is usually most abundant in upstream reaches of headwater streams (Kuehne 1962, Schlosser 1982, Felley and Hill 1983, Robison and Buchanan 1988). Other species demonstrated spatial patterns of distribution based on reproduction and life stage. Certain reproductive strategies result in increased longitudinal distribution of a species during or after the reproductive period (Platania and Altenbach 1998). For example, adult N. autrocaudalis demonstrated a strong upstream site affinity. However, the broadcast spawning strategy of this species resulted in increased downstream occurrence of juvenile and larval fishes, thus dampening the overall site effect for *N. autrocaudalis*. More generalist species, such as *Cyprinella lutrensis*, are capable of persisting throughout large portions of a stream and rarely demonstrate affinities for specific stream reaches (Matthews and Hill 1980, Matthews 1985, Marsh-Matthews et al. 2002).

Seasonal effects on the distribution patterns of the cyprinids of Kisatchie Bayou and Banita Creek varied greatly among species. Seasonal effects (rainfall) were responsible for a large reduction in *C. venusta* in Kisatchie Bayou and smaller reductions in *C. venusta* and *C. lutrensis* in Banita Creek. Several examples of this seasonal displacement of species have been noted and attributed to sampling efficiency, predation, and reduced reproductive effort (Moriarty and Winemiller 1997) or a redistribution of species into areas of refuge during periods of high flow (Whiteside and McNatt 1972, Evans and Noble 1979). Moriarty and Winemiller (1997) reported an increase in *C. venusta* during spring to levels nearly as high as those found during the fall, suggesting this species persisted in stream reaches but were not collected during sampling. Abundances of *C. venusta* during spring never reached the levels encountered during fall in either Kisatchie Bayou or Banito Creek, thus large numbers may have been washed downstream only to be replaced by summer reproduction by remaining individuals. This downstream displacement of reproductive age fishes during winter or spring flooding may drastically affect the structure of these stream fish assemblages (Schlosser 1985). Unlike *C. venusta*, a rapid upstream recovery of *C. lutrensis* abundances occurred in Banita Creek. Thus, *C. lutrensis* may seek out areas of refuge during harsh conditions and return to preferred areas when conditions become more favorable. Alternatively, Minckley and Mefee (1987) found that invasive fishes such as *Cyprinella lutrensis* and *Pimephales vigilax* are often displaced downstream during large rain events.

Physical parameters, site, and season clearly play a significant role in structuring the cyprinid assemblages of Kisatchie Bayou and Banita creek. However, the magnitude of these effects differs between streams and among species. Adequate knowledge of the influences of these structuring processes is important in understanding natural variation within these assemblages and predicting possible impacts of anthropogenic modifications. Better understanding of these processes can also be used to develop more accurate biological monitoring programs and procedures.

**APPENDICES** 

	Kısatchı	e Bayou	Banıta	Creek
	Mean	SD	Mean	, SD
Dissolved oxygen (mg/l)	8.6	0.6	9.7	1.4
Conductivity ( $\mu$ S/cm)	167.8	88.7	122.3	41.5
pH (range)	5.57-7.51		6.43-9.64	
Turbidity (ntu)	34.3	18.05	6.7	2.62
Substrate type (%)				
Sand	86.5	14.3	14.7	13.3
Sılt	12.2	15.6	12.4	6.4
Gravel	0.4	0.63	25.2	17.1
Cobble	0.9	1.64	13.2	19.0
Bedrock	0.2	0.29	34.5	30.9
Detritus	0.0	0.05	3.4	3.6
Woody debris (%)	6.1	3.91	5.9	1.6
Aquatic vegetation (%)	0.3	0.44	0.1	0.2
Mean width (m)	12.4	4.93	5.2	2.4
Mean depth (m)	26.7	5.5	20.5	4.1
Mean current velocity (m/s)	0.2	0.1	0.2	0.1

,

Appendix 1.1. Mean ( $\pm$  SD) physical parameters across time and sites for Kisatchie Bayou (October 2001-September 2002) and Banita Creek (November 2001-October 2002).

Species	Kısatchie Bayou	Banıta Creek
Esox americanus	0.02	
Cyprinella lutrensis	0 04	10.4
Cyprinella venusta	70	6.9
Luxilus chrysocephalus	4	-
Lythrurus fumeus	2	0.5
Lythrurus umbratılıs	13	0.6
Notemigonus crysoleucas	0.1	0.2
Notropis atrocaudalis	0.1	22.9
Notropis sabinae	4	10.2
Notropis texanus	0.04	1.9
Pimephales vıgılax	0.9	8.0
Semotilus atromaculatus	-	7.9
Erimyzon oblongus	0 1	0.1
Erimyzon sucetta	0.04	-
Minytrema melanops	0.1	0.1
Moxostoma poecılurum	0.1	0.1
Ameturus melas	-	0.1
Ameturus natalis	0.02	0.4
Noturus nocturnus	0.1	0.2
Aphredoderus sayanus	-	0.01
Fundulus notatus	-	6.8
Fundulus olivaceus	3	· _
Gambusıa affinıs	0.3	9.5
Lepomis auritus	-	1.2
Lepomis cyanellus	-	1.8
Lepomis gulosus	-	0.04
Lepomis humilis	0.1	-
Lepomis hybrid	-	0.02
Lepomis macrochirus	0.04	4.0
Lepomis marginatus	0.1	0.1
Lepomis megalotis	0 1	1.9
Lepomis microlophus	0.04	0.6
Lepomis punctatus	-	0.02
Lepomis sp.	-	0.6
Micropterus punctulatus	0.3	0.4
Micropterus salmoides	-	0.5
Pomoxis annularis	-	0.02
Pomoxis nigromaculatus	-	0.02
Ammocrypta vivax	1.2	-
Etheostoma chlorosomum	0.2	-
Etheostoma gracıle	-	0.1
Etheostoma parvipinne	-	0.01
Etheostoma whipplei	0.1	1.8
Percina sciera	0.1	0.3
N =	5,578	12,173

Appendix 1.2. Relative abundance (%) of fishes collected from Kisatchie Bayou (October 2001 – September 2002) and Banita Creek (September 2001 – October 2002).

Appendix 1.3. Percent of variance (derived from partial canonical correspondence analysis) in Kisatchie Bayou and Banita Creek fish assemblages explained by physical parameters, site, and season. Statistical significance (p<0.05) with Monte Carlo randomization test indicated by '\*'.

Factor	% Variance Explained		
	Kisatchie Bayou	Banita Creek	
Physical parameters	35.6*	19.3	
Site	6.1*	9.5*	
Season	9.4*	4.7	
Shared	27.0	38.6	
Full Model	78.2*	72.1*	

/



Appendix 1.5. Canonical correspondence analysis ordination plots of (a) physical parameters, (b) site, (c) season, and cyprinid species for Banita Creek, November 2001 through October 2002.



Appendix 1.6. (a) Relative abundance (%) and catch per unit effort of the four most abundant fishes collected from Kisatchie Bayou and (b) daily rainfall totals for Kisatchie Bayou drainage, October 2001 through September 2002.





Appendix 1.7. Percentage of selected species collected from each site of Kisatchie Bayou (October 2001 – September 2002) and Banita Creek (November 2001 – October 2002).

Appendix 1.8. (a) Relative abundance (%) and catch per unit effort of the six most abundant fishes collected from Banita Creek and (b) daily rainfall totals for Banita Creek drainage, November 2001 through October 2002.





Appendix 1.9. Percentage of *Cyprinella lutrensis*, *Notropis atrocaudalis*, and *Notropis sabinae* collected from each site of Banita Creek for each collection date, September 2001 through October 2002.

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# **CHAPTER II**

# LIFE HISTORY AND REPRODUCTIVE ECOLOGY OF THE SABINE SHINER

### ABSTRACT

Habitat associations, population structure, and reproductive ecology of the sabine shiner *Notropis sabinae* was examined from an east Texas stream for one year. *Notropis sabinae* was found predominately in run habitats with adults more abundant in deeper runs with sandy substrate and juveniles found in shallower areas of the run with variable substrate. *Notropis sabinae* population consisted of three age groups (0, 1, 2). Maximum life span was 2.5 years. Reproduction occurred from May through October. Patterns in gonadal development, gonadosomatic index, and occurrence and distribution of age-0 fishes indicate *N. sabinae* is a broadcast spawning species, spawning multiple cohorts of eggs during an extended reproductive period.

#### INTRODUCTION

*Notropis sabinae* inhabits lotic environments ranging from small headwater streams to large rivers in east Texas and central Louisiana (Douglas 1974, Hubbs et al. 1991) with a disjunct population existing in three streams (White, Black, and St. Francis rivers) in northern Arkansas and southern Missouri (Lee et al. 1978, Robison and Buchanan 1988). Apparent declines in abundance and distribution throughout their range in Texas and Louisiana prompted U.S. Forest Service, Region 8 (Dave Peterson, U.S. Forest Service biologist, personal communication) and U.S. Fish and Wildlife Service (USFWS), Region 2 (USFWS 2000) to list *N. sabinae* as a species of conservation concern.

*Notropis sabinae* typically inhabit areas with sandy substrate and moderate current velocities (Lee et al. 1978; Moriarty and Winemiller 1997). In Texas and Louisiana, reproduction extends from April to September (Heins 1981) and abundances range from rare to common (Lee et al. 1978). Aside from this general information, little is known concerning the habitat requirements, population structure, and spatial and temporal distribution of *N. sabinae* within the streams it inhabits.

The purpose of this study was to provide habitat associates, population structure, and reproduction of *N. sabinae* through time and among sites from an east Texas stream that historically (Dickens 1950) and currently supports large numbers of this species. Objectives were to describe distribution among habitat types (e.g., riffles, runs, pool, and backwater areas), to assess affinities for particular substrate type, detritus, woody debris, and aquatic macrophytes, to quantify number of age groups within the population, to ascertain maximum age and sex ratio, to describe trends in gonadal maturation and

gonadosomatic index (GSI), and to assess spatial differences in age group distribution among sites.

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#### MATERIALS AND METHODS

Banita Creek and Lanana Bayou (Nacogdoches County) are tributaries of the Angelina River drainage in east-central Texas. Both streams originate north of the City of Nacogdoches, Texas and flow southerly through the city, eventually merging near the southern extent of the city. Both streams are generally shallow with moderate current velocities and clay, sand, and bedrock substrates. In some reaches, concrete and other municipal debris predominates. Riparian areas and watersheds are used primarily for urban or agriculture purposes.

Notropis sabinae were collected from three sites on Banita Creek and one site on Lanana Bayou (downstream from Banita Creek and Lanana Bayou confluence) monthly from November 2001 through October 2002. Collection sites were established at upstream (Site 1) and middle (sites 2 and 3) reaches of Banita Creek and downstream (Site 4) on Lanana Bayou. At each site, *N. sabinae* were collected from all available habitats (i.e., riffles, runs, and pools) with a Smith-Root Model 12-B POW backpack electrofisher and seines of various mesh sizes ( $\geq$  5 mm). When necessary, block nets (mesh size: 4 mm) were placed upstream and downstream of habitats to prevent escapement of fishes. Within each habitat, fish were collected until all were presumably collected or until no new species were detected (in larger stream reaches), identified, and enumerated. Total lengths of 30 *N. sabinae* were measured to the nearest millimeter when available, of which 10 were exposed to a lethal dose of MS-222 and preserved in 10% buffered formalin. Remaining fish were released. Habitat length, width, percent substrate type (sand, silt, bedrock, gravel, cobble, or detritus from 10 random points), percent woody cover, percent vegetation, mean current velocity (Marsh-McBirney Flowmate), mean depth, and maximum depth were obtained after fish identification. Water temperature, dissolved oxygen, pH, and conductivity were measured with YSI-Model 85 and YSI-Model 60 water quality meters at each collection site.

In the laboratory, *N. sabinae* were weighed (grams) and gonads were removed and weighed. A dissecting microscope was used to determine the sex of each individual, and if female, the stage of ovarian development (immature/resting, developing, mature, and spent; Phillip 1993) was determined. Gonad and somatic weights were used to calculate a gonadosomatic index (GSI; [gonad weight / fish weight]\*100) for each individual. Mean GSIs for males and females of reproductive length were calculated for each date. Monthly length frequency histograms were constructed to determine age structure of *N. sabinae* across all sites (Devries and Frie 1996). Additional length frequency histograms were developed from lengths of individuals collected within each site per sampling date to determine temporal and spatial variation in *N. sabinae* size distribution.

Chi-square analyses were used to assess distribution of *N. sabinae* among habitats and substrate types and to test if males and females were collected in equal proportional. Depth and current velocity was compared with Kolmogorov-Smirnov test (S-Plus 6.1) between habitat available and habitat used by *N. sabinae*.

#### RESULTS

#### Habitat associations

Total length of stream sampled in Banito Creek was 5,825 m. Run habitats comprised 73%, riffle habitats comprised 24%, and chute, backwater, and pool habitats (Arend 1999) comprised <4% of the total habitats available in Banito Creek. Habitats used by *Notropis sabinae* differed ( $X^2_{0.05, 4} = 137, P < 0.05$ ) from habitats available (Appendix 2.1a). *Notropis sabinae* (N = 1,246) were more abundant in run habitats (82%) and less abundant in riffle habitats (14%) than expected. Three percent of *N. sabinae* was found in chute habitats, 1% was found in backwater habitats, and 0% was found in pool habitats.

Percent substrates across all habitats were 36% bedrock, 27% gravel, 13% sand, 12% cobble, and 12% silt (Appendix 2.1b). Among habitats containing *N. sabinae*, percent substrate was 31% bedrock, 26% gravel, 18% sand, 13% cobble, and 12% silt. *Notropis sabinae* was most commonly found in habitats with predominantly bedrock and gravel substrate although a larger number than expected were found in habitats with greater amounts of sand substrate ( $X^2_{0.05,4} = 275, P < 0.05$ ). At Site 3, *Notropis sabinae* were often found over a sand bar within a run habitat. However, *N. sabinae* were also commonly collected from habitats without any sand substrate present.

Habitats within Banito Creek generally were clean swept and contained only small amounts (<10%) of detritus, aquatic macrophytes, and woody debris. Among habitats with *N. sabinae*, habitats on average contained 1% detritus, <1% aquatic macrophytes, and 5% wood debris. No association between the amount of detritus or woody debris and the presence of *N. sabinae* was observed. *Notropis sabinae* were found

in temperatures that ranged from 10.7 to 35.1 C°, dissolved oxygen concentrations that ranged from 6.3 to 12.6 mg/L, pH that ranged from 6.4 to 9.6 and conductivity that ranged from 71 to 223  $\mu$ s/cm.

Mean depth (±SD; maximum depth) was 20.2 (±14.5; 115) cm and mean current velocity (±SD; maximum current velocity) was 0.19 (±0.19; 0.91) m/s among habitats in Banito Creek (Appendices 2.2a and 2.2b). Mean depth was 23.2 (±16.22; 115) cm and mean current velocity was 0.19 (±0.20; 0.91) m/s for habitats containing *N. sabinae*. *Notropis sabinae* distribution deviated from expected in depth ( $D_{0.05, 1246} = 0.5833$ ; P < 0.04) and current velocity ( $D_{0.05, 1246} = 0.5882$ ; P < 0.01). Abundances of *Notropis sabinae* were greater than expected at deeper depths and slow current velocities, thus reflecting its affinity for run type habitats.

#### Population structure

Modality in histograms of lengths from all four sites indicated the presence of three-year classes in the *N. sabinae* population from November 2001 through October 2002 (Appendix 2.3). Year class 2000 (age 1 in 2001 and age 2 in 2002) was represented by a small proportion of large fish in November 2001 and possibly again in May 2002. Maximum length of a year class 2000 individual was 61 mm in May 2002. Year class 2001 (age 0 in 2001 and age 1 in 2002) was represented by individuals with a wide range in total length. Smallest individual (22 mm) of year class 2001 was found in January 2002 and the largest individual (58 mm) was found in August 2002. Year class 2002 (age 0) was first collected in June 2002. Maximum size in June 2002 was 33 mm

although it is possible that this individual was a small year class 2001 fish. Age-0 fish reached a maximum length of 50 mm by the end of their first summer.

# Year class distribution among sites

Ninety eight percent of *N. sabinae* was found within the middle reaches of Banita Creek from November 2001 through April 2002 (sites 2 and 3; Appendix 2.4). In May 2002, abundance of age-1 *N. sabinae* greatly increased at Site 1 and to a lesser extent at site 4 (Appendix 2.5). In June and July 2002, age-0 fish were predominantly collected from sites 3 and 4. From August through October 2002, age-0 fish were found in all four sites.

# Sex ratio, gonadal development, GSI

Females (N = 176) for gonadal examination ranged from 25 to 55 mm and males (N = 171) ranged from 25 to 59 mm. Total lengths were not different ( $t_{0.05, 345} = 0.57$ , P = 0.56) between females and males. Sex ratio did not differ from 1:1 ( $X^2_1 = 0.07$ , P = 0.79, N = 347).

Female gonadal quiescence extended from October 2001 through March 2002 with all ovaries identified as immature or resting (Appendix 2.6). Gonadal recrudescence occurred in April 2002 with 62% of the ovaries identified as developing (smallest individual with developing ovaries was 39 mm). In May 2002, 17% of females contained resting or immature ovaries, 10% contained developing ovaries and 73% contained mature ovaries. All examined female fish contained mature ovaries in June and July 2002. In August, 7% of the females contained immature or resting ovaries. It is unlikely that these females represented resting age-1 individuals but rather large immature age-0 females. In September, 9% of the females contained immature or resting ovaries, 9% contained developing, and 82% contained mature. Based on fast summer growth rates of age-0 *N. sabinae* and the capability for other cyprinid species to reproduce at age-0 (Marsh-Matthews et al. 2002), the late presence of developing ovaries in some individuals suggest age-0 spawning by *N. sabinae*.

Mean monthly GSIs for females corresponded with temporal patterns in ovarian development. Mean GSIs were <2% during gonadal quiescence, elevated (>5%) from May through September (mean for mature fish only), and decreased to 1.3% in October. Mean monthly GSIs for males followed a similar pattern. Mean GSIs were <0.2% from November to April, elevated (>0.6%) from May through September, and decreased to 0.2% in October.

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# DISCUSSION

*Notropis sabinae* were found throughout Banita Creek and generally associated with run habitats. Among sites, *N. sabinae* was most abundant in the lower middle reach (Site 3). This site had large numbers of *N. sabinae* year round and seemed to be the primary source of fish to re-establish presence in upstream sites. Site 3 was predominantly a run habitat bordered by bedrock shelves, providing areas of deeper water. Sand patches were present although the substrate was dominated by bedrock. Adult fish were often associated with these sand patches whereas age-0 *N. sabinae* were found frequently over shallow, silt-laden bedrock. Thus, *N. sabinae* was not exclusively associated with sandy areas as previously reported by Gilbert (1978) and Moriarty and Winemiller (1997). Moriarty and Winemiller (1997) also found segregation of adult and juvenile *N. sabinae* in Village Creek (Texas) with adults associated with deep sand bars and juveniles found within shallow sand riffles.

Maximum life span of *N. sabinae* was 2.5 years. Observed temporal patterns in ovarian development, GSIs, and age-0 lengths, suggest that *N. sabinae* released multiple cohorts of eggs over a protracted spawning period. Appearance of age-0 fish in lower stream reaches and subsequent upstream migration indicate downstream drift of eggs or larval fishes after spawning and is characteristic of broadcast spawning species. These life history traits are common among other *Notropis* species (Heins and Rabito 1986, Johnston and Page 1992, Simon 1998, Bonner 2000).

Presence of developing ovaries late in the spawning season indicates fish reach sexual maturity within their first year. Maturation of age-0 fish is suspected for several cyprinids, including the taillight shiner *Notropis maculatus* (Cowell and Barnett 1974)

and the longnose shiner *Notropis longirostris* (Heins and Clemmer 1976), but only substantiated in *Cyprinella lutrensis* (Marsh-Matthews et al. 2002). Alternatively, presence of developing ovaries late in the spawning season may be attributed to slowgrowing age-1 females. These females may represent a cohort of fish spawned late the previous year and have not reached sexual maturity until later in the spawning season in the succeeding year. Hence, these fishes spawned late may remain small through fall, winter, and spring (Matthews et al. 1978), sometimes erroneously indicating fall and winter spawning.

Early maturation, short life spans, extended spawning periods, and broadcast spawning are common traits for many *Notropis* fishes (Matthews et al. 1978, Heins and Rabito 1986, Platania and Altenbach 1998, Bonner 2000). These traits allow rapid turnover and dispersal rates within and among streams and are characteristic of opportunistic species (Winemiller and Rose 1992). Opportunistic life history strategies are advantageous for fishes that inhabit variable environments, allowing these species to persist or quickly recolonize during natural variation or disturbances in the environment. Streams in east Texas supporting *N. sabinae* populations are affected by frequent spates and periods of drought, making opportunistic characteristics of this species ideal for this area.

Declining populations of *Notropis sabinae* mirrors the recent decline of many other cyprinid species. Declines in cyprinids are often related to anthropogenic disturbances and modifications to aquatic environments that result in alterations of natural habitat and flow conditions (Anderson et al. 1995, Richter et al. 1997, Warren et al. 2000). Specific to *N. sabinae*, changes in flow regimes may disrupt reproductive,

dispersal, or recolonization processes. Decreased flow can affect drift of spawned eggs and thereby hinder downstream dispersal within and among streams (Platania and Altenbach 1998). Water control structures also may block upstream recolonization efforts of juvenile fishes, resulting in decreases or extirpations of upstream populations (Erman 1973, Winston et al. 1991, Wilde and Ostrand 1999). Maintenance of a natural flow regime in streams inhabited by *N. sabinae* may be of utmost importance in supporting healthy populations of this species. APPENDICES

Appendix 2.1. Percent habitat (a) and substrate type (b) of Banita creek, Nacogdoches, Texas, and of habitats where *Notropis sabinae* occurred, November 2001 through October 2002.



Appendix 2.2. Percent occurrence of depth (a) and current velocity values (b) and *Notropis sabinae* for Banita creek, Nacogdoches, Texas, November 2001 through October 2002.





Appendix 2.3. Monthly length frequency histograms of *Notropis sabinae* collected from Banita Creek, Nacogdoches, Texas, from November 2001 through October 2002. Collections were pooled across all sites.



Appendix 2.4. Percentage of *Notropis sabinae* collected from each site of Banita Creek for each collection date, September 2001 through October 2002.

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Site #

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Appendix 2.5. Monthly length frequency histograms for *Notropis sabinae* from four sites of Banita creek, Nacogdoches, Texas, November 2001 through October 2002.

Appendix 2.6. Percent of ovaries classified as immature/resting, developing, mature, and spent per month for *Notropis sabinae* from Banita creek, Nacogdoches, Texas, November 2001 through October 2002.



Appendix 2.7. Mean monthly gonadosomatic index (GSI) for female (a) and male (b) *Notropis sabinae* from Banita creek, Nacogdoches, Texas, November 2001 through October 2002.



Month

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# VITA

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