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Aspects of Chub Shiner Notropis potteri Life History with Comments on Native Distribution and Conservation Status

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Abstract.—Chub shiner *Notropis potteri* is unique among *Notropis* species in dietary habits, but remaining aspects of life history as well as native distribution and current population status are unresolved. Recent work in the lower Brazos River of Texas indicated a significant decline in chub shiner abundance within the native range of the species. Causes for such decline are not fully understood and further life history information is needed. Purpose of this study was to assess life history aspects, conservation status and native distribution of the chub shiner. We collected chub shiner monthly at three sites on the lower Brazos River, Texas from Nov. 2003 through Dec. 2005. Abundance and occurrence of chub shiner throughout our intensive 2 y study was low, precluding comprehensive assessment of reproductive ecology and habitat associations. Chub shiners exhibited three age groups with a maximum life span of 2.5 y. Fish and aquatic insects constituted the largest proportions of diet. Unpublished museum records and zoogeography data suggest that chub shiner is native, rather than introduced, to the Red River Drainage.

Introduction

Chub shiner *Notropis potteri* was first discovered by Potter (1938) and officially described by Hubbs and Bonham (1951). At the time of the published description, chub shiner was considered a Brazos River drainage endemic (Hubbs and Bonham, 1951); however, its native distribution was later extended to include the Colorado River, San Jacinto River, Trinity River and Galveston Bay in Texas (Jurgens, 1954; Blair *et al.*, 1968; Conner, 1977). Also at the time of the published description, the chub shiner was known to occur in streams outside of western gulf slope drainages (Hubbs and Bonham, 1951) and have since been reported in the Red, Muddy Boggy, and Kiamichi rivers of Oklahoma (Hubbs and Bonham, 1951; Pigg, 1977; Miller, 1979), the Red River of Arkansas (Robinson and Buchanan, 1988) and the Mississippi and Atchafalaya rivers in Louisiana (Suttkus and Clemmer, 1968; Conner and Guillory, 1974; Schramm, 2003). Hubbs and Bonham (1951) considered chub shiner occurrences outside of western gulf slope drainages to be the result of bait-bucket introductions in the Red River after the construction of Lake Texoma. Others dispute this claim, suggesting chub shiner is likely native to streams outside the gulf slope drainages (Miller, 1953; Hall, 1956; Suttkus and Clemmer, 1968; Conner, 1977). Contrasting viewpoints were based solely on anecdotal evidence.

Chub shiner populations are susceptible to habitat fragmentation (Winston *et al.*, 1991), declining in abundance in the upper (G. Wilde, Texas Tech University, pers. comm.) and lower Brazos River (Runyan, 2007) and consequently at risk for further declines (Fagan *et al.*, 2002). Although the population status of the chub shiner is considered stable (Warren *et al.*, 2000), declines in abundance and distribution in the Brazos River, likely the source population for other gulf slope drainages (Conner and Suttkus, 1986), suggest that the population is at risk of extinction in its native range as delineated by Hubbs and Bonham (1951).

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Chub shiner life history information is limited to a few studies. Chub shiner is commonly found over clean or silt laden sand and gravel substrates of large turbid rivers (Gilbert, 1978; Robison and Buchanan, 1988). In the Mississippi River, the chub shiner occurs in lotic areas of channel borders including secondary channels and sloughs and relatively shallow sandbar and bank habitats (Schramm, 2003). In the Red River of Oklahoma and Louisiana, chub shiner is primarily a benthic invertivore but also considered piscivorous, which is unique for the Genus *Notropis* (Felley, 1984). Reproductive ecology and population structure are not described (Robison and Buchanan, 1988; Platania and Altenbach, 1998).

The purpose of this study was to describe life history characteristics of the chub shiner and assess current conservation status of this species. Specifically, we assessed habitat associations, gonadal maturation, number of age groups present in the population, maximum life span, diet composition and gape widths of the chub shiner in the lower Brazos River. We compared current and historic abundances of chub shiner in the lower Brazos and Red rivers of Texas and Arkansas to determine population trends through time. In addition, we searched museum records to determine the earliest occurrence in the Mississippi River drainage to aid in the determination of native distribution of the chub shiner.

METHODS

We collected chub shiners and habitat measurements monthly from two sites (Hwy 290 river crossing west of Hempstead, Texas, 30°08′08″N, 96°11′32″W; Hwy 1462 river crossing near Rosharon, Texas, 29°21′12″N, 95°34′28″W) on the lower Brazos River from Nov. 2003 through Dec. 2005. At each site and date, we conducted three 30 to 40 m seine hauls using a 2 × 30 m bag seine (wing mesh size = 7 mm; bag mesh size = 3 mm) in all available habitats: near shore, near channel and in protected eddies of a point sand bars. Point sand bars were targeted for this study due to homogeneity of habitat in the lower Brazos River and because such access points tend to have higher numbers of riverine cyprinids such as chub shiner (Li and Gelwick, 2005). All fishes collected in each seine haul were anesthetized in a lethal dose of MS-222 (80 mg/l) and preserved in 10% formalin. We determined percent substrate type (*i.e.*, sand, silt, gravel) from 10 random points along the length of the seine haul and measured current velocity (m/s) and depth (m) at four points across one transect at the upstream end of each seine haul. Because initial capture rates were low at the two sites, we collected chub shiners from a third site (Hwy 723 river crossing north of Rosenberg, Texas, 29°36′11″N) to increase the number of fish used in gut content and reproductive analyses. However, assemblage abundance and habitat characteristics were not quantified from the third site.

In the laboratory, we measured total length (TL; mm) and weight (0.1 mg) for each chub shiner. The gonads and digestive tract from the esophagus to the anus were removed from each fish. Gonads were weighed to the nearest 0.1 mg. We determined sex and gonadosomatic index [GSI; (gonad weight/somatic weight)*100] for each fish and classified the stage of ovarian development (*i.e.*, immature/resting, developing, mature; Phillip, 1993; Williams and Bonner, 2006) for each female. We used total length of all individuals to construct length frequency histograms. Modal progression analysis in Fish Stocking Assessment Tools Version 2 (FiSAT II) was used to estimate numbers of age groups within the population.

We examined intestinal tract contents of up to five chub shiner from each site and date, when available. Contents were removed from the entire intestinal tract, weighed and separated into broad taxonomic groups (*e.g.*, fish, aquatic insects, terrestrial insects), seeds and vegetation, sand and digested organic and inorganic material. Fish and aquatic insects were further segregated into the lowest practical taxonomic classification (*i.e.*, species for fish and family for aquatic insects). We measured wet weight of each group to the nearest 0.1 mg and assigned a weight of 0.1 mg if measured weight was <0.1 mg. Frequency of occurrence (percentage of fish that contained each food item) was assessed for all taxa. Percent weight (taxon weight/total content weight * 100) was determined for all taxa and averaged across all chub shiners to yield the mean percent by weight.

To assess morphological similarities in gape sizes among piscivorous and insectivorous cyprinids, we compared relative gape size among chub shiners, ghost shiners *Notropis buchanani*, silverband shiners *Notropis shumardi*, red shiners *Cyprinella lutrensis* and creek chub *Semotilus atromaculatus*. For each species, gape size was measured (nearest 0.01 mm) for 20 individuals as the distance between the outermost edges of the maxillary bones when the mouth was in the closed position (Johnson and Post, 1996; Nowlin *et al.*, 2006). Relative gape size (100 * gape width/total length) was calculated for each fish and arcsine transformed before analysis. Analysis of covariance (ANCOVA) was used, with total length as a covariate, to compare gape sizes among species and Fisher's Least Significant Differences (LSD) test was used for pairwise contrasts.

To determine current conservation status, we evaluated historical changes in chub shiner abundance in the lower Brazos River and middle Red River, two large sections of river (>215 km in length) that supported chub shiner at least since the 1950s. Historical changes in chub shiner abundance in the lower Brazos River are reported by Runyan (2007) using recent abundance estimates collected during this study. We conducted an assessment of chub shiner population changes for the Red River of Arkansas following the methods of Runyan (2007). Occurrence and abundance records for fishes were obtained from Sam Noble Museum of Natural History, Texas Memorial Museum, Louisiana Museum of Natural History and Tulane Museum of Natural History. Five locations on the Red River had extensive collection records for chub shiner. These five sites were Highway 160 Crossing (33°05′23″N, 93°51′31″W), Highway 82 Crossing (93°321′48″N, 93°42′11″W), IH-30/ Highway 67 Crossing (33°36′22″N, 93°48′47″W), Highway 59/71 Crossing (33°33′07″N, 94°02′36″W), and Highway 8/41 Crossing (33°34′14″N, 94°24′39″W). We sampled Highway 8/41 Crossing in Nov. 2006 and all five sites in Feb. 2007. At each site, we collected fish with seines from all available habitats. Fish were identified and released except for vouchers. Relative abundances were calculated for historical and recent collections by site and date. As with the lower Brazos River assessment, we transformed [$\log_{10}$ (N + 1)] the relative abundance data and used regression analysis to determine if slope differed from zero (*i.e.*, no change). Relative abundances and slopes were graphically displayed as percentages rather than log-transformed values.

RESULTS

A total of 145 chub shiners were collected from the lower Brazos River during Nov. 2003 through Dec. 2005. Only 29 chub shiners were collected from quantified seine hauls, constituting <0.03% of the total number of fishes collected (N = 111,962). Chub shiners collected during quantified seine hauls were found in shallow runs with moderate current velocities and sand substrate. Twenty-five chub shiners were taken from near shore habitats with a mean current velocity (±SD) of 0.29 (0.10) m/s and mean depth (±SD) of 0.30 (0.08) m; four chub shiners were taken from off-channel habitats with a mean current velocity (±SD) of 0.39 (0.12) m/s and mean depth (±SD) of 0.79 (0.18) m.

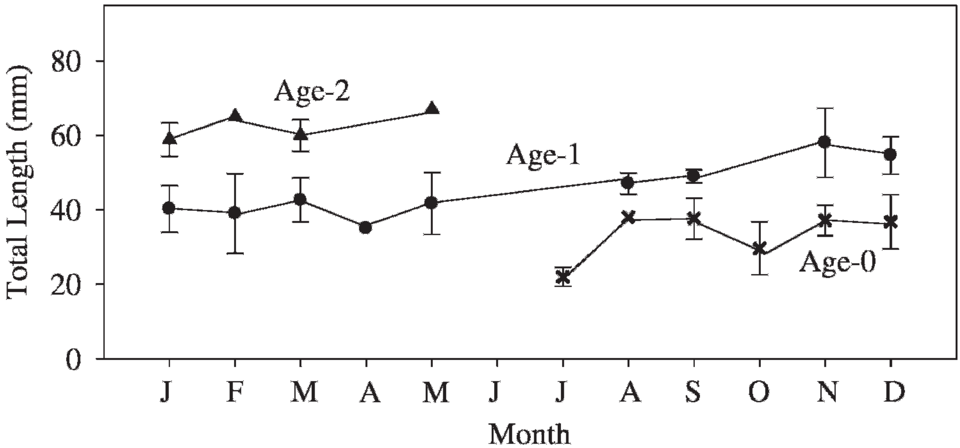

FIG. 1.—Monthly mean total length (±SD) for Age-0, Age-1 and Age-2 chub shiners collected in the lower Brazos River. Years 2004 and 2005 were combined and modal progression analysis used to determine number of age groups present during each month

Seventy two male and 59 female chub shiners were examined for reproductive characteristics. A total of three males (50–67 mm TL) with one taken in Mar., May, and Sep. 2004 had elevated (>0.36%) GSIs. Likewise, only one developing (TL = 51 mm; GSI = 8.95%) female was collected in May 13, 2005, and one mature (TL = 49 mm; GSI = 3.5%) female was collected in 13 Aug. 2004. Remaining males and females were sexually immature or resting.

Modal progression analysis of all 145 individuals collected indicated that chub shiner reached a maximum age of approximately 2.5 y (Fig. 1). Three age classes were present: 0, 1 and 2; however, no age-2 individuals were collected after May. Age-0 individuals reached a maximum length of approximately 45 mm. Age-1 individuals grew to approximately 70 mm, whereas age-2 individuals exhibited little growth before mortality in late spring.

Aquatic insects and fishes were the most abundant food items found among the 72 chub shiners examined. Aquatic insects were found in 40% of fish and constituted 16% of gut contents weight (Table 1). Coleoptera had the highest abundance (19%) and, along with Tricoptera, the highest mean percent by weight (4.7%). Ingested fish were found in 28% of chub shiners and comprised 22% of gut content weight. Red shiners and western mosquitofish were the most abundant prey fish; each occurred in 5.6% of chub shiners and constituted 5.7% and 5.1% of weight respectively. While not a prey item, tapeworms (Class Cestoidea) were found in the stomach and intestines of 26.4% of fish and constituted 8.7% of mean gut content weight. Empty stomachs were uncommon, occurring in only two individuals. Though aquatic insects were the most frequently occurring item in the digestive tract, fishes comprised a higher mean percent of the gut content weight, especially for larger individuals (Fig. 2). Aquatic insects comprised 48% of gut content weight in age-0 chub shiners <29 mm in TL, whereas aquatic insects were not consumed, and fish comprised >90% of gut content items in older chub shiners >60 mm in TL. Among age-0 fish <29 mm in TL, fish comprised 33% of gut content weight.

Relative gape size differed (ANCOVA $F_{9,90} = 77.8$, $P < 0.01$) among piscivorous creek chub and chub shiner and non-piscivorous red shiner, ghost shiner and silverband shiner (Fig. 3). Among pairwise contrasts, relative gape sizes were greater ($P < 0.01$) in creek chub

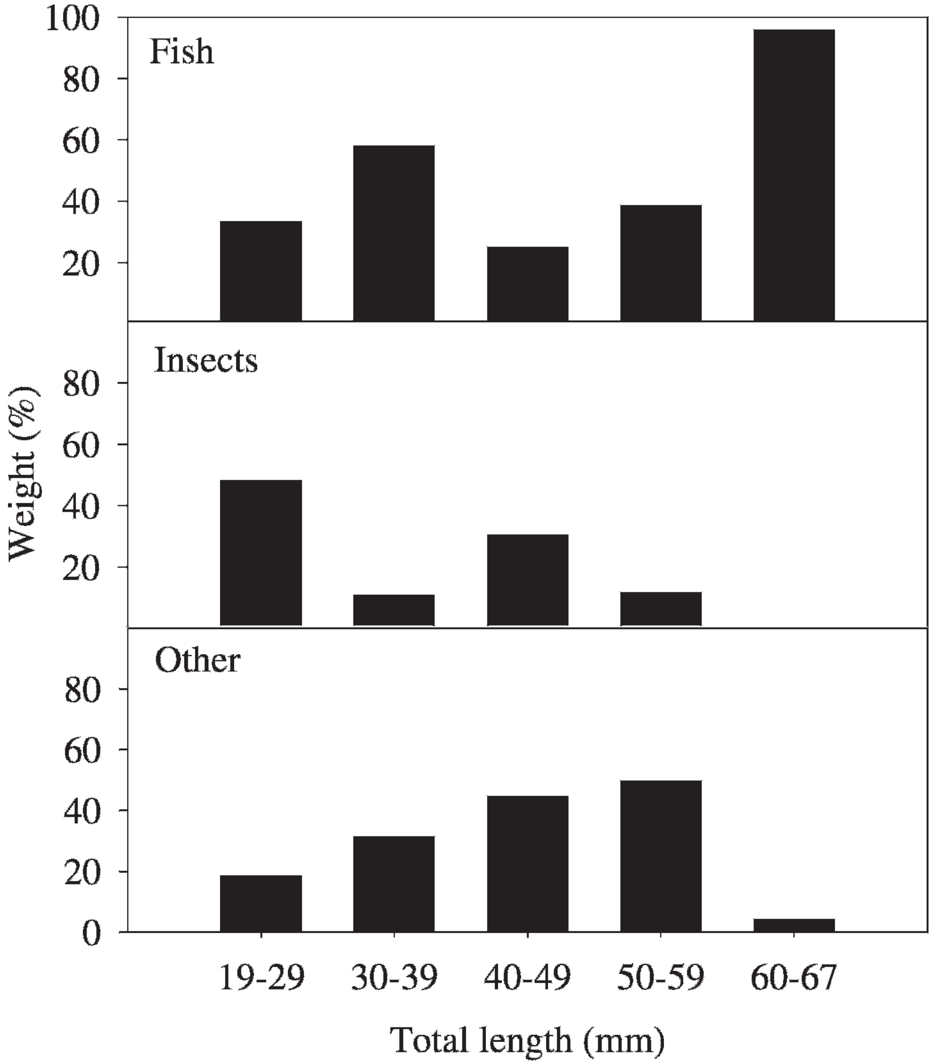

Fig. 2.—Percent by weight of chub shiner gut contents for various length classes. Percentages of Fish, Insects and Other sum to 100 and collectively represent items consumed by all individuals within each length group

and chub shiner than in silverband shiner, ghost shiner or red shiners. Relative gape sizes did not differ between creek chub and chub shiner (P = 0.50) or between ghost shiner and red shiner (P = 0.84). Mean (±sd) relative gape size was 7.4% (±0.89) for creek chub, 7.2% (±0.41) for chub shiner, 5.5% (±0.18) for silverband shiner, 5.2% (±0.26) for ghost shiner and 5.1% (±0.49) for red shiner.

Relative abundances of the chub shiner decreased in the lower Brazos River though time, but remained stable in the Red River. Historical relative abundances were higher than current relative abundance of chub shiners in the lower Brazos River (Fig. 4). Historical

TABLE 1.—Frequency of occurrence and mean percentage by weight of gut contents for 72 chub shiners collected from three sites on the Lower Brazos River, Texas during 2004 and 2005

Taxon	Frequency of occurrence	Mean percentage by weight
	%	%
Fish	27.8	21.5
Cyprinella lutrensis	5.6	5.7
Gambusia affinis	5.6	5.1
Notropis buchanani	1.4	1.4
Menidia beryllina	2.8	2.9
Unidentified fish	12.5	6.4
Aquatic insects	40.3	15.6
Insect parts	25.0	6.1
Tricoptera	18.1	4.7
Odonata	5.6	1.3
Coleoptera	19.4	4.6
Dryopidae	2.8	0.2
Elmidae	4.2	1.2
Hydrophilidae	2.8	1.1
Other Coleoptera	9.7	2.2
Diptera	16.7	2.3
Chironomidae	4.2	1.4
Culicidae	6.9	0.4
Other Diptera	4.2	0.6
Megaloptera	1.4	0.2
Hemiptera	9.7	2.4
Pleidae	1.4	0.1
Corixidae	8.3	2.4
Terrestrial insects	1.4	0.7
Oligochaeta	5.6	0.5
Ostracoda	5.6	0.5
Cestoda	26.4	8.7
Seed/Vegetation	19.4	6.5
Sand	22.2	3.8
Digested matter	76.4	36.1

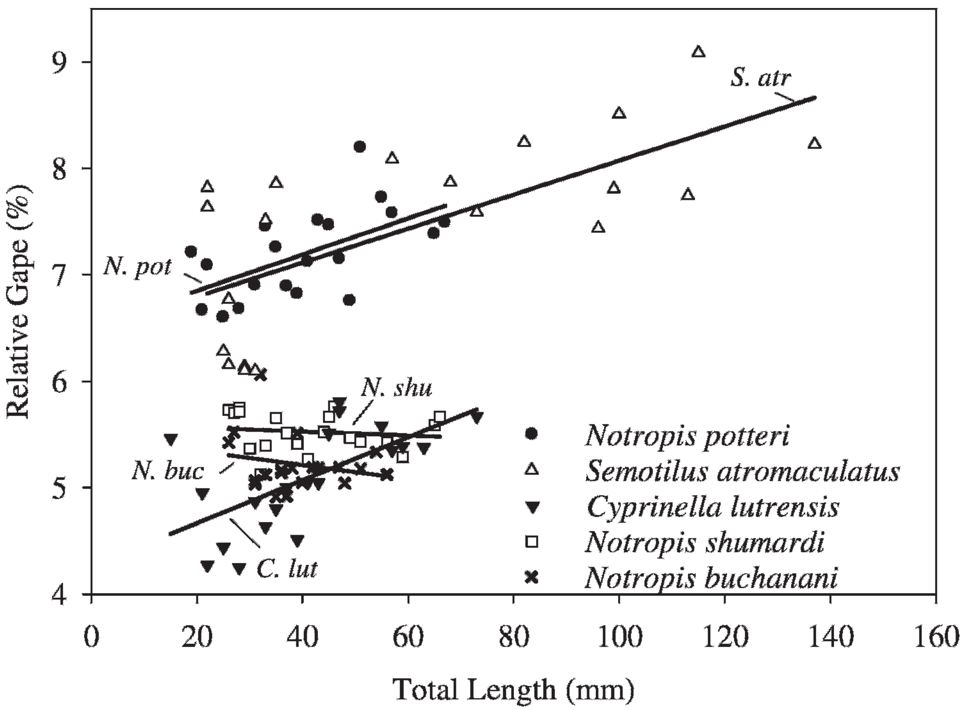

FIG. 3.—Relative gape (100*gape width/total length) comparisons for selected cyprinid species from the lower Brazos River. Relative gape width was measured as the distance between outer edges of the maxillary bone with the mouth closed and divided by total length to adjust for ontological growth

abundances were as high as 65–70%, yet in our recent collections the chub shiner was <0.03% of the relative abundance; additionally, other recent collections in the lower Brazos River report chub shiner relative abundance at zero (Li and Gelwick, 2005). In our recent collections from the Red River of Arkansas, chub shiner abundances were similar to those of historical records (*i.e.*, 20–35%) with an average abundance of 14% across all sites (Fig. 4).

Museum record evaluations produced a previously unpublished record from the Sam Noble Museum of Natural History reporting chub shiner in the Red River drainage. This record was submitted by Riggs and Dowell (1941; OMNH #26949) and reported the collection of two chub shiners in the Red River downstream of Denison Dam before its completion. William J. Matthews (University of Oklahoma) verified the identification of the two individuals as well as collection date and location to ensure accuracy. This collection was significant in that it pre-dated Hubbs and Bonham's (1951) proposed 1948 introduction of chub shiner to the Red River Basin.

DISCUSSION

Diet composition of chub shiner was consistent with that of piscivorous fishes. Percent weight of aquatic insects was greatest in small chub shiners but decreased as chub shiner length increased. In contrast, percent weight of fish and non-insect food items increased as chub shiner length increased, suggesting an ontological shift in diet. Furthermore, chub

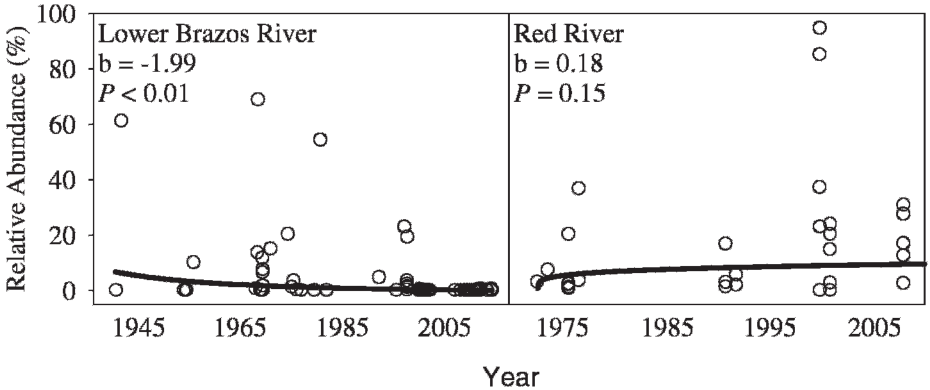

FIG. 4.—Relative abundances of chub shiner in the Lower Brazos River, Texas (with permission from Runyan, 2007) and Red River, Arkansas. Regression lines were plotted following log-transformation of relative abundances though relative abundances are shown as percentages

shiners consumed piscine prey at a young age (19 mm; age 0) as documented by Felley (1984). This pattern of ontological diet shifts from aquatic insects to piscine prey is common for piscivores, as is consumption of piscine prey at an early age (Fraser and Cerri, 1982; Keast, 1985; Juanes *et al.*, 2002). Piscivory among chub shiner in the lower Brazos River closely followed that of chub shiner in the Red River, including piscivorous feeding among small individuals and no apparent seasonal trend (Felley, 1984). Strictly piscivorous feeding by even large chub shiner is likely precluded by absolute gape limitations, nevertheless numerous characteristics of chub shiner favor piscivory.

Morphological and behavioral characteristics of chub shiner facilitate piscivorous feeding. Morphologically, gape sizes of chub shiners are larger than those of two sympatric *Notropis* and one *Cyprinella* invertivores. Instead, chub shiner gape size is similar to that of the creek chub, a piscivorous cyprinid that also exhibits ontological shifts in diet (Fraser and Cerri, 1982). Another morphological trait possibly evolving concurrently with piscivory is the medially enlarged dentary bones and posteriorly enlarged premaxillary of the chub shiner (Hubbs and Bonham, 1951; Douglas, 1974; Robinson and Buchanan, 1988), the latter being a distinguishing morphological characteristic (Douglas, 1974). Enlarged and strong upper and lower jaws are advantageous for a firm bite when consuming large prey (*i.e.*, fish; Gosline, 1973; Porter and Motta, 2004; Hulsey and Garcia De Leon, 2005). Behaviorally, piscivores pursue and ingest the whole body of their piscine prey head first (Simon, 1999; Juanes *et al.*, 2002; Porter and Motta, 2004). Chub shiners held in laboratory aquarium often pursued and ingested piscine prey (*i.e.*, western mosquitofish) head first (J. Perkin, pers. obs.). Likewise, whole bodies of piscine prey were found in the stomachs of chub shiners evaluated in this study. Although many members of the genus *Notropis* occasionally and opportunistically consume fish as prey (Starrett, 1950; Felley, 1984), our findings further support listings that chub shiner target piscine prey, and fish constitute a significant portion of dietary items (Goldstein and Simon, 1999).

The small number of chub shiners collected during this study further illustrates the declining status of the species within its native range. Our intensive sampling over a 2 y period produced only 145 individuals, a sample size that precluded comprehensive assessment of reproductive ecology and habitat associations. Historical abundances of chub shiner for both the Brazos and Red rivers indicated chub shiner dominated some collections (*e.g.*, 60% R.A. in the lower Brazos River and 80 to 90% R.A. in the Red River of Arkansas), yet were in lower abundances or absent from others. Such variation suggests chub shiner exhibit patchy distributions, at times appearing locally abundant. These locally abundant collections may represent preferred microhabitat; unfortunately, such data are not available for many museum collections. Despite locally abundant collections in the 1950s and 1960s, Runyan (2007) indicated a declining population in the lower Brazos River.

Decline of chub shiner in both the lower Brazos River and portions of the Red River is attributed to anthropogenic stream regulation. Runyan (2007) attributed decline of chub shiner, among other fishes in the lower Brazos River, to alterations in flow regime negatively affecting reproductive success. Similarly, Winston *et al.* (1991) found that chub shiner was extirpated from the North Fork of the Red River due to impoundment. Dam construction on the North Fork of the Red River effectively fragmented the chub shiner population, thereby isolating the sink population from the source population in the continually flowing lower North Fork and mainstem Red rivers (Winston *et al.*, 1991). There is nothing to suggest that the Brazos River chub shiner population operated as a source-sink dynamic before fragmentation of the mainstem channel; however, chub shiner has declined in abundance in the regulated middle and upper Brazos River as well (G. Wilde, Texas Tech University, pers. comm.). Decline throughout the Brazos River Basin suggests that if source populations once existed, they too might now be imperiled. As future demand for anthropogenic regulation of the Brazos River increases, impacts upon special concern species should be carefully considered and further investigated.

Chub shiner was recently listed as a species of special concern in Texas (Hubbs *et al.*, 2008). However, this is inconsistent with Warren *et al.* (2000), which lists the chub shiner as currently stable throughout its range. This contrast is likely due to the abundance of chub shiner in the Red River proper downstream of Denison Dam at Lake Texoma. Our sampling in Jan. of 2007 indicated chub shiner were in high abundance in the Arkansas stretch of the Red River. Similar high abundance of chub shiner in the middle Red River has been reported (*e.g.*, Suttkus and Clemmer, 1968; Conner, 1977) and is likely the source of the Warren *et al.* (2000) listing as currently stable. Such population stability in the middle Red River might be facilitated by the low occurrence of mainstem anthropogenic regulation (*i.e.*, only Denison Dam at Lake Texoma) and the size and abundance of tributaries downstream of Lake Texoma (*i.e.*, Muddy Boggy Creek, Blue River and Kiamichi River of Oklahoma and Little River of Arkansas). The low abundance of chub shiner in the Red River upstream of Denison Dam (Lienesch and Matthews, 2000; Gido *et al.*, 2002) is likely a case of habitat degradation and riverscape fragmentation as with Winston *et al.* (1991). Suttkus and Clemmer (1968) cited chub shiner as being the dominate species downstream of Denison Dam, and we found their numbers to still be high. Fragmentation of chub shiner moving from downstream of Lake Texoma to the upper Red River was indirectly documented by Riggs and Bonn (1959), who found that chub shiner were frequently collected in the tailwaters of Denison Dam during the spring.

The significant decline of chub shiner in the Brazos River of Texas strengthens the importance of determining whether the species is native to drainages outside of the Western Gulf Slope. Hubbs and Bonham (1951) originally described chub shiner native range as restricted to the Brazos River of Texas and postulated that bait-bucket releases were responsible for introductions into Lake Texoma and the Red River circa 1948, and subsequently the Mississippi and Atchafalaya river systems. The authors justified this conclusion by citing that Ortenburger and Hubbs (1927) and Hubbs and Ortenburger (1929a, b) did not collect a single specimen in their sampling of the Red River and many tributaries prior to 1948 (Hubbs and Bonham, 1951). Based on museum records we evaluated for the Red River, we agree with Miller's (1953) assertion that many sites sampled by Hubbs and Ortenburger have not produced chub shiner even to date. Furthermore, we have shown chub shiner occurred in the Red River before Hubbs and Bonham's (1951) proposed introduction date, acknowledging that one collection alone does not refute the idea that introductions occurred. Whereas there is no way to explicitly contradict bait-bucket introductions (Miller, 1953), we believe supporting evidence exists for chub shiner native status in the Red River Basin.

Suttkus and Clemmer (1968) concluded chub shiner were native to the Red River Basin following natural distribution mechanisms such as stream captures and tributary connections. Conner and Suttkus (1986) suggest that chub shiner, along with numerous other species, arose in the Red River Basin and were captured into western Gulf Slope drainages (*i.e.*, Colorado, Brazos and Trinity rivers) during early glacial times. This conclusion is further supported by collections of chub shiner in the Colorado (Jurgens, 1954) and Trinity (Conner, 1977) rivers. Occurrence of chub shiner in the Trinity River was not known at the time of proposed introduction to the Red River (Hubbs and Bonham, 1951: 108) and may have been a contributing factor to the conclusion of bait-bucket introduction. Available distributional evidence collectively suggests chub shiner is native to the Red River; however, further study may provide more conclusive support.

Further investigation into the biology of chub shiner is merited. Hendry *et al.* (1996) used allelic frequencies of two populations of sockeye salmon *Oncorhynchus nerka* to determine introduced and native status of each population. A similar study could be used to address the native status of chub shiner in the Red River Drainage. The locally abundant population of chub shiner in the Red River of Arkansas should be used to address the reproductive ecology of chub shiner. Our study in the lower Brazos River suffered from low abundances, but given the likely native status of chub shiner in the Red River, abundant populations could be sampled monthly to determine reproductive seasonality. Furthermore, reproductive mechanism of chub shiner from this location may well be determined following the methods of Platania and Altenbach (1998). This subject is of importance given reproductive mechanism may be a critical factor causing chub shiner decline in the lower Brazos River (Runyan, 2007).

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