Fish Communities, Species of Greatest Conservation Need, and Potential Protected Areas in Southeastern Oklahoma, 2014-2016

Zachery D. Zbinden
Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701

Aaron D. Geheber
School of Natural Sciences, University of Central Missouri, Warrensburg, MO 64093

William J. Matthews
Biology Department, University of Oklahoma, Norman, OK 73019

Edie Marsh-Matthews
Biology Department, University of Oklahoma, Norman, OK 73019

Abstract: Conservation of native fish species relies on contemporary knowledge about their distributions and abundances. The Muddy Boggy, Kiamichi, and Little River drainages in southeast Oklahoma have diverse native fish communities, including numerous species with limited ranges within the state (i.e., "Species of Greatest Conservation Need" or SGCN). Comprehensive surveys of fish diversity had not been conducted within these drainages since the 1960s or '70s, meaning the current distribution and status of SGCN was not known. Therefore, we surveyed fish diversity in these drainages by making 167 collections by seine net in 2014-2016. We collected 35,236 individuals, 83 total species, and 11 of the 19 SGCN expected to occur in this region. Native fish communities throughout the region were similar relative to historical information from the 1920s through the 1970s. We suggest surveys of fish in streams of this region should be continued on a regular basis and priority should be given to locations with known populations of SGCN or high diversity of native species. We suggest that priority sites with 15 or more native species, high priority sites with 19 or more native species, or sites with multiple SGCN, should be candidates for special protection. We also provide suggestions about the status of several SGCN.

Introduction

The Muddy Boggy, Kiamichi, and Little River drainages in southeast Oklahoma (Figure 1) have diverse native fish communities, including numerous species with small, or very limited ranges within the state (Miller and Robison, 2004). The first scientific fish collections in the region were made in the Kiamichi drainage in 1894 by S. Meek (Meek 1896), and in the Muddy Boggy drainage by H. Pilsbry in 1903 (Fowler 1904). Fishes in Little River, and its Oklahoma tributaries (Glover River and Mountain Fork) were first collected for science in 1925 by A. I. Ortenburger from the University of Oklahoma and the newly formed Oklahoma Biological Survey (Ortenburger and Hubbs, 1926). Subsequent Little River collections were made in 1927 (Hubbs and Ortenburger 1929a, b), and during subsequent summers until 1934. Following the Ortenburger surveys, sampling within these rivers was sporadic until surveys of the Mountain Fork drainage in the late 1940s (Reeves 1950), the Little River drainage in the 1950s (Finnell *et al*. 1956), the Kiamichi River system by J. Pigg in 1972-1973 (Pigg and Hill, 1974), the Muddy Boggy drainage by J. Pigg

in 1974-1975 (Pigg 1977), the Little River drainage by D. A. Rutherford, A. A. Echelle, and O. E. Maughan in 1981 and 1982 (Rutherford *et al*. 1987, 1992), and the Mountain Fork drainage in the 1970s (Eley *et al*. 1981). These included thorough descriptions of the river drainages, of previous fish sampling, and an annotated list of localities where fish occurred. Subsequently, there was annual sampling of about a dozen sites on larger streams in the region by J. Pigg or R. Parham until 2004 (Parham 2009), but no more drainage-wide surveys were conducted that included mainstems and tributaries of all sizes.

More recent fish sampling efforts were limited, but include: eight sites in the Kiamichi, Glover, and Little River drainages (Vaughn *et al.* 2021); targeted sampling for minnows in the three drainages (Wagner *et al*. 1987); sampling of numerous upland sites across the drainages (Dauwalter *et al*. 2008); and five sites in the Boggy drainage (Schenck and Smith 1973). Additionally, Matthews *et al*. (1988), Pyron *et al*. (1998), Porter and Patton (2015), and Sansom *et al*. (2017) sampled sites throughout the Kiamichi River mainstem; Pyron and Taylor (1993) surveyed the lower Little River drainage, and Taylor and Lienesch (1995) sampled minnows in the Little River drainage. These surveys, however, were all spatially limited and/or they focused on a subset of species. Therefore, a current survey was warranted to document contemporary fish species distributions and composition of fish communities throughout the region. From our survey, three papers have been published to date including a study addressing Beta diversity of fish communities in the Muddy Boggy system (Zbinden and Matthews 2017), and two papers focused on comparing recent collections to those of Pigg in the 1970s (Zbinden 2020, 2021). Here we summarize our fish collections from 2014-2016 across three Red River tributary drainages of southeast Oklahoma.

The Oklahoma Department of Wildlife Conservation (ODWC) periodically updates lists of fish (and other taxa) that are considered "Species of Greatest Conservation Need" (SGCN). SGCN designation is based on input from knowledgeable experts from ODWC, other agencies, non-governmental organizations, and universities. The SGCN are ones which experts have concern about their precarious existence in Oklahoma or a general lack of knowledge about their status. We were funded by a State Wildlife Grant from ODWC to conduct comprehensive fish community surveys throughout the Muddy Boggy, Kiamichi, and Little River drainages, with emphasis on detection of fish species listed as SGCN.

The ranks of SGCN include Tier I species (with the greatest need for information), followed by Tier II, and Tier III. The ODWC has identified 52 fish SGCN (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E, ODWC 2013), of which 19 SGCN are Tier I (N = 11) or Tier II (N = 8) documented to occur in the drainages we surveyed (Miller and Robison 2004, W. J. Matthews collections from 1976 to present). The goals of this study were (1) determining the current distributions and community composition of native fishes in the Muddy and Clear Boggy, Kiamichi and Little River (including Glover River and Mountain Fork) drainages; and (2) assessing the status and distribution of Tier I and II SGCN in the region. For some SGCN we added information based on earlier collections we (WJM, EMM) made in southeast Oklahoma with university classes or during other research projects (e.g., Matthews *et al*. 1988, Cashner *et al*. 2010, Matthews and Marsh-Matthews 2015). We also evaluated the spatial overlap between sites with high numbers of species and/or SGCN and areas in which fish or streams have potential protection from state or federal land ownership or agreements.

Methods

Study Area

The rivers in the study area are direct tributaries of the Red River. Each tributary flows southward from high gradient lands in or at the western edge of the Ouachita Mountains into low gradient reaches near Red River. The Muddy Boggy and Kiamichi rivers flow directly into the Red River in south Oklahoma (Figure 1). The Little River flows eastward from Oklahoma

into Arkansas, where it receives additional tributaries (Rolling Fork, Cossatot, and Saline) then joins the Red River near Fulton, Arkansas. The physical and geologic characteristics of each drainage are well documented (Muddy Boggy – Pigg 1977, Zbinden and Matthews 2017; Kiamichi – Pigg and Hill 1974, Matthews and Marsh-Matthews 2017; Little – Rutherford *et al*. 1987) and not repeated here. Upper reaches of the mainstems and upland tributaries are mostly clear water, over rocky substrate with distinct and repeating riffle-pool habitats. Mainstems and many tributaries lower in the drainages are mud or sand-bottomed, with moderate to high turbidity. Most river mainstem sites are wadeable in upper and middle reaches, but lower reaches are too deep to be sampled by wading, except at stream edges.

The Muddy Boggy drainage consists of two main branches (Clear Boggy Creek and Muddy Boggy Creek), and although the branches join just prior to connection with the Red River, the two branches are considered separately in results. The Kiamichi drainage has one mainstem that flows between two high ridges of the Ouachita Mountains and is therefore treated as a singular system in our results. The Little River drainage has two major sub-drainages in Oklahoma, the Glover River and Mountain Fork, also considered separately in some parts of results.

Study design

To aid selection of field sites we reviewed fish collection records from the Sam Noble Oklahoma Museum of Natural History, which included many samples by A. I. Ortenburger, C. Riggs, J. Pigg and R. Parham, and our own collections from much of the region (Matthews and Marsh-Matthews 2017). Site selection also depended on access, often on private land, so before collecting any fishes, WJM, EMM, and ZDZ traveled to many potential sites to determine stream accessibility and request landowner permission in person. During subsequent fish sampling, other sites were added by simply driving county roads to look for other accessible stream locations. The result was a semi-planned, haphazard sampling pattern, scattered throughout all drainages, to provide samples in all sizes of wadeable streams from river mainstems to small creeks or spring runs.

Sampling

A total of 167 fish collections was made during summers of 2014 and 2015 via seining. Collections included 66 sites in the Muddy Boggy River drainage (with 16 sites sampled a second time in 2016), 40 sites in the Kiamichi River drainage, and 45 sites in the Little River drainage, including 8 sites in the Glover River, 13 sites in the Mountain Fork, and 24 sites in Little River proper or its direct tributaries (Figure 1).

Fish communities were collected by seining all identifiable habitats, as described in detail in Matthews and Marsh-Matthews (2017, pages 5-10), within a target of 100 m of wadeable stream reach (sometimes shorter in small creeks if access was limited) using nets, 4.57 m × 1.22 m × 4.88 mm mesh and/or 2.44 m × 1.22 m × 4.88 mm mesh, depending on the width of the stream. Channel and pool habitats were sampled by pulling seines downstream; riffle and edge habitat including undercut banks were sampled by kick-seining. Specimens were preserved in 10% formalin, with large-bodied adults such as adult gars or buffalos identified and released. All other fishes were identified in our laboratory at the University of Oklahoma, then archived and cataloged in the Sam Noble Museum of Natural History.

At each seining site physical environmental variables were recorded by instream measurement (reach size, water quality, estimates of substrates and habitat types), riparian observation (land use, vegetation, and bank stability). The protocol used for gathering this data is described elsewhere (Zbinden and Matthews 2017), and these data are not analyzed directly herein but are provided for future reference. Exact geographic locations and environmental conditions for each site are provided in the Supplementary Material (Table S1).

We made no boat-mounted samples, so

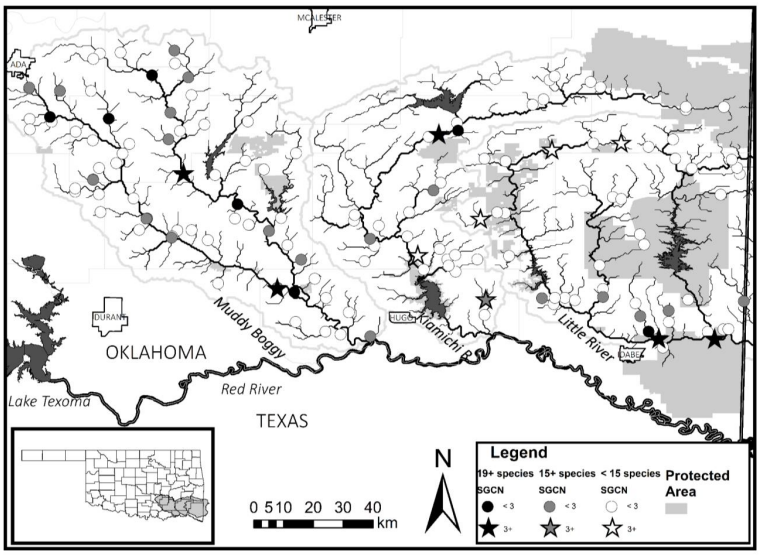

Figure 1. Sampled locations across the study region. Sites are color coded by the number of species collected (white ≤ 14, gray =15 to 18, and black ≥ 19). Sites with fewer than 3 SGCN are denoted by a circle and those with 3+ SGCN are denoted with a star. Protected areas from the Protected Areas Database (United States Geological Survey 2020).

large-bodied riverine species (e.g., skipjack herring, carpsuckers, buffalos, blue sucker) are under-represented in our collections. However, in June 2016, we set 15.2 m gill nets with 48 mm mesh in wadeable areas at two sites in the Muddy Boggy mainstem, one on the Kiamichi mainstem, one on the Glover River (Little River drainage) mainstem (overnight), and one on the lower Little River mainstem to seek larger species. Abundances of species collected at each site are provided in the Supplementary Material (Table S2).

Results and Discussion

Survey summary and community structure

Table 1 lists all species collected by seining, with their total abundances per drainage. We omitted individuals that were too young to identify (in order to prevent inflation of species numbers) and did not include them in diversity or similarity calculations. We also omitted a total of 172 putative hybrids of red shiner x blacktail shiner that we found in the Clear Boggy drainage, to avoid inflating numbers of species (not included in Table 1). We included in Table 1 one larval lamprey ammocoete that we collected in the Kiamichi drainage, as it was a putative SGCN (see below).

For taxonomy, we followed nomenclature in Robison and Buchanan (2020), which is the most recent authoritative work that includes detailed taxonomic accounts related to eastern Oklahoma species. Thus, *Phoxinus erythrogaster* is now *Chrosomus erythrogaster*, *Erimyzon oblongus* is now *Erimyzon claviformis*, and the orangethroat darter (formerly *Etheostoma spectabile*) in southeast Oklahoma is now *Etheostoma pulchellum*. In addition, we referred to all logperch captured in any of the drainages as *Percina caprodes*, although there is uncertainty as to the correct identity of some logperches in the Boggy or Kiamichi drainages (D. Lynch, pers. comm), and more research is needed on their systematics.

Across all seine collections, with 16 sites sampled twice, we netted a total of 35,236 fishes, including individuals that were released. Gill netting in 2016 added one species not included in Table 1, as two adult shortnose gar (*Lepisosteus platostomus*) were captured in the Muddy Boggy mainstem near Lane, Oklahoma.

Table 1: Fish collection summary. Number of fish collections made and species richness across each major drainage basins are shown. Each unique species collected, and the number of individuals collected in each of the major drainages are listed.

		CLEAR	MUDDY	KIAMICHI	LITTLE	GLOVER	MTN FK	TOTAL
	Number of Collections	40	42	40	24	8	13	167
	Number of species	54	54	51	54	25	32	83
Common Name	**Scientific Name**	CLEAR	MUDDY	KIAMICHI	LITTLE	GLOVER	MTN FK	TOTAL
Lamprey ammocoete	*Ichthyomyzon sp.*			1				1
Spotted gar	*Lepisosteus oculatus*	3	28	5	2			38
Longnose gar	*Lepisosteus osseus*	2	2	1	1		7	13
Gizzard shad	*Dorosoma cepedianum*	18	2	17	4			41
Threadfin shad	*Dorosoma petenense*	2		6				8
Central stoneroller	*Campostoma anomalum*	596						596
Highland stoneroller	*Campostoma spadiceum*	1	496	488	133	88	28	1234
Southern redbelly dace	*Chrosomus erythrogaster*	19						19
Red shiner	*Cyprinella lutrensis*	1747	792					2539
Blacktail shiner	*Cyprinella venusta*	1331	26	11	108			1476
Steelcolor shiner	*Cyprinella whipplei*		460	391	111	259	146	1367
Common carp	*Cyprinus carpio*	2						2
Pallid shiner	*Hybopsis amnis*		1					1
Striped shiner	*Luxilus chrysocephalus*				152		74	226
Ouachita Mtn. shiner	*Lythrurus snelsoni*				125	279	822	1226
Redfin shiner	*Lythrurus umbratilis*	339	498	2400	521		170	3928
Golden shiner	*Notemigonus crysoleucas*	175	151	39	16		2	383
Emerald shiner	*Notropis atherinoides*	1		30	51			82
Blackspot shiner	*Notropis atrocaudalis*	3	193	33	43			272
Bigeye shiner	*Notropis boops*	597	795	966	1550	1332	1138	6378
Ghost shiner	*Notropis buchanani*	14	187					201
Ironcolor shiner	*Notropis chalybaeus*				1			1
Kiamichi shiner	*Notropis ortenburgeri*			195	46			241
Sand shiner	*Notropis stramineus*	54						54
Rocky shiner	*Notropis suttkusi*	566	1307	680	128	24	19	2724
Mimic shiner	*Notropis volucellus*		1	19				20
Suckermouth minnow	*Phenacobius mirabilis*	75	68					143
Bluntnose minnow	*Pimephales notatus*	131	61	50	20	13	5	280
Fathead minnow	*Pimephales promelas*	379						379
Bullhead minnow	*Pimephales vigilax*	208	129	3				340
Creek chub	*Semotilus atromaculatus*					14	4	18
River carpsucker	*Carpiodes carpio*		3					3
Blue sucker	*Cycleptus elongatus*	1						1
Creek chubsucker	*Erimyzon claviformis*			72	17	3	6	98
Smallmouth buffalo	*Ictiobus bubalus*	6		2				8
Spotted sucker	*Minytrema melanops*	23	10	6	1	1		41
Black redhorse	*Moxostoma duquesnei*	1	1	7	4			13
Golden redhorse	*Moxostoma erythrurum*	10	5	24	1	1		41
Black bullhead	*Ameiurus melas*	12	23	4	1			40
Yellow bullhead	*Ameiurus natalis*	4	3	3	5	2		17
Blue catfish	*Ictalurus furcatus*		2					2

Table 1. Continued

Channel catfish	*Ictalurus punctatus*	15	73					88
Slender madtom	*Noturus exilis*						7	7
Tadpole madtom	*Noturus gyrinus*	1	4		1			6
Freckled madtom	*Noturus nocturnus*	101	45		1	1		148
Flathead catfish	*Pylodictis olivaris*	1	2			1		4
Redfin pickerel	*Esox americanus*		4	26	30	9	5	74
Starhead topminnow	*Fundulus blairae*				8			8
Blackstripe topminnow	*Fundulus notatus*	2	23	74	29	5	11	144
Blackspotted topminnow	*Fundulus olivaceous*			75	57		1	133
Pirate perch	*Aphredoderus sayanus*		18	5	3		1	27
Western mosquitofish	*Gambusia affinis*	936	1301	499	82	5	4	2827
Brook silverside	*Labidesthes sicculus*	67	289	394	90	24	107	971
Banded pygmy sunfish	*Elassoma zonatum*			1	9			10
Flier	*Centrarchus macropterus*				6			6
Green sunfish	*Lepomis cyanellus*	87	52	92	69	17	46	363
Warmouth	*Lepomis gulosus*	11	13	6	6			36
Orangespotted sunfish	*Lepomis humilis*	43	99	9				151
Bluegill	*Lepomis macrochirus*	382	363	367	145	5	99	1361
Longear sunfish	*Lepomis megalotis*	376	564	300	292	257	117	1906
Redear sunfish	*Lepomis microlophus*	54	39	47	24		16	180
Redspotted sunfish	*Lepomis miniatus*				1			1
Smallmouth bass	*Micropterus dolomieu*						4	4
Spotted bass	*Micropterus punctulatus*	13	7	1	6	18	6	51
Largemouth bass	*Micropterus salmoides*	80	87	179	106		37	489
White crappie	*Pomoxis annularis*	30	36	10	5			81
Black crappie	*Pomoxis nigromaculatus*	2	1	1	3		17	24
Scaly sand darter	*Ammocrypta vivax*				1			1
Bluntnose darter	*Etheostoma chlorosoma*		46	5				51
Swamp darter	*Etheostoma fusiforme*		8					8
Slough darter	*Etheostoma gracile*	14	144	28	2			188
Harlequin darter	*Etheostoma histrio*				34			34
Johnny darter	*Etheostoma nigrum*			12	1			13
Goldstripe darter	*Etheostoma parvipinne*	1	18					19
Cypress darter	*Etheostoma proeliare*			1				1
Plains darter	*Etheostoma pulchellum*	53	22		65	1		141
Orangebelly darter	*Etheostoma radiosum*	260	197	109	59	17	25	667
Logperch	*Percina caprodes*		1	3	3	1	5	13
Channel darter	*Percina copelandi*	1	4	4	1		8	18
Leopard darter	*Percina pantherina*						1	1
Slenderhead darter	*Percina phoxocephala*	31	27		5			63
Dusky darter	*Percina sciera*	70	29	3	18	1	3	124
Freshwater drum	*Aplodinotus grunniens*	2		1				3

For all fishes captured by seining, we averaged 211 individuals per sample, and number of species ranged from 1 to 28, with an average of 11.5 species per collection (Figure 2).

We found a total of 83 distinct species (by major drainage): Muddy (including Clear) Boggy, 64; Kiamichi, 51; and Little, 59 species. Thirteen species were found in all major and minor drainages. Conversely, some species were found in only one of the minor drainages, including (number of species in parentheses), from west to east: Clear Boggy (5), Muddy Boggy (5), Kiamichi (2), Little

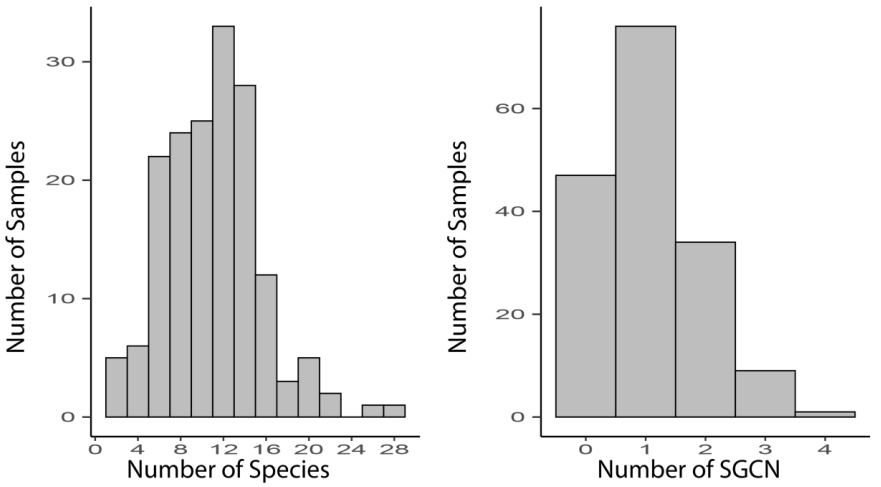

Figure 2: These histograms illustrate the frequency distribution of species richness (left) and total number of species of greatest conservation need collected at a site.

proper (6), Glover (none), and Mountain Fork (3). Localization, discussed more fully below for individual species, was increased by several western species not being found east of the Boggy drainages, and by some Coastal Plain species being found only in swampy habitats in the far southeast corner of the state in the lower parts of Little River drainage.

The site where we found the greatest number of species (N = 28) was at the "Cow Crossing" site east of Idabel on the Little River mainstem within the Little River Wildlife Refuge (McCurtain County). This was a complex site about 25 m wide with a mix of swift riffles and runs, channels, and backwaters, and substrates of sand, gravel, and cobble, offering a wide range of fish microhabitat. The site yielding only one species was a very small tributary of Cloudy Creek (Pushmataha County) where seining was difficult, and we caught only one golden shiner (*Notemigonus crysoleucas*). [We also saw several western mosquitofish (*Gambusia affinis*) and a green sunfish (*Lepomis cyanellus*), but they were not captured]. Several other sites on small tributaries yielded only 3 to 5 species each. But many of the local fish communities ranged from 8 to 16 species (Figure 2), with a few sites having more than 20 species. Sites with 15 or more species exceeded the 75th percentile of species per collection, and sites with 19 or more exceeded the 90th percentile. The values of 15 and 19 species per collection were used (below) to consider sites appropriate for protection because of high species richness.

Similarities among drainages

Qualitative (species presence) similarities between contiguous major drainages (Muddy Boggy, Kiamichi, Little) were calculated by Jaccard's Index, which ignores negative matches, and ranges from zero (no shared species) to one (if all species are shared). There were moderate, and nearly identical, similarities in species identities between contiguous drainages, with Jaccard's similarity of 0.6197 between Boggy and Kiamichi drainages, and 0.6176 between Kiamichi and Little drainages. Across the Boggy and Kiamichi drainages, combined, we found a total of 71 species, of which 44 were common to both drainages and 27 species were found in one of the drainages but not both. Comparing the Kiamichi to Little drainages, we found a combined total of 68 species, of which 42 were common to both drainages and 26 that were found in one drainage but not both. Thus, regarding species identity each major drainage was roughly 60% similar to the next, and, conversely, about 40% different. This level of similarity between adjacent drainages closely approximates similarities between adjacent river drainages in southwest Arkansas (Matthews and Robison 1998, their Table 1). All evidence within the region at large suggests that management

plans for native fishes may need to be tailored to individual drainages, instead of expecting one broader plan to fit all.

Quantitative similarities between contiguous major drainages (Muddy Boggy, Kiamichi, Little) were calculated as Percent Similarity Index (PSI), based on the lesser proportion each species made up across any two drainages being compared. The PSI value can range from zero (no species in common) to 1.00 (perfect match in abundances of all species). In a comparison of the major drainages, from west to east, the Muddy Boggy and Kiamichi had a PSI = 0.50, and Kiamichi and Little had PSI = 0.47. Thus, there is not only substantial turnover in species presence (as above) but also in species abundances from one major drainage to the next in southeast Oklahoma, further suggesting that approaches to conservation and management of native fishes may need to be planned on a local basis.

Individual species abundances

Thirteen species each made up more than 1% of all individuals sampled (Table 2) across all drainages. Bigeye shiner (*Notropis boops*) was the most abundant, comprising 18% of all individuals, and abundant in all three major drainages (Table 1). The redfin shiner (*Lythrurus umbratilis*) was second in abundance, with 11% of all captures and common in all drainages. Other species comprising more than 5% of all individuals were: western mosquitofish, rocky shiner (*Notropis suttkusi*), red shiner (*Cyprinella lutrensis*), and longear sunfish (*Lepomis megalotis*) (Table 2).

Collectively, these species made up approximately 58% of all individuals in our samples. Conversely, we found 10 or fewer individuals for 22 species (Table 3). Of these, seven were "big water" species like blue catfish (*Ictalurus furcatus*), flathead catfish (*Pylodictis olivaris*), blue sucker (*Cycleptus elongatus*), or smallmouth buffalo (*Ictiobus bubalus*) that were under-represented by seining in wadeable streams. The other 15 were species amenable to collection by seining, and probably are truly scarce in the region [lamprey (*Ichthyomyzon* sp.), ironcolor shiner (*Notropis chalybaeus*)] or are restricted to specialized habitats [e.g., banded pygmy sunfish (*Elassoma zonatum*) flier (*Centrarchus micropterus*) or western starhead

Table 2: The most abundant species in southeastern Oklahoma ranked by total individuals collected and their percent contribution to the total of all individuals.

Common Name	Scientific Name	Total	Percent
Bigeye shiner	*Notropis boops*	6378	18.10%
Redfin shiner	*Lythrurus umbratilis*	3928	11.15%
Western mosquitofish	*Gambusia affinis*	2827	8.02%
Rocky shiner	*Notropis suttkusi*	2724	7.73%
Red shiner	*Cyprinella lutrensis*	2539	7.21%
Longear sunfish	*Lepomis megalotis*	1906	5.41%
Blacktail shiner	*Cyprinella venusta*	1476	4.19%
Steelcolor shiner	*Cyprinella whipplei*	1367	3.88%
Bluegill	*Lepomis macrochirus*	1361	3.86%
Highland stoneroller	*Campostoma spadiceum*	1234	3.50%
Kiamichi shiner	*Lythrurus snelsoni*	1226	3.48%
Brook silverside	*Labidesthes sicculus*	971	2.76%
Orangebelly darter	*Etheostoma radiosum*	667	1.89%
Central stoneroller	*Campostoma anomalum*	596	1.69%
Largemouth bass	*Micropterus salmoides*	489	1.39%
Golden shiner	*Notemigonus crysoleucas*	383	1.09%
Fathead minnow	*Pimephales promelas*	379	1.08%
Green sunfish	*Lepomis cyanellus*	363	1.03%

Table 3: Scarce species in our samples: asterisk indicates a "big water" species with lower probability of capture by seining.

Common name	Scientific name	Number	Percent
Banded Pygmy sunfish	*Elassoma zonatum*	10	0.03%
Threadfin shad	*Dorosoma petenense*	8	0.02%
Smallmouth buffalo	*Ictiobus bubalus**	8	0.02%
Western starhead topminnow	*Fundulus blairae*	8	0.02%
Swamp darter	*Etheostoma fusiforme*	8	0.02%
Slender madtom	*Noturus exilis*	7	0.02%
Tadpole madtom	*Noturus gyrinus*	6	0.02%
Flier	*Centrarchus macropterus*	6	0.02%
Flathead catfish	*Pylodictis olivaris**	4	0.01%
Smallmouth bass	*Micropterus dolomieu*	4	0.01%
River carpsucker	*Carpiodes carpio**	3	0.01%
Freshwater drum	*Aplodinotus grunniens**	3	0.01%
Common carp	*Cyprinus carpio**	2	0.01%
Blue catfish	*Ictalurus furcatus **	2	0.01%
Lamprey species	*Ichthyomyzon sp.*	1	0.00%
Pallid shiner	*Hybopsis amnis*	1	0.00%
Ironcolor shiner	*Notropis chalybaeus*	1	0.00%
Blue sucker	*Cycleptus elongatus**	1	0.00%
Redspotted sunfish	*Lepomis miniatus*	1	0.00%
Scaly sand darter	*Ammocrypta vivax*	1	0.00%
Cypress darter	*Etheostoma proeliare*	1	0.00%
Leopard darter	*Percina pantherina*	1	0.00%

topminnow (*Fundulus blairae*) that are found only in swamp-like habitats in far southeast Oklahoma]. The ten species that occurred most frequently (in 77 to 133 samples, Table 4) were from several families, including three minnows (Leuciscidae), one livebearer (Poeciliidae), one silverside (Atherinopsidae), four sunfish (Centrarchidae), and one darter (Percidae). Most widely occurring, overall, were longear sunfish, western mosquitofish, and bluegill (*Lepomis macrochirus*), occurring in 79.6%, 69.5%, and 66.5% of all samples, respectively. No other species occurred in more than 47 (28.1%) of our samples.

Species of greatest conservation need (SGCN)

We found 11 of the 19 SGCN that historically were known from the region (Table 5). Several in Tier I [blackspot shiner (*Notropis atrocaudalis*), Kiamichi shiner (*Notropis ortenburgeri*), Ouachita Mountain shiner (*Lythrurus snelsoni*), rocky shiner] and one in Tier II, the orangebelly darter (*Etheostoma radiosum*) were abundant at numerous sites in their historical ranges and are likely secure barring any widespread land use or water quality changes. We failed to find eight of the regional Tier I or II SGCN, some of which, like Alabama shad (*Alosa alabamae*) or alligator gar (*Atractosteus spatula*), likely were due to lack of sampling in their habitats. Failure to detect others, like bluehead shiner (*Pternotropis hubbsi*), crystal darter (*Crystallaria asprella*), peppered shiner (*Notropis perpallidus*), Creole darter (*Etheostoma collettei*), and mountain madtom (*Noturus eleutherus*), could have been lack of sampling in their preferred microhabitats, or because they actually are rare in southeast Oklahoma.

Tier I SGCN

Pallid shiner (*Hybopsis amnis*) was found only once, in extreme headwaters of the Muddy Boggy River drainage. One individual was taken in Caney Boggy Creek, Hughes County, at a stream site 4 m wide, including a water willow covered riffle feeding into a muddy channel. This species is rare in Oklahoma, and Matthews found it in the region only in 1990, as a single individual in each of two collections on the lower Little River within the Little River Wildlife Refuge (McCurtain County).

Ouachita Mountain shiner (*Lythrurus*

Table 4: The ten most frequently encountered species, and numbers of samples in which detected.

Common name	Scientific name	Occurrences
Longear sunfish	*Lepomis megalotis*	133
Western mosquitofish	*Gambusia affinis*	116
Bluegill	*Lepomis macrochirus*	111
Largemouth bass	*Micropterus salmoides*	94
Orangebelly darter	*Etheostoma radiosum*	91
Redfin shiner	*Lythrurus umbratilis*	89
Highland stoneroller	*Campostoma spadiceum*	85
Green sunfish	*Lepomis cyanellus*	80
Brook silverside	*Labidesthes sicculus*	79
Bigeye shiner	*Notropis boops*	77

snelsoni) was widespread in the upland parts of the Little, Glover, and Mountain Fork, occurring at 17 sites. There were more than 100 individuals in several collections, including 390 in Little Eagle Creek in the upper Mountain Fork drainage in LeFlore County. Being limited to and widespread in the upper Little River system is consistent with its historical distribution above the Fall Line (Taylor and Lienesch 1995, 1996). The species is probably secure, barring widespread changes in land use practices, or reservoir construction (Taylor and Lienesch 1995).

Blackspot shiner (*Notropis atrocaudalis*) was in all three major drainages, in the middle to lower Clear and Muddy Boggy drainage, in tributary creeks in the lower Kiamichi drainage and one creek at midstream near Clayton, in two tributaries to Little River downstream from Pine Creek Lake, and at two sites on the lower Little River mainstem. Blackspot shiner was mostly in small streams, and typically scarce when found (e.g., 1-5 individuals). However, we took 120 and 38 blackspot shiners, respectively, in Crooked and Lick creeks in Choctaw County, and 39 in Little River (McCurtain County) at the mouth of Yashau Creek within the Little River Wildlife Refuge.

Kiamichi shiner (*Notropis ortenburgeri*) was collected at seven sites, with a spotty distribution in the eastern part of our study region. It was at three sites in the upper Little River drainage and in Rock Creek near the Arkansas border, at two sites in the far upstream Kiamachi drainage, and one eastern tributary to the lower Kiamichi. The Kiamichi shiner was mostly in creeks 7-10 m wide, but also in streams up to 25 m wide with rocky riffles. The species can be locally abundant, and in this survey, we collected 25 at the Little River headwaters, 34 in Bohanan Creek and 157 in Little Pigeon Creek, in the upper Kiamichi drainage, all in Leflore County. Porter and Patton (2015) found a total of 126 Kiamichi shiners at seven sites on the mainstem Kiamichi River in 2012-2013.

Rocky shiner (*Notropis suttkusi*) was found at 11, 6, and 6 sites, respectively, in the Muddy Boggy, Kiamichi, and Little drainages. It was most common in river mainstems or large tributaries, not typically occurring in small creeks. It was locally abundant at several sites, with hundreds of individuals per collection. Our largest collection of 553 individuals was on the Kiamichi River mainstem between the towns of Antlers and Clayton. There, the river had a braided channel with riffles, rapids and runs, over large gravel and cobble. Channels were up to 20 m wide, with pool depths to 2 m. Most individuals, especially males in breeding colors of bright orange, were taken by seining in swift runs in knee deep water over bottoms of large gravel. Although the species is somewhat localized in abundance, it appears secure throughout the study region, and is also abundant in upper Blue River, to the west (Matthews and Marsh-Matthews collections in 2018). This species was called *Notropis rubellus* before it was elevated to species by Humphries and Cashner (1994), who designated the holotype and paratypes from a collection by Matthews *et al*. (1990) in the lower Little River east of Idabel.

Table 5. For SGCN in the study region: total individuals found, total number of sites where they occurred, and river drainages where they occurred.

Tier I Species

Common Name	Scientific Name	Total Found	Total Sites	River Drainage
Alabama shad	*Alosa alabamae*	0	0	n/a
Pallid shiner	*Hybopsis amnis*	1	1	Muddy Boggy
Ouachita Mountain shiner	*Lythrurus snelsoni*	1226	17	Little River
Blackspot shiner	*Notropis atrocaudalis*	272	20	All three drainages
Kiamichi shiner	*Notropis ortenburgeri*	241	7	Kiamichi & Little
Peppered shiner	*Notropis perpallidus*	0	0	n/a
Rocky shiner	*Notropis suttkusi*	2253	25	All three drainages
Bluehead shiner	*Pteronotropis hubbsi*	0	0	n/a
Western sand darter	*Ammocrypta clara*	0	0	n/a
Crystal darter	*Crystallaria asprella*	0	0	n/a
Leopard darter	*Percina pantherina*	1	1	Little River

Tier II Species

Common Name	Scientific Name	Total Found	Total Sites	River Drainage
Southern brook lamprey*	*Ichthyomyzon gagei**	1	1	Kiamichi
Alligator gar	*Atractosteus spatula*	0	0	n/a
Ironcolor shiner	*Notropis chalybaeus*	1	1	Little
Blue sucker	*Cycleptus elongatus*	1	1	Muddy Boggy
Mountain madtom	*Noturus eleutherus*	0	0	n/a
Creole darter	*Etheostoma collettei*	0	0	n/a
Goldstripe darter	*Etheostoma parvipinne*	19	2	Muddy Boggy
Orangebelly darter	*Etheostoma radiosum*	552	80	All three drainages

*Larval ammocoete, could not identify to species. It also could be *Ichthyomyzon castaneus.*

One leopard darter (*Percina pantherina*) was netted and released unharmed in Big Eagle Creek northwest of Smithville, McCurtain County. Because of its protected status as a Federally Threatened Species, we avoided its optimal habitat where it was known to occur (larger clear streams with flowing water over large boulders) and made no targeted search for this species. The US Fish and Wildlife Service, Tulsa, surveys leopard darters annually throughout its range. Working with USFWS, we found it common in the midreach of the Glover River in 1999-2000 (Schaefer *et al*. 2003). Matthews' only other collection of the species was in West Fork Glover River at Battiest, in 1982.

In addition, one ammocete (larval lamprey) was collected in the Kiamichi drainage, over a mud-sand bottom in Tuttle Branch of Bull Creek, in Choctaw County. This specimen was too small to identify to species and could be either the SGCN southern brook lamprey (*Ichthyomyzon gagei*) [Tier II] or chestnut lamprey (*I. castaneus*). Porter and Patten (2015) found one *I. castaneus* in the Kiamichi mainstem, but reported no *I. gagei*. Pigg (1974) found one specimens of *I. gagei*, but no *I. castaneus*. The ammocoete collected in our study could be either species.

Tier II SGCN

Ironcolor shiner (*Notropis chalybaeus*) was found only once, a single individual in Wildhorse Creek of the upper Little River, just west of Fewell, in Pushmataha County. The stream at this site was about 25 m wide, with boulders and bedrock, and fast flow in rapids and riffles. The species has been considered quite rare in Oklahoma (Williams and Echelle 1998).

Blue sucker (*Cycleptus elongatus*) was found at only one site, as a single individual netted in the lower mainstem of Clear Boggy Creek. At this site, maximum width was 7 m and maximum depth of 1.8 m, with a mix of pools and riffles. Finding only one blue sucker in our survey reflects the difficulty of capturing this big-water species using a seine, and not that it is rare. Using boat-mounted electrofishing, Dyer and Brewer (2020) found the species abundant in lower river reaches in southeast Oklahoma.

Goldstripe darter (*Etheostoma parvipinne*) was found only at two sites in the Muddy Boggy drainage. A single individual was taken in Davis Creek (Atoka County) of the Clear Boggy system, and 18 were found in Tanyard Creek (Choctaw County), a small tributary to the Muddy Boggy, dominated by riffles over a mostly sand bed. WJM had previously taken goldstripe darter only in Parker Creek, a small, sand-bed stream in southeastern McCurtain County, in 1993, within the Tiak District of the Ouachita National Forest.

Orangebelly darter (*Etheostoma radiosum*) was widespread throughout the study area, occurring at 36, 18, and 26 sites, respectively, in the Muddy Boggy, Kiamichi, and Little River drainages. It was essentially in streams of all sizes, but especially in medium to large upland streams wherever rocky riffle or rapids habitat was present, and often was the most abundant darter. It was not usually found in small headwater creeks. In numerous collections we found 20 to 40 individuals and took 56 in Clear Boggy Creek northeast of Boswell, Choctaw County. In this survey, and historically, this has been one of the most widespread and abundant darter species in the region. Note that designation of orangebelly darter as an SGCN included populations in Blue River, which have recently been elevated to full species status as the Blue River orangebelly darter (*Etheostoma cyanorum*) by Matthews and Turner (2019). This unique species, found only in the Blue River system, will likely deserve consideration for separate SGCN status in the future, or for other forms of legal protection. However, because of the widespread and abundant distribution of orangebelly darter (not including Blue River *E. cyanorum*) we suspect that it no longer needs to be a SGCN.

SGCN not found

We failed to find several small-bodied SGCN captured previously in southeast Oklahoma including bluehead shiner (Tier I), mountain madtom (Tier II), crystal darter (Tier I), peppered shiner (Tier I), and Creole darter (Tier II). Previous occurrences noted below are from collections by W. Matthews (WJM).

Bluehead shiner (*Pternotropis hubbsi*) – One adult male in breeding color was collected in a slough tributary to Crooked Creek in the Little River Wildlife Refuge in July 1990, the only capture of the species in WJM records, despite his dozens of samples in swampy, low-gradient habitats in the area in 1990 or 1993. Lemmons *et al*. (1997) found 16 bluehead shiners in borrow pits along Hwy 70 (Little River drainage), north of Idabel in 1996.

Mountain madtom (*Noturus eleutherus*) – Also collected only once in southeast Oklahoma by WJM, a single specimen was found in Little River near the mouth of Yashau Creek (McCurtain County) in 1990. We found none in the present survey, although many of our samples were in its appropriate habitat (i.e., flowing riffle-pool habitats in clear rocky streams). This indicates rarity in the state. K. Gido and G. Hopper (pers. comm.) found one individual in Little Yashau Creek (Little River drainage) in August 2015.

Crystal darter (*Crystallaria asprella*) – Found several times 1976 to 1990 (WJM) in waist-deep water flowing over a gravel bed in the main channel of the Little River mainstem west of US Hwy 70, McCurtain County, but in this survey and a collection at that site in 2018 they were not found. K. Gido and G. Hopper (pers. comm.) found one individual in August 2015 in Little Yashau Creek.

Peppered shiner (*Notropis perpallidus*) – Found in small numbers by WJM from 1976 to 1986 at several sites in the Glover, Little, and Kiamichi River mainstems, including 35

specimens in one seine haul below a fast rapid in the Glover River south of Hwy 3 (McCurtain County) in July 1982, but not seen by us since 1986. Wagner *et al*. (1987) found 172 individuals in 19 collections in the Kiamichi and Little River drainages in surveys in 1982. Robison (2006) searched 81 sites in Arkansas and Oklahoma for peppered shiners, including sites in the Kiamichi, Glover, and Mountain Fork Rivers, finding 17 individuals in Arkansas but none in Oklahoma. K. Gido and G. Hopper found none in their 2015 collections (pers. comm.). An exhaustive search was made for peppered shiners in 2018-2019 throughout their historical range in Oklahoma by Allen (2020) and his students, making 163 seining collections but finding no confirmed specimens (one juvenile in Little River downstream from Pine Creek reservoir was identified as "possible" peppered shiner but was too small to positively identify). The last known collections of peppered shiner in museum records at OU or OSU includes a single individual each in Kiamichi River near Clayton and in Glover River near Golden, in 1990 and 1991. The species must be extremely rare in Oklahoma if it still exists in the state.

Creole darter (*Etheostoma collettei*) – The species was initially determined to exist in Oklahoma by examination of old museum specimens (Matthews and Robison 1982). WJM took a single Creole darter at each of two sites on the lower Little River mainstem in October 1990, at "Cow Crossing" east of Idabel, and west of US Hwy 70, both within the Little River Wildlife Refuge. We took none in our recent survey, but Dr. Nick Lang (pers. comm.) found 2 or 3 individuals in Yashau Creek northwest of Broken Bow in 2018.

Other noteworthy local species distributions

Numerous other species were very localized or found in only one of the minor drainages (Table 1). Among minnows (Leuciscidae), the central stoneroller (*Campostoma anomalum*) was abundant in the Clear Boggy drainage but replaced to the east by highland stoneroller (*Campostoma spadiceum*). Southern redbelly dace (*Chrosomus erythrogaster*), characteristic of small, spring-fed streams, was found only once, in a clear, spring-fed creek in the Clear Boggy drainage. Red shiner was abundant in the Clear and Muddy Boggy drainage, but we took none in drainages to the east. Striped shiner (*Luxilus chrysocephalus*) was abundant in our survey but found only in the Little River and its minor drainages. Sand shiner (*Notropis stramineus*), and fathead minnow (*Pimephales promelas*) are two of the most widespread minnows in Oklahoma, but we found them only in the Clear Boggy drainage. The creek chub (*Semotilus atromaculatus*) was found only in the Glover River and Mountain Fork tributaries in the Little River drainage.

Among other families, we only found the slender madtom (*Noturus exilis*; Family Ictaluridae) in the Mountain Fork drainage. This species is more typical of Ozark streams in northeast Oklahoma and occurs in small numbers in upper Mountain Fork riffles or rapids. Western starhead topminnow (*Fundulus blairae*; Family Fundulidae) is endemic to and was found only in lower reaches of the Little River system. Banded pygmy sunfish (*Elassoma zonatum*; Family Elassomatidae) were in the lower Little River system, with one individual found in a small eastern tributary of the Kiamichi drainage. Banded pygmy sunfish were abundant in a marsh just north of Fort Towson in the 1970s and 1980s (WJM collections), but that marsh has since been highly modified or drained and our recent efforts to find the species there were unsuccessful. Echelle and Echelle (2005) reported taking the species in "the city spring at Fort Towson" in 1994. Two species in the family Centrarchidae, flier (*Centrarchus macropterus*) and redspotted sunfish (*Lepomis miniatus*), were found only in sluggish, coastal plain habitats of the Little River drainage in far southeastern Oklahoma. Several darters (Family Percidae) were limited to a single major or minor drainage. Scaly sand darter (*Ammocrypta vivax*) and harlequin darter (*Etheostoma histrio*) were found only in the Little River drainage. Cypress darter (*Etheostoma proeliare*) was found only in one eastern tributary of the Kiamichi drainage, and we only found swamp darter (*Etheostoma fusiforme*) in the Muddy Boggy drainage. This appears to be a westward range extension for the

swamp darter, per Pigg (1977) and Miller and Robison (2004).

Species richness, SGCN and protected areas

An important question for native fish conservation is whether localities with high species richness or SGCN are in areas that offer some protection from change or degradation, by virtue of being owned by state or federal governments or non-governmental conservation organizations. Figure 1 shows locations with high species richness and/or three or more SGCN, versus protected areas in southeast Oklahoma. Sites are shown where we found 15-18 species (15 (> 75th percentile of species richness) and 19 or more (>90th percentile of species richness) species, which could be considered "priority" or "high priority" sites for conservation of native fishes. Sites are also shown that had 3 or 4 designated SGCN. The maps provide outlines (dark gray) of areas where streams and stream fishes could be protected by virtue of ownership or agreements that provide federal (e.g., national forest) or state control of the lands (e.g., wildlife management areas - WMA). The maps show protected areas compiled nationally (United States Geological Survey 2020). For each specific area, detailed maps or regulations by the controlling agency should be consulted.

In the Muddy Boggy drainage, there were 11 sites with 15-18 species, and 6 sites with 19 or more species (Figure 1), with priority sites occurring from lower mainstems to headwaters. The Muddy Boggy branch of the drainage had more of the highest priority sites with 19 or more species than the Clear Boggy, and more of the priority sites with 15 to 18 species. However, some sites on the Clear Boggy branch also were of high quality and had complex native fish communities. One site on the Muddy Boggy mainstem and one on the Clear Boggy mainstem had three SGCN, the latter being the only site where we seined a blue sucker. In the Muddy Boggy drainage (Figure 1), the protected areas are east of Atoka Reservoir to upper McGee Creek, including the Atoka WMA, Stringtown WMA, and McGee Creek WMA. In the drainage there were 17 sites with 15 or more species, scattered widely throughout the basin, but none specifically within the protected areas. There were two sites in the drainage where we found three or more SGCN, but not within the protected areas.

The upper reaches of the Kiamichi River drainage (Figure 1) have substantial protection with headwaters of the river and some tributary creeks in the Ouachita National Forest or the Leflore Unit of the Ouachita WMA. Downstream, the Pushmataha WMA provides some protection for southern tributaries of the Kiamichi River, and the small Hugo WMA can provide some protection for the river downstream from Hugo Reservoir. However, much of the lower and middle part of the Kiamichi River drainage is in private ownership, so protection of streams and native fishes would depend on landowner cooperation. In the Kiamichi River basin, only five of our samples had 15 or more species, but the most speciose sites, near Clayton, Oklahoma, were near but not within the Pushmataha WMA. One of those sites also had three SGCN.

In the Little River drainage, including Glover River and Mountain Fork, a combination of WMAs, the Three Rivers Area, wilderness areas, and the USFWS Little River Wildlife Refuge collectively protect large areas in the upper Little River and near Pine Creek Reservoir, the upper Glover River, much of the Mountain Fork River above and below Broken Bow Lake, and much of the lower Little River downstream from Idabel to the Arkansas state line (Figure 1). The Little River basin has numerous downstream sites, particularly in the lower Little River where we found 15 or more native species. Several of these sites are protected within the Little River Wildlife Refuge, and others are in or near the Three Rivers WMA. The Little River Wildlife Refuge provides protection for two sites where we detected three SGCN, but three other sites upstream in Little River where we detected three SGCN, are not within government protected areas. In general, much of the midreach of the three named rivers, and the lower Little River mainstem in Oklahoma has protection by government ownership or agreements. There is little or no protection of lands by government ownership or agreements in the headwaters of

any of the Little River drainages, and 8 of the 11 sites with high native fish species richness or numbers of SGCN (Figure 1) are in areas with private ownership. Landowner cooperation is essential for protection of diverse native fishes throughout much of the Little River drainage.

Conclusions and recommendations

Documenting contemporary abundances and distributions of fishes is foundational for identifying appropriate conservation and management efforts. Our survey in 2014-2016 in the Muddy Boggy, Kiamichi, and Little River drainages of southeast Oklahoma provides recent information for SGCN, other native species, and the composition of local communities or the fish faunas of these river basins. This paper (and data provided in the Supplementary Material) provides a baseline for future assessment of fishes in these three major drainages.

Native fish communities throughout the region generally remained similar to historical information from the 1920s through the 1970s, with numbers of species per site in this survey typical of the diversity we found in our samples in the region from the 1970s to now (Matthews, unpublished data) or in other streams in Oklahoma (Matthews *et al*. 2013, Matthews and Marsh-Matthews 2015, 2017). The average of 11.1 species per site in this survey is extremely similar to that for many streams throughout North America. Matthews (1998, pp 39-40) found a modal number of 11 to 12 species per sample for 815 different whole-community samples streams throughout North America, and (Matthews 1998, pp 33-34) a mean of 12.9 species per collection for 182 collections in the Ouachita uplift in Oklahoma and Arkansas. Thus, streams in the three drainages we surveyed had species richness matching expectations for streams in this part of the United States. None of the sites we visited exhibited visible evidence of pollution, harmful exotic species, or any other obvious factors that would have impacted species richness. The low numbers of species at a few sites were probably natural, as can be expected at smaller stream sizes (Matthews 1998; Matthews and Marsh-Matthews 2017).

From sampling streams and observing environmental conditions across southeast Oklahoma, we offer suggestions for current actions and for future studies. First, surveys of fishes in streams of this region should be continued on a regular basis, more frequently than in the past, and should incorporate standardized sampling and metadata acquisition to allow accurate comparative temporal analysis. The ongoing efforts of the ODWC "Stream Team" to sample fishes in all regions of the state (T. Rodger, personal communication) are an excellent way to meet this need. In southeast Oklahoma, future surveys should include streams of all sizes because both headwaters and lower mainstems have fish communities that would benefit from protection. Additionally, local fish communities in these drainages can differ sharply in species composition from place to place (Zbinden and Matthews 2017), so broad coverage within drainages is essential. Our surveys in 2014-2015 were the first comprehensive fish surveys in the region since the 1960s or 1970s. More frequent assessment of status of SGCN and of entire native fish communities at least once per decade would be advisable, and more frequently at targeted locations with known populations of SGCN or high diversity of native species. The survey we report here provides one comprehensive snapshot in time, as a baseline against which managers can assess future changes in these communities, or in abundance and distribution of individual species. Long-term, repeated sampling will allow identification of trends in local and regional fish species abundances or community dynamics (Zbinden 2020, 2021). Long-term data are necessary to assess changes to community structure which may vary "loosely" around an equilibrium state (i.e., normal variance) or may undergo directional change (Matthews and Marsh-Matthews 2016, 2017).

We suggest that priority sites with 15 or more native species, high priority sites with 19 or more native species, or sites with multiple SGCN, should be identified for ODWC regional biologists and game wardens for special protection, and landowners or river

regulation authorities should be so advised. For such sites on private property special efforts should be made to work cooperatively with landowners to assist in protection of streams and the surrounding land. Although there are stream reaches in all three drainages that can protect fish communities by virtue of state or federal ownership or cooperative agreements, managers should seek opportunities to expand areas protecting streams and complex fish communities in the region. Further efforts should be made to secure protection for stream reaches with multiple SGCN in headwaters of the Little River drainage.

We also have suggestions about the SGCN status of several species. The orangebelly darter (*Etheostoma radiosum*) (SGCN Tier II) was extremely widespread in the Muddy-Clear Boggy, Kiamichi, and Little River drainages, occurring in 80 of our sampling sites, often in large numbers in rocky riffle habitats. It is sufficiently secure in the region of study that might be considered for removal from SGCN status. However, the form of orangebelly darter in Blue River, now considered a distinct species (*Etheostoma cyanorum*) separate from *E. radiosum*, should continue to be (or be added to) the list of SGCN. The rocky shiner (*Notropis suttkusi*) occurred in 25 of our sampling sites across all three major drainages and was extremely abundant in some locations. Based on its wide distribution and abundance it is probably secure in Oklahoma and might be considered for removal from the SGCN list or in being lowered from Tier I to Tier II. The Ouachita Mountain shiner (*Lythrurus snelsoni*) (SGCN Tier I) is limited in Oklahoma to the upper portions of the Little, Glover, and Mountain Fork drainages, but where it occurred it often was in large numbers. Because of its limited range in Oklahoma, it should be retained on the SGCN list to encourage continued monitoring, but perhaps lowered from Tier I to Tier II priority. We envision no outright threats to this species so long as an abundance of high-quality water continues to flow in upland streams throughout the Little River drainage.

We recommend all other Tier I and Tier II fish species in southeastern Oklahoma remain as SGCN because their distributions or abundances remain poorly known or their existence in the state may be tenuous. Effort should be directed toward sampling more locations for crystal darter (*Crystallaria asprella*), because we occasionally found these in the Little River west of US Hwy 70 (Matthews, unpublished data) but they were not detected at their primary historic site, or elsewhere, in this survey. And in a subsequent effort at their historic site in 2018 (Matthews unpublished data) we also failed to find any crystal darters. Continued efforts should be made to determine if peppered shiner (*Notropis perpallidus*) still exists in Oklahoma. None were found in our survey or in a widespread survey in 2018-2019 by Dan Allen and students targeted specifically for peppered shiners (Allen 2020).

Other than as noted for some individual species, fish communities in southeastern Oklahoma streams seemed to be in good condition, relative to expectations from historical surveys or our own collections in the region over more than 40 years. This is consistent with the finding by Matthews and Marsh-Matthews (2015) that contemporary fish communities in much of Oklahoma were relatively similar to those found by Ortenburger almost a century ago. Emphasis should be placed on conservation actions within these river basins that assure continued availability of sufficient flow of high-quality water for fish or stream macroinvertebrates. Reduction of water volumes or quality in river mainstems or in their tributaries should be vigorously avoided. Any proposed removal of water by transfers out of basin, or by within-basin withdrawals, should be reviewed critically to assure that habitat needs of all the diverse native species in these streams are met. Dam operations that limit availability of downstream waters, especially in summer or during droughts, should be modified to assure adequate flow to maintain high quality habitats for all fish species. Likewise, timber harvest operations should be carried out with minimal disturbance of water quality, particularly as related to road construction, bridging of streams, or any activity that increases input of silt to these streams. The cooperation of agencies and environmental or political stakeholders in

southeast Oklahoma to assure stream protection will have a tremendous impact on the future of the diverse native fishes in the region.

Acknowledgments

Financial support was provided by the Oklahoma Department of Wildlife Conservation through State Wildlife Grant FI 3AF01213 (T-74-1) and by the University of Oklahoma. We thank Barry Bolton, Chief of Fisheries, ODWC for providing collecting permits, Richard Standage and Elaine Sharp of the USDA Forest Service for approval to collect on the Ouachita National Forest, and David Weaver, Refuge Manager, for approval to collect on the Little River National Wildlife Refuge. We thank J. Cureton, D. Curtis, R. Lehrter, T. Shadid, and B. Tweedy for assistance in the field. We thank S. Cartwright and the Sam Noble Oklahoma Museum of Natural History for archiving fish collections and providing museum data, and D. Lynch and J. Agan for data from the Oklahoma State University collection of fishes. We thank S. Brewer, A. Echelle, D. Fenner, K. Gido, J. Schaefer, and J. Tucker for information on fish distributions in the study area. K. Carter, L. Cooley, and G. Martin of the OU Biology Department provided critical logistical support. All collections were made under approval by the IACUC of the University of Oklahoma, Protocol Number R14-002.

Supplementary material

Supplementary table S1 and S2 are available online at https://ojs.library.okstate.edu/osu/index.php/OAS)

References

Allen DC. 2020. Targeted surveys for the Peppered Shiner in the Kiamichi, Little, Glover and Mountain Fork rivers. Oklahoma Department of Wildlife Conservation Final Report F17AF01107 (T-100-R-1).

Cashner RC, Matthews WJ, Marsh-Matthews E, Unmack PJ, Cashner FM. 2010. Recognition and redescription of a distinctive stoneroller from the southern Interior Highlands Copeia 2010:300-311.

Dauwalter DC, Splinter DK, Fisher WL, Marston RA. 2008. Biogeography, ecoregions, and geomorphology affect fish species composition in streams of eastern Oklahoma, USA. Environ Biol Fish 82:237-249.

Dyer JJ, Brewer SK. 2020. Seasonal movements and tributary-specific fidelity of blue sucker *Cycleptus elongatus* in a Southern Plains riverscape. J Fish Biol 97:279-292.

Echelle AF, Echelle AA. 2005. Reproductive behavior in Banded Pygmy sunfish, *Elassoma zonatum* (Elassomatidae), with comments on implication for relationships in the genus. Amer Currents 31:1-6.

Eley R, Randolph J, Carroll J. 1981. A comparison of the pre- and post-impoundment fish populations in the Mountain Fork River in southeastern Oklahoma. Proc Okla Acad Sci 61:7-14.

Finnell JC, Jenkins RM, Hall GE. 1956. The fishery resources of the Little River system, McCurtain County, Oklahoma. Okla Fish Res Lab Rpt No 55, Norman, OK.

Fowler HW. 1904. Notes on fishes from Arkansas, Indian Territory and Texas. Proc Acad Nat Sci Philadelphia 56:242-249.

Hubbs CL, Ortenburger AI. 1929a. Further notes on the fishes of Oklahoma with descriptions of new species of Cyprinidae. Publ Univ Okla Biol Surv 1:17-43.

Hubbs CL, Ortenburger AI. 1929b. Fishes collected in Oklahoma and Arkansas in 1927. Publ Univ Okla Biol Surv 1: 47-112, with Plates I-XIII.

Humphries JM, Cashner RC. 1994. *Notropis suttkusi*, a new Cyprinid from the Ouachita uplands of Oklahoma and Arkansas, with comments on the status of Ozarkian populations of *N. rubellus*. Copeia 1994:82-90.

Lemmons, RP, Hood MJ, Hill LG. 1997. New Oklahoma localities for Shortnose Gar (*Lepisosteus platostomus*), Largescale Stoneroller (*Campostoma oligolepis*), and Bluehead Shiner (*Pternotropis hubbsi*). Proc Okla Acad Sci 77:125-126.

Matthews WJ, Cashner RC, Gelwick FP. 1988. Stability and persistence of fish faunas and assemblages in three midwestern streams. Copeia. 1988:947957.

Matthews WJ, Turner T. 2019. Redescription and recognition of *Etheostoma cyanorum* from Blue River, Oklahoma. Copeia 107:208-218.

Matthews WJ. 1998. Patterns in freshwater fish ecology. Chapman and Hall, New York. 756 p.

Matthews WJ, Marsh-Matthews E. 2015. Comparison of historical and recent fish distribution patterns in Oklahoma and western Arkansas. Copeia 103:170-180.

Matthews WJ, Marsh-Matthews E. 2016. Dynamics of an upland stream fish community over 40 years: trajectories and support for the loose equilibrium concept. Ecology 97:706-719.

Matthews WJ, Marsh-Matthews E. 2017. Stream Fish Community Dynamics: A Critical Synthesis. Johns Hopkins University Press. Baltimore, MD. 330 p.

Matthews WJ, Marsh-Matthews E, Adams GL, Adams SR. 2014. Two catastrophic floods: similarities and differences in effects on an Ozark stream fish community. Copeia 2014:682-693.

Matthews WJ, Marsh-Matthews E, Cashner RC, Gelwick F. 2013. Disturbance and trajectory of change in a stream fish community over four decades. Oecologia 173:955-969.

Matthews WJ, Robison HW. 1982. Addition of *Etheostoma collettei* (Percidae) to the fish fauna of Oklahoma and of the Red River drainage in Arkansas. SW Nat 27:215216.

Matthews WJ, Robison HW. 1998. Influence of drainage connectivity, drainage area and regional species richness on fishes of the Interior Highlands in Arkansas. Am Midl Nat 139:1-19.

Meek SE. 1896. A list of fishes and mollusks collected in Arkansas and Indian Territory in 1894. Bull U S Fish Commission for 1895 (printed in 1896) 15:341-349.

Miller RJ, Robison HW. 2004. The fishes of Oklahoma, 2d Edition. Norman (OK): University of Oklahoma Press. 450 p.

Oklahoma Department of Wildlife Conservation. 2013. Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E.

Ortenburger AI, Hubbs CL. 1926. A report on the fishes of Oklahoma with descriptions of new genera and species. Proceedings of the Oklahoma Academy of Science 6:123-141.

Parham RW. 2009. Structure of assemblages and recent distribution of riverine fishes in Oklahoma. SW Nat 54:382-399.

Pigg J. 1977. A survey of the fishes of the Muddy Boggy River in south central Oklahoma. Proc Okla Acad Sci 57:68-82.

Pigg J. 1978. Unpublished field notes from Little River survey. Original field notes are in the Ichthyology Library of the Sam Noble Oklahoma Museum of Natural History.

Pigg J, Hill LG. 1974. Fishes of the Kiamichi River, Oklahoma. Proc Okla Acad Sci 54:121-130.

Porter CP, Patton TM. 2015. Patterns of fish diversity and community structure along the longitudinal gradient of the Kiamichi River in southeastern Oklahoma. Proc Okla Acad Sci 95:104-118.

Pyron M, Taylor C. M. 1993. Fish community structure of Oklahoma Gulf Coastal Plains. Hydrobiologia 257:29-35.

Pyron M, Vaughn CC, Winston MR, Pigg J. 1998. Fish assemblage structure from 20 years of collections in the Kiamichi River, Oklahoma. SW Nat 43:336-343.

Reeves JD. 1950. The fishes of the Mountain Fork River in Arkansas and Oklahoma with descriptions of two new percid fishes. Unpublished M.S. thesis, Oklahoma A&M College, Stillwater, OK.

Robison HW. 2006. Status survey of the Peppered Shiner, *Notropis perpallidus* Hubbs and Black, in Arkansas and Oklahoma. J Ark Acad Sci 60:101-107.

Robison HW, Buchanan TM. 2020. The fishes of Arkansas, 2d Edition. University of Arkansas Press, Fayetteville, AR. 959 p.

Ross ST, Matthews WJ, Echelle AA. 1985. Persistence of stream fish assemblages: effects of environmental change. Am Nat 126:24-40.

DA, Echelle AA, Maughn OE. 1987. Changes in the fauna of the Little River drainage, southeastern Oklahoma, 1948-1955 to 1981-1982: A test of the hypothesis of environmental degradation. In: Matthews WJ, Heins DC, editors. Community and Evolutionary Ecology of North American Stream Fishes. University of Oklahoma Press, Norman, OK. p. 178-183.

Rutherford DA, Echelle AA, Maughn OE. 1992. Drainage-wide effects of timber harvesting on the structure of stream fish assemblages in southeastern Oklahoma. Trans Amer Fish Soc 121:716-728.

Sansom BJ, Tweedy BN, Vaughn CC. 2017. Composition of fish communities on and off mussel beds in the Kiamichi River, Oklahoma. Proc Okla Acad Sci 97:1-7.

Schaefer JF, Marsh-Matthews E, Spooner DH, Gido KB, Matthews WJ. 2003. Effects of barriers and thermal refugia on local movement of the threatened leopard darter, *Percina pantherina*. Envir Biol Fish 66:391-400.

Schenck JR, Smith AL. 1973. Stream fishes in Pontotoc County, Oklahoma. Proc Okla Acad Sci 53:65-68.

Taylor CM, Lienesch PW. 1995. Environmental correlates of distribution and abundance for *Lythrurus snelsoni*: A range-wide analysis of an endemic fish species. SW Nat 40:373-378.

Taylor CM, Lienesch PW. 1996. Regional parapatry of the congeneric cyprinids *Lythrurus snelsoni* and *L. umbratilis*: Replacement along a complex environmental gradient. Copeia 1996:493-497.

Taylor CM. 2010. Covariation among plains stream fish assemblages, flow regimes, and patterns of water use. Pages 447 to 460 in: Gido KB and Jackson DA, editors. Community Ecology of Stream Fishes: Concepts, Approaches, and Techniques. American Fisheries Society Symposium 73, Bethesda, MD.

United States Geological Survey. 2020. Gap Analysis Project (GAP) Protected Areas Database of the United States (PAD-US) 2.1: U.S. Geological Survey data release [online]. Available from: https://doi.org/10.5066/P92QM3NT. (Accessed March 23, 2021).

Vaugh CC, Gido KB, Parr T. 2021. Overlapping fish and mussel hotspots. OSF [online]. Available from: https://doi.org/10.17605/OSF.IO/FWJH9. (Accessed March 23, 2021).

Wagner BA, Echelle AA, Maughn OE. 1987. Abundance and habitat use of an uncommon fish, *Notropis perpallidus* (Cyprinidae): comparison with sympatric congeners. SW Nat 32:251-260.

Williams LR, Echelle AA. 1998. Collection in Oklahoma of a rare fish species, *Notropis chalybaeus* (Cyprinidae). Proc Okla Acad Sci 78:115-116

Zbinden ZD. 2020. Temporal dynamics of stream fish assemblages and the role of spatial scale in quantifying change. Ecol Evol 10:952-961.

Zbinden ZD. 2021. A needle in the haystack? Applying species co-occurrence frameworks with fish assemblage data to identify species association and sharpen ecological hypotheses. J Fish Biol 2021: 1-13.

Zbinden ZD, Matthews WJ. 2017. Beta diversity of stream fish assemblages: partitioning variation between spatial and environmental factors. Freshwater Biol 62:1460-1471.

Submitted April 13, 2021 Accepted July 14, 2021