

RFP No. 212f for Endangered Species Research Projects for the Prairie Chub

Final Report

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Summary

Four hundred mesohabitats were sampled from 36 sites and 20 reaches within the upper Red River drainage from September 2015 through September 2016. Fishes (N = 36,211) taken from the mesohabitats represented 14 families and 49 species with the most abundant species consisting of Red Shiner *Cyprinella lutrensis*, Red River Shiner *Notropis bairdi*, Plains Minnow *Hybognathus placitus*, and Western Mosquitofish *Gambusia affinis*. Red River Pupfish *Cyprinodon rubrofluviatilis* (a species of greatest conservation need, SGCN) and Plains Killifish *Fundulus zebrinus* were more abundant within prairie streams (e.g., swift and shallow runs with sand and silt substrates) with high specific conductance. Red River Shiner (SGCN), Prairie Chub *Macrhybopsis australis* (SGCN), and Plains Minnow were more abundant within prairie

streams with lower specific conductance. The remaining 44 species of fishes were more abundant in non-prairie stream habitats with shallow to deep waters, which were more common in eastern tributaries of the upper Red River drainage and Red River mainstem. Prairie Chubs comprised 1.3% of the overall fish community and were most abundant in Pease River and Wichita River. Relative abundances were similar to relative abundances from historical collections. Red River Shiners comprised 18% of the overall fish community and were most abundant within western tributaries of the upper Red River drainage. Red River Pupfish comprised 7.6% of the overall fish community and were most abundant within western saline portion of the upper Red River drainage.

Prairie Chubs and Red River Shiners are fast-growing, short-lived (up to age 2), and small body fishes. Reproductive seasons are from March through September with the greatest reproductive investment occurring May through July. Patterns in gonadal development and oocyte diameters in both species are consistent with multiple spawning reproductive strategy. Prairie Chubs and Red River Shiners primarily consumed aquatic and terrestrial insects.

High amount of genetic differentiation was detected between the Brazos River Shoal Chubs and the Red River Shoal Chub - Prairie Chub group. Relatively low genetic differentiation was found among Shoal Chubs taken from two the Brazos River sites and among Prairie Chubs taken from the Pease River, Wichita River, and upper Red River sites. Greater amounts of differentiation were found among sites farther apart, indicating that mainstem Red River sites upstream from Lake Texoma and mainstem Red River sites downstream from Lake Texoma were the most differentiated from Prairie Chubs taken from Pease River, Wichita River, and upper Red River sites. Hybridization was detected between Prairie Chubs and Shoal Chubs within the mainstem Red River upstream from Lake Texoma. Based on intermediate assignment

probabilities from ENTROPY ($k = 2, 3$, and 4) and PCA plots, individuals taken from Red River mainstem sites upstream from Lake Texoma had a wide range of assignment probabilities, indicating a complex hybrid zone (i.e. beyond the F1 hybrids) has formed.

I. Study objectives:

Objectives were 1) to quantify current habitats, fish distributions, and fish-habitat associations at site and reach scales within the upper Red River basin of Texas (i.e., main stem and tributaries upstream from Lake Texoma) and to compare current relative abundances of three fishes identified as Species of Greatest Conservation Need (SGCN; Prairie Chub, Red River Shiner, and Red River Pupfish) to historical relative abundances, 2) to describe univariate and multivariate habitat associations, growth, age groups, age group distributions (Prairie Chub only), food habits, and reproduction for Prairie Chub and Red River Shiner, 3) to assess genetic structure and diversity within Prairie and Shoal Chubs, and 4) to provide instream flow recommendations, following procedures established by Senate Bill 3 Environmental Flow Program, for Pease River, Wichita River, and Red River mainstem.

II. Methods

Longitudinal Surveys of upper Red River Fish Community and Habitats

Fish and habitat surveys of wadeable waters were conducted among 20 river reaches (i.e., named river or tributary) and 36 sites within the upper Red River drainage between September 2015 and September 2016 (Figure 1). Reaches were selected based on accessibility and to represent the diversity of streams and habitats within the upper Red River drainage, such as small western tributaries (e.g., Groesbeck Creek), small eastern tributaries (e.g., South Fish Creek),

small rivers (e.g., Pease River), and large rivers (e.g., Red River). Sites were selected based on accessibility within a reach and to capture upstream to downstream gradients in fish communities and habitats within small and large rivers. Therefore, only one site was sampled on most tributaries, and multiple sites were sampled on small and large rivers. Sites were sampled twice, once during the cool season (September through March) and again during the warm season (April through August), unless the stream was dry.

At each site, available habitats (i.e., riffle, run, pool, backwater, and eddy) were delineated and sampled in proportion to their availability. In smaller systems, single to multiple passes were made with a standard seine (3 m x 1.8 m, mesh size = 3.2 mm) or bag seine (5 m x 1.8 m, mesh size = 3.2 mm). Single passes were made when large number ($N > 100$) individuals were taken from a habitat (e.g., shallow backwater habitat with sand or silt substrate and no woody debris) on the first seine haul. Multiple passes were made if few individuals were taken in complex habitats (e.g., deep backwater with cobble substrates and woody debris). Multiple passes were made until no new species were taken. In larger systems (e.g., lower Little Wichita River, Red River), multiple long (> 100 m) hauls were made with bag seines in run habitats. Seine hauls were constrained to similar depths and current velocities. Deep runs were separated from shallow runs. Likewise, swift runs were separated from sluggish runs. In small and large systems (sites and habitats), effort was made until species and numbers of fishes captured were believed to be representative of the fishes available within wadeable waters at each habitat and at each site. A minimum of two hours was spent at most sites, with up to five hours spent at larger systems. Fishes taken from habitats were identified to species, and the first 30 individuals of a species were measured (i.e., total length, nearest mm). Voucher specimens, small fishes, and individuals lacking certainty in identification were anesthetized with a lethal dose of tricane

methanesulfonate and fixed in 10% formalin. Identification of all *Macrhybopsis australis* and *M. hyostoma* followed Eisenhour (2004), although genetics work in this study indicates hybridization of the two species. Otherwise, species were identified with keys and descriptions provided by Hubbs et al. (2008) and Thomas et al. (2008). Length and width of area sampled (e.g., long seine hauls) or length and width of habitats were measured. Substrate (i.e., clay, silt, sand, gravel, cobble, boulder, and bedrock), vegetation, and woody debris were visually or tactilely estimated and represented as a percent coverage of the total habitat area. Water depth (m) and current velocities ($\text{m}\cdot\text{s}^{-1}$) were estimated from three to five point estimates within a representative cross section of the habitat. Dissolved oxygen ($\text{mg}\cdot\text{l}^{-1}$), pH, specific conductance ($\mu\text{S}\cdot\text{cm}^{-1}$), and temperature ($^{\circ}\text{C}$) were measured at each site with YSI 556 multi-probe sonde.

Principal component analysis (PCA; SAS Institute, Cary, NC) was used to calculate linear combinations of habitat parameters for assessing variability among habitats. Qualitative parameters (e.g., habitat types) were denoted as binary numbers, whereas quantitative parameters (e.g., percent substrate and current velocity) were z-transformed (Krebs 1999). Resulting PCA loadings of axes I and II were plotted to express similarities and differences among habitats, and loadings were averaged for habitats within a reach to express similarities and differences among reaches. Renkonen similarity index (Renkonen 1938) was used to assess patterns in fish community similarities among reaches and to identify species related to reach-level similarity. Bray-Curtis similarity matrices (Primer v6, Primer-E Ltd) was used to construct fish community similarity dendrogram by reach. Fish community data by reach was used to calculate relative abundances for each species by site and reach. Relative abundances were compared to past collections and reaches reported by Wilde et al. (1996). Preliminary assessment of changes in relative abundances through time were assessed with diagnostics plots for most abundant SGCN

species. Fish densities also were calculated but not reported herein. Canonical correspondence analysis (CCA; Canoco 4.5) was used to assess patterns in habitat associations for upper Red River fishes. Total variation was partitioned into pure effects of physical parameters (i.e., qualitative and quantitative parameters used in PCA), season (i.e., cool and warm), and reach (Borcard et al. 1992), and Monte Carlo tests (1,000 permutations) were used to determine significance ($\alpha = 0.05$) of each pure effect.

Life History of Prairie Chubs and Red River Shiners

Prairie Chubs and Red River Shiners were collected monthly between February 2016 and January 2017 from three sites on the Pease River (i.e., FM 104, Hwy 6, Hwy 283) and two sites on the North Wichita – Wichita River (i.e., Hwy 6 and FM 1919). Sites on the Pease River were located within a continuous river reach (i.e., not separated by dams), and the Pease River is continuous with the Red River. Sites on the North Wichita – Wichita River were located within a continuous river reach; however, the two sites were discontinuous with downstream reach of the Wichita River because of Lake Kemp and Lake Diversion. At each site and date, multiple seine hauls were made to capture up to 10 Prairie Chubs (≥ 35 mm in total length; minimum length for sexual maturity in congenera Peppered Chub *M. tetranema*, Bonner 2000) and 10 Red River Shiners (> 24 mm in total length; Hubbs and Ortenburger 1929). Fishes were anesthetized with a lethal dose of tricane methanesulfonate and fixed in 10% formalin. When available, additional Prairie Chubs and Red River Shiners were measured (total length) and released.

In the laboratory, up to five females were selected, measured to the nearest mm, and weighed to the nearest mg for each site and month. Incision was made from the urogenital opening to isthmus. The esophagus was severed and the stomach, intestine, and ovaries were

removed. With the use of a dissecting scope, the stomach was severed from the intestine at the pyloric sphincter muscle, and ovaries were removed. The stomach wall was cut longitudinally from the sphincter muscle to the esophagus, carefully exposing the gut contents. Stomach fullness (i.e., proportion of stomach filled by contents) was determined by two independent observers, assigning a number from 0 (empty) to 100 (full) in increments of 10. Stomach contents were sorted and identified. Percent volume was defined as the volume of algae, invertebrate and vertebrate material, substrate, and plastics comprising the total volume of stomach fullness. Percent occurrence was defined as the number of fish with a food item identified to the lowest practical taxonomic level. Invertebrate and vertebrate material was counted by lowest practical taxonomic level to calculate relative abundance of each item.

Ovaries were weighed, and gonadosomatic index (GSI; $[\text{mass of ovaries} / \text{mass of fish}] \times 100$) was calculated for each fish. Ovaries were macroscopically categorized as 1) immature or resting ovaries with small, translucent oocytes; 2) developing ovaries with small (< 0.2 mm in diameter), translucent oocytes and small (< 0.5 mm) opaque oocytes indicating early stages of yolk deposition; 3) mature ovaries with small translucent oocytes, small opaque oocytes, and large (> 0.5 mm in diameter) vitellogenic oocytes; and 4) spent ovaries with small translucent oocytes and a few large vitellogenic oocytes (Williams and Bonner 2006). The left ovary of up to three females with mature ovaries were selected, and individually oocytes were removed by teasing oocyte mass apart and redistributing them on a petri dish with a gentle swirling. Oocyte diameters were measured for oocytes > 0.2 mm to the nearest 0.01 mm for the first 100 oocytes in the field of view with dissection microscope fitted with an ocular micrometer. Oocyte diameters were plotted by percent frequency of occurrence to estimate number of modality of clutch production (i.e., single spawning or multiple batch spawning), maximum oocyte diameter

size, and range of oocyte diameters for the final batch of oocytes. Minimum oocyte diameters for the final batch was 0.8 mm for Prairie Chub and 0.6 mm for Red River Shiner. Minimum oocyte diameter was used in all other mature females (left side only and doubled) to estimate batch fecundity. Only range of batch fecundity was reported to indicate reproductive potential of Prairie Chub and Red River Shiner. Batch fecundity estimates of multiple spawning fishes are underestimations of spawning season fecundity.

Habitat associations were assessed from PCA model developed for the longitudinal survey of upper Red River fish community and habitats. Habitat PC axes I and II scores with Prairie Chub and Red River Shiner occurrences were compared to habitat PC scores without Prairie Chub or Red River Shiner occurrences, individually, with t-tests. Association between numbers of Prairie Chubs and Red River Shiners with $\log_{10}(N+1)$ transformation (i.e., dependent variable) and habitat PC axes I and II scores (i.e., independent variables) were assessed with linear regression. Habitat type, water depth, current velocity, and specific conductance were identified as indicators of fish community segregation with CCA. As such, occurrences and abundances of Prairie Chubs and Red River Shiners were assessed among habitat types with Chi-square test and among depth, current velocity, and specific conductance gradients with a Kolmogorov-Smirnoff (KS) tests. Significance was set at $\alpha = 0.05$ for each test.

Length frequency histograms were constructed from monthly collections of Prairie Chub and Red River Shiner using 2-mm bin increments combined across sites to assess number of age groups within each population and life span. Modal progression analysis (Bhattacharya's Method; Fish Stock Assessment Tools II; FiSAT II) was used to estimate the number of age groups and their sizes monthly between February 2016 and January 2017. Birth date follows conventional standard of January 1. Age-0 fish were spawned in 2016, age-1 fish were spawned

in 2015, and age-2 fish were spawned in 2014. Analysis of growth increments (Appeldoorn's Method; FiSAT II) was used to estimate growth rates of Prairie Chub and Red River Shiner. Asymptotic length (L_{∞}) maximum was set at 5 mm larger than reported maximum length to account for larger fish within the population.

Population Genetic Structure of the Prairie Chub

Prairie Chubs and Shoal Chubs were collected with seines from 15 sites within the Red River and Brazos River drainages (Figure 2), anesthetized with a lethal dose of tricaine methanesulfonate, and stored in 95% ethanol. Sample sizes and coordinates of each site are reported in Table 1. In the laboratory, DNA was extracted from fin clips taken from a total of 368 individuals in 96-well format using Qiagen DNEasy blood and tissue extraction kits and prepared for genotyping. For each individual, a reduced-complexity genomic library was prepared for genotyping by sequencing protocols modified from Meyer and Kircher (2010), Gompert et al. (2012), Parchman et al. (2012), and Mandeville et al. (2015). DNA from each individual was digested with the restriction enzymes EcoRI and MseI (New England Biolabs; NEB, Inc.). Fragments were labeled by ligating 8-10 base pair (bp) barcodes to the fragmented DNA. Two separate rounds of polymerase chain reaction (PCR) were performed on these restriction-ligation products using Illumina primers, and the final PCR products were pooled into a single library. This library was then sent to the University of Texas Genomic Sequencing and Analysis Facility (Austin, TX, USA), and two lanes were sequenced on an Illumina HiSeq 4000 SR 1x 100 platform after size selection between 300 and 400 bp via Blue Pippin. Sequence reads were ultimately processed to remove barcode and adapter sequences and reads of 20-136 bp were ultimately produced.

Because a reference genome is not available for *Macrhybopsis*, a de novo assembly was formed using dDocent de novo assembly. Allele frequencies were estimated directly from genotype likelihood estimates. A minimum of 50% of all sampled fish must have had at least one read at a particular single nucleotide polymorphisms (SNP), and a minor allele frequency of > 0.05 was necessary in order to be included in the analysis. A single SNP was randomly chosen from each consensus sequence, and in all, genotype likelihood data were obtained for a total of 39,124 SNPs.

To examine the genetic structure of *Macrhybopsis* and to identify the extent to which hybridization and introgression is occurring among species in the Red River drainage, population genetic parameters were estimated using ENTROPY (Gompert et al. 2014; Mandeville et al. 2015). ENTROPY is a hierarchical model whereby an individual's assignment probability to each of any number of pre-assigned populations is estimated in a Bayesian framework. Models with different numbers of populations (k) were compared. Posterior distributions of genotypes and admixture proportions were calculated for k ranging from 2 to 4 using Markov Chain Monte Carlo (MCMC) with 100,000 iteration chains, discarding the first 5,000 chains and then sampling every 10th chain; each k was run twice, and the genotype and admixture proportions were averaged across both runs. Principal Component Analysis (PCA) was performed using Program R. Assignment probabilities were determined for each individual with ENTROPY and were plotted in Program R. Pairwise G_{ST} and allele frequencies were performed in Program R, and genetic diversity indices (π and θ) were calculated with SAMTools. Mantel's test was utilized to assess isolation by distance using Program R.

Instream flow recommendations

Three reaches were selected for instream flow recommendations because the reaches were among reaches with highest numbers of Prairie Chubs and flows within the reaches were monitored by USGS for at least 40 years. Pease River USGS Station (07308200, near Vernon, TX) period of record was 1959 through 2017 but with missing daily records between 1982 to 1992. Wichita River USGS Station (07311900, near Seymour, TX) period of record was 1959 through 2017 but with missing dates between 1979 to 1996. Red River USGS Station (07315500, near Terrell, TX) period of record was 1938 to 2017. Daily data were processed through Indicator of Hydrological Alterations (IHA) to separate the hydrograph into individual flow components. Individual flow components were processed through Hydrology-based Environmental Flow Regime (Opdyke et al. 2014). Subsistence flows $< 1 \text{ ft}^3/\text{sec}$ were rounded up to $1 \text{ ft}^3/\text{sec}$.

III. Results

A. Upper Red River habitats and fish community

Habitats

Thirty-six sites among 20 reaches were sampled within the upper Red River drainage. Habitats (N = 400) among sites primarily consisted of runs (70%) and pools (12%). Mean (± 1 SE) depths among sites was $0.3 (\pm 0.3) \text{ m}$ and ranged from 0.02 to 1.6 m. Mean current velocity among sites was $0.2 (\pm 0.2) \text{ m}\cdot\text{s}^{-1}$ and ranged from 0 to $0.9 \text{ m}\cdot\text{s}^{-1}$. Specific conductance ranged from 115 to 49,968 $\mu\text{S}\cdot\text{cm}^{-1}$ with greater specific conductance observed in the western portion of the study area and lower specific conductance observed in the eastern portion of the study area. Dominate substrate comprised of sand (57%), silt (30%), and gravel (9%). Woody debris,

detritus, and aquatic vegetation were rare among habitats and sites. See Appendix A for habitat parameters by site.

Principal component axes I and II explained 24% of the variation among the 400 habitats. Axis I explained 13% of the variation and represented habitat type (i.e., pool and run) and substrate gradients. Strongest loadings for PC axis I were pool (0.33), silt (0.30), run (-0.46), and sand (-0.45) (Figure 3). Axis II explained 11% of the variation and represented a habitat type (i.e., riffle and backwater), substrate, and current velocity gradients. Strongest loadings for PC axis II were riffle (0.42), gravel (0.40), current velocity (0.39), and silt (-0.37). Mean PC I scores, averaged across habitats and sites for each reach, ranged between -2.30 for North Fork Red River to 3.83 for Pecan Creek, contrasting prairie-type streams with shallow to moderate depths, flowing run and pool habitats with sand and silt substrates (negatively associated with PC I) versus more entrenched channel streams, common to eastern tributaries within the upper Red River drainage, with predominantly run and pool habitats with shallow to deep depths, sluggish current velocities except in riffle habitats, and silt and gravel habitats.

Fish community

A total of 36,211 fishes were taken, representing 14 families and 49 species of fishes. Most abundant family was Cyprinidae (71% in relative abundance), followed by Poeciliidae (8.9%), Cyprinodontidae (7.6%), and Fundulidae (3.6%). Most abundant species were Red Shiner *Cyprinella lutrensis* (26%), followed by Red River Shiner *Notropis bairdi* (18%), Plains Minnow *Hybognathus placitus* (14%), and Western Mosquitofish *Gambusia affinis* (9.0%) (Table 2). In addition to Red River Shiner, relative abundances of other Texas Species of greatest conservation need (SGCN) were 7.6% for Red River Pupfish *Cyprinodon*

rubrofluvialis, 1.3% for Prairie Chub *Macrhybopsis australis*, 0.01% for Silver Chub *M. storeriana*, and <0.01% for Goldeye *Hiodon alosoides*. Relative abundance was 0.3% for non-native fishes (Common Carp *Cyprinus carpio*, Gulf Killifish *Fundulus grandis*, Striped Bass or hybrid *Morone saxatilis*, and Redbreast Sunfish *Lepomis auritus*).

Among 20 river reaches, most ubiquitously distributed fishes were Western Mosquitofish, taken from 19 reaches, followed by Red Shiner (18 reaches), Green Sunfish *Lepomis cyanellus* (13 reaches), and Bluegill *Lepomis macrochirus*, Longear Sunfish *Lepomis megalotis*, and Largemouth Bass *Micropterus salmoides* (12 reaches each) (Appendix B). Ten species were taken only from one river reach. Among SGCN fishes, most ubiquitously distributed fishes were Red River Shiner (8 reaches), Red River Pupfish (8 reaches), and Prairie Chub (6 reaches). Mean (± 1 SE) Renkonen similarity index (RSI) was 23.5% (1.59) among all pairwise comparisons. Greatest mean RSI was Adams Creek (36%), and lowest mean RSI was China Creek (4.3%). Adams Creek was dominated by the two most ubiquitously distributed fishes (i.e., Western Mosquitofish and Red Shiner), whereas China Creek was dominated by Bluegill and consisted of only two other species (i.e., Fathead Minnow *Pimephales promelas* and Common Carp *Cyprinus carpio*). Clustering based on Bray-Curtis dissimilarity separated reaches into two primary groups (Group I and II; Figure 4). Fish communities within Group I consisted primarily of Red Shiners and Western Mosquitofish with no to rare occurrences of Red River Shiner, Prairie Chub, Plains Minnow, Plains Killifish, and Red River Pupfish. Three of seven streams had prairie-stream type habitats and all were consisted of specific conductance < 3,500 $\mu\text{S}\cdot\text{cm}^{-1}$. Fish communities within Group II usually consisted of Red Shiner and Western Mosquitofish, sometimes in great abundances as in Adams Creek and Groesbeck Creek, but typically consisted of Red River Shiner, Prairie Chub, Plains Minnow, Plains Killifish, and Red

River Pupfish. Eight of the 10 reaches had prairie-stream type habitats and all but one reach (i.e., Mountain Creek) had specific conductance $> 3,500 \mu\text{S}\cdot\text{cm}^{-1}$.

Among 36 sites, most ubiquitously distributed fishes were Red Shiner (30 sites), Western Mosquitofish (30 sites), Red River Shiner (21 sites), and Green Sunfish (20 sites) (Appendix C). Nine species were taken only from one site. In addition to Red River Shiner, numbers of occurrence for SGCN species were 16 sites for Prairie Chub, 14 sites for Red River Pupfish, and 1 site each for Goldeye and Silver Chub. Greatest mean (± 1 SE) relative abundances among sites were 28% (5.2) for Red Shiner, 13% (3.8) for Red River Shiner, 12% (3.7) for Western Mosquitofish, 7.8% (2.29) for Plains Minnow *Hybognathus placitus*, and 7.3% (3.7) for Red River Pupfish. Among remaining SGCN species, mean (± 1 SE) relative abundances among sites were 1.2% (0.51) for Prairie Chub and $<0.01\%$ (<0.01) for Goldeye and Silver Chub.

Fish-habitat associations

Axes I and II from CCA analysis explained 43% ($P < 0.01$) of the variability within the Red River fish community (Figure 5a & b). Pure effects of reach explained 17% ($P < 0.01$), physical parameters explained 13% ($P < 0.01$), and season explained $<1\%$ ($P < 0.01$) of community variation. Shared effects (two- and three-way interactions) among reach, physical parameters, and season accounted for 13% of the community variation. Environmental parameters strongly associated with CCA axis I were specific conductance (-0.77), Prairie Dog Town Fork (-0.42), mean depth (0.48), and South Fish Creek (0.50). Environmental parameters strongly associated with CCA axis II were Red River (-0.41), specific conductance (0.41), and South Fish Creek (0.64). Among fishes with $>1\%$ in overall relative abundance, Red River Pupfish and Plains Killifish were associated with greater specific conductance in Prairie Dog

Town Fork and Pease River, and Red River Shiner, Plains Minnow, and Prairie Chub were associated with moderate specific conductance, run habitats with swifter current velocities, and sand substrates. Gizzard Shad, Red Shiner, Emerald Shiner, Ghost Shiner, Bullhead Minnow, and Mississippi Silverside, which collectively were numerically most abundant in Red River, Wichita River, and Little Wichita River, were associated with lower specific conductance, moderate current velocities, and deep water habitats. Western Mosquitofish and Bluegill were associated with lower specific conductance, slack water, and pool habitats. Remaining fishes were generally associated with lower specific conductance, low to swift current velocities, and deeper habitats.

Specific conductance strongly influenced species segregation along CCA axes I and II. Mean (± 1 SD) specific conductivity based on occurrence among all habitats was 17,700 ($13,700$) $\mu\text{S}\cdot\text{cm}^{-1}$. Mean (± 1 SD) specific conductivity based on occurrence ranged between 14,900 ($7,580$) $\mu\text{S}\cdot\text{cm}^{-1}$ for Prairie Chub to 30,100 ($12,890$) $\mu\text{S}\cdot\text{cm}^{-1}$ for Red River Pupfish among fishes with $> 1\%$ in relative abundance and moderate to strong positive association with specific conductance (Figure 6). Mean (± 1 SD) specific conductivity ranged between 6,700 ($3,340$) $\mu\text{S}\cdot\text{cm}^{-1}$ for Bluegill to 11,600 ($8,580$) $\mu\text{S}\cdot\text{cm}^{-1}$ for Western Mosquitofish among fishes with $> 1\%$ in relative abundance and moderate to strong negative association with specific conductance. Sites with specific conductance $> 15,000$ $\mu\text{S}\cdot\text{cm}^{-1}$ at the time of measurement were within Prairie Dog Town Fork, Red River (upper), Pease River (upper), North Pease River, North Wichita River reaches. Collectively, these sites were within the western range of the study area also consisted of swift to moderate current velocities with sand to silt substrates. Sites with specific conductance ≤ 3000 $\mu\text{S}\cdot\text{cm}^{-1}$ were within the Red River (e.g., I-35) and tributaries within the eastern range of the study area. However, three western range reaches (i.e., Adams

Creek, Wonderers Creek, and North Fork of Red River) have specific conductance of $\leq 3000 \mu\text{S}\cdot\text{cm}^{-1}$. Sites and reaches with specific conductance of $\leq 3000 \mu\text{S}\cdot\text{cm}^{-1}$ consisted of a mix of swift water run and riffle habitats to slack water pools with silt, sand, and gravel substrates.

Historical perspectives: Prairie Chub, Red River Shiner, Red River Pupfish

Contemporary collections were added to historical collections reported by Wilde et al. (1996) for eight unique reaches of upper Red River drainage (Appendix D). To date, only trends in the most abundant SGCN species Prairie Chub, Red River Shiner, and Red River Pupfish were assessed by plotting relative abundances across decades (1920 to 2010; 2016 – 2017 data reported herein is represented in 2010). Mean relative abundance (± 1 SE) among all reaches was 1.7% (0.43; range: 0 – 12%) for Prairie Chub. Decreasing trends were observed in the Prairie Dog Town Fork and Red River (including Hwy 6, Hwy 283, and Hwy 183) reach and in the North Red River reach (Figure 7). Increasing trends were observed in the North Wichita River, Middle Wichita River, and Red River (Hwy 79 to Lake Texoma). Mean relative abundance (± 1 SE) among all reaches was 9.8% (1.8; range: 0 – 53%) for Red River Shiner. Decreasing trend was observed, although variable, in the Prairie Dog Town Fork and Red River (including Hwy 6, Hwy 283, and Hwy 183) reach. Increasing trends were observed in the Upper Pease River reach and in the North Wichita River. Mean relative abundance (± 1 SE) among all reaches was 9.5% (2.5; range: 0 – 84%) for Red River Pupfish. Decreasing trends were observed in Upper Pease River reach.

Relative abundances of SGCN species from historical collections (1950 – 1990) and contemporary (2016 – 2017) were assessed within fragmented reaches of the Wichita River, upstream and downstream of Lake Kemp (impounded in 1923) and Lake Diversion (impounded

in 1924). Historical relative abundances at Hwy 6 on the North Wichita River (i.e., upstream from Lake Kemp) ranged from 0 to 9.4% for Prairie Chub, 0.5 to 68% for Red River Shiner (excluding a 100% relative abundance taken from a Total N = 10 collection), and 0 to 57% for Red River Pupfish; contemporary relative abundances were 9.6% for Prairie Chub, 37% for Red River Shiner, and 3.6% for Red River Pupfish. Historical relative abundances at FM 1919 on the Wichita River (i.e., upstream of Lake Kemp) ranged from 5.6 to 9.8% for Prairie Chub, 2.1 to 2.9% for Red River Shiner, and 0.3 to 0.7% for Red River Pupfish; contemporary relative abundances were 14% for Prairie Chub, 11% for Red River Shiner, and 1.2% for Red River Pupfish. Historical relative abundances at Hwy 283 on the Wichita River (i.e., between Lake Kemp and Lake Diversion) ranged from 0.2 to 8.2% for Red River Shiner and 1 to 2.6% for Red River Pupfish; contemporary relative abundance was 0% for Red River Shiner and Red River Pupfish. Historical relative abundances among sites downstream from Lake Diversion on the Wichita River ranged from 0 to 0.2% for Prairie Chub, 0.2 to 3.3% for Red River Shiner, and 0.6 to 1.7% for Red River Pupfish; contemporary relative abundances ranged from 0.1 to 0.2% for Prairie Chub and 1.1 to 2.2% for Red River Shiner.

B. Prairie Chub life history

Habitat associations

From upper Red River fish community surveys, Prairie Chubs (N = 486) were taken from 51 (13%) of 400 mesohabitats, 16 (44%) of the 36 sites, and 6 (30%) of the 20 reaches. Habitats with Prairie Chub occurrences were not associated with PC axis I (t-test; $t_{0.05(2), 398} = 0.42$, $P = 0.67$) or PC axis II ($t_{0.05(2), 398} = 0.37$, $P = 0.67$) (Figure 8). Likewise, habitats with Prairie Chub abundances were not associated with PC axis I (linear regression; $F_{1,398} = 0.14$, $P = 0.71$) or PC

axis II ($F_{1,398} = 0.13$, $P = 0.72$). Habitats among the six reaches with Prairie Chubs did not differ from habitats among 14 reaches without Prairie Chubs for PC I (t-test; $t_{0.05(2), 398} = 1.80$, $P = 0.07$) but differed for PC II (t-test; $t_{0.05(2), 398} = 3.25$, $P < 0.01$). Reaches with Prairie Chubs generally consisted more of swifter waters (i.e., prairie-type streams common in Red River and western tributaries) than reaches without Prairie Chubs, which consisted of more slow-moving pools with silt substrates within the eastern tributaries of the upper Red River drainage. However, Prairie Chubs were not taken from several prairie-type streams (i.e., negative reach scores on PC I). Prairie Chubs were not detected in Prairie Dog Town Fork, Salt Fork Red River, North Fork Red River, Adams Creek, or Cottonwood Creek.

Prairie Chubs were taken more often in run (76%) and riffle (10%) habitats than available (70% runs, 9% riffles) and less often in pool (8%) and backwater (6%) habitats than available (12% pools, 9% backwater; Chi-square, $X^2 = 16.8$, $P < 0.01$). Prairie Chub occurrences among current velocities ranged between 0 and $0.6 \text{ m}\cdot\text{s}^{-1}$ with 66% of Prairie Chubs captured between 0 and $0.2 \text{ m}\cdot\text{s}^{-1}$. Use of slower current velocities did not differ from expected for Prairie Chub occurrences ($KS = 0.12$, $P > 0.05$), but differed for abundances ($KS = 0.24$, $P < 0.01$) (Figure 9). Prairie Chub occurrences among water depths ranged between 0.04 and 1.2 m with 88% of Prairie Chubs captured between 0.1 and 0.4 m. Use of shallow water depths differed from expected for Prairie Chub occurrences ($KS = 0.22$, $P < 0.05$) and abundances ($KS = 0.20$, $P < 0.01$). Prairie Chubs occurrences among specific conductance ranged between 2,215 and 26,408 $\mu\text{S}\cdot\text{cm}^{-1}$ with 77% of Prairie Chubs captured between 10,000 and 20,000 $\mu\text{S}\cdot\text{cm}^{-1}$. Use of moderately high specific conductance differed from expected for Prairie Chub occurrences ($KS = 0.19$, $P < 0.05$) and abundances ($KS = 0.28$, $P < 0.01$).

Age Classes

Among monthly collections at three sites on the Pease River and two sites on the Wichita River, a total of 1,295 Prairie Chubs were taken between February 2016 and January 2017. Within the time frame, Prairie Chubs consisted of three age classes: Age 0, Age 1, and Age 2 (Figure 10). Age-2 fish represented 11% of the adult population, were observed February through August 2016, and reached a maximum total length of 67 mm. Age-1 fish represented 89% of the adult population and were observed year-round. Age-0 fish were first observed in July 2016 and reached a mean length of $40 (\pm 4)$ mm TL by December 2016 (i.e., end of Age 0). Growth rate was $k = 1.146 \text{ year}^{-1}$ and $L_{\infty} = 75 \text{ mm}$.

Age group distribution among sites

Among the 1,295 Prairie Chubs, 569 Prairie Chubs were captured from the Pease River. Within the upper site (Farm to Market 104) of the Pease River, Prairie Chubs were absent between March and April and again October through December corresponding with specific conductance $> 26,000 \mu\text{S}\cdot\text{cm}^{-1}$ (Figure 11). All age groups of Prairie Chubs were observed during the period between June and September, which followed rainfall, flow pulses, and lower ($< 26,000 \mu\text{S}\cdot\text{cm}^{-1}$) specific conductance. Within the middle site (Hwy 6), age-2 and age-1 fish were observed March through May and absent in June, corresponding with a flow pulse. Age-2 (August only), age-1, and age-0 fish were observed during the period of July through December. Specific conductance ranged between 1,731 and $25,725 \mu\text{S}\cdot\text{cm}^{-1}$ at the middle site. Within the lower site (Hwy 283), age-2 and age-1 fish were observed March through May and absent in

June, corresponding with a flow pulse. Age-0 fish were the only age group observed July and through August, followed by age-1 and age-0 fish between October and December. Specific conductance ranged between 2,722 and 20,715 $\mu\text{S}\cdot\text{cm}^{-1}$ at the lower site.

Among the 1,295 Prairie Chubs, 726 Prairie Chubs were taken from the Wichita River. Within the upper site (North Wichita River-Hwy 6), age-2 and age-1 fish were observed during the period February through July (Figure 12). Age-1 and age-0 fish were observed during the period of August and December. Specific conductance ranged between 3,878 and 25,257 $\mu\text{S}\cdot\text{cm}^{-1}$ at the upper site. Within the lower site (FM 1919), age-2 and age-1 fish were observed during the period February through May and absent in June, corresponding with a flow pulse. All age groups were observed during the period July through December. Specific conductance ranged between 4,186 and 21,377 $\mu\text{S}\cdot\text{cm}^{-1}$ at the lower site.

Gonadal development and GSI

A total of 193 Prairie Chubs were taken for reproductive assessments between February 2016 through January 2017. Prairie Chubs invested energy into reproduction (i.e., reproductive season) between the months of March through September (Figure 13). Ovaries from adult fishes ($N = 70$; range in total length [TL]: 40 - 61 mm) were taken between October through January and classified as immature or resting. Developing ovaries were observed in nine females (40 – 61 mm in TL) in March and were observed through September. Mature ovaries ($N = 64$; 38 – 66 mm in TL) were observed from May through September (i.e., spawning season).

Mean monthly GSI for Prairie Chub females corresponded with stages of ovarian development. Mean monthly GSIs were greatest (13 to 14%) May through July. Female GSI with immature or resting ovaries ranged between 0.2 to 3.6%. Female GSI with developing

ovaries ranged between 0.9 to 8.8%. Female GSI with mature ovaries ranged between 6.0% to 23%.

Size distribution of oocytes taken from one female per month with mature ovary indicated continuous recruitment of oocytes (Figure 14). Maximum size of a vitellogenic oocyte was 1.24 mm. Batch fecundity ranged from 30 to 448 late vitellogenic oocytes (diameter: 0.80 - 1.24 mm) among 21 females with mature ovaries.

Food Habitats

A total of 197 Prairie Chubs were examined for diet analysis from February 2016 through January 2017. Gut content by volume consist of aquatic invertebrates, terrestrial invertebrates, and vertebrates (99%), clay or silt (0.7%), filamentous algae (0.2%), sand (0.2%), and plastic (< 0.1%) (Table 3). Mean (\pm 1 SD) monthly gut fullness ranged from 4.6% (\pm 7.6) in November 2016 to 65% (\pm 41.1) in May 2016. Frequency of empty stomachs was 4.5%.

The most frequently occurring gut contents were Chironomidae (88% occurrence), sand (37%), clay or silt (14%), and Diptera pupa (11%). Chironomidae occurred in Prairie Chubs stomachs year-round with monthly occurrences ranging from 70% in December 2016 to 100% in July 2016. Among aquatic invertebrates, terrestrial invertebrates, and vertebrates, Chironomidae was the most abundant food item (95%) followed by Diptera pupa (2%). Eight other aquatic invertebrate taxa were consumed but at low (<1%) relative abundance. Likewise, terrestrial invertebrates and parts of vertebrates (e.g., fish scales) were consumed but at low relative abundance.

C. Prairie Chub population genetics

Genotype likelihood estimates were calculated for all SNPs for each individual. Highest π diversity levels were found in the mainstem Red River sites upstream from Lake Texoma, followed by the Wichita and Pease Rivers, with the lowest observed in the Brazos River (Table 1; Figure 15). Highest θ diversity levels were found in the Brazos River sites, with all other sites being relatively close. Highest amount of genetic differentiation was found between the Brazos River sites and all the Red River drainage sites, followed by the site downstream from Lake Texoma (RR_259) and the Pease and Wichita River sites (Table 4). There was lower relative genetic differentiation between the Pease and Wichita River sites and between mainstem Red River sites.

Admixture proportions for each individual calculated at k equals 2, 3, and 4 are provided in Figure 16. For $k = 2$, Shoal Chubs from Brazos River were separated from Shoal Chubs-Red River drainage and Prairie Chubs. At $k = 3$, the two Brazos River Shoal Chub sites separated from every other sites sampled, and all the individuals sampled from the site downstream from Lake Texoma, RR_259 were grouped in one cluster with high probability. The third cluster consisted of individuals from the Wichita, Pease, and upstream Red River sites which corresponds with the Prairie Chub. Shoal and Prairie Chubs collected from RR_79 downstream to the site just upstream from Lake Texoma (RR_35) are hybridizing, with a majority of the individuals from these sites having intermediate assignment probabilities, indicating a complex hybrid zone. For $k = 4$, the plot closely resembles $k = 3$, though no individuals have high assignment probability to the fourth cluster; the fourth cluster appears in the Prairie Chubs and hybrid individuals.

Three primary groups were observed within the PCA plot, corresponding to assignment probabilities of $k = 3$ (i.e., (1) Brazos River sites, (2) Pease River, Wichita River, and upper Red

River sites, and (3) mainstem Red River sites and the Red River site downstream from Lake Texoma; Figure 17). PC axis I explained 43% of the variation and described a gradient between Brazos River (i.e., negative scores on PC I) and Red River drainage (i.e., negative to positive scores on PC I). PC axis II explained 7% of the variation and described a gradient between Pease River, Wichita River, and upper Red River sites (i.e., negative scores on PC II) and Red River sites downstream from Lake Texoma (i.e., positive scores on PC II). Individual fishes outside of the three primary groups suggest hybrids between Prairie Chubs and Red River Shoal Chubs. Within the Red River basin, isolation by distance is present with genetic differentiation increasing ($r = 0.51$, $P < 0.01$) as sites are further apart (Figure 18).

Currently, we are running an additional plate with more *M. australis* and *hyostoma* from other sites in the Red River basin. Also on the plate are individuals from the entire *Macrhybopsis* complex (*M. tetranima*, *aestivalis*, and *marconis*) of Texas. We are processing *M. tetranima* from the Canadian River, *M. aestivalis* from the Rio Grande, *M. marconis* from the Guadalupe River, and *M. hyostoma* from the Colorado River. This will allow us to assess genetic structuring and diversity of the entire complex, and give us insight into the relationship and speciation of the species in the complex.

C. Red River Shiner life history

Habitat association

From upper Red River fish community surveys, Red River Shiners ($N = 6,387$) were taken from 185 (46%) of 400 mesohabitats, 21 (58%) of the 36 sites, and 8 (40%) of the 20 reaches. Habitats with Red River Shiner occurrences were associated with PC axis I (t-test, $t_{0.05(2), 398} = 3.11$, $P < 0.01$) but were not associated with PC axis II (t-test, $t_{0.05(2), 398} = 0.09$, $P =$

0.93) (Figure 19). However, habitats with Red River Shiner abundances were not associated with PC axis I (linear regression; $F_{1,398} = 0.64$, slope = -0.015, $P = 0.42$) or PC axis II ($F_{1,398} = 0.08$, slope = -0.006, $P = 0.78$). Habitats among the eight reaches with Red River Shiners differed from habitats among 12 reaches without Red River Shiners for PC I (t-test, $t_{0.05(2), 398} = -9.80$, $P < 0.01$), but did not differ for PC II (t-test, $t_{0.05(2), 398} = -0.79$, $P = 0.43$). Reaches with Red River shiners generally consisted more of swifter waters (i.e., prairie-type streams common in Red River and western tributaries) than reaches without Red River Shiners, which consisted of more slow-moving pools with silt substrates within the eastern tributaries of the upper Red River drainage. However, Red River Shiners were not taken from several prairie-type streams (i.e., negative reach scores on PC I). Red River Shiners were not detected in North Fork Red River, Adams Creek, or Cottonwood Creek.

Red River Shiners were taken more often in run (74%) and riffle (10%) habitats than available (70% runs, 9% riffles) and less often in pool (7%) habitats than available (12% pools; Chi-square, $X^2 = 17.4$, $P < 0.01$). Red River Shiner occurrence among current velocities ranged between 0.1 and 1.6 $\text{m}\cdot\text{s}^{-1}$ with 90% of Red River Shiners captured between 0.1 and 0.7 $\text{m}\cdot\text{s}^{-1}$. Use of slower current velocities did not differ from expected for Red River Shiner occurrence ($KS = 0.08$, $P > 0.05$), but differed for abundances ($KS = 0.16$, $P < 0.01$) (Figure 20). Red River Shiner occurrences among water depths ranged between 0.01 and 1.5 m with 96% of Red River Shiners captured between 0 and 0.5 m. Use of shallow water depths did not differ from expected for Red River Shiner occurrence ($KS = 0.03$, $P > 0.05$), but differed for abundances ($KS = 0.13$, $P < 0.01$). Red River Shiner occurrence among specific conductance range between 2,215 and 38,420 $\mu\text{S}\cdot\text{cm}^{-1}$ with 73% of Red River Shiners captured between 2,500 and 27,500 μcm^2 . Use

of moderate to moderately high specific conductance differed from expected for Red River Shiner occurrence ($KS = 0.24$, $P < 0.01$) and abundance ($KS = 0.34$, $P < 0.01$).

Age Classes

Among monthly collections at three sites on the Pease River and two sites on the Wichita River, 2,342 Red River Shiners were taken between February 2016 and January 2017. Within the time frame, Red River Shiners consisted of three age classes: Age-0, Age-1, Age-2 (Figure 21). Age-2 fish represented 7% of the adult population, were observed February through August 2016, and reached a maximum total length of 74 mm. Age-1 fish represented 93% of the adult population and were observed every month except December 2016. Age-0 fish were first observed in July 2016 and reached a mean length of $36 (\pm 7)$ mm TL by December 2016. Growth rate was $k = 0.636 \text{ year}^{-1}$ and $L_{\infty} = 85 \text{ mm}$.

Gonadal development and GSI

A total of 260 Red River Shiners was taken for reproductive assessments between February 2016 through January 2017. Red River Shiners invested energy into reproduction (i.e., reproductive season) between the months of March through September (Figure 22). Ovaries from adult fishes ($N = 101$; range in total length [TL]: 35 – 75 mm) were taken between October through February and classified as immature or resting. Developing ovaries were observed in two females (45 – 53 mm in TL) in March and were observed through April. Mature ovaries ($N = 94$; 35 – 72 mm in TL) in April and were observed through September (i.e., spawning season). Spent ovaries ($N = 4$; 40 – 54 mm in TL) were observed in September.

Mean monthly GSI for Red River Shiner females corresponded with stages of ovarian development. Mean monthly GSIs were greatest (9.6% to 11.4%) May through July. Female GSI with immature or resting ovaries range between 0.9% to 3.4%. Female GSI with developing ovaries ranged between 1.0% to 6.5%. Female GSI with mature ovaries ranged between 1.1% to 24%.

Size distribution of oocytes taken from one female per month with mature ovary indicated continuous recruitment of oocytes (Figure 23). Maximum size of a vitellogenic oocyte was 1.04 mm, and batch fecundity ranged from 44 to 882 late vitellogenic oocytes (diameter: 0.60 – 1.04 mm) among 19 females with mature ovaries.

Food Habitats

A total of 261 Red River Shiners were examined for diet analysis from February 2016 through January 2017. Gut content by volume consist of aquatic invertebrates, terrestrial invertebrates, and vertebrates (79%), clay/silt (13%), filamentous algae (5%), grass seed (2%), sand (0.5%), aquatic plants (0.1%), diatoms (<0.1%) and plastic (<0.1%) (Table 5). Mean (\pm 1 SD) monthly gut fullness ranged from 1% (\pm 0.4) in December 2016 to 67% (\pm 28.8) in May 2016. Frequency of empty stomachs was 4.2%.

The most frequently occurring gut contents were silt or clay (63% occurrence), filamentous algae (53%), and sand (33%). Silt or clay substrate occurred in Red River Shiners stomachs year-round with monthly occurrences ranging from 14% in May 2016 to 95% in August 2016. Among aquatic invertebrates, terrestrial invertebrates, and vertebrates, Chironomidae was the most abundant food item (17%) followed by unidentifiable aquatic invertebrates (15%) and Coleoptera (1%). Eleven other aquatic invertebrate taxa were consumed

but at low (<1%) relative abundance. Likewise, terrestrial invertebrates and vertebrates (e.g., Red River Pupfish *Cyprinodont rubrofluviatilis*) were consumed but at low relative abundance.

Instream flow recommendations

Subsistence, base, and high flow pulse tiers are provided in Appendix E for Pease River, Wichita River, and Red River. Seasonal and annual flow magnitudes and durations serve as the basis of instream flow recommendations.

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Table 1. Collection locales of *Macrhybopsis* with their codes, river, road crossing, latitude and longitude, sample sizes (N), and genetic diversity indices theta (θ) and pi (π).

Code	River	Road Crossing	Latitude	Longitude	N	θ	π
BR_1462	Brazos River	1462	29.34994	-95.58269	29	0.0074	0.0038
BR_290	Brazos River	290	30.12944	-96.18693	30	0.0071	0.0039
PR_104	Pease River	104	34.22786	-100.07375	8	0.0060	0.0049
PR_283	Pease River	283	34.17915	-99.27841	7	0.0058	0.0050
PR_287	Pease River	287	34.17982	-99.32343	19	0.0060	0.0051
PR_6	Pease River	6	34.09471	-99.73016	27	0.0059	0.0050
RR_259	Red River	259	33.68678	-94.69449	18	0.0065	0.0053
RR_283	Red River	283	34.43119	-99.34181	17	0.0061	0.0051
RR_35	Red River	35	33.72738	-97.15930	10	0.0061	0.0057
RR_70	Red River	70	34.20985	-99.08233	10	0.0060	0.0054
RR_79	Red River	79	34.13253	-98.09267	14	0.0059	0.0057
RR_81	Red River	81	33.87807	-97.93435	14	0.0060	0.0056
RR_89	Red River	89	33.91691	-97.51055	70	0.0057	0.0055
WR_1919	Wichita River	1919	33.70029	-99.38871	66	0.0058	0.0049
WR_6	Wichita River	6	33.82076	-99.78663	29	0.0058	0.0049

Table 2. Common names, scientific names, species codes, and relative abundances for fishes taken among all sites within the upper Red River drainage from September 2015 through September 2016.

Common name	Scientific name	Code	Relative abundance (%)
Red Shiner	<i>Cyprinella lutrensis</i>	Cyp lut	26
Red River Shiner	<i>Notropis bairdi</i>	Not bai	18
Plains Minnow	<i>Hybognathus placitus</i>	Hyb pla	14
Western Mosquitofish	<i>Gambusia affinis</i>	Gam aff	9.0
Red River Pupfish	<i>Cyprinodon rubrofluviatilis</i>	Cyp rub	7.6
Emerald Shiner	<i>Notropis atherinoides</i>	Not ath	5.9
Plains Killifish	<i>Fundulus zebrinus</i>	Fun zeb	3.2
Gizzard Shad	<i>Dorosoma cepedianum</i>	Dor cep	2.7
Ghost Shiner	<i>Notropis buchanani</i>	Not buc	2.5
Mississippi Silverside	<i>Menidia audens</i>	Men aud	1.4
Prairie Chub	<i>Macrhybopsis australis</i>	Mac aus	1.3
Bullhead Minnow	<i>Pimephales vigilax</i>	Pim vig	1.2
Bluegill	<i>Lepomis macrochirus</i>	Lep mac	1.1
Blue Catfish	<i>Ictalurus furcatus</i>	Ict fur	0.91
Shoal Chub	<i>Macrhybopsis hyostoma</i>	Mac hyo	0.71
Green Sunfish	<i>Lepomis cyanellus</i>	Lep cya	0.46
Central Stoneroller	<i>Campostoma anomalum</i>	Cam ano	0.41
Fathead Minnow	<i>Pimephales promelas</i>	Pim pro	0.38
Blackstripe Topminnow	<i>Fundulus notatus</i>	Fun not	0.36
White Crappie	<i>Pomoxis annularis</i>	Pom ann	0.31
Sunfish larvae	<i>Lepomis larvae</i>		0.22
Longear Sunfish	<i>Lepomis megalotis</i>	Lep meg	0.21
Orangespotted Sunfish	<i>Lepomis humilis</i>	Lep hum	0.20
Redbreast Sunfish	<i>Lepomis auritus</i>	Lep aur	0.17
Largemouth Bass	<i>Micropterus salmoides</i>	Mic sal	0.17
Suckermouth Minnow	<i>Phenacobius mirabilis</i>	Phe mir	0.16
Channel Catfish	<i>Ictalurus punctatus</i>	Ict pun	0.15
Sand Shiner	<i>Notropis stramineus</i>	Not str	0.11
Freshwater Drum	<i>Aplodinotus grunniens</i>	Apl gru	0.10
Smallmouth Buffalo	<i>Ictiobus bubalus</i>	Ict bub	0.09
Orangethroat Darter	<i>Etheostoma spectabile</i>	Eth spe	0.08
River Carpsucker	<i>Carpiodes carpio</i>	Car car	0.07
Common Carp	<i>Cyprinus carpio</i>	Cyp car	0.06
Bigscale Logperch	<i>Percina macrolepida</i>	Per mac	0.06
Threadfin Shad	<i>Dorosoma petenense</i>	Dor pet	0.04
Golden Shiner	<i>Notemigonus crysoleucas</i>	Not cry	0.04
Longnose Gar	<i>Lepisosteus osseus</i>	Lep oss	0.04
Striped Bass	<i>Morone saxatilis</i>	Mor sax	0.02

Table 2. Continued.

Common name	Scientific name	Code	Relative abundance (%)
Spotted Gar	<i>Lepisosteus oculatus</i>	Lep ocu	0.01
Blacktail Shiner	<i>Cyprinella venusta</i>	Cyp ven	0.01
Yellow Bullhead	<i>Ameiurus natalis</i>	Ame nat	0.01
Shortnose Gar	<i>Lepisosteus platostomus</i>	Lep plat	0.01
Silver Chub	<i>Macrhybopsis storeriana</i>	Mac sto	0.01
Brook Silverside	<i>Labidesthes sicculus</i>	Lab sic	0.01
Gar larvae	<i>Lepisosteus</i> larvae		0.01
Black Bullhead	<i>Ameiurus melas</i>	Ame mel	0.01
Logperch	<i>Percina caprodes</i>	Per cap	0.01
Goldeye	<i>Hiodon alosoides</i>	Hio alo	<0.01
Chub larvae	<i>Macrhybopsis</i> larvae		<0.01
Flathead Catfish	<i>Pylodictis olivaris</i>	Pyl oli	<0.01
Gulf Killifish	<i>Fundulus grandis</i>	Fun gra	<0.01
Redear Sunfish	<i>Lepomis microlophus</i>	Lep mic	<0.01
Richness			49
Total N			36,211

Table 3. Percent volumes, occurrences, and relative abundances of food items in stomachs of Prairie Chubs taken from February 2016 through January 2017.

Food Items	Volume (%)	Occurrence (%)	Relative abundance (%)
Plant			
Algae	0.2	8	
Animal	99		
Aquatic invertebrates			
Crustacea		0.5	< 0.1
Copepoda		0.5	0.1
Isopoda		0.5	< 0.1
<i>Daphnia</i>		0.5	0.1
Trombidiformes		0.5	< 0.1
Diptera			
Chironomidae		88	95
Pupa		11	2
Ephemeroptera		2	< 0.1
Odonata			
Gomphidae		0.5	< 0.1
Trichoptera		1	< 0.1
Hydropsychidae		0.5	< 0.1
Unidentifiable		3	< 0.1
Pupa		4	< 0.1
Invertebrate egg		1	1
Terrestrial invertebrates			
Diptera		1	< 0.1
Unidentifiable		0.5	< 0.1
Vertebrates			
Scales		0.5	< 0.1
Gill filaments		0.5	< 0.1
Substrate			
Clay/Silt	0.7	14	
Sand	0.1	37	
Plastic	< 0.1	2	
Total N	197		

Table 4. Pairwise genetic differentiation (G_{ST}) between all sites where genetic analysis was performed.

[illegible]

Table 5. Percent volumes, occurrences, and relative abundances of food items in stomachs of Red River Shiners taken from February 2016 through January 2017.

Food Items	Volume (%)	Occurrence (%)	Relative Abundance (%)
Plant			
Algae	5	52	
Diatom	< 0.1	7	
Aquatic plant	0.1	2	
Grass Seed	2	6	4
Animal	79		
Aquatic invertebrates			
Crustacea		5	3
Copepoda		1	0.7
Isopoda		1	0.7
<i>Daphnia</i>		2	1
Trombidiformes			
Hydrachnidia		0.8	0.5
Coleoptera			
Dytiscidae		0.4	0.2
Hydrophilidae		1	0.7
Diptera			
Chironomidae		26	17
Chironomidae eggs		0.4	0.2
Simuliidae		0.4	0.2
Diptera pupa		0.4	0.2
Hemiptera		0.4	0.2
Neuroptera		0.4	0.2
Odonata		2	1
Gomphidae		3	2
Trichoptera		3	2
Hydropsychidae		0.4	0.2
Unidentifiable		23	15
Unidentifiable pupa		13	8
Invertebrate egg		5	3

Food Items	Volume (%)	Occurrence (%)	Relative Abundance (%)
Terrestrial invertebrates		13	9
Araneae		0.4	0.2
Cicadidae		1	0.7
Coleoptera		16	10
Scarabaeidae		0.4	0.2
Diptera		15	9
Ceratopogonidae		3	2
Hymenoptera		7	4
Apidae		0.4	0.2
Formicidae		3	2
Lepidoptera		0.8	0.5
Unidentifiable		13	9
Vertebrates			
<i>C. rubrofluvitalus</i>		0.4	0.2
Scales		2	1
otolith		0.4	0.2
Substrate			
Clay/Silt	13	63	
Sand	0.5	33	
Detritus	0.3	0.4	
Plastic	< 0.1	0.4	
Total N	261		

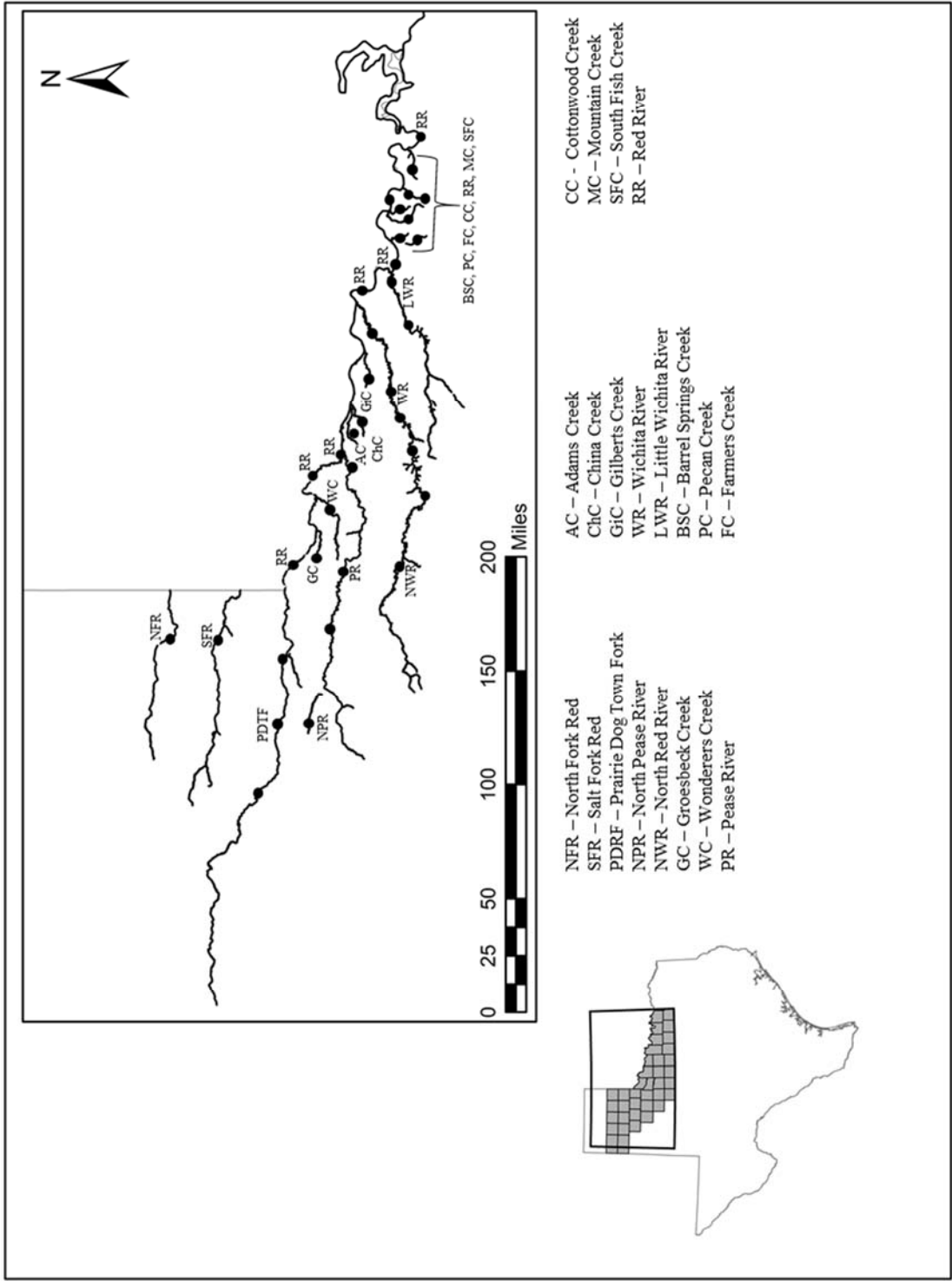


Figure 1. Locations of sites sampled along the upper Red River of Texas and Oklahoma from September 2015 through January 2017. Additional information for location, environmental, and habitat parameters can be found in Appendix A

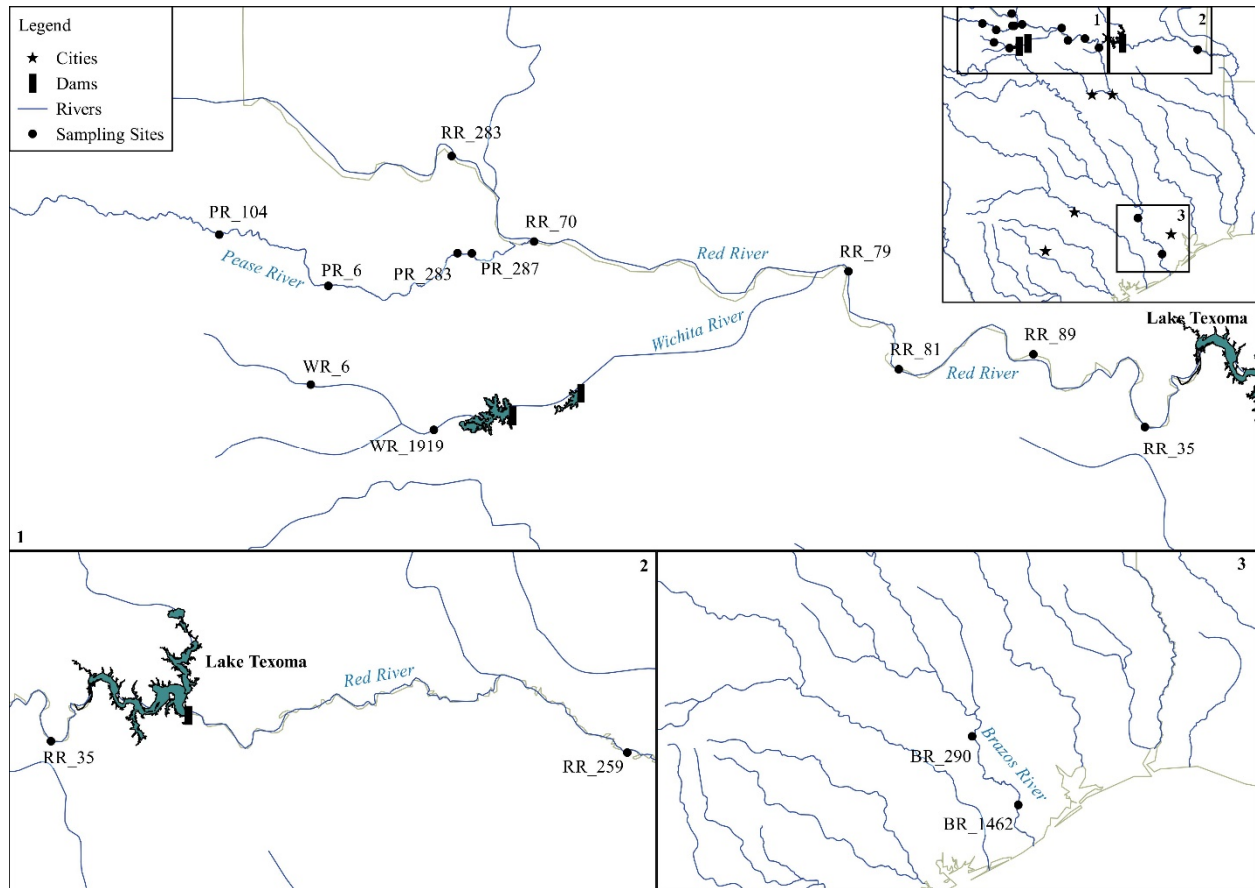


Figure 2. Location of sites for *Macrhybopsis* genetic assessments. Fishes were taken from the Red River (RR), Pease River (PR), Wichita River (WR), and Brazos River (BR); numbers in corners correspond to location in Texas in the overall map in the top right corner. Site codes are defined in Table 2.

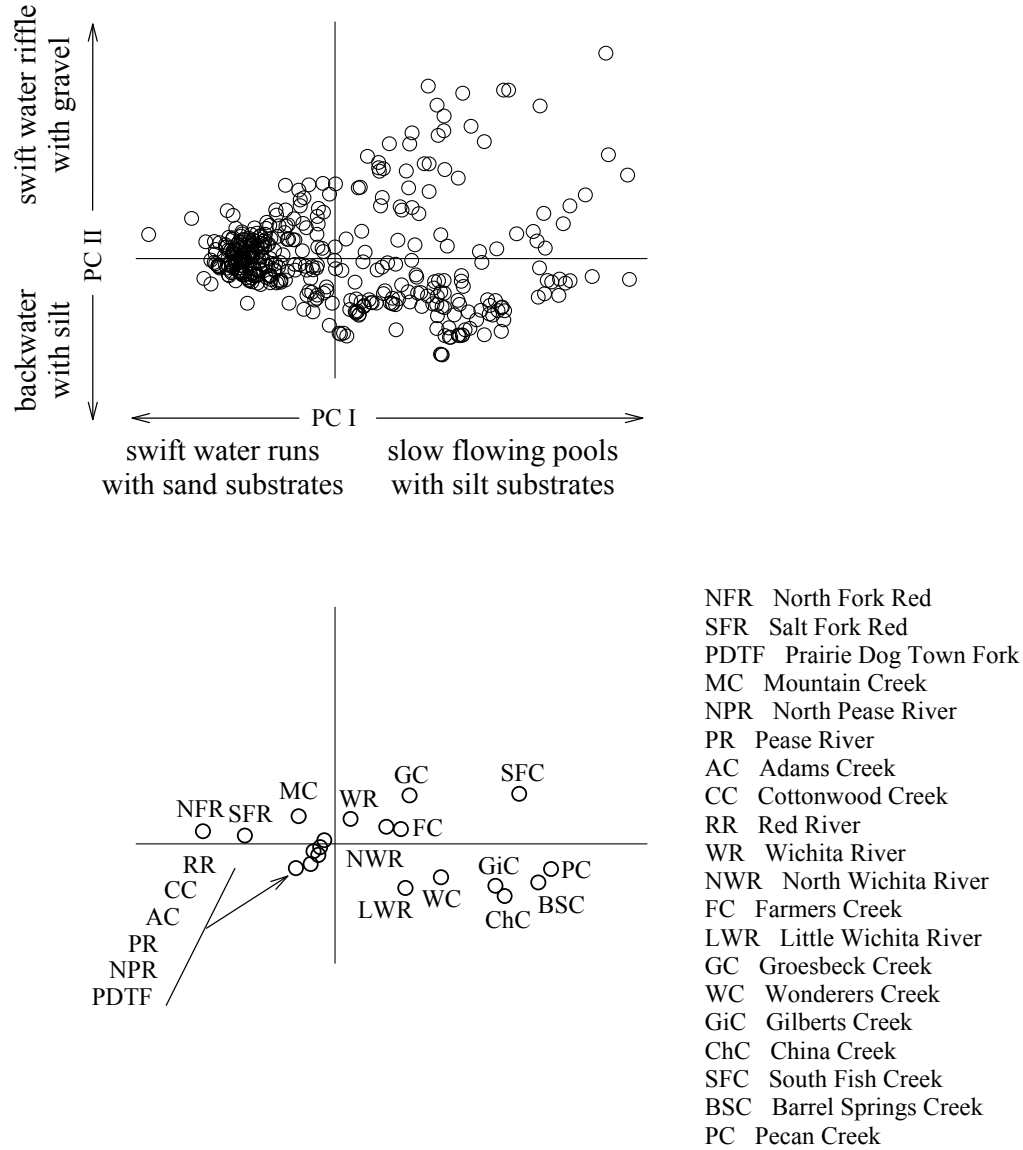


Figure 3. Circles represent each mesohabitat (N = 400) along PC I and PC II gradients (top panel). Circles represent reaches (average PC I and PC II mesohabitat scores) along PC I and PC II gradients (bottom panel).

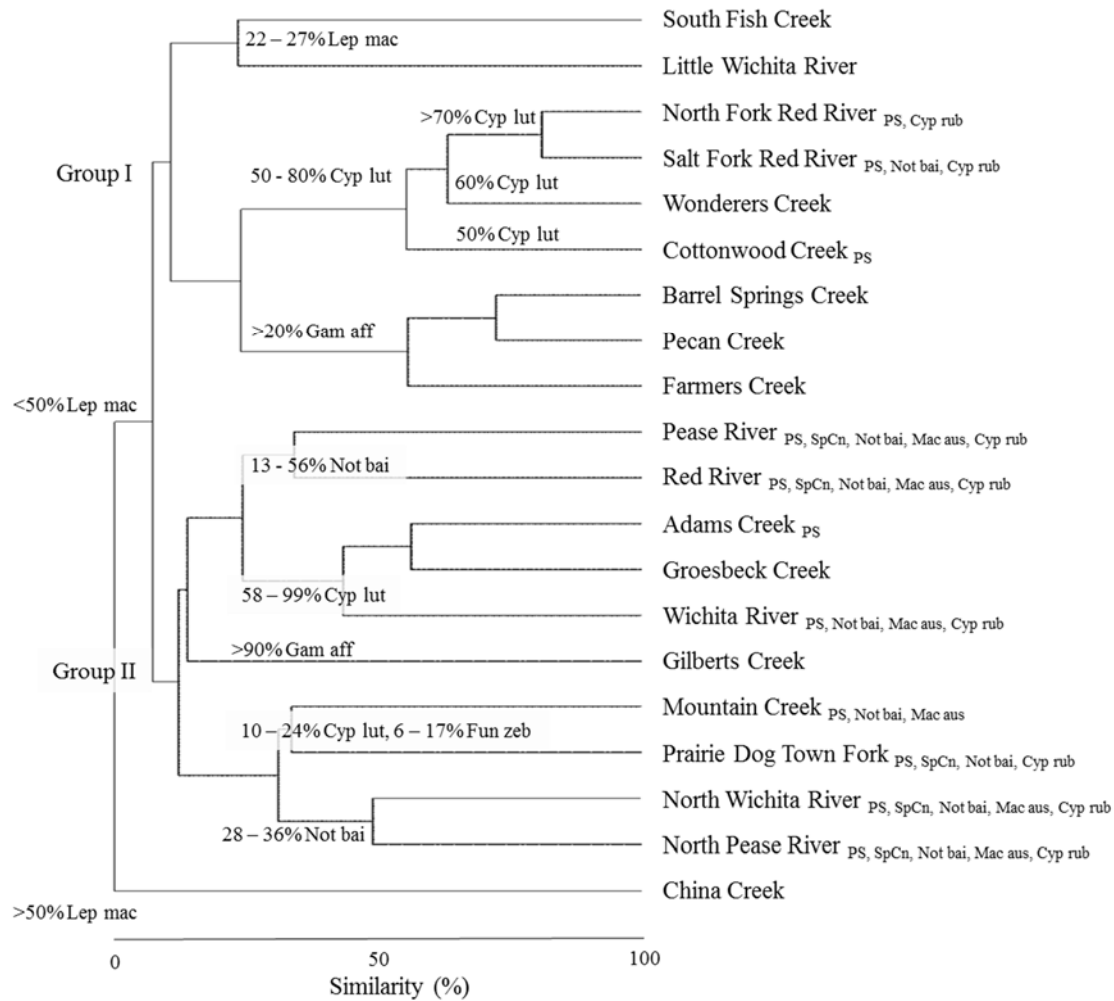


Figure 4. Fish community similarity groupings among reaches explained by relative abundance of species in common between each reach. Reaches classified as Prairie stream (PS) are annotated next to the reach. Reaches with $> 3,500 \mu\text{S}\cdot\text{cm}^{-1}$ are annotated with specific conductance (SpCn). Genus and species are abbreviated to three characters.

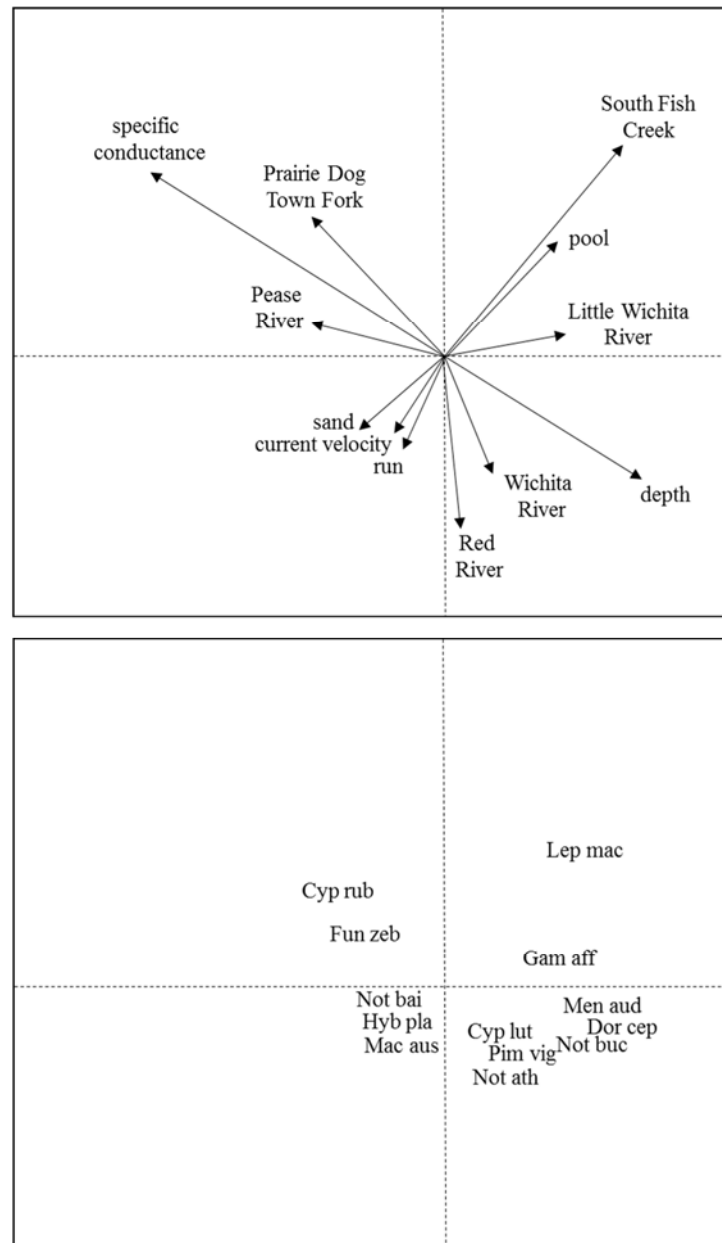


Figure 5a. Fish-habitat associations between Canonical Correspondence Analysis (CCA) axis I (x-axis) and CCA axis II (y-axis) for fishes with >1% relative abundance in the upper Red River drainage. Genus and species are abbreviated to three characters.

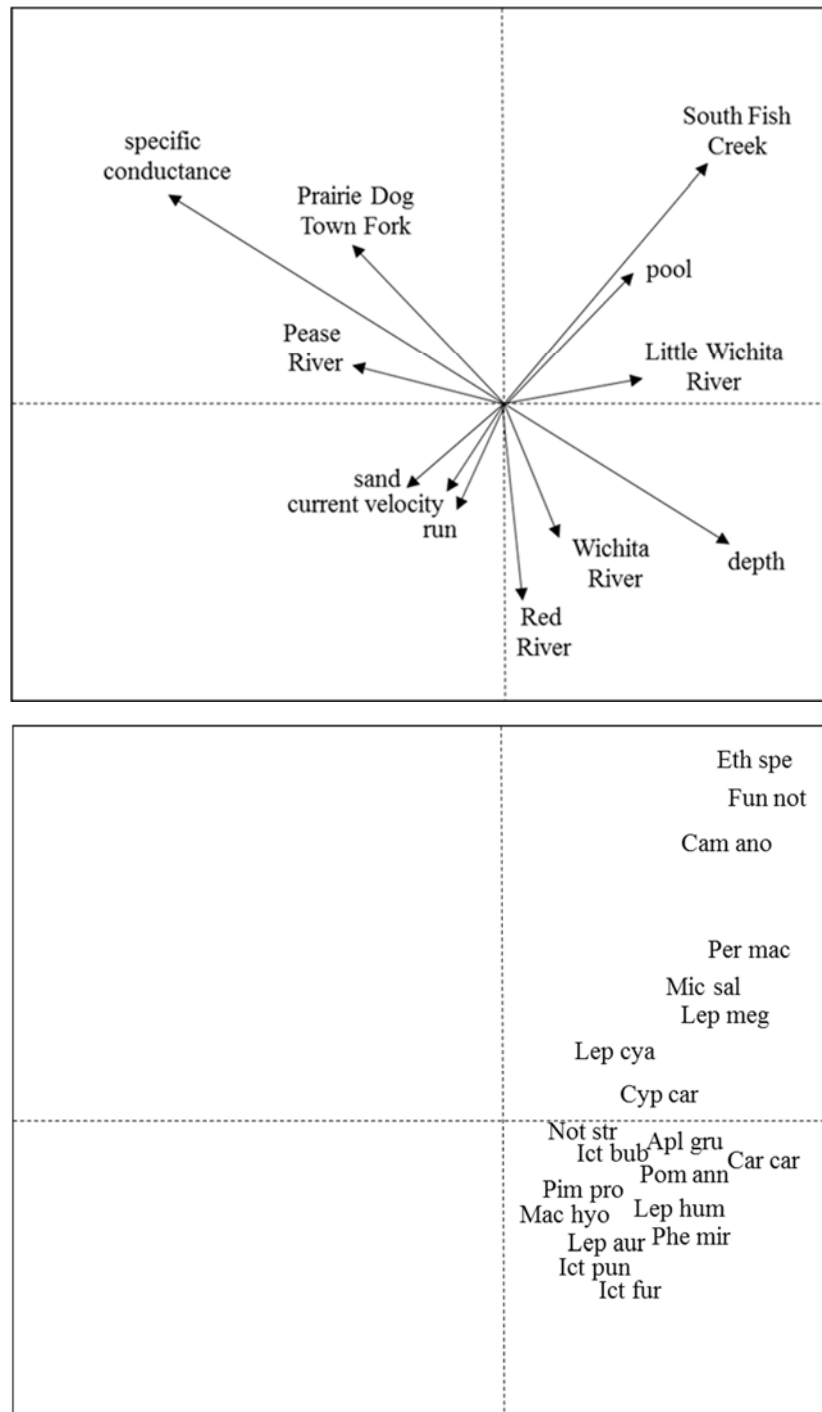


Figure 5b. Fish-habitat associations between Canonical Correspondence Analysis (CCA) axis I (x-axis) and CCA axis II (y-axis) for fishes with <1% relative abundance in the upper Red River drainage. Genus and species are abbreviated to three characters.

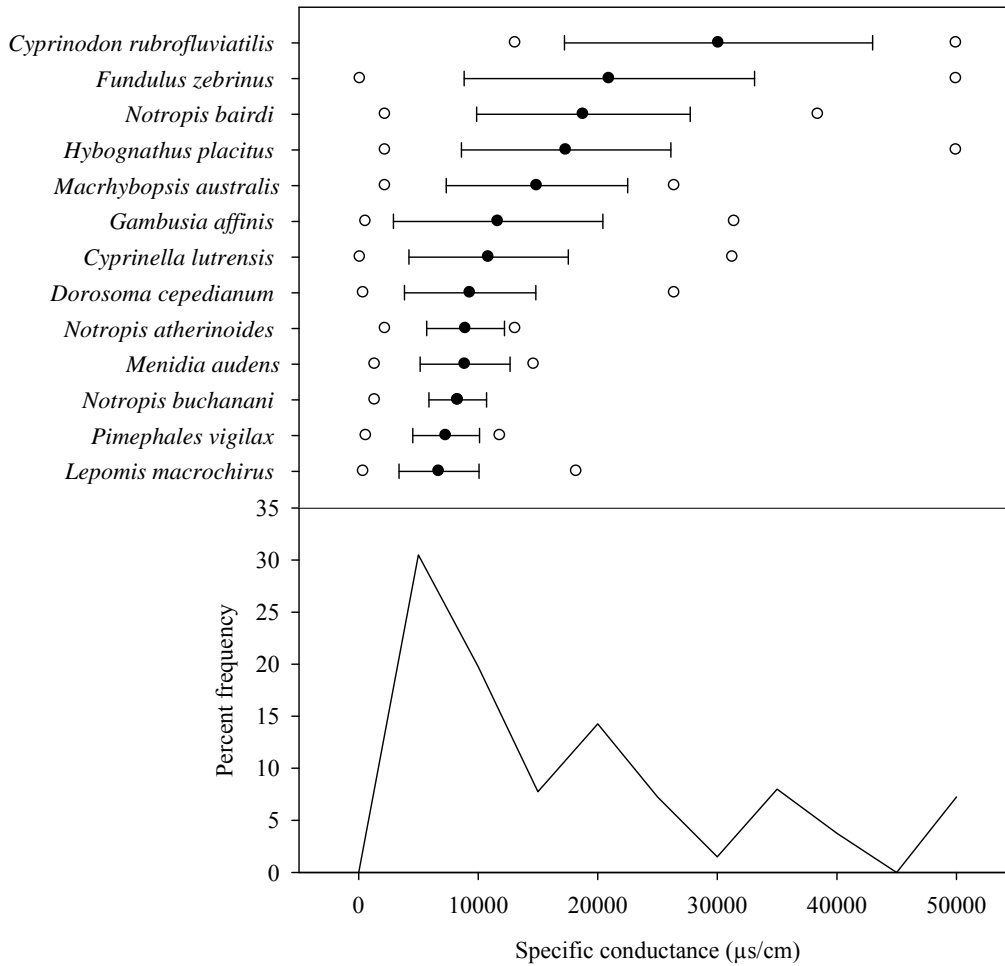


Figure 6. Mean (black circle), 1 SE (whisker), and minimum and maximum (open circle) specific conductance for fishes with >1% relative abundance within the upper Red River drainage (top panel). Amount of habitats available along specific conductance gradient (bottom panel).

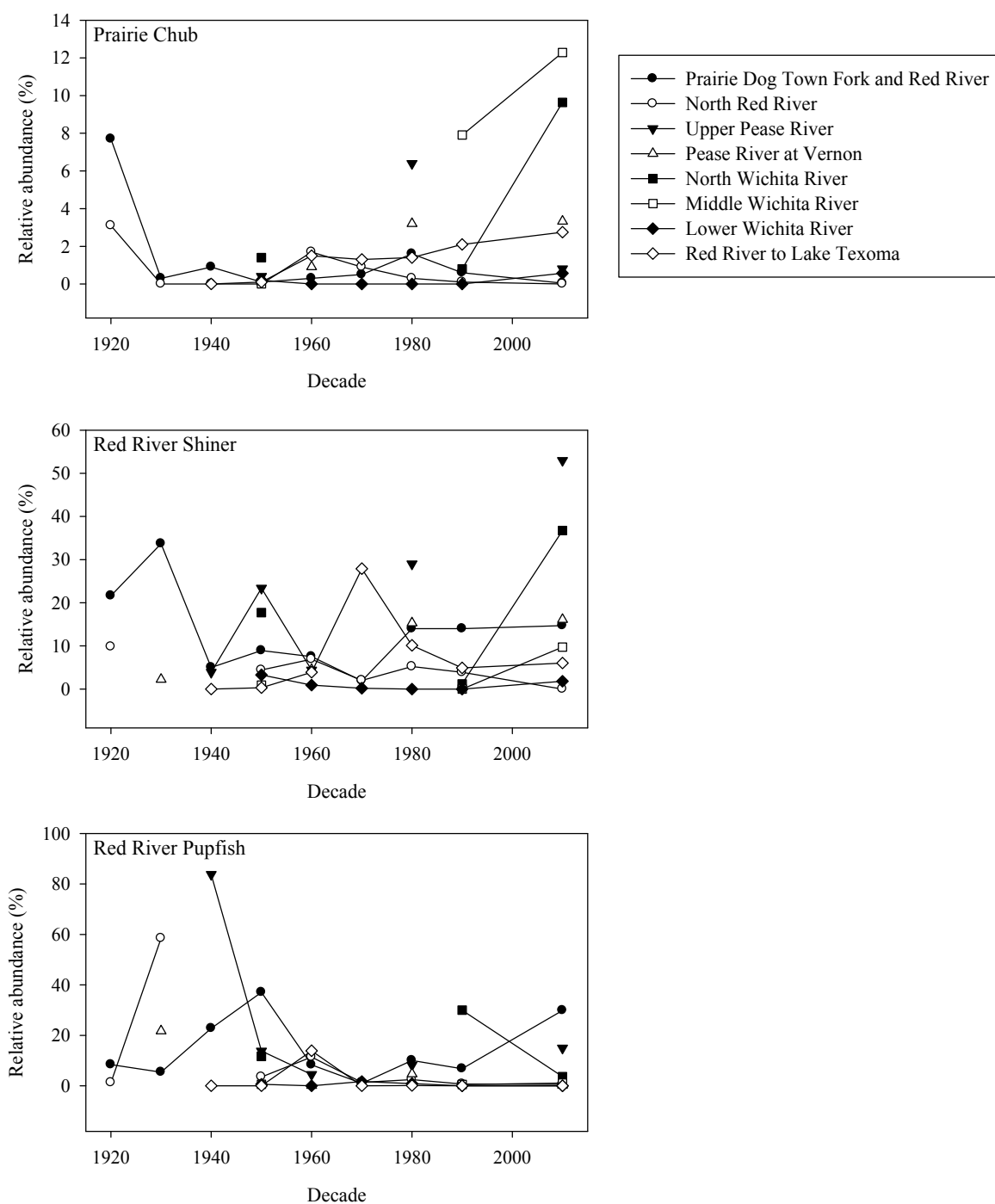


Figure 7. Mean relative abundances of Prairie Chub, Red River Shiner, and Red River Pupfish among decades (1920 – 2010) for eight reaches within the upper Red River drainage.

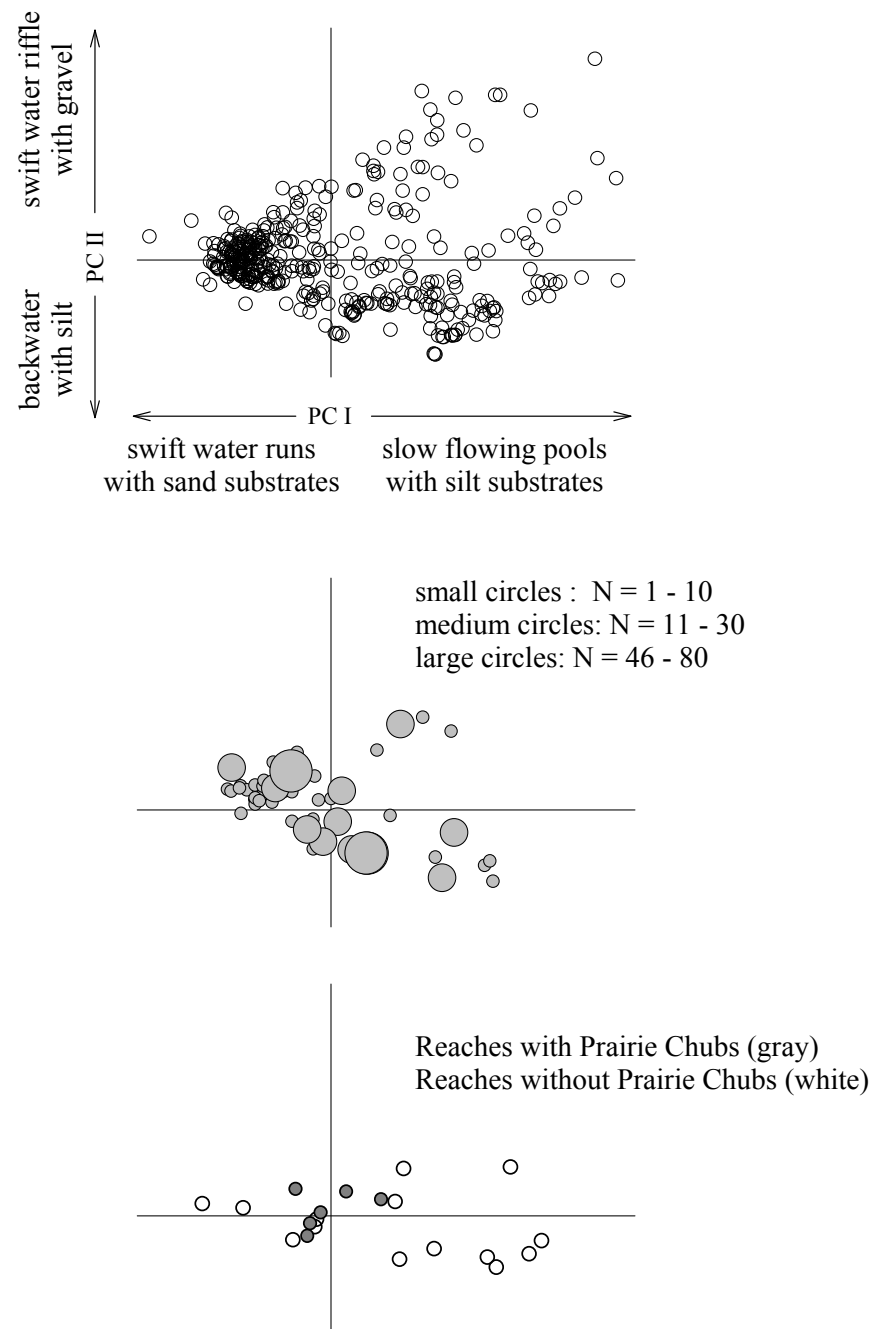


Figure 8. Circles represent each mesohabitat ($N = 400$) along PC I and PC II gradients (top panel). Shaded circles represent the number of Prairie Chubs taken from each mesohabitat (middle panel) or reaches with Prairie Chub occurrences (bottom panel) from the upper Red River drainage.

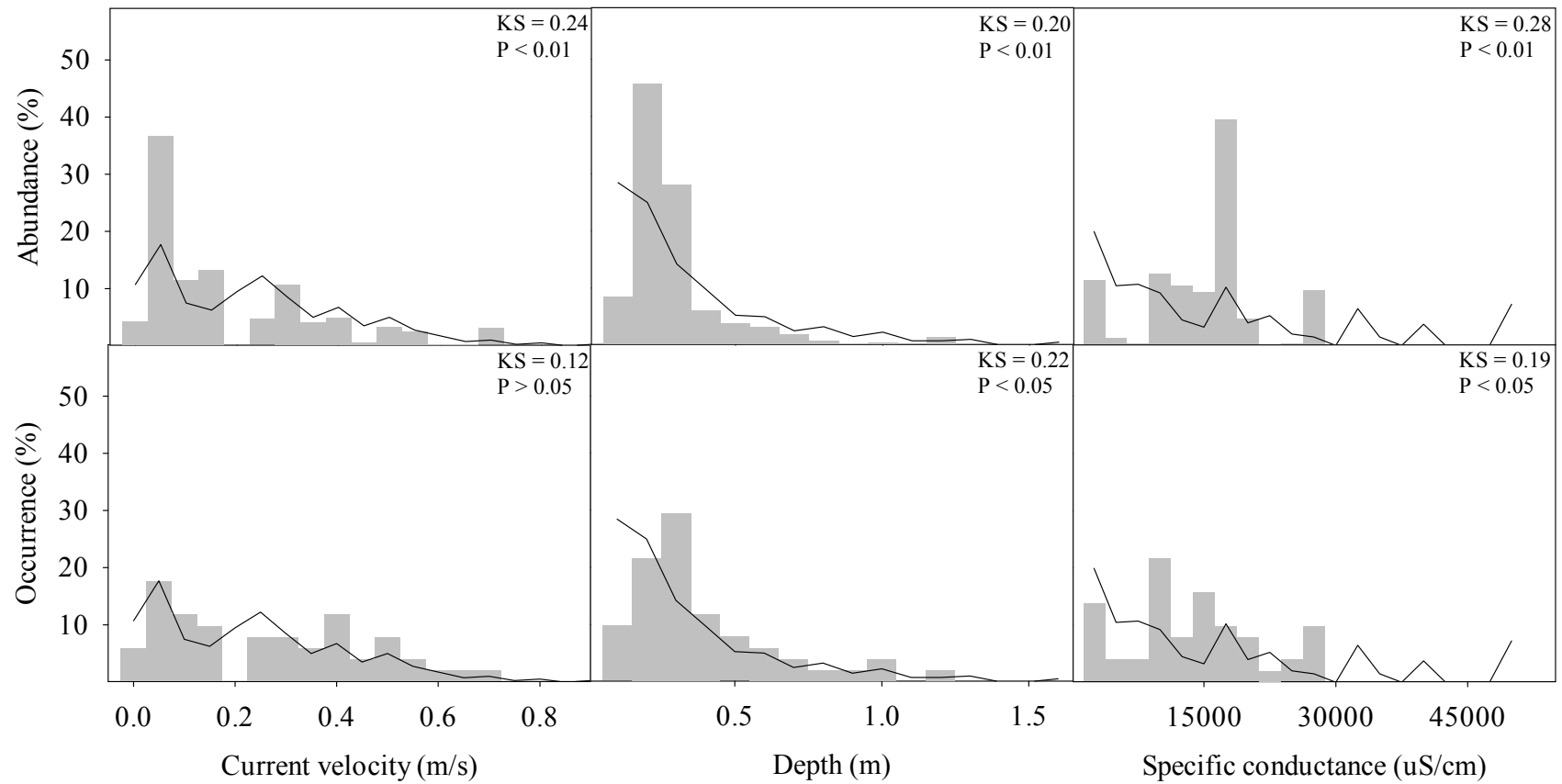


Figure 9. Frequency of abundances (top panel) and occurrences (bottom panel) of available habitats (line) and used habitats (bars) by Prairie Chub along current velocity, depth, and specific conductance gradients. Kolmogorov-Smirnov (KS) test statistic and associated P-value are provided.

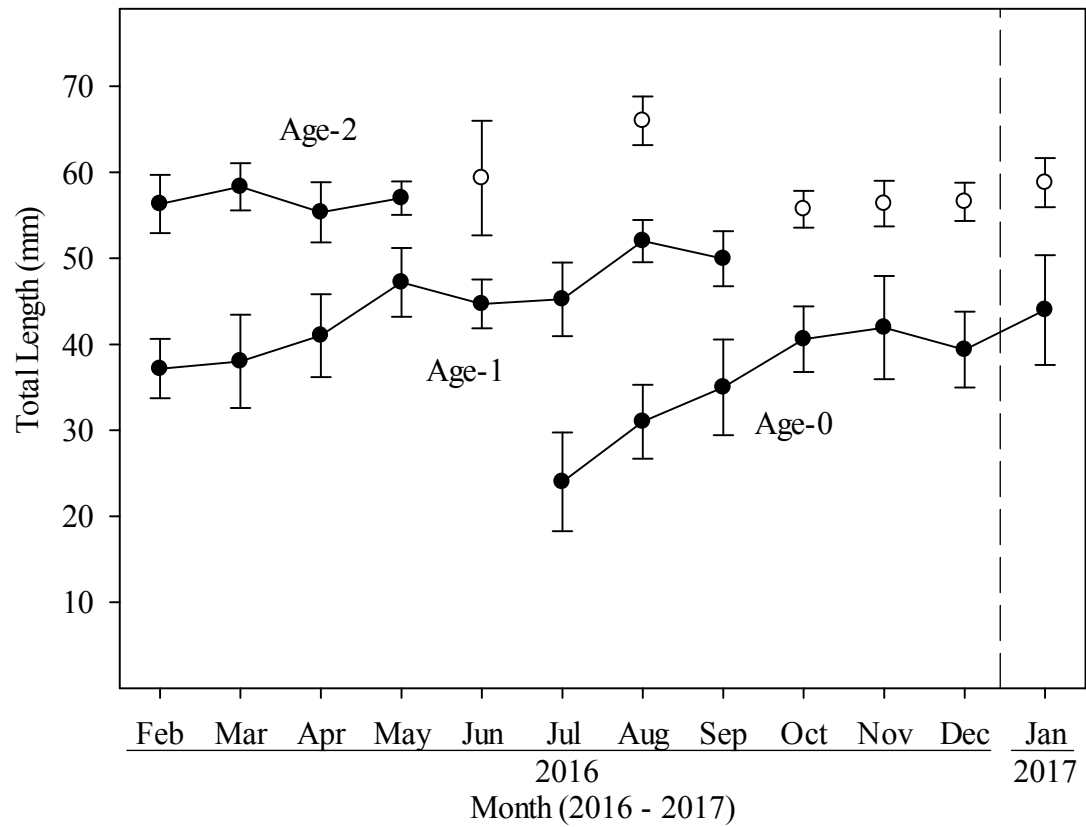


Figure 10. Mean ± 1 SD total lengths (black circles) for Age-0, Age-1, and Age-2 Prairie Chubs taken monthly from February 2016 through January 2017. White circles represent mean and ± 1 SE of total lengths taken from ≤ 3 individuals within an age group per month. Dashed line indicates the transition into the next age class.

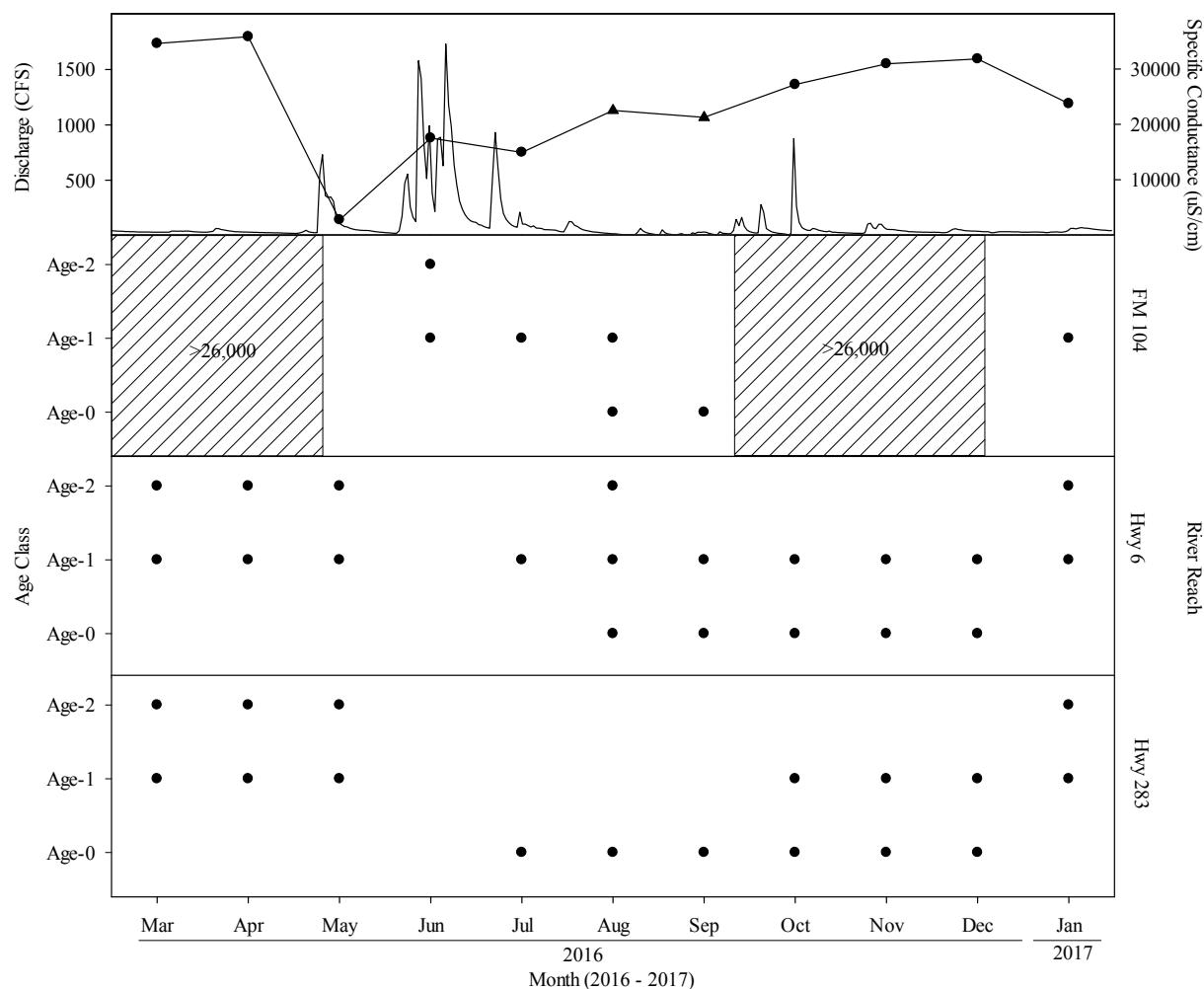


Figure 11. Daily flow (line; USGS Station 07308200 near Vernon Texas) and monthly estimates of specific conductance (symbol and line) taken from FM 104 crossing on the Pease River (1st panel). Next three panels represent the occurrences of Prairie Chub age groups (denotes with a black circle) among months within the upper site (FM 104), middle site (Hwy 6), and lower site (Hwy 283). Shaded boxes represents specific conductance $>26,000 \mu\text{S}\cdot\text{cm}^{-1}$, which is greater than the limit of specific conductance inhabited by Prairie Chub.

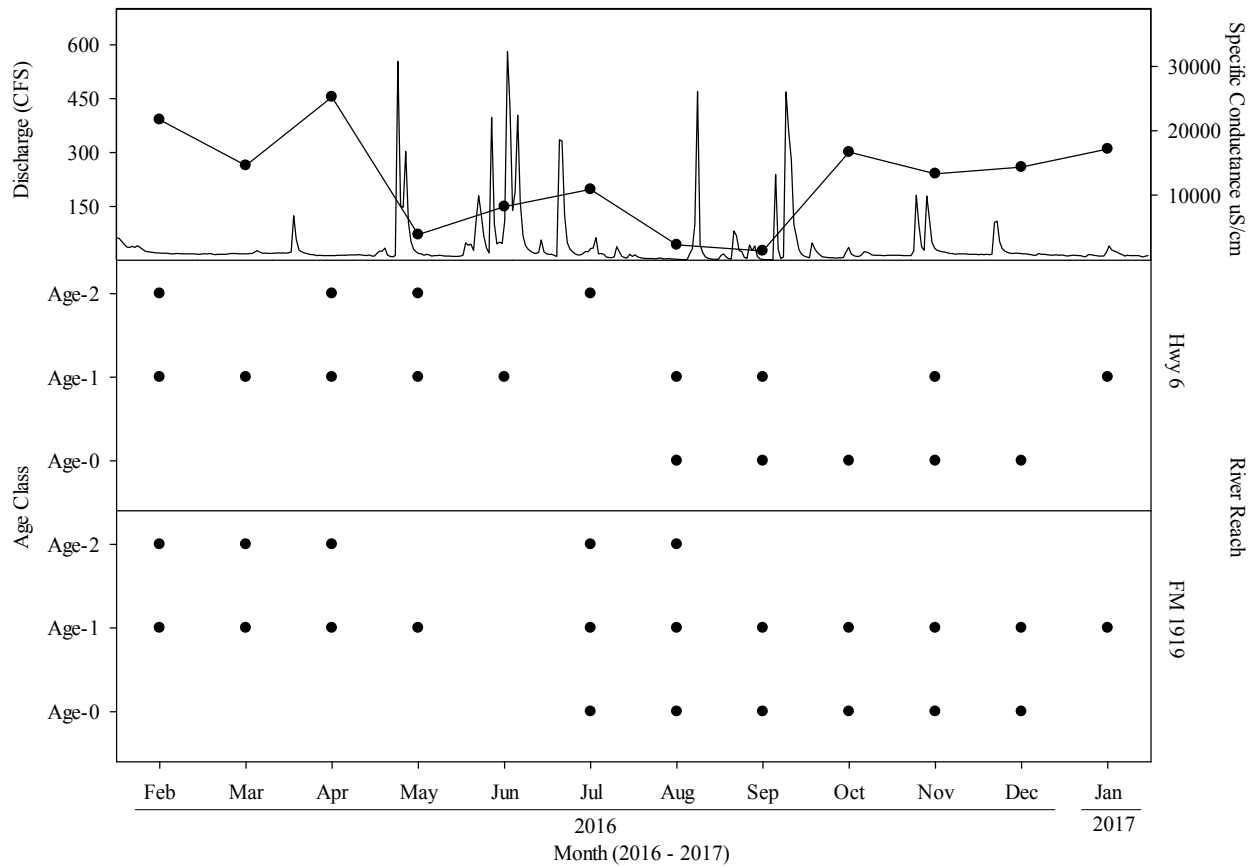


Figure 12. Daily flow (line; USGS Station 07311700) and monthly estimates of specific conductance (symbol and line) taken from Hwy 6 crossing on the North Wichita River (1st panel). Next two panels represent the occurrences of Prairie Chub age groups (denotes with a black circle) among months within the upper site (North Wichita River, Hwy 6) and lower site (Wichita River, FM 1919).

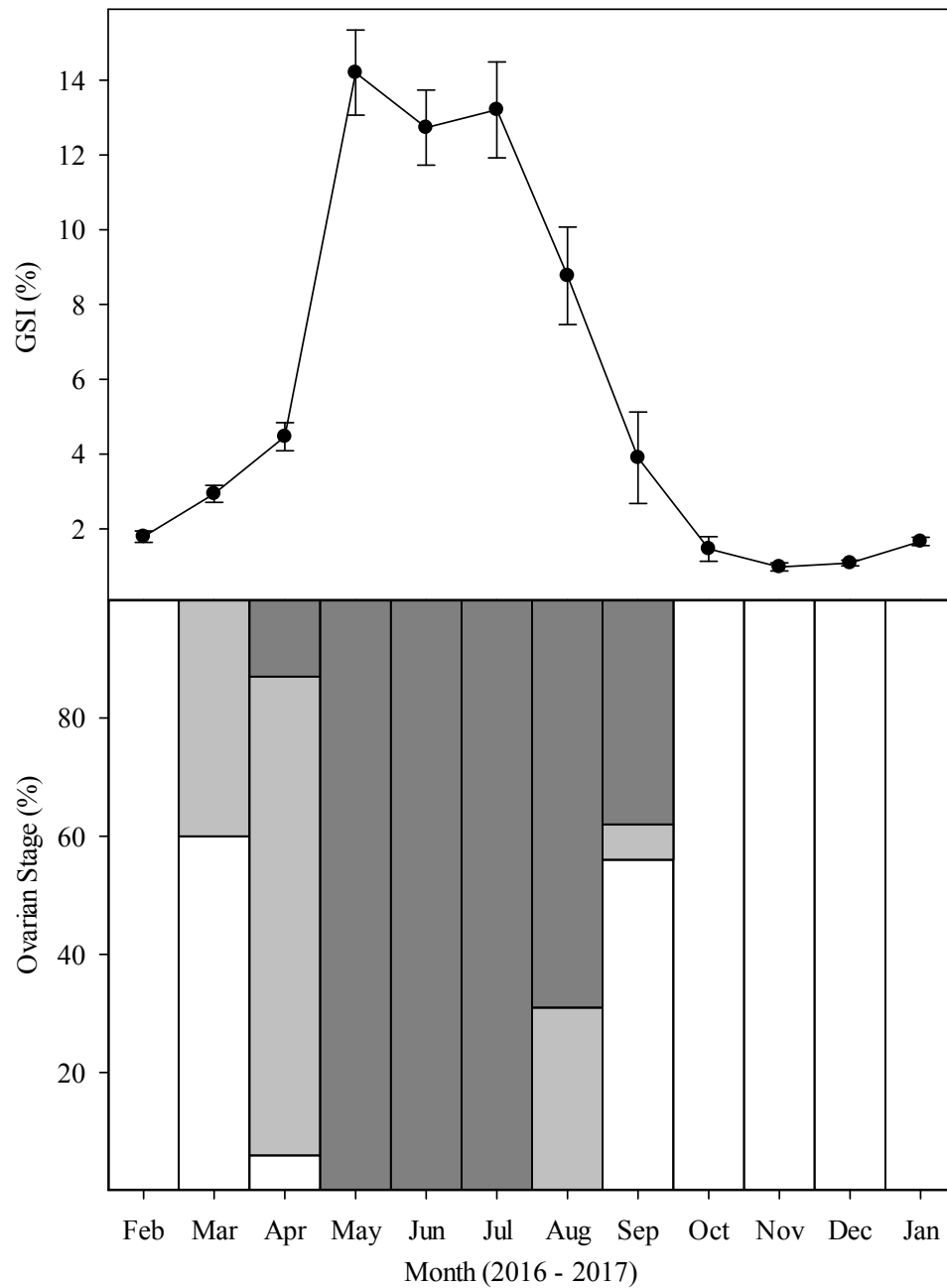


Figure 13. Mean (± 1 SE) monthly gonadosomatic index (GSI) for Prairie Chubs taken from February 2016 through January 2017 (top panel). Percent ovarian stages by month for immature (white), developing (light gray), and mature (dark gray) females (bottom panel).

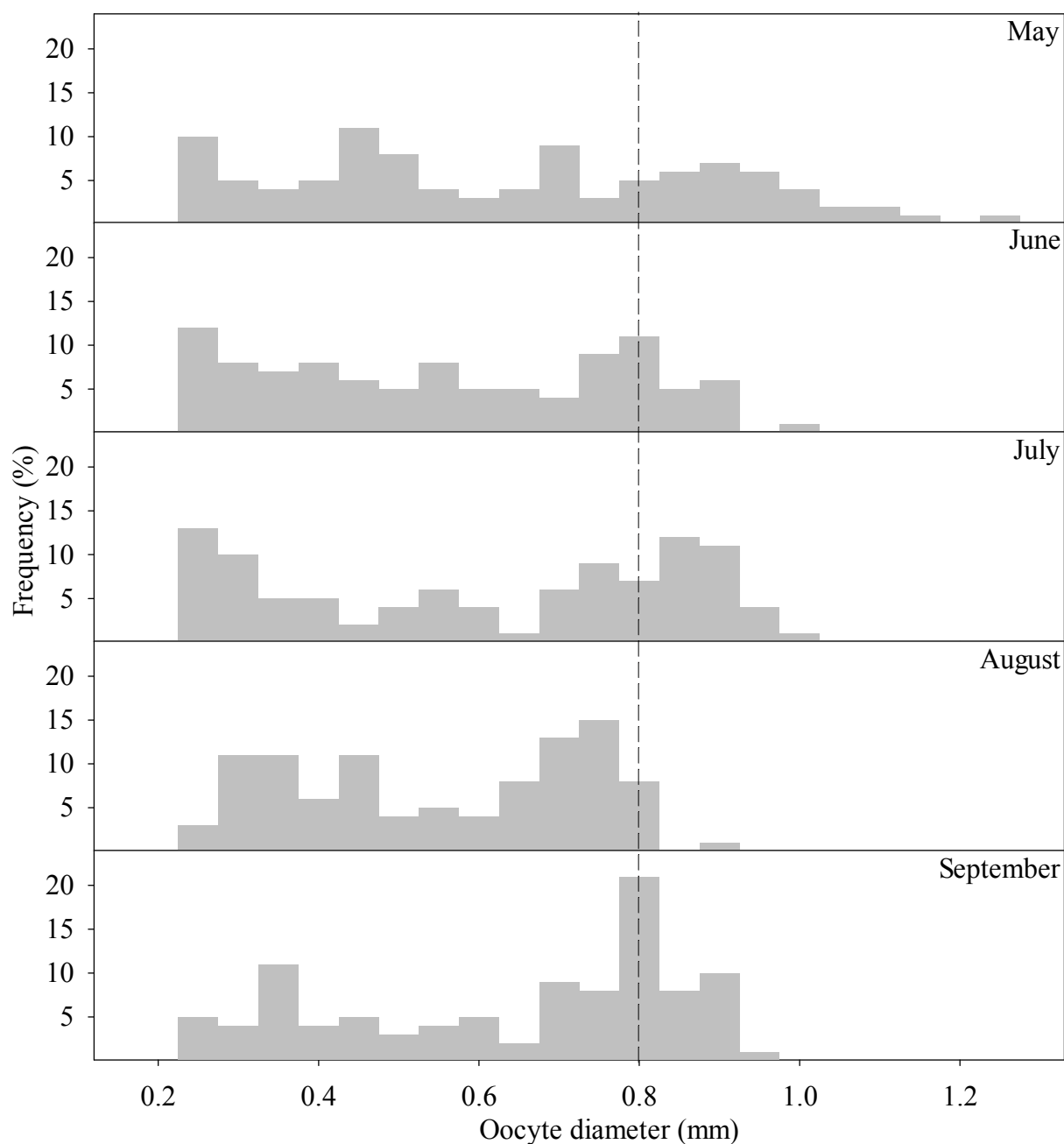


Figure 14. Frequency of oocyte size distribution in mature ovaries of Prairie Chubs taken May 2016 through September 2016. Dashed line indicates estimated size of late vitellogenic oocytes.

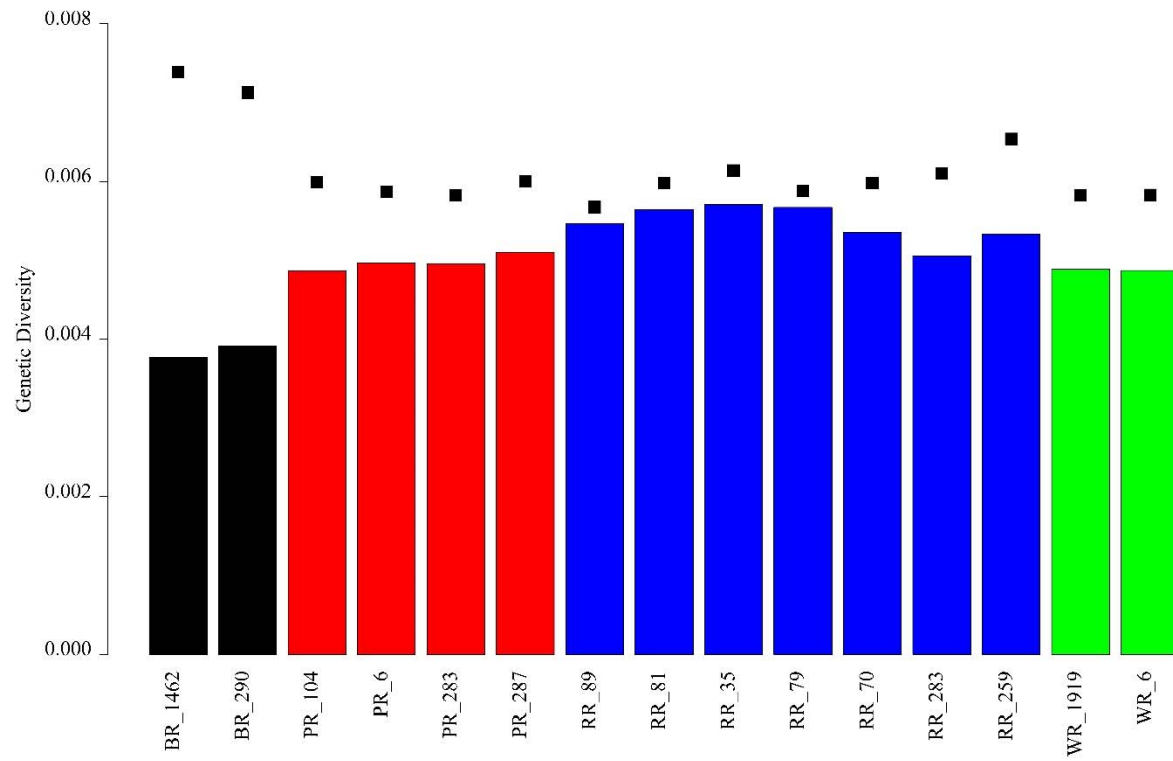


Figure 15. Plot of θ and π genetic diversity indices; π is represented by the bars and θ is represented by the black points.

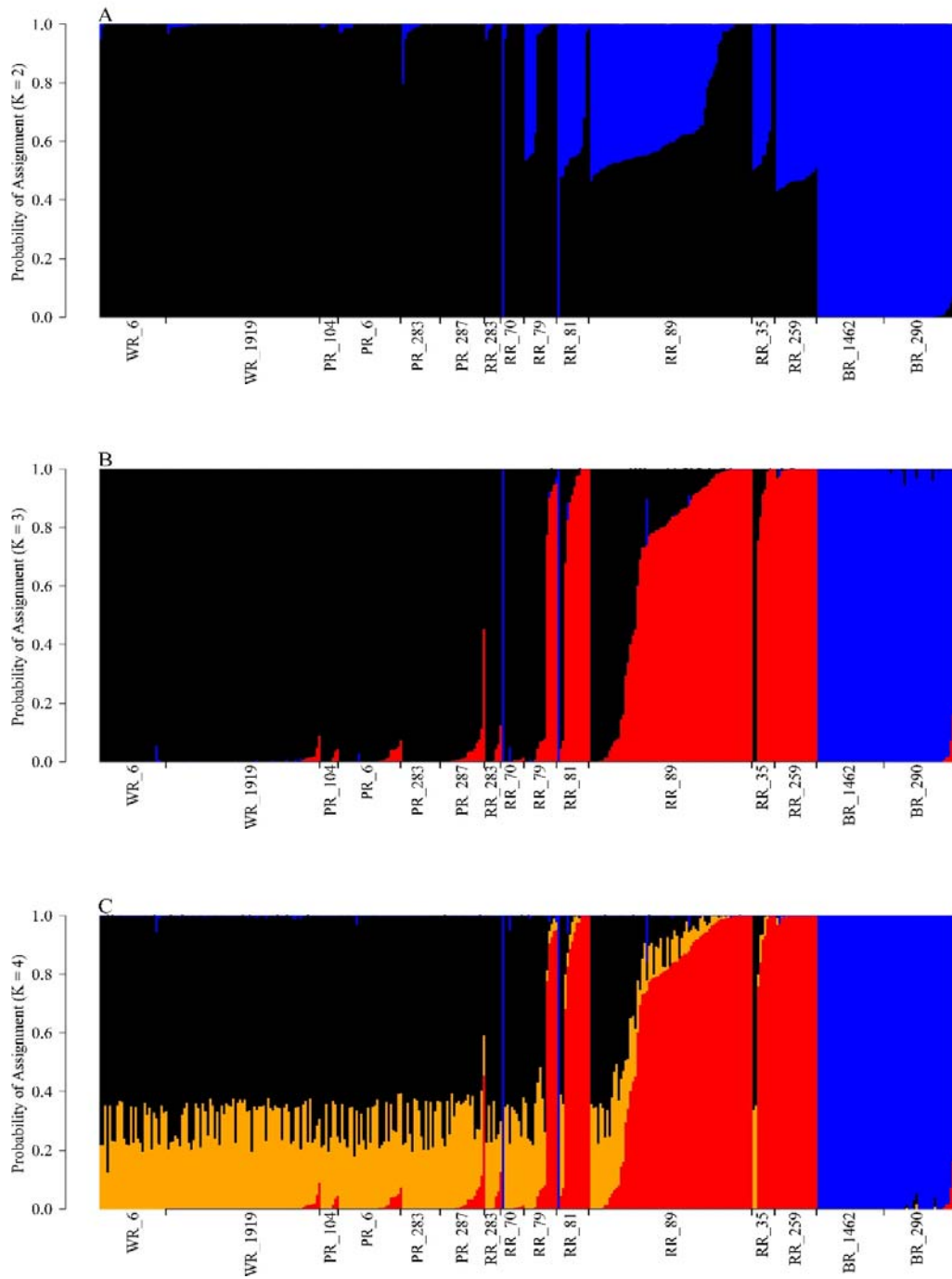


Figure 16. Entropy plots for $k = 2$ (A), $k = 3$ (B), and $k = 4$ (C). Site codes on X axis are defined in Table 1. Each bar along the X axis represents a single individual, and assignment probabilities to different groups (1 – 4) are represented along the Y axis.

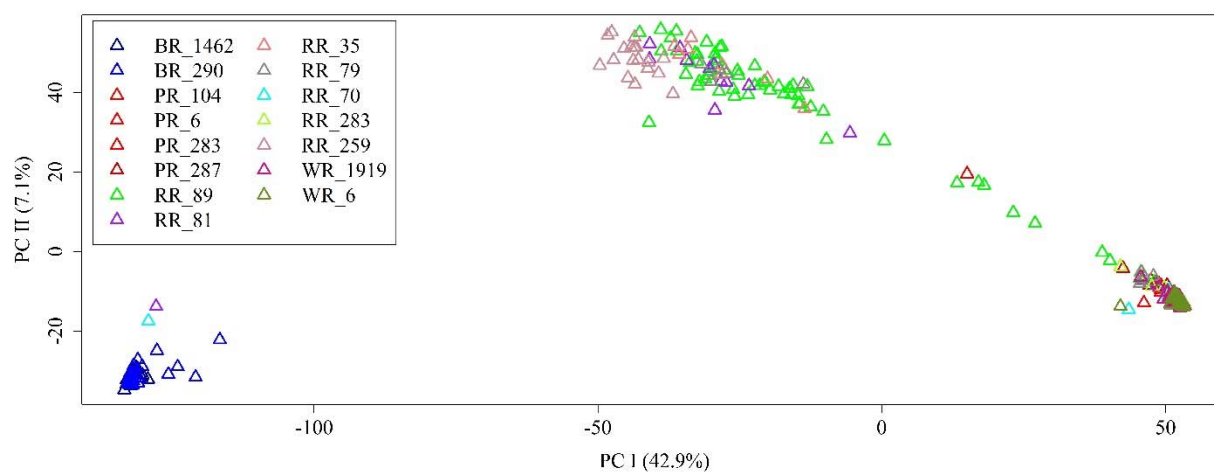


Figure 17. Principal component analysis (PCA) of genetic differentiation of all individuals from each collection locale. Site codes are in Table 1.

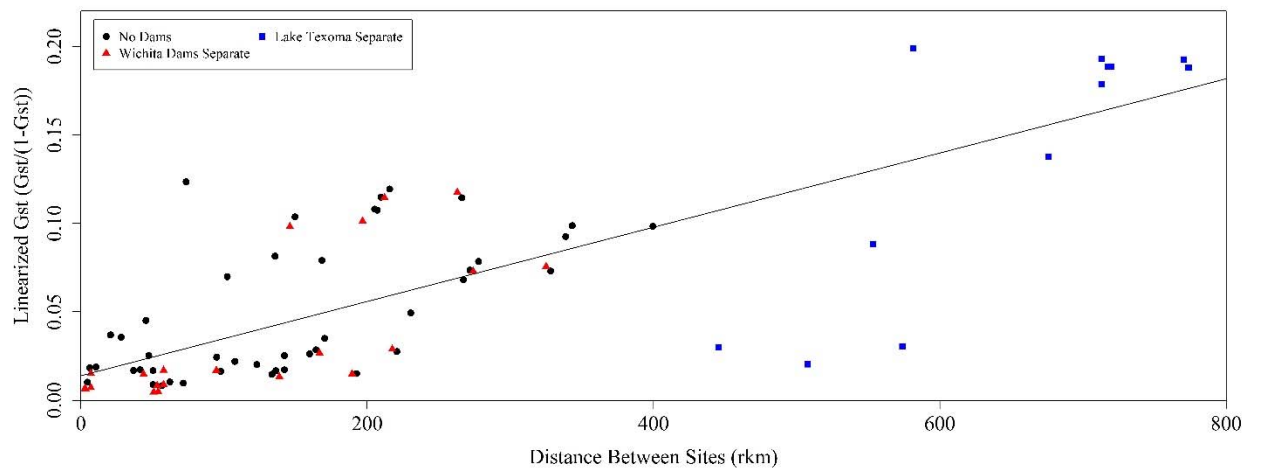


Figure 18. Scatter plot of pairwise genetic differentiation ($G_{ST}/(1-G_{ST})$) and river kilometers between sites (rkm).

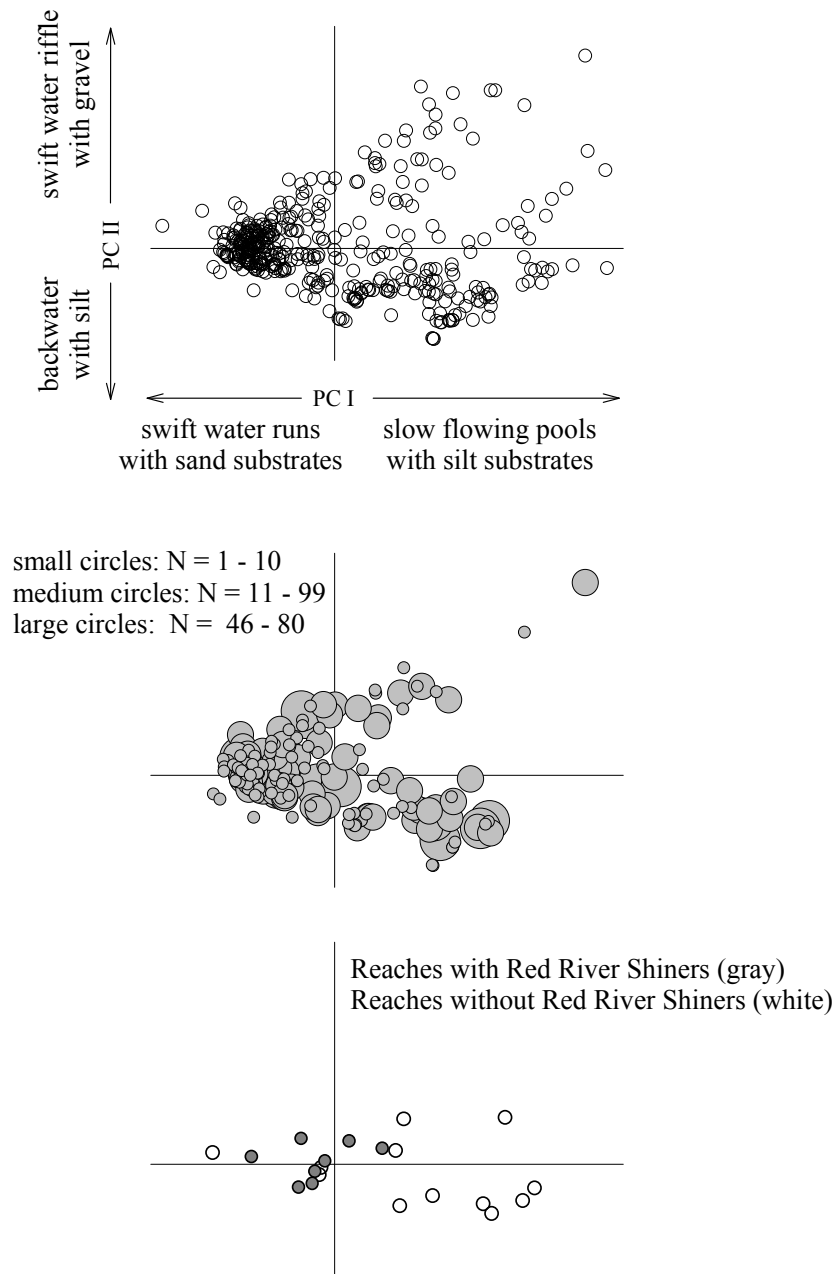


Figure 19. Circles represent each mesohabitat (N = 400) along PC I and PC II gradients (top panel). Shaded circles represent the number of Red River Shiners taken from each mesohabitat (middle panel) or reaches with Red River Shiner occurrences (bottom panel) from the upper Red River drainage.

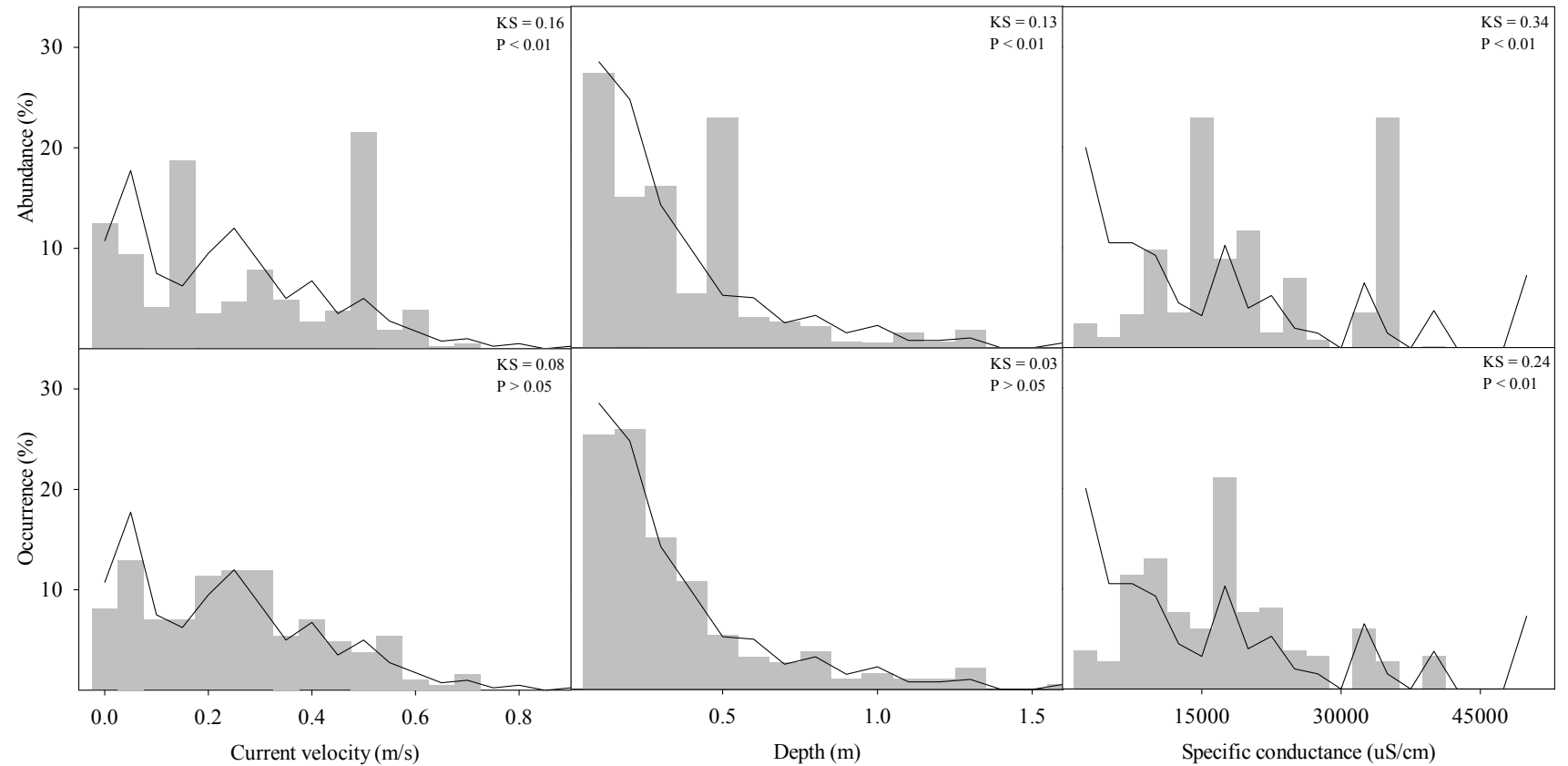


Figure 20. Frequency of abundances (top panel) and occurrences (bottom panel) of available habitats (line) and used habitats (bars) by Red River Shiners along current velocity, depth, and specific conductance gradients. Kolmogorov-Smirnov (KS) test statistic and associated P-value are provided.

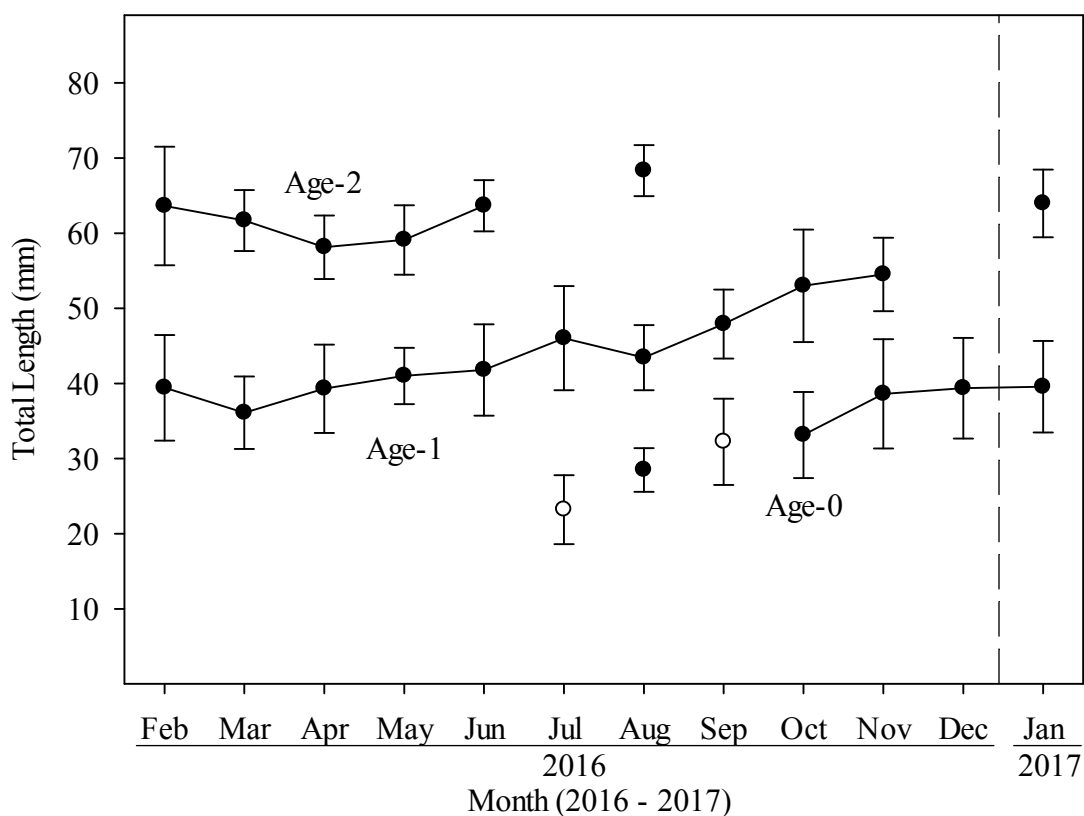


Figure 21. Mean ± 1 SD total lengths (black circles) for Age-0, Age-1, and Age-2 Red River Shiners taken monthly from February 2016 through January 2017. White circles represent mean and ± 1 SE of total lengths taken from ≤ 3 individuals within an age group per month. Dashed line indicates the transition into the next age class.

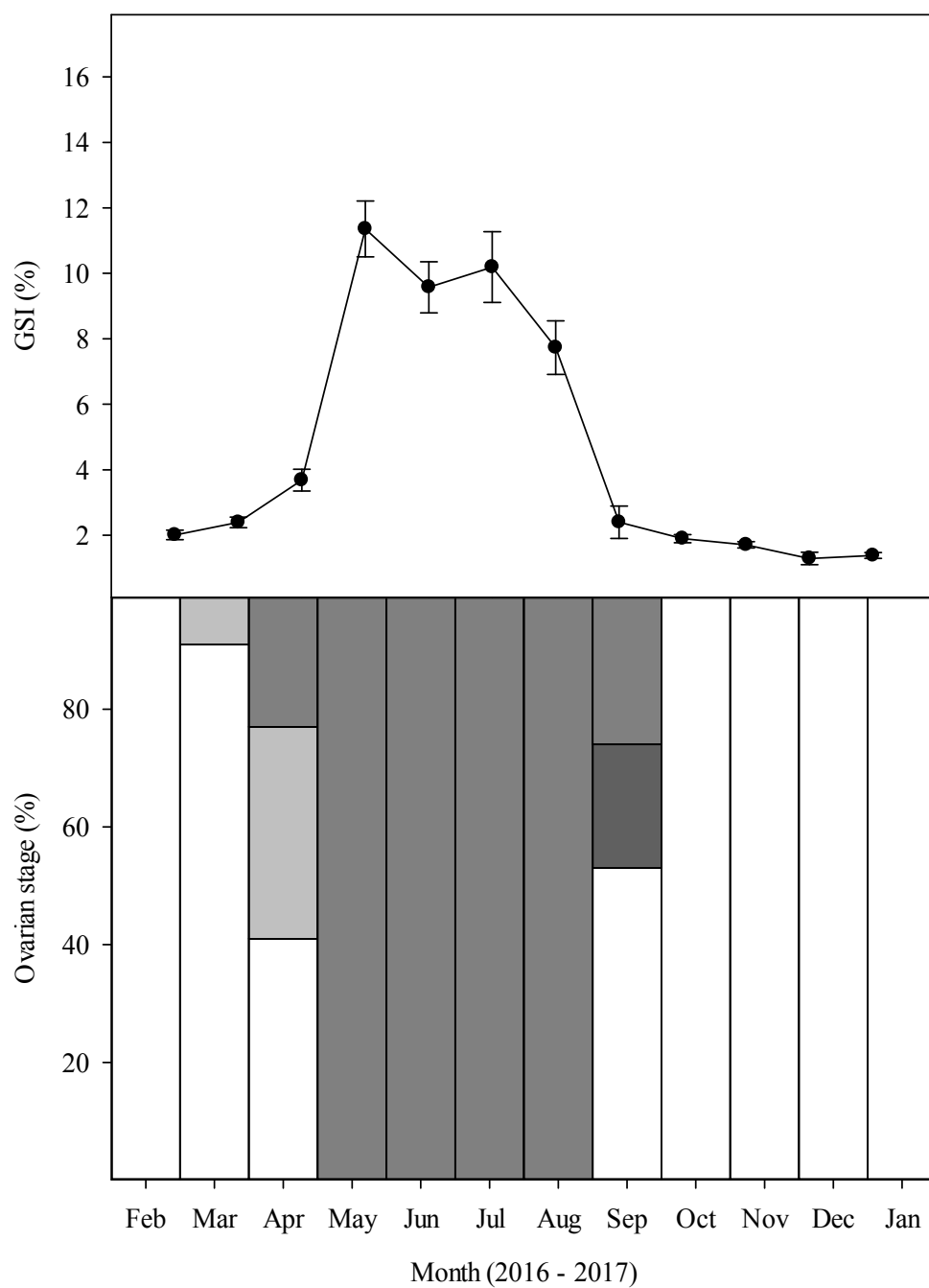


Figure 22. Mean (± 1 SE) monthly gonadosomatic index (GSI) for Red River Shiners taken from February 2016 through January 2017 (top panel). Percent ovarian stages by month for immature (white), developing (light gray), mature (gray), and spent (dark gray) females (bottom panel).

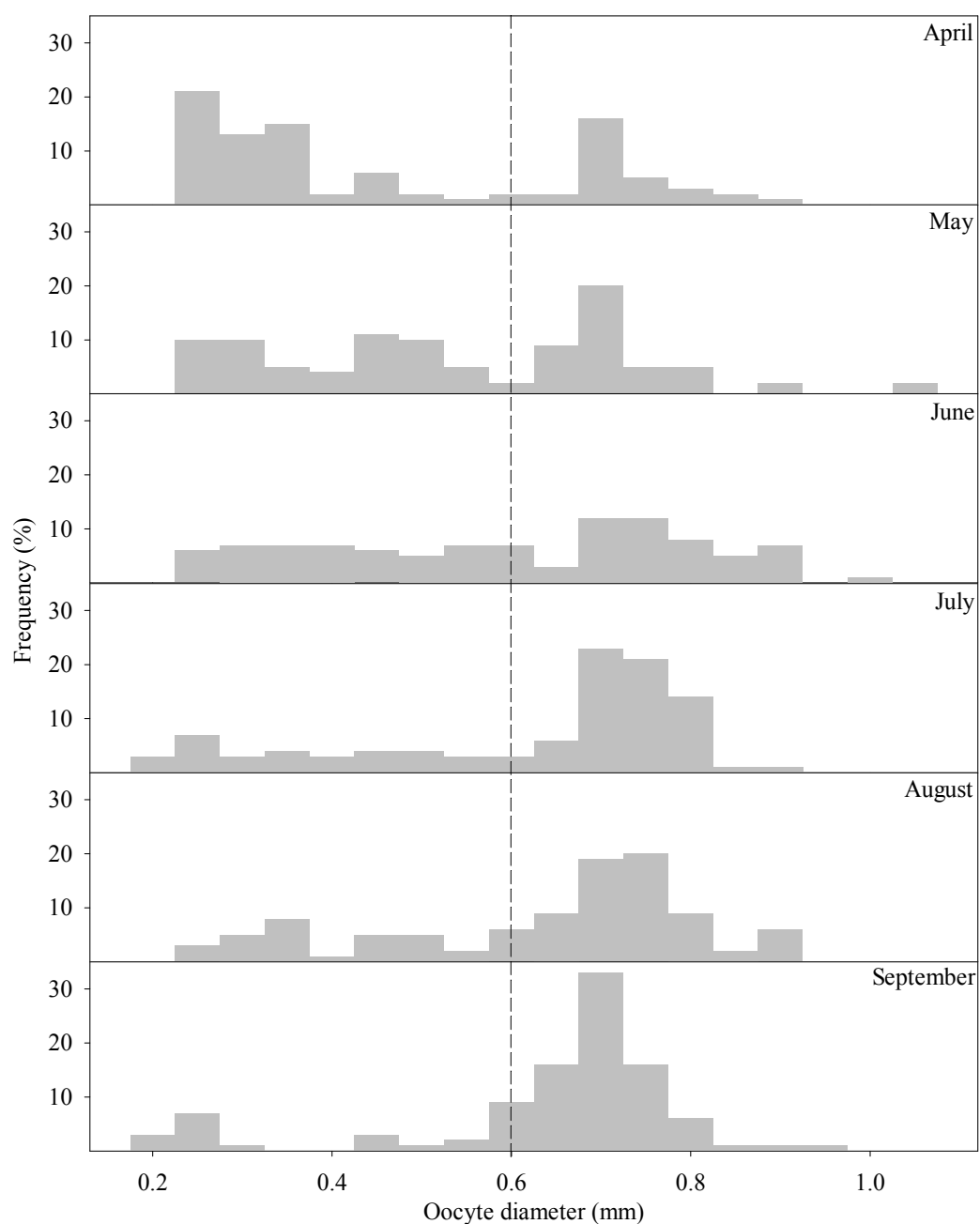


Figure 23. Frequency of oocyte size distribution in mature ovaries of Red River Shiner taken from May 2016 through September 2016. The dashed line indicates estimated size of late vitellogenic oocyte.

Appendix A. Mean (± 1 SD) habitat parameters of sites within the upper Red River drainage from September 2015 through September 2016. Reaches and sites are list in order from upstream to downstream.

Site parameters	Prairie Dog Town Fork			Groesbeck Creek	Wonderers Creek
	Hwy 207	Hwy 70	Hwy 83	Hwy 6	FM 2379
Habitat					
Run	69	73	84	100	
Riffle	23				
Pool	8	7	4		100
Backwater		20	12		
Eddy					
Depth	0.1 (0)	0.2 (0.2)	0.2 (0.1)	0.6 (0.2)	0.6
Current velocity	0.3 (0.1)	0.1 (0.2)	0.2 (0.2)	0.1 (0.1)	0.02
Area (Sum)	440	450	1370	209	42
Substrate					
Clay					
Silt	9	78	30	20	49
Sand	64	22	68	20	49
Gravel	26		2	20	
Cobble	1			20	
Boulder			1	20	2
Bedrock					
Cover type					
Detritus					
Large woody debris				10	
Filamentous Algae					
Algae					
Macrophytes					
<i>Chara</i>					
Riparian vegetation					
Water quality					
Temperature	26	33	22.3 (4.5)	25.4 (4.5)	19.1
Dissolved Oxygen	7.2	4.4	7.1 (0.1)	7.3 (1.2)	5.6
Specific conductance	15,675	38,420	42,115 (9,322)	4,971 (994)	2,614
pH	8.3	8.1	8.1 (0.1)	8.1 (0.03)	8.1
Total N	13	15	50	2	1

Site parameters	Red River						
	Hwy 6	Hwy 283	Hwy 183	Hwy 79	Hwy 81	Hwy 89	I-35
Habitat							
Run	54	75	72	86	70	50	100
Riffle	15	13			10		
Pool	15		14			10	
Backwater	15	13	14	14	20	30	
Eddy						10	
Depth	0.2 (0.1)	0.2 (0.1)	0.5 (0.4)	0.3 (1.9)	0.6 (0.3)	0.8 (0.4)	0.5 (0.4)
Current velocity	0.3 (0.2)	0.4 (0.2)	0.3 (0.2)	0.3 (0.2)	0.3 (0.3)	0.2 (0.2)	0.2 (.01)
Area (Sum)	1931	3658	1083	6836	3691	5169	6409
Substrate							
Clay							
Silt	24	25	27	5	30	46	60
Sand	69	69	67	94	60	53	40
Gravel	7	6	6	1	6	2	
Cobble							
Boulder					4		
Bedrock							
Cover type							
Detritus							
Large woody debris	1.2 (3)	0.1 (0.4)		0.7 (1.9)	1.5 (3.4)	4.2 (8.3)	
Filamentous Algae		0.6 (1.8)					
Algae							
Macrophytes							
<i>Chara</i>							
Riparian vegetation		0.1 (0.4)					
Water quality							
Temperature	20.3(3.3)	18.6 (4.7)	20.2	21.4 (6)	22.6 (4.8)	24.8 (7.4)	28.7 (5.6)
Dissolved Oxygen	7(1.2)	8.3 (0.9)	10.5	7.7 (1.6)	12.3 (0.9)	8.5 (0.3)	8 (1.3)
Specific conductance	26,048 (4,422)	12747 (653)	11,740	6832 (1840)	6863 (1138)	4483 (2857)	3,000 (1,570)
pH	7.9(0.1)	8.2 (0.1)	8.4	7.7 (0.2)	7.9 (0.1)	8.2 (0.1)	8.1 (0.3)
Total N	13	8	7	7	10	10	4

Site parameters	Salt Fork Red River Hwy 83	North Fork Red River Hwy 83	North Pease River Hwy 83
Habitat			
Run	100	100	68
Riffle			8
Pool			12
Backwater			12
Eddy			
Depth	0.2 (0.1)	0.2 (0.1)	0.1 (0.1)
Current velocity	0.4 (0.2)	0.4 (0.1)	0.1 (0.1)
Area (Sum)	330	1227	394
Substrate			
Clay			
Silt	2		25
Sand	98	100	74
Gravel			
Cobble			
Boulder			1.2
Bedrock			
Cover type			
Detritus			9.2 (26)
Large woody debris	3.2 (8.9)		0.2 (1)
Filamentous Algae	5.2 (7.9)		0.8 (4)
Algae			
Macrophytes			
<i>Chara</i>			
Riparian vegetation		15 (17)	
Water quality			
Temperature	30.5	32	25.3 (0.5)
Dissolved Oxygen	6.6	6.97	6.2 (0.8)
Specific conductance	3,350	2,441	21039 (1340)
pH	8	8.2	7.9 (0.1)
Total N	22	4	25

Site parameters	Pease River			Adams Creek	China Creek	Gilberts Creek
	FM 104	Hwy 6	Hwy 283	TX 25	Flippin Rd	FM 369
Habitat						
Run	77	84	56	100		
Riffle	15	4	6			
Pool		8	19		100	100
Backwater	8	4	19			
Eddy						
Depth	0.2 (0.1)	0.6 (0.4)	0.2 (0.2)	0.08 (0.1)	0.5	0.2
Current velocity	0.3 (.2)	0.2 (0.1)	0.2 (0.2)	0.3 (0.2)	0	0
Area (Sum)	2292	434	2245	436	33	147
Substrate						
Clay						
Silt	14	34	33	67	100	100
Sand	67	65	65	33		
Gravel	18	1.2	1.9			
Cobble						
Boulder	0.8					
Bedrock						
Cover type						
Detritus			0.3 (1.3)			
Large woody debris	1.2 (3)		0.3 (1.3)	6.7 (11.5)	10	
Filamentous Algae			0.6 (2.5)			
Algae		3.6 (16)		1.7 (2.9)		
Macrophytes						
<i>Chara</i>						
Riparian vegetation				5 (5)		
Water quality						
Temperature	14.6 (8.8)	28.6 (4.8)	24.4 (4.3)	24.8 (3)	18.3	18.7
Dissolved Oxygen	7.6 (1.9)	5.9 (0.8)	8.1 (1.9)	9.8 (1.3)	6.6	8.5
Specific conductance	25412 (8849)	15867 (1197)	13055 (1450)	1179 (48)	4599	3842
pH	7.5 (0.5)	8 (0.1)	8 (0.1)	8.7 (0.6)	8.2	8.3
Total N	13	25	16	3	1	1

Site parameters	North Wichita River	Wichita				
	Hwy 6	FM 1919	Hwy 283	Hwy 368	Hwy 11	Hwy 810
Habitat						
Run	60	89	80	83	63	29
Riffle	40	4		17	38	43
Pool		4				14
Backwater		4	20			14
Eddy						
Depth	0.2 (0.1)	0.2 (0.1)	0.4 (0.3)	0.4 (0.2)	0.5 (0.2)	0.4 (0.2)
Current velocity	0.2 (0.2)	0.2 (0.2)	0.01 (0.01)	0.2 (0.1)	0.3 (0.2)	0.3 (0.2)
Area (Sum)	925	686	1658	1415	2102	1528
Substrate						
Clay						
Silt	63	27	47	22	31	6
Sand	1	56		70	31	38
Gravel	34	17	24	7	26	9
Cobble	2		7		0.6	9
Boulder	1		22	2	11	29
Bedrock						10
Cover type						
Detritus						
Large woody debris	0.3 (0.7)	1.4 (5.8)			1.9 (3.7)	1.4 (3.8)
Filamentous Algae	2 (6.3)				0.6 (1.8)	11.4 (21.9)
Algae			1 (2.2)			
Macrophytes			1.2 (2.2)			
<i>Chara</i>			13 (29.1)			
Riparian vegetation						
Water quality						
Temperature	25.5 (5.2)	27 (0.1)	18.5 (5)	20 (5)	22.8 (5.5)	25.5 (5.5)
Dissolved Oxygen	7.3 (1.1)	7.3 (0.9)	6.1 (0.1)	9.6 (0.2)	11.5 (1.7)	9.1 (4.5)
Specific conductance	19131 (9395)	9876 (3623)	5677 (173)	6058 (1124)	5165 (1642)	4045 (479)
pH	8.3 (0)	8.1 (0)	7.2 (0.3)	7.5 (0.4)	7.9 (0.4)	7.9 (0.3)
Total N	10	28	5	6	8	7

Site parameters	Little Wichita		Barrel Springs Creek	Pecan Creek	Farmers Creek
	Hwy 287	FM 2332	Crain Rd	FM 2849	FM 103
Habitat					
Run	50	100			33
Riffle					25
Pool	50		100	100	33
Backwater					8
Eddy					
Depth	0.8 (0.2)	0.9 (0.3)	0.2	0.3 (0.2)	0.3 (0.2)
Current velocity	0	0.02 (0.01)	0	0.04 (0.02)	0.1 (0.2)
Area (Sum)	375	2512	41	409	984
Substrate					
Clay					3
Silt	88	97	90	33	20
Sand		2		6	51
Gravel	13		10	2	19
Cobble				1	1
Boulder		1			
Bedrock				58	6
Cover type					
Detritus	15 (21)				
Large woody debris		1 (1.9)		5.6 (11)	4.6 (11)
Filamentous Algae			40	20 (20)	3.3 (12)
Algae					
Macrophytes					
<i>Chara</i>					
Riparian vegetation					
Water quality					
Temperature	25.7 (2.2)	28.9 (0.5)	33.2	26.3	27.3 (0.7)
Dissolved Oxygen	3.1 (0.7)	10.1 (0)	7.4	6.9	8.1 (1.2)
Specific conductance	488 (132)	4153 (2623)	1036	986	1743 (8)
pH	7.9 (0.2)	8.4 (0.1)	8.7	8.2	8 (0.2)
Total N	2	7	1	9	12

Site parameters	Cottonwood Creek	Mountain Creek		South Fish Creek
	FM 2953	Childress Rd	FM 373	CR 411
Habitat				
Run	63	58	89	12
Riffle	13	25		18
Pool	25			65
Backwater		8.3	11	6
Eddy		8.3		
Depth	0.3 (0.4)	0.2 (0.2)	0.1 (0.1)	0.4 (0.2)
Current velocity	0.2 (0.2)	0.5 (0.3)	0.2 (0.1)	0.1 (0.1)
Area (Sum)	576	718	1116	1222
Substrate				
Clay				
Silt	19	22	7	30
Sand	70	51	91	18
Gravel	11	16	2	35
Cobble		9		8
Boulder		3	1	6
Bedrock				3
Cover type				
Detritus				1.9 (5.7)
Large woody debris	1.9 (2.6)			0.3 (1.2)
Filamentous Algae				20.2 (28)
Algae				
Macrophytes				
<i>Chara</i>			0.6 (2.4)	4.6 (13)
Riparian vegetation			1.9 (3.9)	
Water quality				
Temperature	34.5 (5.7)	19.4 (4.7)	27.7 (0.3)	26.1 (2.5)
Dissolved Oxygen	6.4 (1.4)	9.8 (0.3)	7.9 (0.1)	10.6 (1.3)
Specific conductance	1529 (251)	895 (814)	5421 (531)	663 (37)
pH	8.1 (0.1)	8.2 (0.2)	8 (0.1)	7.8 (0.1)
Total N	8	12	18	17

Appendix B. Relative abundance of fishes by reach within the upper Red River drainage from September 2015 through September 2016. Reaches are list in order from upstream to downstream.

Scientific Name	Prairie Dog Town Fork	Groesbeck Creek	Wonderers Creek	Red River	Salt Fork Red River
<i>Lepisosteus larvae</i>				0.02	
<i>Lepisosteus oculatus</i>				0.01	
<i>Lepisosteus osseus</i>		0.11		0.06	
<i>Lepisosteus platostomus</i>				0.02	
<i>Hiodon alosoides</i>				0.01	
<i>Dorosoma cepedianum</i>				6.59	
<i>Dorosoma petenense</i>				0.03	
<i>Campostoma anomalum</i>					
<i>Cyprinella lutrensis</i>	10.16	99.08	63.89	14.37	73.64
<i>Cyprinella venusta</i>					
<i>Cyprinus carpio</i>				0.01	
<i>Hybognathus placitus</i>	5.65			27.65	8.14
<i>Macrhybopsis larvae</i>				0.01	
<i>Macrhybopsis australis</i>				1.21	
<i>Macrhybopsis hyostoma</i>				2.03	
<i>Macrhybopsis storeriana</i>				0.03	
<i>Notemigonus crysoleucas</i>					
<i>Notropis atherinoides</i>				16.49	
<i>Notropis bairdi</i>	5.13			13.44	0.39
<i>Notropis buechanani</i>				4.00	
<i>Notropis stramineus</i>				0.04	1.55
<i>Phenacobius mirabilis</i>					
<i>Pimephales promelas</i>		0.49		0.07	
<i>Pimephales vigilax</i>		0.11	21.11	0.22	2.71
<i>Carpionodes carpio</i>				0.11	
<i>Ictiobus bubalus</i>				0.14	
<i>Ameiurus natalis</i>					
<i>Ameiurus melas</i>				0.02	
<i>Ictalurus furcatus</i>				2.60	
<i>Ictalurus punctatus</i>				0.19	0.39
<i>Pylodictis olivaris</i>					
<i>Labidesthes sicculus</i>					
<i>Menidia audens</i>				2.17	
<i>Fundulus notatus</i>					
<i>Fundulus grandis</i>					
<i>Fundulus zebrinus</i>	6.41			0.35	6.98
<i>Gambusia affinis</i>	0.57	0.05	9.44	5.81	4.65
<i>Cyprinodon rubrofluviatilis</i>	72.08			0.35	0.78
<i>Morone saxatilis</i>				0.04	
<i>Lepomis larvae</i>				0.02	
<i>Lepomis auritus</i>				0.47	
<i>Lepomis cyanellus</i>				0.14	0.78
<i>Lepomis humilis</i>		0.05		0.39	
<i>Lepomis macrochirus</i>			2.22	0.03	
<i>Lepomis megalotis</i>		0.05	3.33	0.03	
<i>Lepomis microlophus</i>					
<i>Micropterus salmoides</i>		0.05		0.03	
<i>Pomoxis annularis</i>				0.55	
<i>Percina caprodes</i>					
<i>Percina macrolepida</i>				0.01	
<i>Etheostoma spectabile</i>					
<i>Aplodinotus grunniens</i>				0.24	
Richness	6	8	5	37	10
Total N	2,106	1,841	180	12,437	258

Scientific Name	North Fork Red River	North Pease River	Pease River	Adams Creek	China Creek
<i>Lepisosteus larvae</i>					
<i>Lepisosteus oculatus</i>					
<i>Lepisosteus osseus</i>					
<i>Lepisosteus platostomus</i>					
<i>Hiodon alosoides</i>					
<i>Dorosoma cepedianum</i>			0.34		
<i>Dorosoma petenense</i>					
<i>Campostoma anomalum</i>					
<i>Cyprinella lutrensis</i>	89.19	0.71	10.09	58.28	
<i>Cyprinella venusta</i>					
<i>Cyprinus carpio</i>					16.67
<i>Hybognathus placitus</i>		12.41	9.81		
<i>Macrhybopsis larvae</i>					
<i>Macrhybopsis australis</i>		0.12	0.89		
<i>Macrhybopsis hyostoma</i>					
<i>Macrhybopsis storeriana</i>					
<i>Notemigonus crysoleucas</i>					
<i>Notropis atherinoides</i>					
<i>Notropis bairdi</i>		27.78	56.10		
<i>Notropis buchanaani</i>					
<i>Notropis stramineus</i>	2.70				
<i>Phenacobius mirabilis</i>				0.23	
<i>Pimephales promelas</i>			1.08	1.23	16.67
<i>Pimephales vigilax</i>	1.62		0.03	0.06	
<i>Carpionodes carpio</i>				0.12	
<i>Ictiobus bubalus</i>				0.18	
<i>Ameiurus natalis</i>					
<i>Ameiurus melas</i>					
<i>Ictalurus furcatus</i>					
<i>Ictalurus punctatus</i>			0.01	0.06	
<i>Pylodictis olivaris</i>					
<i>Labidesthes sicculus</i>					
<i>Menidia audens</i>			0.06		
<i>Fundulus notatus</i>					
<i>Fundulus grandis</i>					
<i>Fundulus zebrinus</i>	2.70	31.56	5.70		
<i>Gambusia affinis</i>	0.54	0.35	2.25	38.45	
<i>Cyprinodon rubrofluviatilis</i>	0.54	27.07	13.48		
<i>Morone saxatilis</i>					
<i>Lepomis larvae</i>	0.54				
<i>Lepomis auritus</i>					
<i>Lepomis cyanellus</i>	0.54		0.04	0.99	
<i>Lepomis humilis</i>				0.06	
<i>Lepomis macrochirus</i>	0.54		0.01		66.67
<i>Lepomis megalotis</i>	0.54			0.29	
<i>Lepomis microlophus</i>					
<i>Micropterus salmoides</i>	0.54		0.09	0.06	
<i>Pomoxis annularis</i>					
<i>Percina caprodes</i>					
<i>Percina macrolepida</i>					
<i>Etheostoma spectabile</i>					
<i>Aplodinotus grunniens</i>					
Richness	10	7	15	12	3
Total N	185	846	6,838	1,714	6

Scientific Name	Gilberts Creek	North Wichita River	Wichita River	Little Wichita River	Barrel Springs Creek
<i>Lepisosteus larvae</i>			0.02		
<i>Lepisosteus oculatus</i>					
<i>Lepisosteus osseus</i>			0.02	0.25	
<i>Lepisosteus platostomus</i>			0.02		
<i>Hiodon alosoides</i>					
<i>Dorosoma cepedianum</i>		0.39	0.10	9.23	
<i>Dorosoma petenense</i>			0.15		
<i>Campostoma anomalum</i>					
<i>Cyprinella lutrensis</i>	0.81	2.86	59.32	1.50	14.63
<i>Cyprinella venusta</i>			0.02		
<i>Cyprinus carpio</i>		0.13	0.17	0.12	
<i>Hybognathus placitus</i>		41.15	8.09		
<i>Macrhybopsis larvae</i>					
<i>Macrhybopsis australis</i>		9.64	3.74		
<i>Macrhybopsis hyostoma</i>			0.04		
<i>Macrhybopsis storeriana</i>					
<i>Notemigonus crysoleucas</i>					
<i>Notropis atherinoides</i>			1.26	1.50	
<i>Notropis bairdi</i>		36.72	4.14		
<i>Notropis buchani</i>			3.00	32.42	
<i>Notropis stramineus</i>			0.02		
<i>Phenacobius mirabilis</i>			0.63		
<i>Pimephales promelas</i>		0.13	0.44		
<i>Pimephales vigilax</i>			6.36	0.25	
<i>Carpionodes carpio</i>				0.12	
<i>Ictiobus bubalus</i>			0.02		
<i>Ameiurus natalis</i>		0.13			
<i>Ameiurus melas</i>			0.02		
<i>Ictalurus furcatus</i>					
<i>Ictalurus punctatus</i>			0.42	0.12	0.81
<i>Pylodictis olivaris</i>					
<i>Labidesthes sicculus</i>					
<i>Menidia audens</i>			3.19	6.23	
<i>Fundulus notatus</i>					
<i>Fundulus grandis</i>			0.02		
<i>Fundulus zebrinus</i>		3.13	2.77		
<i>Gambusia affinis</i>	97.70	1.69	4.18	6.36	78.05
<i>Cyprinodon rubrofluviatilis</i>		3.65	0.32		
<i>Morone saxatilis</i>					
<i>Lepomis larvae</i>			0.06	6.98	
<i>Lepomis auritus</i>			0.06		
<i>Lepomis cyanellus</i>	0.46		0.78	0.75	
<i>Lepomis humilis</i>	1.04	0.39	0.15	0.25	
<i>Lepomis macrochirus</i>			0.10	27.18	6.50
<i>Lepomis megalotis</i>			0.21	0.37	
<i>Lepomis microlophus</i>			0.02		
<i>Micropterus salmoides</i>			0.13	0.62	
<i>Pomoxis annularis</i>			0.02	4.86	
<i>Percina caprodes</i>					
<i>Percina macrolepida</i>					
<i>Etheostoma spectabile</i>					
<i>Aplodinotus grunniens</i>				0.87	
Richness	4	12	33	18	4
Total N	869	768	5,239	802	123

Scientific Name	Pecan Creek	Farmers Creek	Cottonwood Creek	Mountain Creek	South Fish Creek
<i>Lepisosteus larvae</i>					
<i>Lepisosteus oculatus</i>	1.48	0.32			
<i>Lepisosteus osseus</i>					
<i>Lepisosteus platostomus</i>					
<i>Hiodon alosoides</i>					
<i>Dorosoma cepedianum</i>	11.33	4.17	9.09		
<i>Dorosoma petenense</i>		0.96			
<i>Campostoma anomalum</i>				1.83	26.71
<i>Cyprinella lutrensis</i>	11.33	17.63	53.33	24.85	
<i>Cyprinella venusta</i>		0.96	0.61		
<i>Cyprinus carpio</i>	2.46	0.32		0.37	
<i>Hybognathus placitus</i>				18.51	
<i>Macrhybopsis larvae</i>					
<i>Macrhybopsis australis</i>				0.37	
<i>Macrhybopsis hyostoma</i>				0.37	
<i>Macrhybopsis storeriana</i>					
<i>Notemigonus crysoleucas</i>	0.49	4.17			
<i>Notropis atherinoides</i>					
<i>Notropis bairdi</i>				4.51	
<i>Notropis buchanaui</i>					
<i>Notropis stramineus</i>			4.24	2.19	
<i>Phenacobius mirabilis</i>		6.09		0.12	
<i>Pimephales promelas</i>					
<i>Pimephales vigilax</i>					0.80
<i>Carpionodes carpio</i>		2.24			
<i>Ictiobus bubalus</i>	3.45	0.96		0.24	
<i>Ameiurus natalis</i>				0.37	0.20
<i>Ameiurus melas</i>					
<i>Ictalurus furcatus</i>		2.56			
<i>Ictalurus punctatus</i>		1.28			
<i>Pylodictis olivaris</i>		0.32			
<i>Labidesthes sicculus</i>					0.80
<i>Menidia audens</i>		8.97			
<i>Fundulus notatus</i>					26.10
<i>Fundulus grandis</i>					
<i>Fundulus zebrinus</i>				17.17	
<i>Gambusia affinis</i>	48.28	27.88	7.27	26.80	4.22
<i>Cyprinodon rubrofluviatilis</i>					
<i>Morone saxatilis</i>		1.28			
<i>Lepomis larvae</i>	0.99	0.32			2.81
<i>Lepomis auritus</i>					
<i>Lepomis cyanellus</i>	3.94	3.53	16.36	1.95	2.81
<i>Lepomis humilis</i>					
<i>Lepomis macrochirus</i>	1.97	5.13	6.06		22.89
<i>Lepomis megalotis</i>	5.42	2.24	1.82	0.24	4.22
<i>Lepomis microlophus</i>					
<i>Micropterus salmoides</i>	8.87	1.92	1.21	0.12	1.81
<i>Pomoxis annularis</i>		0.96			
<i>Percina caprodes</i>		0.64			
<i>Percina macrolepida</i>		5.13			0.80
<i>Etheostoma spectabile</i>					5.82
<i>Aplodinotus grunniens</i>					
Richness	11	23	9	16	12
Total N	203	312	165	821	498

Appendix C. Relative abundance of fishes by site within the upper Red River drainage from September 2015 through September 2016. Sites are list in order from upstream to downstream.

Scientific Name	Prairie Dog Town Fork			Groesbeck Creek	Wonderers Creek
	Hwy 207	Hwy 70	Hwy 83	Hwy 6	FM 2379
<i>Lepisosteus larvae</i>					
<i>Lepisosteus oculatus</i>					
<i>Lepisosteus osseus</i>				0.11	
<i>Lepisosteus platostomus</i>					
<i>Hiodon alosoides</i>					
<i>Dorosoma cepedianum</i>					
<i>Dorosoma petenense</i>					
<i>Camptostoma anomalum</i>					
<i>Cyprinella lutrensis</i>	38.49		0.76	99.08	63.89
<i>Cyprinella venusta</i>					
<i>Cyprinus carpio</i>					
<i>Hybognathus placitus</i>	20.26		1.37		
<i>Macrhybopsis larvae</i>					
<i>Macrhybopsis australis</i>					
<i>Macrhybopsis hyostoma</i>					
<i>Macrhybopsis storeriana</i>					
<i>Notemigonus crysoleucas</i>					
<i>Notropis atherinoides</i>					
<i>Notropis bairdi</i>	15.29	1.33	1.97		
<i>Notropis buechanani</i>					
<i>Notropis stramineus</i>					
<i>Phenacobius mirabilis</i>					
<i>Pimephales promelas</i>				0.49	
<i>Pimephales vigilax</i>				0.11	21.11
<i>Carpiodes carpio</i>					
<i>Ictiobus bubalus</i>					
<i>Ameiurus natalis</i>					
<i>Ameiurus melas</i>					
<i>Ictalurus furcatus</i>					
<i>Ictalurus punctatus</i>					
<i>Pylodictis olivaris</i>					
<i>Labidesthes sicculus</i>					
<i>Menidia audens</i>					
<i>Fundulus notatus</i>					
<i>Fundulus grandis</i>					
<i>Fundulus zebrinus</i>	15.65	1.00	6.22		
<i>Gambusia affinis</i>			1.82	0.05	9.44
<i>Cyprinodon rubrofluvialis</i>	10.31	97.68	87.86		
<i>Morone saxatilis</i>					
<i>Lepomis larvae</i>					
<i>Lepomis auritus</i>					
<i>Lepomis cyanellus</i>					
<i>Lepomis humilis</i>				0.05	
<i>Lepomis macrochirus</i>					2.22
<i>Lepomis megalotis</i>				0.05	3.33
<i>Lepomis microlophus</i>					
<i>Micropterus salmoides</i>				0.05	
<i>Pomoxis annularis</i>					
<i>Percina caprodes</i>					
<i>Percina macrolepida</i>					
<i>Etheostoma spectabile</i>					
<i>Aplodinotus grunniens</i>					
Richness	5	3	6	8	5
Total N	543	904	659	1,841	180

Scientific Name	Red River						
	Hwy 6	Hwy 283	Hwy 183	Hwy 79	Hwy 81	Hwy 89	I-35
<i>Lepisosteus larvae</i>						0.04	
<i>Lepisosteus oculatus</i>						0.02	
<i>Lepisosteus osseus</i>			0.36		0.16	0.09	
<i>Lepisosteus platostomus</i>						0.07	
<i>Hiodon alosoides</i>					0.16		
<i>Dorosoma cepedianum</i>		0.33	0.12	1.24	12.58	16.01	0.02
<i>Dorosoma petenense</i>							0.09
<i>Campostoma anomalum</i>							
<i>Cyprinella lutrensis</i>		67.80	59.95	22.31	7.92	11.71	0.70
<i>Cyprinella venusta</i>							
<i>Cyprinus carpio</i>		0.11					
<i>Hybognathus placitus</i>	9.96	2.75	2.88	15.70	0.78	13.02	60.50
<i>Macrhybopsis larvae</i>					0.16		
<i>Macrhybopsis australis</i>	0.24	0.88	6.00	6.20	0.31	0.86	0.79
<i>Macrhybopsis hyostoma</i>				4.55	2.64	2.83	2.18
<i>Macrhybopsis storeriana</i>							0.09
<i>Notemigonus crysoleucas</i>							
<i>Notropis atherinoides</i>		0.55	1.32	26.86	24.38	14.78	25.81
<i>Notropis bairdi</i>	79.23	14.84	17.51	19.01	39.75	6.58	2.90
<i>Notropis buchanaui</i>				3.72	2.02	10.39	0.02
<i>Notropis stramineus</i>						0.11	
<i>Phenacobius mirabilis</i>							
<i>Pimephales promelas</i>		0.66				0.07	
<i>Pimephales vigilax</i>					0.47	0.48	0.05
<i>Carpionodes carpio</i>					1.55	0.09	
<i>Ictiobus bubalus</i>		0.11			0.31	0.31	
<i>Ameiurus natalis</i>							
<i>Ameiurus melas</i>	0.24						
<i>Ictalurus furcatus</i>						0.86	6.44
<i>Ictalurus punctatus</i>		0.44	0.12	0.41	0.47	0.31	0.02
<i>Pylodictis olivaris</i>							
<i>Labidesthes sicculus</i>							
<i>Menidia audens</i>			2.64		1.09	5.24	0.05
<i>Fundulus notatus</i>							
<i>Fundulus grandis</i>							
<i>Fundulus zebrinus</i>	3.48	1.43	0.12				
<i>Gambusia affinis</i>	2.16	8.24	8.27		1.40	11.99	0.09
<i>Cyprinodon rubrofluviatilis</i>	4.68	0.33	0.12				
<i>Morone saxatilis</i>			0.12			0.09	
<i>Lepomis larvae</i>						0.07	
<i>Lepomis auritus</i>						1.29	
<i>Lepomis cyanellus</i>		1.21	0.12			0.13	
<i>Lepomis humilis</i>		0.22			0.16	0.94	0.05
<i>Lepomis macrochirus</i>			0.12			0.07	
<i>Lepomis megalotis</i>		0.11				0.07	
<i>Lepomis microlophus</i>							
<i>Micropterus salmoides</i>						0.09	
<i>Pomoxis annularis</i>			0.24		3.57	0.90	0.07
<i>Percina caprodes</i>							
<i>Percina macrolepidia</i>							0.02
<i>Etheostoma spectabile</i>							
<i>Aplodinotus grunniens</i>					0.16	0.53	0.11
Richness	7	16	16	9	20	29	19
Total N	833	910	834	242	644	4,561	4,413

Scientific Name	Salt Fork Red River Hwy 83	North Fork Red River Hwy 83	North Pease River Hwy 83
<i>Lepisosteus larvae</i>			
<i>Lepisosteus oculatus</i>			
<i>Lepisosteus osseus</i>			
<i>Lepisosteus platostomus</i>			
<i>Hiodon alosoides</i>			
<i>Dorosoma cepedianum</i>			
<i>Dorosoma petenense</i>			
<i>Campostoma anomalum</i>			
<i>Cyprinella lutrensis</i>	73.64	89.19	0.71
<i>Cyprinella venusta</i>			
<i>Cyprinus carpio</i>			
<i>Hybognathus placitus</i>	8.14		12.41
<i>Macrhybopsis larvae</i>			
<i>Macrhybopsis australis</i>			0.12
<i>Macrhybopsis hyostoma</i>			
<i>Macrhybopsis storeriana</i>			
<i>Notemigonus crysoleucas</i>			
<i>Notropis atherinoides</i>			
<i>Notropis bairdi</i>	0.39		27.78
<i>Notropis buechanani</i>			
<i>Notropis stramineus</i>	1.55	2.70	
<i>Phenacobius mirabilis</i>			
<i>Pimephales promelas</i>			
<i>Pimephales vigilax</i>	2.71	1.62	
<i>Carpiodes carpio</i>			
<i>Ictiobus bubalus</i>			
<i>Ameiurus natalis</i>			
<i>Ameiurus melas</i>			
<i>Ictalurus furcatus</i>			
<i>Ictalurus punctatus</i>	0.39		
<i>Pylodictis olivaris</i>			
<i>Labidesthes sicculus</i>			
<i>Menidia audens</i>			
<i>Fundulus notatus</i>			
<i>Fundulus grandis</i>			
<i>Fundulus zebrinus</i>	6.98	2.70	31.56
<i>Gambusia affinis</i>	4.65	0.54	0.35
<i>Cyprinodon rubrofluviatilis</i>	0.78	0.54	27.07
<i>Morone saxatilis</i>			
<i>Lepomis larvae</i>		0.54	
<i>Lepomis auritus</i>			
<i>Lepomis cyanellus</i>	0.78	0.54	
<i>Lepomis humilis</i>			
<i>Lepomis macrochirus</i>		0.54	
<i>Lepomis megalotis</i>		0.54	
<i>Lepomis microlophus</i>			
<i>Micropterus salmoides</i>		0.54	
<i>Pomoxis annularis</i>			
<i>Percina caprodes</i>			
<i>Percina macrolepida</i>			
<i>Etheostoma spectabile</i>			
<i>Aplodinotus grunniens</i>			
Richness	10	10	7
Total N	258	185	846

Scientific Name	Pease River			Adams Creek	China Creek	Gilberts Creek
	FM 104	Hwy 6	Hwy 283	TX 25	Flippin Rd	FM 369
<i>Lepisosteus</i> larvae						
<i>Lepisosteus oculatus</i>						
<i>Lepisosteus osseus</i>						
<i>Lepisosteus platostomus</i>						
<i>Hiodon alosoides</i>						
<i>Dorosoma cepedianum</i>		1.54	0.03			
<i>Dorosoma petenense</i>						
<i>Campostoma anomalum</i>						
<i>Cyprinella lutrensis</i>		1.68	18.54	58.28		0.81
<i>Cyprinella venusta</i>						
<i>Cyprinus carpio</i>					16.67	
<i>Hybognathus placitus</i>	0.39	25.84	8.21			
<i>Macrhybopsis</i> larvae						
<i>Macrhybopsis australis</i>	0.28	1.26	1.06			
<i>Macrhybopsis hyostoma</i>						
<i>Macrhybopsis storeriana</i>						
<i>Notemigonus crysoleucas</i>						
<i>Notropis atherinoides</i>						
<i>Notropis bairdi</i>	90.92	53.78	39.39			
<i>Notropis buchanani</i>						
<i>Notropis stramineus</i>						
<i>Phenacobius mirabilis</i>				0.23		
<i>Pimephales promelas</i>			2.06	1.23	16.67	
<i>Pimephales vigilax</i>			0.06	0.06		
<i>Carpionodes carpio</i>				0.12		
<i>Ictiobus bubalus</i>				0.18		
<i>Ameiurus natalis</i>						
<i>Ameiurus melas</i>						
<i>Ictalurus furcatus</i>						
<i>Ictalurus punctatus</i>			0.03	0.06		
<i>Pylodictis olivaris</i>						
<i>Labidesthes sicculus</i>						
<i>Menidia audens</i>			0.11			
<i>Fundulus notatus</i>						
<i>Fundulus grandis</i>						
<i>Fundulus zebrinus</i>	5.78	12.61	2.92			
<i>Gambusia affinis</i>	0.06	1.96	3.48	38.45		97.70
<i>Cyprinodon rubrofluviatilis</i>	2.59	1.26	23.86			
<i>Morone saxatilis</i>						
<i>Lepomis</i> larvae						
<i>Lepomis auritus</i>						
<i>Lepomis cyanellus</i>			0.08	0.99		0.46
<i>Lepomis humilis</i>				0.06		1.04
<i>Lepomis macrochirus</i>		0.07			66.67	
<i>Lepomis megalotis</i>				0.29		
<i>Lepomis microlophus</i>						
<i>Micropterus salmoides</i>			0.17	0.06		
<i>Pomoxis annularis</i>						
<i>Percina caprodes</i>						
<i>Percina macrolepidia</i>						
<i>Etheostoma spectabile</i>						
<i>Aplodinotus grunniens</i>						
Richness	6	9	14	12	3	4
Total N	1,818	1,428	3,592	1,714	6	869

Scientific Name	North Wichita River	Wichita River				
	Hwy 6	FM 1919	Hwy 283	Hwy 368	Hwy 11	Hwy 810
<i>Lepisosteus larvae</i>						0.05
<i>Lepisosteus oculatus</i>						
<i>Lepisosteus osseus</i>				0.14		
<i>Lepisosteus platostomus</i>						0.05
<i>Hiodon alosoides</i>						
<i>Dorosoma cepedianum</i>	0.39		0.85			0.14
<i>Dorosoma petenense</i>		0.30				0.19
<i>Campostoma anomalum</i>						
<i>Cyprinella lutrensis</i>	2.86	16.52	15.32	62.45	70.48	85.72
<i>Cyprinella venusta</i>						0.05
<i>Cyprinus carpio</i>	0.13		2.98		0.11	0.05
<i>Hybognathus placitus</i>	41.15	30.53		2.89		
<i>Macrhybopsis larvae</i>						
<i>Macrhybopsis australis</i>	9.64	14.47		0.14		0.19
<i>Macrhybopsis hyostoma</i>						0.10
<i>Macrhybopsis storeriana</i>						
<i>Notemigonus crysoleucas</i>						
<i>Notropis atherinoides</i>				0.14	0.34	2.99
<i>Notropis bairdi</i>	36.72	11.44		1.51	1.02	2.22
<i>Notropis buchmanii</i>				7.43	6.67	2.12
<i>Notropis stramineus</i>						0.05
<i>Phenacobius mirabilis</i>				0.55	1.70	0.68
<i>Pimephales promelas</i>	0.13	0.15		2.61	0.11	0.05
<i>Pimephales vigilax</i>				19.12	14.14	3.33
<i>Carpiodes carpio</i>						
<i>Ictiobus bubalus</i>					0.11	
<i>Ameiurus natalis</i>	0.13					
<i>Ameiurus melas</i>			0.43			
<i>Ictalurus furcatus</i>						
<i>Ictalurus punctatus</i>				0.14	0.34	0.87
<i>Pylodictis olivaris</i>						
<i>Labidesthes sicculus</i>						
<i>Menidia audens</i>			61.70			1.06
<i>Fundulus notatus</i>						
<i>Fundulus grandis</i>				0.14		
<i>Fundulus zebrinus</i>	3.13	10.98				
<i>Gambusia affinis</i>	1.69	14.17	7.66	1.79	0.11	
<i>Cyprinodon rubrofluviatilis</i>	3.65	1.29				
<i>Morone saxatilis</i>						
<i>Lepomis larvae</i>					0.34	
<i>Lepomis auroch</i>			1.28			
<i>Lepomis cyanellus</i>		0.08	4.26	0.14	3.05	0.10
<i>Lepomis humilis</i>	0.39		0.43	0.14	0.68	
<i>Lepomis macrochirus</i>			1.28		0.23	
<i>Lepomis megalotis</i>		0.08	0.85	0.41	0.57	
<i>Lepomis microlophus</i>			0.43			
<i>Micropterus salmoides</i>			2.55	0.14		
<i>Pomoxis annularis</i>				0.14		
<i>Percina caprodes</i>						
<i>Percina macrolepidia</i>						
<i>Etheostoma spectabile</i>						
<i>Aplodinotus grunniens</i>						
Richness	12	11	13	18	15	18
Total N	768	1,320	235	727	884	2,073

Scientific Name	Little Wichita River		Barrel Springs Creek Crain Rd	Pecan Creek FM 2849	Farmers Creek FM 103
	Hwy 287	FM 2332			
<i>Lepisosteus</i> larvae					
<i>Lepisosteus oculatus</i>				1.48	0.32
<i>Lepisosteus osseus</i>	5.88				
<i>Lepisosteus platostomus</i>					
<i>Hiodon alosoides</i>					
<i>Dorosoma cepedianum</i>	2.94	9.51		11.33	4.17
<i>Dorosoma petenense</i>					0.96
<i>Campostoma anomalum</i>					
<i>Cyprinella lutrensis</i>		1.56	14.63	11.33	17.63
<i>Cyprinella venusta</i>					0.96
<i>Cyprinus carpio</i>	2.94			2.46	0.32
<i>Hybognathus placitus</i>					
<i>Macrhybopsis</i> larvae					
<i>Macrhybopsis australis</i>					
<i>Macrhybopsis hyostoma</i>					
<i>Macrhybopsis storeriana</i>					
<i>Notemigonus crysoleucas</i>				0.49	4.17
<i>Notropis atherinoides</i>		1.56			
<i>Notropis bairdi</i>					
<i>Notropis buchanani</i>		33.85			
<i>Notropis stramineus</i>					
<i>Phenacobius mirabilis</i>					6.09
<i>Pimephales promelas</i>					
<i>Pimephales vigilax</i>		0.26			
<i>Carpionodes carpio</i>		0.13			2.24
<i>Ictiobus bubalus</i>				3.45	0.96
<i>Ameiurus natalis</i>					
<i>Ameiurus melas</i>					
<i>Ictalurus furcatus</i>					2.56
<i>Ictalurus punctatus</i>	2.94		0.81		1.28
<i>Pylodictis olivaris</i>					0.32
<i>Labidesthes sicculus</i>					
<i>Menidia audens</i>		6.51			8.97
<i>Fundulus notatus</i>					
<i>Fundulus grandis</i>					
<i>Fundulus zebrinus</i>					
<i>Gambusia affinis</i>	5.88	6.38	78.05	48.28	27.88
<i>Cyprinodon rubrofluviatilis</i>					
<i>Morone saxatilis</i>					1.28
<i>Lepomis</i> larvae		7.29		0.99	0.32
<i>Lepomis auritus</i>					
<i>Lepomis cyanellus</i>		0.78		3.94	3.53
<i>Lepomis humilis</i>	2.94	0.13			
<i>Lepomis macrochirus</i>	8.82	27.99	6.50	1.97	5.13
<i>Lepomis megalotis</i>		0.39		5.42	2.24
<i>Lepomis microlophus</i>					
<i>Micropterus salmoides</i>	2.94	0.52		8.87	1.92
<i>Pomoxis annularis</i>	64.71	2.21			0.96
<i>Percina caprodes</i>					0.64
<i>Percina macrolepidia</i>					5.13
<i>Etheostoma spectabile</i>					
<i>Aplodinotus grunniens</i>		0.91			
Richness	9	15	4	11	23
Total N	34	768	123	203	312

Scientific Name	Cottonwood Creek	Mountain Creek		South Fish Creek
	FM 2953	Childress Rd	FM 373	CR 411
<i>Lepisosteus larvae</i>				
<i>Lepisosteus oculatus</i>				
<i>Lepisosteus osseus</i>				
<i>Lepisosteus platostomus</i>				
<i>Hiodon alosoides</i>				
<i>Dorosoma cepedianum</i>	9.09			
<i>Dorosoma petenense</i>				
<i>Campostoma anomalum</i>		7.85		26.71
<i>Cyprinella lutrensis</i>	53.33	34.03	22.06	
<i>Cyprinella venusta</i>	0.61			
<i>Cyprinus carpio</i>			0.48	
<i>Hybognathus placitus</i>			24.13	
<i>Macrhybopsis larvae</i>				
<i>Macrhybopsis australis</i>			0.48	
<i>Macrhybopsis hyostoma</i>			0.48	
<i>Macrhybopsis storeriana</i>				
<i>Notemigonus crysoleucas</i>				
<i>Notropis atherinoides</i>				
<i>Notropis bairdi</i>			5.87	
<i>Notropis buechanani</i>				
<i>Notropis stramineus</i>	4.24	9.42		
<i>Phenacobius mirabilis</i>			0.16	
<i>Pimephales promelas</i>				
<i>Pimephales vigilax</i>				0.80
<i>Carpiodes carpio</i>				
<i>Ictiobus bubalus</i>			0.32	
<i>Ameiurus natalis</i>		1.57		0.20
<i>Ameiurus melas</i>				
<i>Ictalurus furcatus</i>				
<i>Ictalurus punctatus</i>				
<i>Pylodictis olivaris</i>				
<i>Labidesthes sicculus</i>				0.80
<i>Menidia audens</i>				
<i>Fundulus notatus</i>				26.10
<i>Fundulus grandis</i>				
<i>Fundulus zebrinus</i>		40.31	10.16	
<i>Gambusia affinis</i>	7.27		34.92	4.22
<i>Cyprinodon rubrofluviatilis</i>				
<i>Morone saxatilis</i>				
<i>Lepomis larvae</i>				2.81
<i>Lepomis auritus</i>				
<i>Lepomis cyanellus</i>	16.36	6.28	0.63	2.81
<i>Lepomis humilis</i>				
<i>Lepomis macrochirus</i>	6.06			22.89
<i>Lepomis megalotis</i>	1.82	0.52	0.16	4.22
<i>Lepomis microlophus</i>				
<i>Micropterus salmoides</i>	1.21		0.16	1.81
<i>Pomoxis annularis</i>				
<i>Percina caprodes</i>				
<i>Percina macrolepidia</i>				0.80
<i>Etheostoma spectabile</i>				5.82
<i>Aplodinotus grunniens</i>				
Richness	9	7	13	12
Total N	165	191	630	498

Appendix D. Relative abundances of fishes captured among eight river reaches by decade from 1920 through 1990 (Wilde et al. 1996). Data from this study (2016 – 2017) is presented as the 2010 decade. Asterisk (*) denotes the combination of *Macrhybopsis aestivalis* and *M. hyostoma* into one species (*Macrhybopsis aestivalis*) since only *M. aestivalis* was recognized species prior to Eisenhour (2004). Letter X denotes species occurrence, but relative abundance was not reported. Tilde (~) denotes estimated relative abundance for both Mississippi Silvery Minnow *Hybognathus nuchalis* and Plains Minnow *H. placitus*

Scientific name	Prairie Dog Town Fork								
	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Scaphirhynchus platyrhynchus</i>									
<i>Polyodon spathula</i>									
<i>Lepisosteus oculatus</i>									
<i>Lepisosteus osseus</i>									0.04
<i>Lepisosteus platostomus</i>									
<i>Hiodon alosoides</i>									
<i>Dorosoma cepedianum</i>						< 0.01		< 0.01	
<i>Dorosoma petenense</i>									
<i>Campostoma anomalum</i>									
<i>Cyprinella lutrensis</i>	0.04	0.09	0.16	0.13	0.40	0.76	0.42	0.50	44.90
<i>Cyprinella venusta</i>									
<i>Cyprinus carpio</i>								< 0.01	
<i>Hybognathus placitus</i>	0.55	0.36	0.32	0.12	0.23	0.11	0.11	0.04	4.27
<i>Macrhybopsis sp</i>								0.01	
<i>Macrhybopsis aestivalis</i> *	0.08	< 0.01	0.01	< 0.01	< 0.01	0.01	0.02	0.01	0.04
<i>Macrhybopsis storeriana</i>						0.01			
<i>Notemigonus crysoleucas</i>									
<i>Notropis atherinoides</i>		0.01			< 0.01	< 0.01	< 0.01	< 0.01	
<i>Notropis bairdi</i>	0.22	0.34	0.05	0.09	0.08	0.02	0.14	0.14	14.73
<i>Notropis buchanani</i>									
<i>Notropis girardi</i>									
<i>Notropis oxyrhynchus</i>									
<i>Notropis potteri</i>				< 0.01				< 0.01	
<i>Notropis stramineus</i>		X			< 0.01	< 0.01	0.01		0.08

Scientific name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>	< 0.01		0.01	0.01	0.00	0.01	0.01	0.01	0.04
<i>Lepomis gulosus</i>									
<i>Lepomis humilis</i>			< 0.01	< 0.01	< 0.01		< 0.01	0.01	0.02
<i>Lepomis macrochirus</i>			0.01			< 0.01	< 0.01	0.02	0.08
<i>Lepomis megalotis</i>	0.01			< 0.01	< 0.01	< 0.01	< 0.01	0.00	0.13
<i>Lepomis microlophus</i>								0.00	
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>			< 0.01			< 0.01		< 0.01	0.02
<i>Pomoxis annularis</i>									
<i>Percina caprodes</i>									
<i>Percina macrolepida</i>									
<i>Etheostoma spectabile</i>									
<i>Aplodinotus grunniens</i>		X							
Total N	14,471	1,006	1,315	23,916	15,852	5,018	187,250	33,988	5,218

	North Fork Red River								
Scientific Name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Scaphirhynchus platyrhynchus</i>				X					
<i>Polyodon spathula</i>									
<i>Lepisosteus oculatus</i>									
<i>Lepisosteus osseus</i>							0.10		
<i>Lepisosteus platostomus</i>									
<i>Hiodon alosoides</i>									
<i>Dorosoma cepedianum</i>		0.50		0.10	0.30	1.00	0.40	1.30	
<i>Dorosoma petenense</i>								0.10	
<i>Campostoma anomalum</i>	0.60								
<i>Cyprinella lutrensis</i>	7.90	2.30	X	42.20	35.20	73.20	60.70	68.60	89.67
<i>Cyprinella venusta</i>									
<i>Cyprinus carpio</i>		0.20			0.10	0.20	0.20	0.10	
<i>Hybognathus placitus</i>	62.20	9.90	4.60	1.50	13.00	8.60	6.70	3.00	
<i>Macrhybopsis aestivalis</i> *	3.10				1.70	0.90	0.30	0.10	
<i>Macrhybopsis storeriana</i>									
<i>Notemigonus crysoleucas</i>									
<i>Notropis atherinoides</i>				0.10	1.40	1.30	2.20	0.90	
<i>Notropis bairdi</i>	9.80			4.40	6.90	2.00	5.20	3.90	
<i>Notropis buchanani</i>	0.80	0.10							
<i>Notropis girardi</i>									
<i>Notropis oxyrhynchus</i>									
<i>Notropis potteri</i>								0.10	
<i>Notropis stramineus</i>	0.70			4.10	3.10	1.70	1.40	0.20	2.72

Scientific Name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>	0.10			2.50	0.60	0.10	0.20	0.20	0.54
<i>Lepomis gulosus</i>				0.10					
<i>Lepomis humilis</i>	3.50		2.30	0.90	0.40		0.20	0.10	
<i>Lepomis macrochirus</i>	0.10			0.40	1.00		0.10	0.20	0.54
<i>Lepomis megalotis</i>	4.60			1.00	0.30	0.20	0.30	0.10	0.54
<i>Lepomis microlophus</i>			0.80		0.10				
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>				0.10	0.20			0.10	0.54
<i>Pomoxis annularis</i>				0.10	0.10				
<i>Percina caprodes</i>				0.10					
<i>Percina macrolepida</i>									
<i>Etheostoma spectabile</i>									
<i>Aplodinotus grunniens</i>									
Total N	2,423	1,055	131	3,423	9,585	18,386	181,345	97,147	184

Scientific Name	Pease River								
	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Scaphirhynchus platyrhynchus</i>									
<i>Polyodon spathula</i>									
<i>Lepisosteus oculatus</i>									
<i>Lepisosteus osseus</i>									
<i>Lepisosteus platostomus</i>									
<i>Hiodon alosoides</i>									
<i>Dorosoma cepedianum</i>				0.30					0.30
<i>Dorosoma petenense</i>									
<i>Campostoma anomalum</i>									
<i>Cyprinella lutrensis</i>				17.00	44.30		18.04		9.06
<i>Cyprinella venusta</i>									
<i>Cyprinus carpio</i>				0.10			8.22		
<i>Hybognathus placitus</i>			1.30	25.90	13.10		~26.15		10.10
<i>Macrhybopsis aestivalis</i> *				0.40			6.41		0.81
<i>Macrhybopsis storeriana</i>									
<i>Notemigonus crysoleucas</i>									
<i>Notropis atherinoides</i>				0.10					
<i>Notropis bairdi</i>			3.90	23.40	4.40		29.06		52.98
<i>Notropis buechanani</i>				0.50					
<i>Notropis girardi</i>									
<i>Notropis oxyrhynchus</i>									
<i>Notropis potteri</i>				0.40					
<i>Notropis stramineus</i>					1.60				

Scientific Name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>				0.60	0.80		0.30		0.04
<i>Lepomis gulosus</i>									
<i>Lepomis humilis</i>				0.50					
<i>Lepomis macrochirus</i>				0.10	0.80				0.01
<i>Lepomis megalotis</i>					0.10				
<i>Lepomis microlophus</i>									
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>					0.20		0.20		0.08
<i>Pomoxis annularis</i>									
<i>Percina caprodes</i>									
<i>Percina macrolepida</i>									
<i>Etheostoma spectabile</i>									
<i>Aplodinotus grunniens</i>									
Total N			932	20,976	2,597		14,256		7,684

Scientific Name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>									0.69
<i>Lepomis gulosus</i>									
<i>Lepomis humilis</i>							0.50		0.11
<i>Lepomis macrochirus</i>							0.20		0.06
<i>Lepomis megalotis</i>							0.10		0.06
<i>Lepomis microlophus</i>									
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>									
<i>Pomoxis annularis</i>									0.11
<i>Percina caprodes</i>									
<i>Percina macrolepida</i>									
<i>Etheostoma spectabile</i>									
<i>Aplodinotus grunniens</i>									
Total N		46	124		4,136		12,871		1,744

Scientific Name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>				2.10			13.50		
<i>Lepomis gulosus</i>									
<i>Lepomis humilis</i>				0.70			1.80		0.39
<i>Lepomis macrochirus</i>				0.10			15.30		
<i>Lepomis megalotis</i>				0.20			5.40		
<i>Lepomis microlophus</i>									
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>							2.70		
<i>Pomoxis annularis</i>									
<i>Percina caprodes</i>									
<i>Percina macrolepida</i>									
<i>Etheostoma spectabile</i>									
<i>Aplodinotus grunniens</i>									
Total N				10,239			141	3,756	768

Scientific Names	Middle Wichita River								
	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Scaphirhynchus platorynchus</i>									
<i>Polyodon spathula</i>			X						
<i>Lepisosteus oculatus</i>									
<i>Lepisosteus osseus</i>									
<i>Lepisosteus platostomus</i>									
<i>Hiodon alosoides</i>									
<i>Dorosoma cepedianum</i>				10.00					0.13
<i>Dorosoma petenense</i>									0.26
<i>Campostoma anomalum</i>									
<i>Cyprinella lutrensis</i>				26.70				57.20	16.33
<i>Cyprinella venusta</i>									
<i>Cyprinus carpio</i>				0.30					0.45
<i>Hybognathus placitus</i>								0.60	25.92
<i>Macrhybopsis aestivalis*</i>								7.90	12.28
<i>Macrhybopsis storeriana</i>									
<i>Notemigonus crysoleucas</i>									
<i>Notropis atherinoides</i>				3.00					
<i>Notropis bairdi</i>				0.90					9.71
<i>Notropis buchanani</i>			18.40	4.40				0.10	
<i>Notropis girardi</i>									
<i>Notropis oxyrhynchus</i>				1.20					
<i>Notropis potteri</i>				0.20					
<i>Notropis stramineus</i>				1.10					

Scientific Names	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>			5.30	0.80				0.20	0.71
<i>Lepomis gulosus</i>				0.10					
<i>Lepomis humilis</i>				0.40				0.40	0.06
<i>Lepomis macrochirus</i>				6.60					0.19
<i>Lepomis megalotis</i>				6.10					0.19
<i>Lepomis microlophus</i>									0.06
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>				1.20					0.39
<i>Pomoxis annularis</i>			10.50	2.20					
<i>Percina caprodes</i>									
<i>Percina macrolepida</i>									
<i>Etheostoma spectabile</i>			47.40	0.90					
<i>Aplodinotus grunniens</i>									
Total N			38	1,847				811	1,555

Scientific Name	Lower Wichita River								
	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Scaphirhynchus platyrhynchus</i>									
<i>Polyodon spathula</i>									
<i>Lepisosteus oculatus</i>									
<i>Lepisosteus osseus</i>				2.50	0.90			1.00	0.03
<i>Lepisosteus platostomus</i>									0.03
<i>Hiodon alosoides</i>		100.00							
<i>Dorosoma cepedianum</i>				5.70			0.10		0.08
<i>Dorosoma petenense</i>									0.11
<i>Camptostoma anomalum</i>									
<i>Cyprinella lutrensis</i>				31.70	84.10	61.80	80.40	93.10	77.49
<i>Cyprinella venusta</i>				0.10					0.03
<i>Cyprinus carpio</i>				0.10			0.10		0.05
<i>Hybognathus placitus</i>				21.50		0.20	0.50	0.50	0.57
<i>Macrhybopsis aestivalis</i> *				0.20					0.19
<i>Macrhybopsis storeriana</i>									
<i>Notemigonus crysoleucas</i>									
<i>Notropis atherinoides</i>				5.70					1.79
<i>Notropis bairdi</i>				3.30	0.90	0.20			1.79
<i>Notropis buchanani</i>						0.20	0.30		4.26
<i>Notropis girardi</i>									
<i>Notropis oxyrhynchus</i>				2.50					
<i>Notropis potteri</i>				0.90					
<i>Notropis stramineus</i>				0.40					0.03

Scientific Names	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>				1.10		0.20	0.50		0.19
<i>Lepomis gulosus</i>				0.10					
<i>Lepomis humilis</i>				0.20			0.20	2.00	0.05
<i>Lepomis macrochirus</i>				1.50			0.20		0.22
<i>Lepomis megalotis</i>				2.30		2.40	0.80		
<i>Lepomis microlophus</i>									0.03
<i>Micropterus punctulatus</i>							0.10		
<i>Micropterus salmoides</i>				0.40					0.03
<i>Pomoxis annularis</i>				0.30	0.90		0.10		
<i>Percina caprodes</i>									
<i>Percina macrolepida</i>				0.10			0.20		
<i>Etheostoma spectabile</i>									
<i>Aplodinotus grunniens</i>				1.00			0.10		
Total N		1		7904	113	414	3155	204	3683

Scientific Name	Red River between HWY 79 and I-35								
	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2010s
<i>Scaphirhynchus platyrhynchus</i>									
<i>Polyodon spathula</i>									
<i>Lepisosteus oculatus</i>									0.04
<i>Lepisosteus osseus</i>				0.50			0.10	0.20	0.06
<i>Lepisosteus platostomus</i>				0.10				0.20	0.02
<i>Hiodon alosoides</i>				1.10				0.50	0.01
<i>Dorosoma cepedianum</i>				6.00	2.90	0.30	1.10	2.30	7.40
<i>Dorosoma petenense</i>							0.20	0.40	0.06
<i>Campostoma anomalum</i>					0.10				1.16
<i>Cyprinella lutrensis</i>			1.90	11.50	3.60	2.60	8.40	27.40	8.42
<i>Cyprinella venusta</i>									0.03
<i>Cyprinus carpio</i>				0.60			0.10	0.50	0.08
<i>Hybognathus placitus</i>				46.60	68.40	61.50	56.00	14.00	27.22
<i>Macrhybopsis aestivalis</i> *				0.10	1.50	1.30	1.40	2.10	2.76
<i>Macrhybopsis storeriana</i>								0.10	0.03
<i>Notemigonus crysoleucas</i>			0.20				0.10	0.20	0.11
<i>Notropis atherinoides</i>			97.10	1.00	0.30	2.50	10.30	15.70	16.11
<i>Notropis bairdi</i>				0.30	3.90	27.90	10.10	4.90	6.04
<i>Notropis buchanani</i>				5.80		0.10	0.40	0.70	5.96
<i>Notropis girardi</i>									
<i>Notropis oxyrhynchus</i>									
<i>Notropis potteri</i>				0.10	0.40	0.80	0.70	1.90	
<i>Notropis stramineus</i>					0.30	0.50	0.20		0.24

Scientific Name	1920	1930	1940	1950	1960	1970	1980	1990	2010
<i>Lepomis cyanellus</i>				1.30	0.10		0.20	0.80	0.69
<i>Lepomis gulosus</i>									
<i>Lepomis humilis</i>			0.40	4.30	0.10			0.40	0.38
<i>Lepomis macrochirus</i>				0.50			0.10	0.70	2.94
<i>Lepomis megalotis</i>				2.00	0.50		0.10	1.10	0.39
<i>Lepomis microlophus</i>									
<i>Micropterus punctulatus</i>									
<i>Micropterus salmoides</i>				0.10				0.10	0.35
<i>Pomoxis annularis</i>	X			1.40	0.10		0.10	0.70	0.86
<i>Percina caprodes</i>								0.10	0.02
<i>Percina macrolepida</i>									0.17
<i>Etheostoma spectabile</i>									0.23
<i>Aplodinotus grunniens</i>				0.20				0.20	0.29
Total N		6	516	15,916	14,425	53,702	334,349	46,187	12,706

Appendix D. Flow recommendations for Pease River.

High Flow Pulses	Qp: 8,090 cfs with Average Frequency 1 per 5 years Regressed Volume is 33,709 to 122,107 (64,157) Regressed Duration is 14 to 72 (32)																																					
	Qp: 2,080 cfs with Average Frequency 1 per year Regressed Volume is 7,054 to 25,415 (13,390) Regressed Duration is 7 to 33 (15)																																					
	Qp: 913 cfs with Average Frequency 2 per year Regressed Volume is 2,731 to 9,821 (5,179) Regressed Duration is 4 to 21 (9)																																					
				Qp: 335 cfs with Average Frequency 1 per season Regressed Volume is 934 to 2,926 (1,654) Regressed Duration is 3 to 12 (6)			Qp: 558 cfs with Average Frequency 1 per season Regressed Volume is 1,714 to 4,496 (2,776) Regressed Duration is 3 to 12 (6)			Qp: 285 cfs with Average Frequency 1 per season Regressed Volume is 629 to 2,136 (1,159) Regressed Duration is 2 to 9 (4)																												
				Qp: 59 cfs with Average Frequency 2 per season Regressed Volume is 110 to 346 (195) Regressed Duration is 1 to 4 (2)			Qp: 92 cfs with Average Frequency 2 per season Regressed Volume is 198 to 521 (321) Regressed Duration is 1 to 4 (2)			Qp: 48 cfs with Average Frequency 2 per season Regressed Volume is 83 to 285 (154) Regressed Duration is 1 to 4 (2)																												
Base Flows (cfs)	18 (34.5%)			18 (46.1%)			14 (44.8%)			16 (36.6%)																												
	11 (53.3%)			8.2 (61.9%)			7.2 (57.2%)			7.1 (51.9%)																												
	6 (71.6%)			4.1 (78.2%)			2.2 (69.0%)			2.3 (66.9%)																												
Subsistence Flows (cfs)	1			1			1			1																												
<table><tr><td colspan="2">Dec</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>3</td><td>Jul</td><td>Aug</td><td>Sep</td><td>Oct</td><td>Nov</td></tr><tr><td colspan="4">Winter</td><td colspan="3">Spring</td><td colspan="3">Summer</td><td colspan="3">Fall</td></tr></table>													Dec		Jan	Feb	Mar	Apr	May	3	Jul	Aug	Sep	Oct	Nov	Winter				Spring			Summer			Fall		
Dec		Jan	Feb	Mar	Apr	May	3	Jul	Aug	Sep	Oct	Nov																										
Winter				Spring			Summer			Fall																												
<table><tr><td rowspan="3">Base Flow Levels</td><td colspan="3">High (75th %ile)</td><td colspan="9" rowspan="3">Pulse volumes are in units of acre-feet and durations are in days. User did not input bankfull; all episodic events are labeled as high flow pulses.</td></tr><tr><td colspan="3">Medium (50th %ile)</td></tr><tr><td colspan="3">Low (25th %ile)</td></tr></table>													Base Flow Levels	High (75th %ile)			Pulse volumes are in units of acre-feet and durations are in days. User did not input bankfull; all episodic events are labeled as high flow pulses.									Medium (50th %ile)			Low (25th %ile)									
Base Flow Levels	High (75th %ile)			Pulse volumes are in units of acre-feet and durations are in days. User did not input bankfull; all episodic events are labeled as high flow pulses.																																		
	Medium (50th %ile)																																					
	Low (25th %ile)																																					

Pulse volumes are in units of acre-feet and durations are in days.

User did not input bankfull; all episodic events are labeled as high flow pulses.

User did not input bankfull: all episodic events are labeled as high flow pulses.

User did not input bankfull; all episodic events are labeled as high flow pulses.