FINAL PERFORMANCE REPORT

Federal Aid Grant No. F13AF01213 (T-74-1)

Survey of Clear Boggy, Muddy Boggy, Kiamichi and Little River Drainages in Oklahoma to Determine Current Distribution and Status of Fish Species of Greatest Conservation Need and Potential Change in Fish Communities

Oklahoma Department of Wildlife Conservation

January 1, 2014 through June 30, 2016

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Report Period: January 1, 2014 – June 30, 2016

Project Leader:
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I. **OBJECTIVE(S):** To estimate the distribution and abundance of fish species in the Muddy Boggy, Clear Boggy, Kiamichi and Little River waters by field surveys primarily using seines but supplementing with gill nets in lower parts of rivers. The locations and numbers of all fishes of greatest conservation need captured during the project and communities in which they occurred are provided in each performance report.

II. **METHODS AND RESULTS:**

<u>Executive Summary</u>

The overall goal of the project was to assess the distribution of "species of greatest conservation need" (=SGCN species), and the status of native fish communities in the Clear Boggy, Muddy Boggy, Kiamichi, and Little river drainages in Oklahoma. The Clear Boggy drainage is a tributary of the Muddy Boggy river drainage, and in this report we refer to the Muddy Boggy drainage to include both, unless otherwise specified.

All goals of the project were met or exceeded, and no deviations from the project took place. The project was initiated in January 2014. In May-July 2014 a total of 106 sites was sampled by standardized seining throughout the Muddy Boggy and Kiamichi drainages, meeting or exceeding the goals of the project. In June-July 2015 a total of 45 collections was made by seining throughout the Little River drainage, meeting the goals of the project. In September 2015, 16 additional field samples were made in the Muddy Boggy drainage, to match sites sampled in 2015, providing information on variability in local fish communities between years, and additional information on the distribution of some SGCN species. Overall, the project produced a total of 167 standardized seining samples. In total, 167 seining samples, representing 151 different sites, were made in the Muddy Boggy, Kiamichi, and Little river drainages. All fish have been identified, enumerated, and placed in archival storage in Sam Noble Oklahoma Museum of Natural History. For all 167 seining collections, detailed environmental data were recorded. In June 2016, gill netting was accomplished at five sites, including sites in the lower reaches in all three major drainages. Electronic databases including all fish samples and all environmental data are included as appendices to this report.

A total of 11 SGCN fish species was found in the region in the two years of surveys. The Little River drainage had the highest proportion (84.4%) of sites that contained at least one SGCN species. Across all drainages, nine sites had three SGCN species and one site had four. The number of SGCN species per site was positively related to total number of species per site, so protecting species rich sites may help provide protection for SGCN species. Some SGCN species were widespread in the region and may merit removal from the SGCN list or downgrading from Tier 1 to Tier 2. Blackspot Shiner, Ouachita Mountain Shiner, Rocky Shiner, and Orangebelly Darter appear to be secure in the region. The Kiamichi Shiner was also found in numerous locations and in moderate numbers, but populations may be less secure because of localized occurrence in headwaters. Tier 1 fish species that were found only once, and should be considered scarce across in the region in general, include Pallid Shiner and Leopard Darter. Tier 2 species found only once included Blue Sucker and Ironcolor Shiner, and the Goldstripe Darter was found at two sites. No other Tier 1 or Tier 2 species were found.

Across the study area native fish communities generally remained in good condition relative to historical information from the 1920s through the 1970s, with current numbers of species per site (median of 11 and the third quartile of 14 species) typical of the diversity we have found in previous sampling in the region. Sites with 15 to 18 native species or with 19 or more native species could be considered, respectively, to be "priority" or "high priority" sites for protection or conservation efforts. Sites with 15 or more native species included 16 in the Muddy Boggy River drainage, 5 in the Kiamichi River drainage, and 8 in the Little River drainage.

Predictions of potential for future change in native fish communities in the region included the tendency for many local communities to be in "loose equilibrium" changing from year to year, but remaining within typical community structure boundaries over longer periods of time. Predictions were also based on the average amount of change in local fish communities over time. Most streams in the region for which we have long-term data exhibit average percentage similarities from time to time (across years to decades) of 60 to 70% similarity in relative abundances of species. The 16 sites in the Muddy Boggy River drainage for which we had samples in 2014 and 2015 matched this expectation. The most likely or "default" expectation for stream fish communities in the region is that they may change substantially from one time to the next, but remain relatively similar to some average condition over longer periods of time. We have no evidence that stream fish communities in the region have grossly changed since surveys in the 1920s to 1970s.

Tolerances of individual species for environmental change or habitat degradation were used to estimate the probability of the fish community at each sampling site changing over time. More local fish communities in the Little River drainage were on average rated "moderately intolerant" or "intolerant" than communities in the Muddy Boggy River or Kiamichi River drainages. Local communities with lower average tolerances were generally toward the upper or headwaters parts of all three drainages, suggesting that protection of headwaters can be an important conservation issue. Assessment of currently protected areas in all three drainages (by state, federal, or NGO ownership or conservation areas) indicated that a relatively small part of the Muddy Boggy drainage has protected stream areas, that protected areas in the Kiamichi River drainage are mostly in the uppermost part of the drainage, and that protected areas in the Little River drainage are in lower and mid-reaches. More opportunities should be sought for establishment of protected stream habitat in the upper Little River drainage.

The final report for this project provides managers and all interested stake-holders with the most recent updated information on occurrences of SGCN fish species throughout all southeast Oklahoma river drainages. The report also provides ODWC and all interested parties with current information on the status of whole fish communities throughout the region, identifying areas where natural, native fish communities remain in healthy condition and potential areas where additional protection would be desirable. All the information from this project can be included in discussions on management issues like stream flows, public access, riparian corridor protection, road crossing design, timber harvest practices, and conservation easements or stream protection areas. Because many of the smaller streams that are the focus of the project are on private land, this information can also assist ODWC in working with land owners to inform or to seek protection of critical stream areas for SGCN species or for native fish in general.

Survey Sites

Sixty-six sites were sampled in the Muddy Boggy River drainage (with 16 sites sampled twice) (Fig. 1). Forty sites were sampled in the Kiamichi River drainage (Fig. 2). Forty-five sites were sampled in the Little River drainage (Fig. 3). Site numbers on the maps in Figs. 1-3 represent original field numbers by the collecting crews. Appendix A to this report describes the numbered locations and environmental conditions at the site at the time of sampling.

Fig. 1. Collection sites in the Muddy Boggy River drainage. Site numbers represent original field numbers by collecting crews.

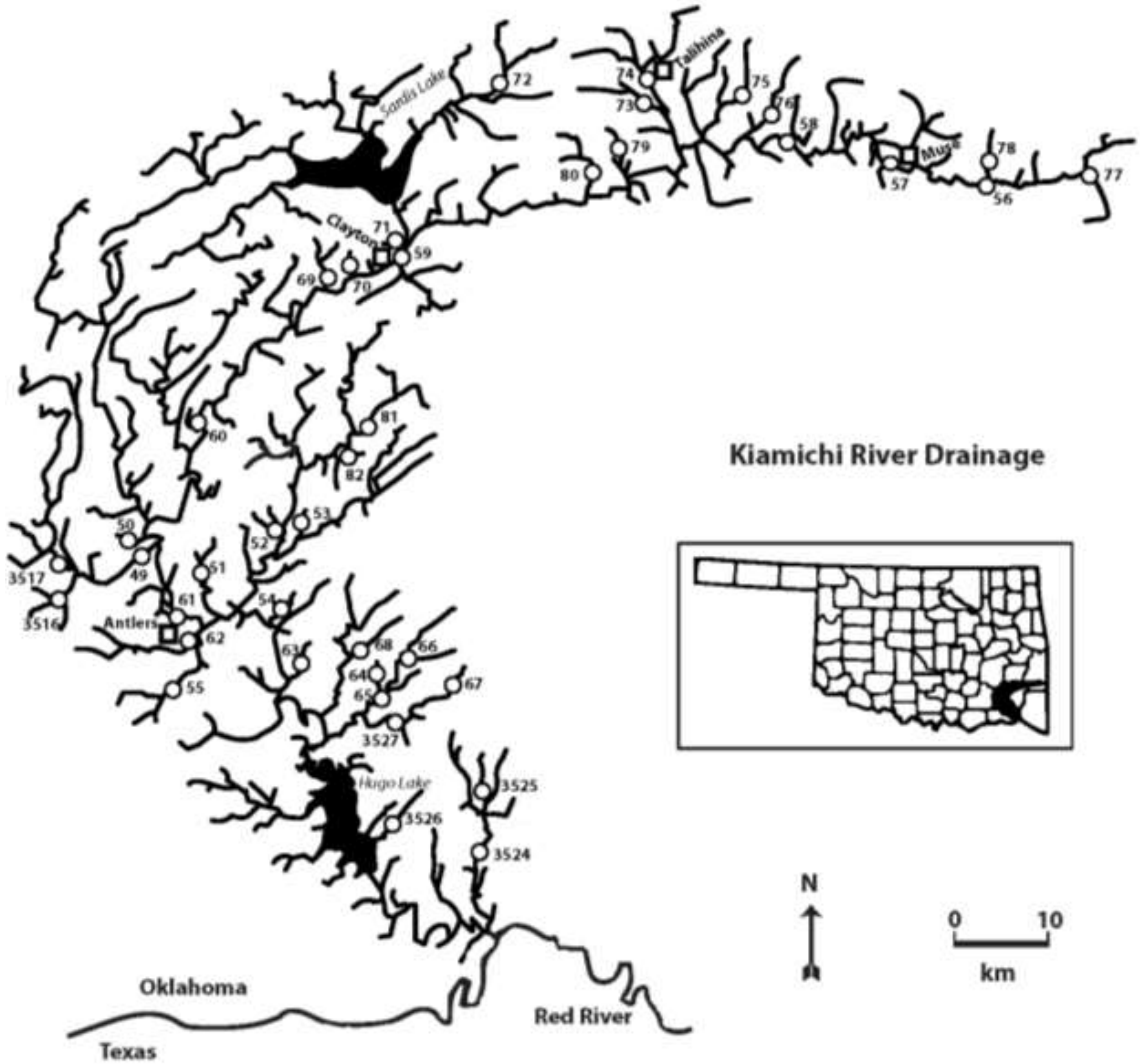


Fig. 2. Collection sites in the Kiamichi River drainage. Site numbers represent original field numbers by collecting crews.

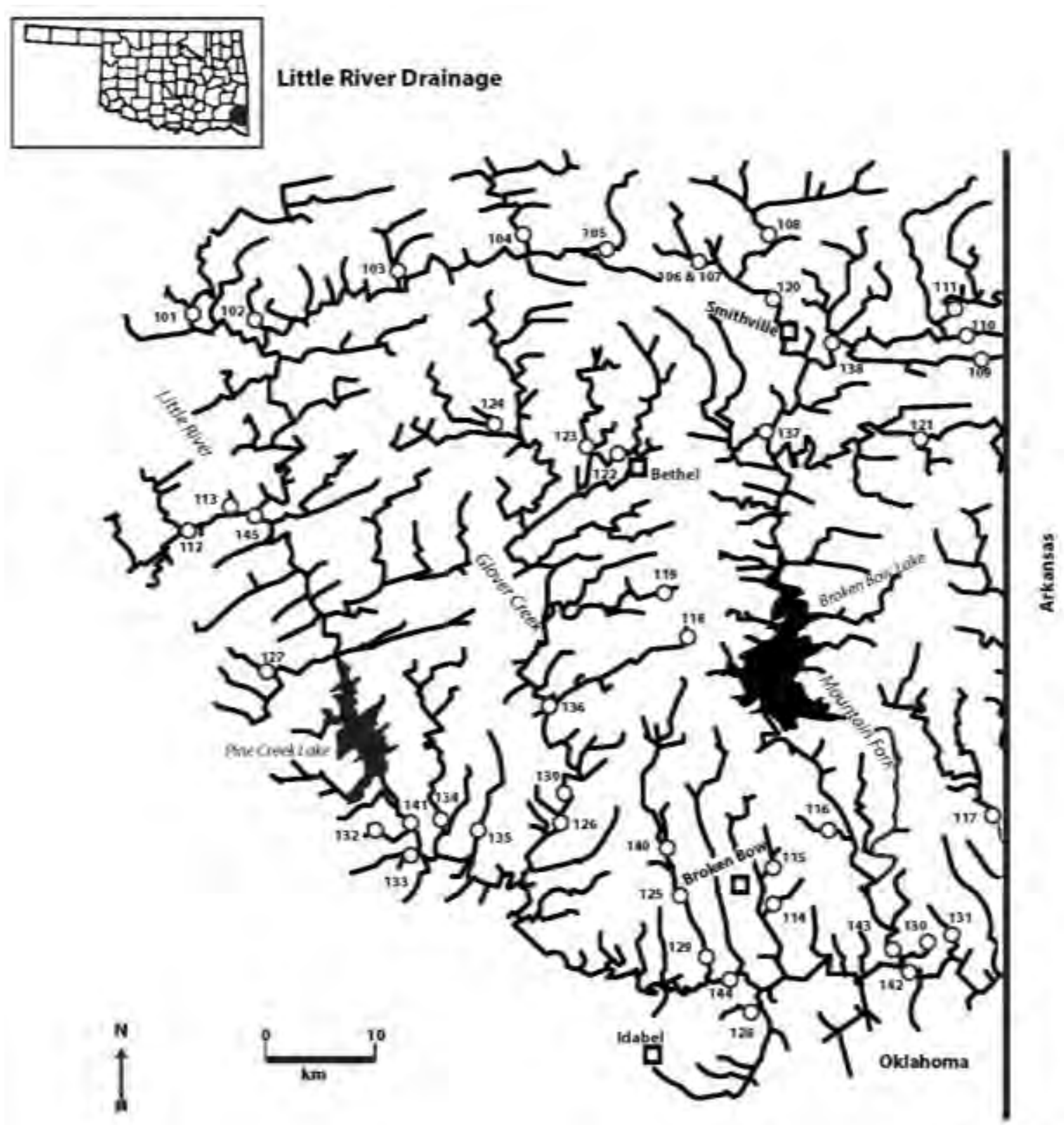


Fig. 3. Collection sites in the Little River drainage. Site numbers represent original field numbers by collecting crews.

Collection Methods

Fish communities were collected by seining all habitats within approximately 100 m of wadeable stream reach using one or two sizes of net, depending on the width of the stream (4.57 m × 1.22 m × 4.88 mm mesh and/or 2.44 m × 1.22 m × 4.88 mm mesh). Channel and pool habitats were sampled by pulling seines downstream; riffle and edge habitat were sampled by kick-seining. Specimens were preserved in 10% formalin with the exception of one Leopard Darter, which was immediately released unharmed, and numerous large-bodied fishes such as gars or buffalo that were identified and released, with notes kept on numbers and sizes, for inclusion in totals in Appendix B. All other fishes were identified in our laboratory at the University of Oklahoma, and archived in the Sam Noble Museum of Natural History, Norman, Oklahoma. 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.

Data Analyses

Appendix A to this report summarizes environmental data at all sites, and Appendix B to this report summarizes all fish collected by seining. Data analyses were carried out by summarizing findings from those tables, and using the NT-SYSpc package of multivariate analyses to assess fish community structure.

Results: Fish Species of Greatest Conservation Need

Occurrences of SGCN Species

In seine samples in 2014 or 2015 we found 11 of the 19 fish "species of greatest conservation need" (SGCN) that potentially occur in the drainages included in our surveys. No additional SGCN species were captured by gill netting. As indicated in Table 1 (below), some of the SGCN taxa were widespread in the region, and we address these in the "recommendations" section. Others were found only once, or in only one site. The following species were commonly encountered in all or parts of the project area and in substantial numbers: Blackspot Shiner, Ouachita Mountain Shiner, Rocky Shiner, and Orangebelly Darter. These species appear to be secure in the region, relative to their previous known ranges, or to have expanded to the west (Blackspot Shiner). The Kiamichi Shiner was also found in numerous locations and in moderate numbers, but populations may be less secure than those of the species above. Tier 1 fish species that were found only once, and should be considered scarce across in the region in general include Pallid Shiner and Leopard Darter. Tier 2 species found only once included Blue Sucker and Ironcolor Shiner, and the Goldstripe Darter was found at two sites. No other Tier 1 or Tier 2 species were found.

Table 1. For SGCN species 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
Blackspot Shiner	*Notropis atrocaudalis*	268	19	All three drainages
Bluehead Shiner	*Pteronotropis hubbsi*	0	0	n/a
Crystal Darter	*Crystallaria asprella*	0	0	n/a
Kiamichi Shiner	*Notropis ortenburgeri*	241	7	Kiamichi & Little
Leopard Darter	*Percina pantherina*	1	1	Little River
Ouachita Mountain Shiner	*Lythrurus snelsoni*	1226	17	Little River
Pallid Shiner	*Hybopsis amnis*	1	1	Muddy Boggy
Peppered Shiner	*Notropis perpallidus*	0	0	n/a
Rocky Shiner	*Notropis suttkusi*	2253	25	All three drainages
Western Sand Darter	*Ammocrypta clara*	0	0	n/a

Tier II Species

Common Name	Scientific Name	Total Found	Total Sites	River Drainage
Alligator Gar	*Atractosteus spatula*	0	0	n/a
Blue Sucker	*Cycleptus elongatus*	1	1	Muddy Boggy
Creole Darter	*Etheostoma collettei*	0	0	n/a
Goldstripe Darter	*Etheostoma parvipinne*	19	2	Muddy Boggy
Ironcolor Shiner	*Notropis chalybaeus*	1	1	Little
Mountain Madtom	*Noturus eleutherus*	0	0	n/a
Orangebelly Darter	*Etheostoma radiosum*	552	80	All three drainages
Southern Brook Lamprey	*Ichthyomyzon gagei*	1*	1*	Kiamichi

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

Distribution of SGCN Species across Basins

For each of the SGCN species captured during this study, we provide detailed maps below (Figures 4-14) of sites where it was detected across all basins.

Blackspot Shiner (*Notropis atrocaudalis*) was found at eight sites in the Muddy Boggy River drainage (Fig. 4A), seven sites in the Kiamichi River drainage (Fig. 4B) and four sites in the Little River drainage (Fig. 4C).

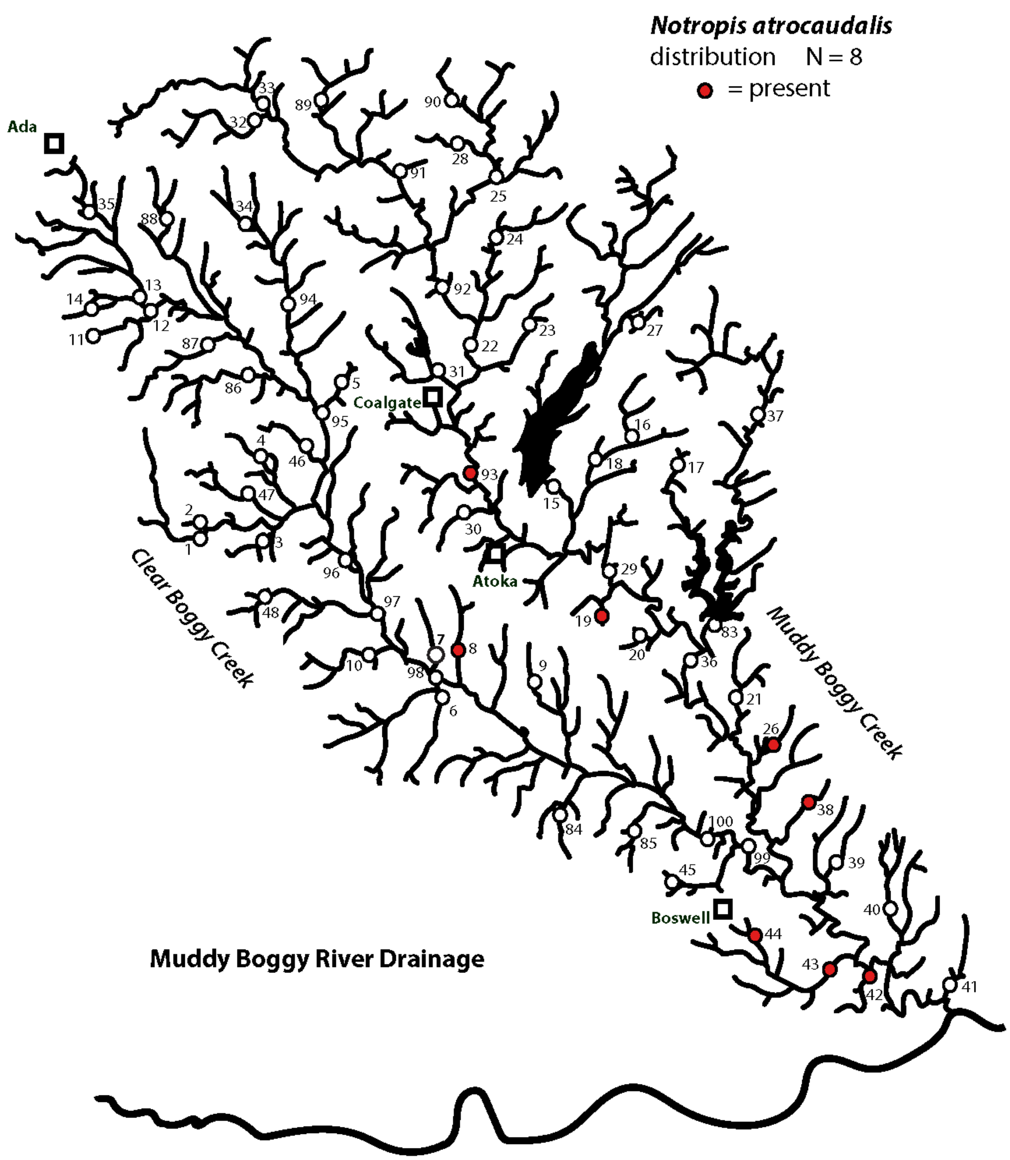


Fig. 4A. Distribution of Blackspot Shiner (*Notropis atrocaudalis*) in the Muddy Boggy River drainage based on collections made summer 2014.

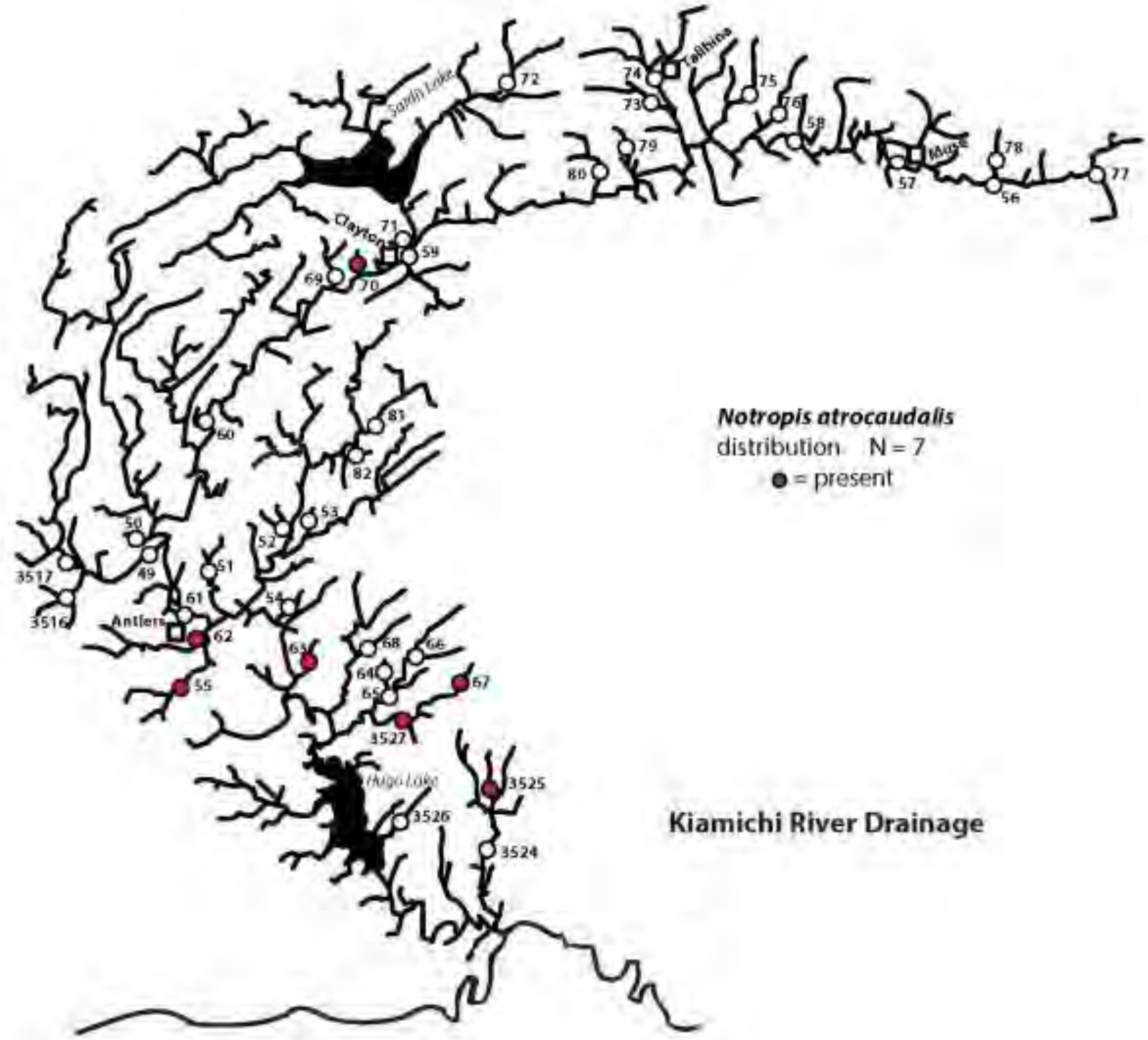


Fig. 4B. Distribution of Blackspot Shiner (*Notropis atrocaudalis*) in the Kiamichi River drainage based on collections made summer 2014.

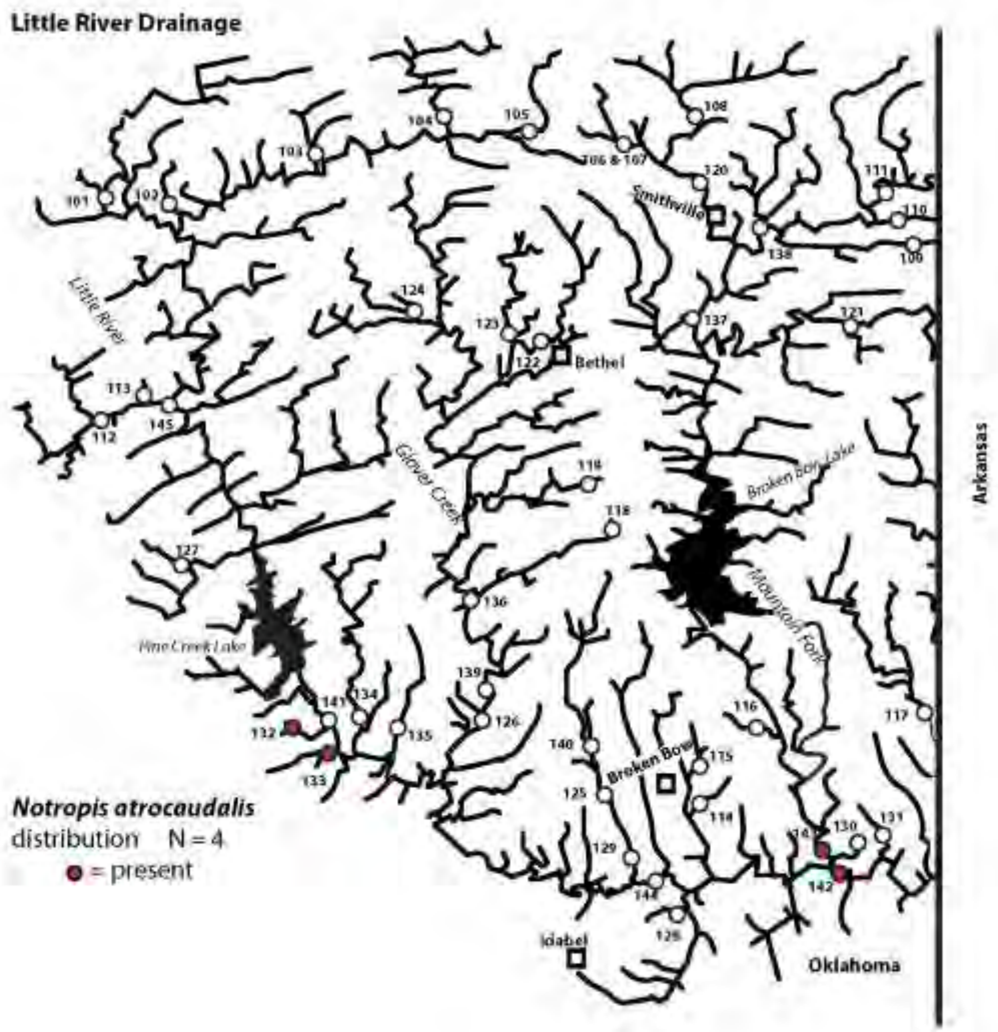


Fig. 4C. Distribution of Blackspot Shiner (*Notropis atrocaudalis*) in the Little River drainage based on collections made summer 2015.

Blue Sucker (*Cycleptus elongatus*) was captured at only one site during the study. This site was in the lower Clear Boggy of the Muddy Boggy basin (Fig. 5).

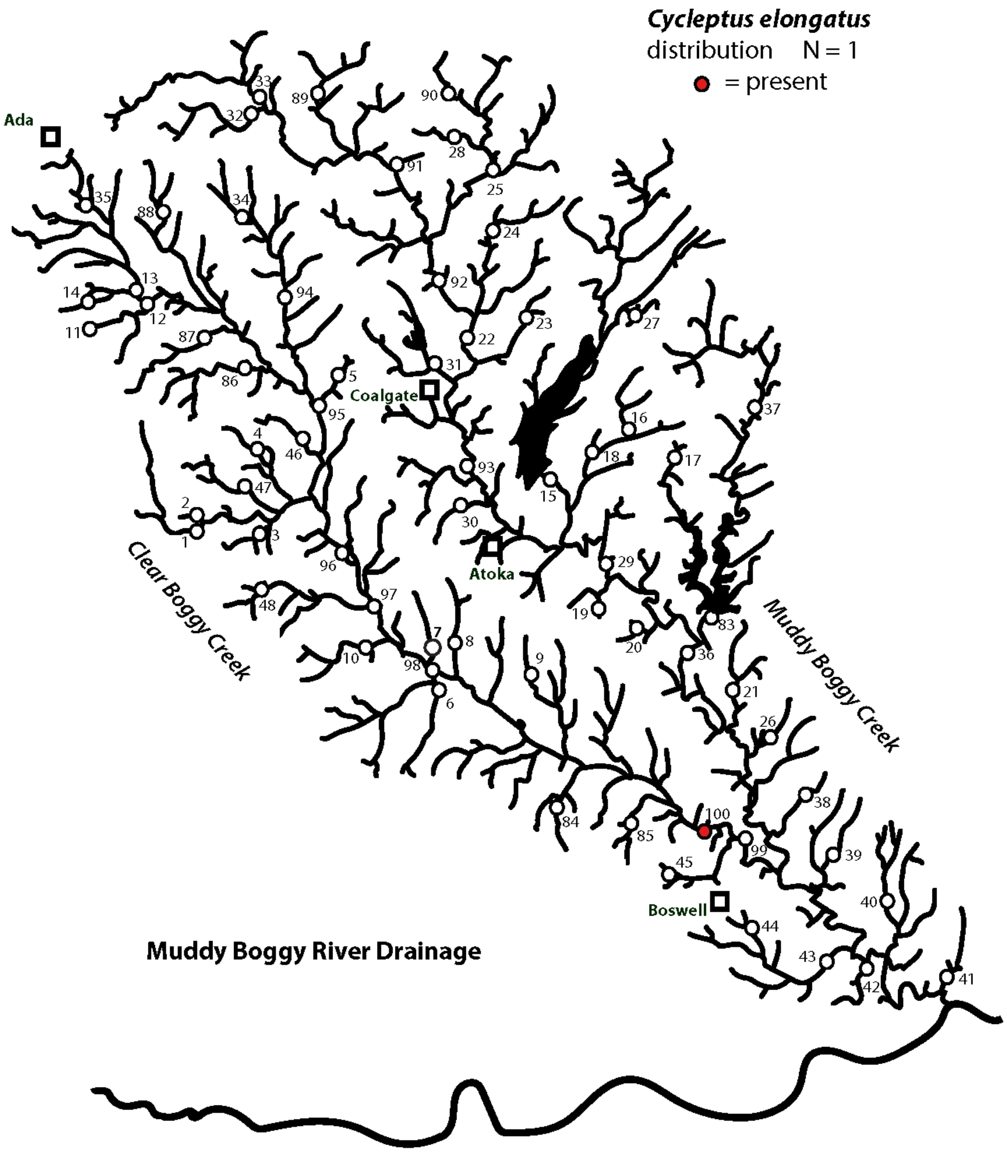


Fig. 5. Distribution of Blue Sucker (*Cycleptus elongatus*) in the Muddy Boggy River drainage based on collections made summers 2014 and 2015.

Goldstripe Darter (*Etheostoma parvipinne*) was found at two sites in the Muddy Boggy River drainage (Fig. 6)

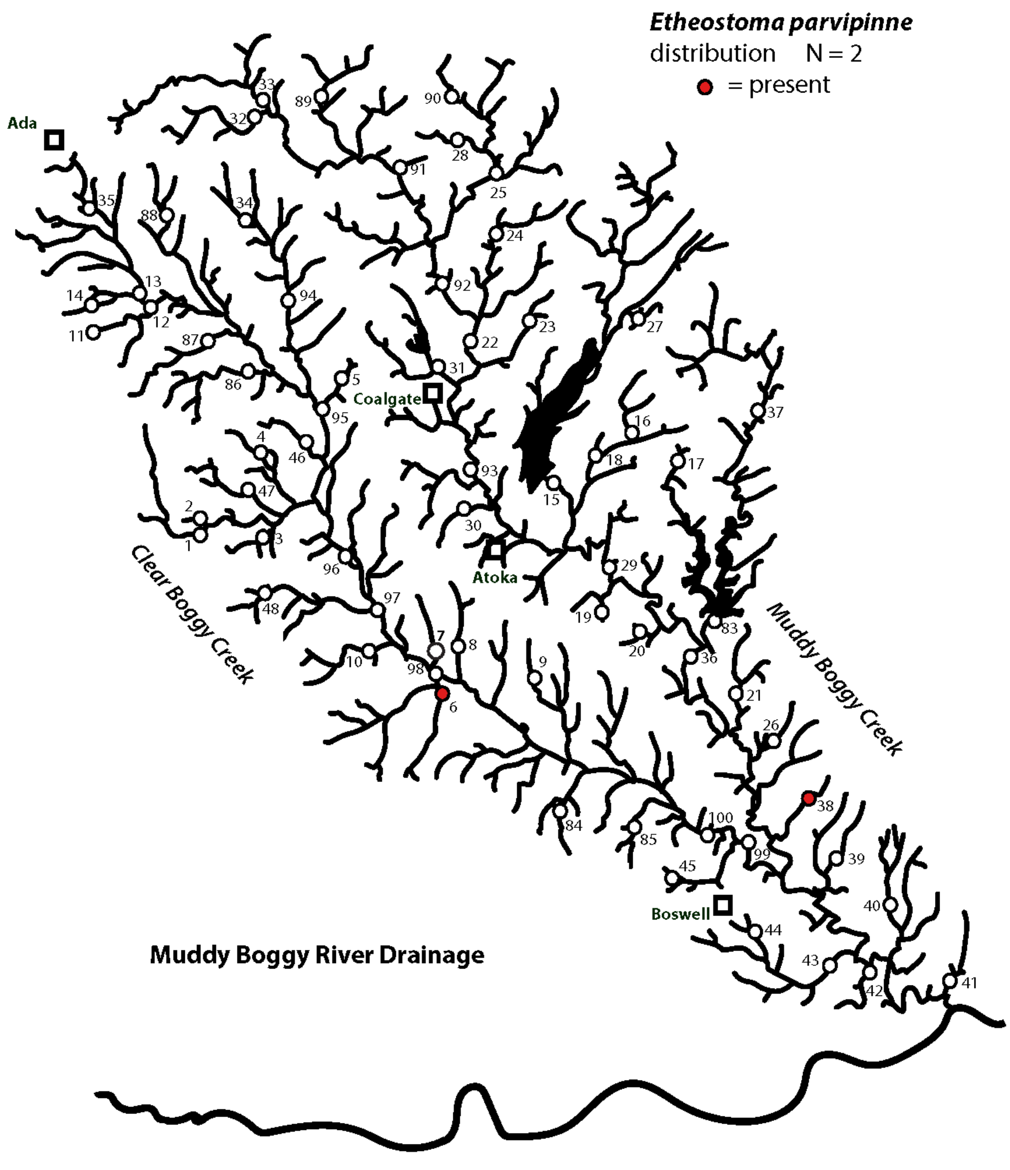


Fig. 6. Occurrence of Goldstripe Darter (*Etheostoma parvipinne*) at a single site in the Muddy Boggy River drainage based on collections made summer 2014.

Ironcolor Shiner (*Notropis chalybaeus*) was found at a single site in the Muddy Boggy River drainage (Fig. 7).

Fig. 7. Distribution of Ironcolor Shiner (*Notropis chalybeaus*) in the Muddy Boggy River drainage based on collections made summer 2014.

Kiamichi Shiner (*Notropis ortenburgeri*) was collected at three sites in the Kiamichi River basin (Fig. 8A) and four sites in the Little River basin (Fig. 8B).

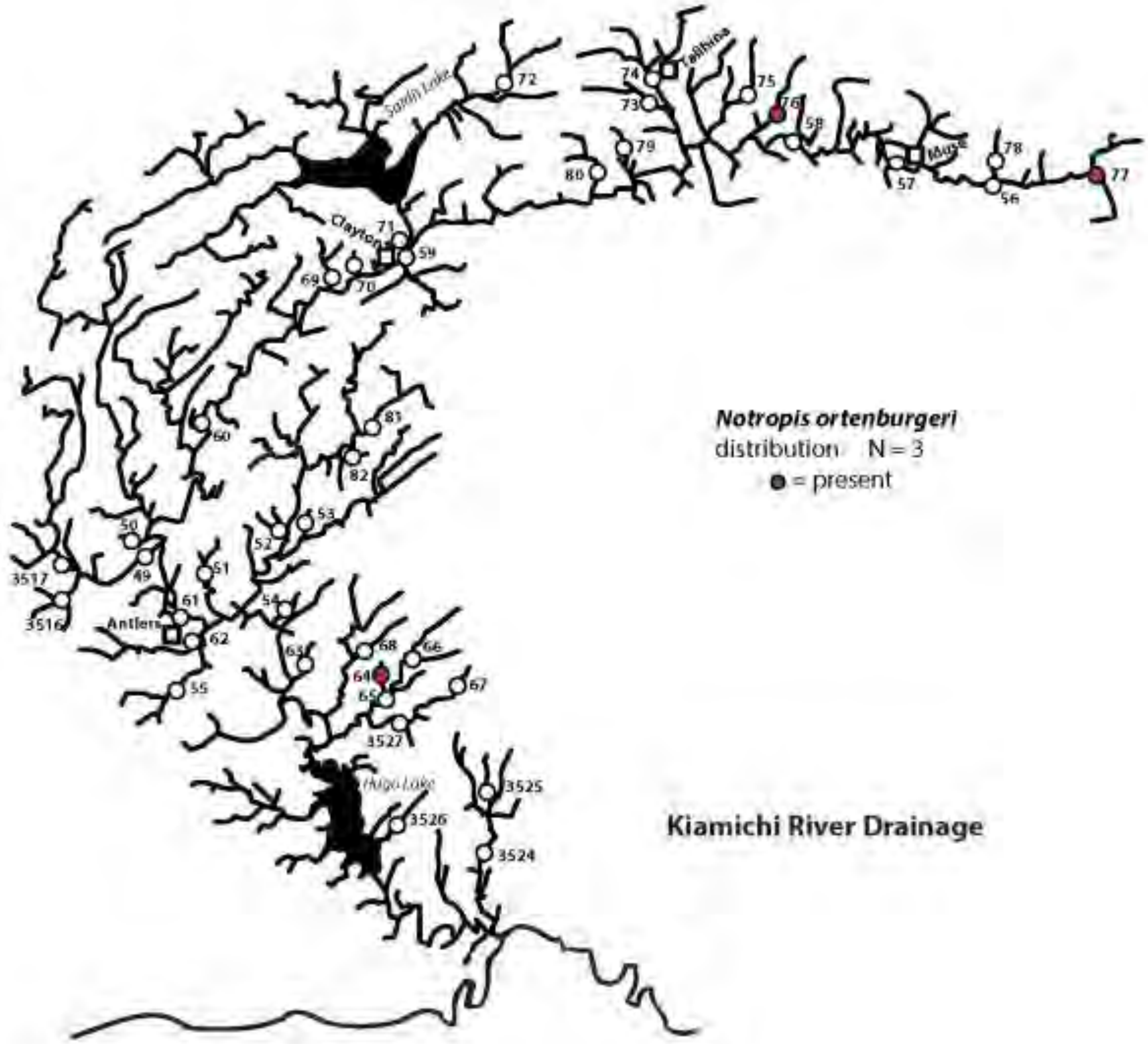


Fig. 8A. Distribution of Kiamichi Shiner (*Notropis ortenburgeri*) in the Kiamichi basin based on collections made summer 2014.

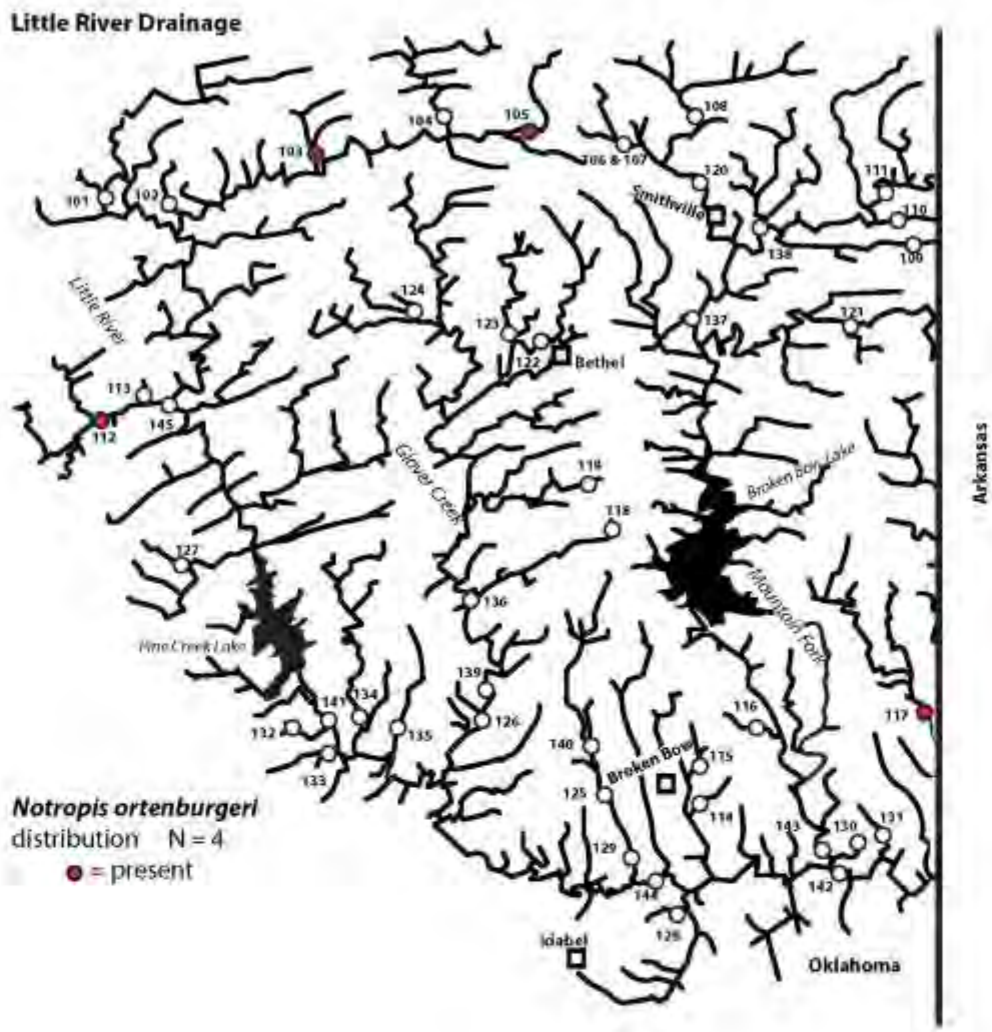


Fig. 8B. Distribution of Kiamichi Shiner (*Notropis ortenburgeri*) in the Little River basin based on collections made summer 2015.

Leopard Darter (*Percina pantherina*) was collected at a single site in the Little River basin (Fig. 9) and immediately released unharmed.

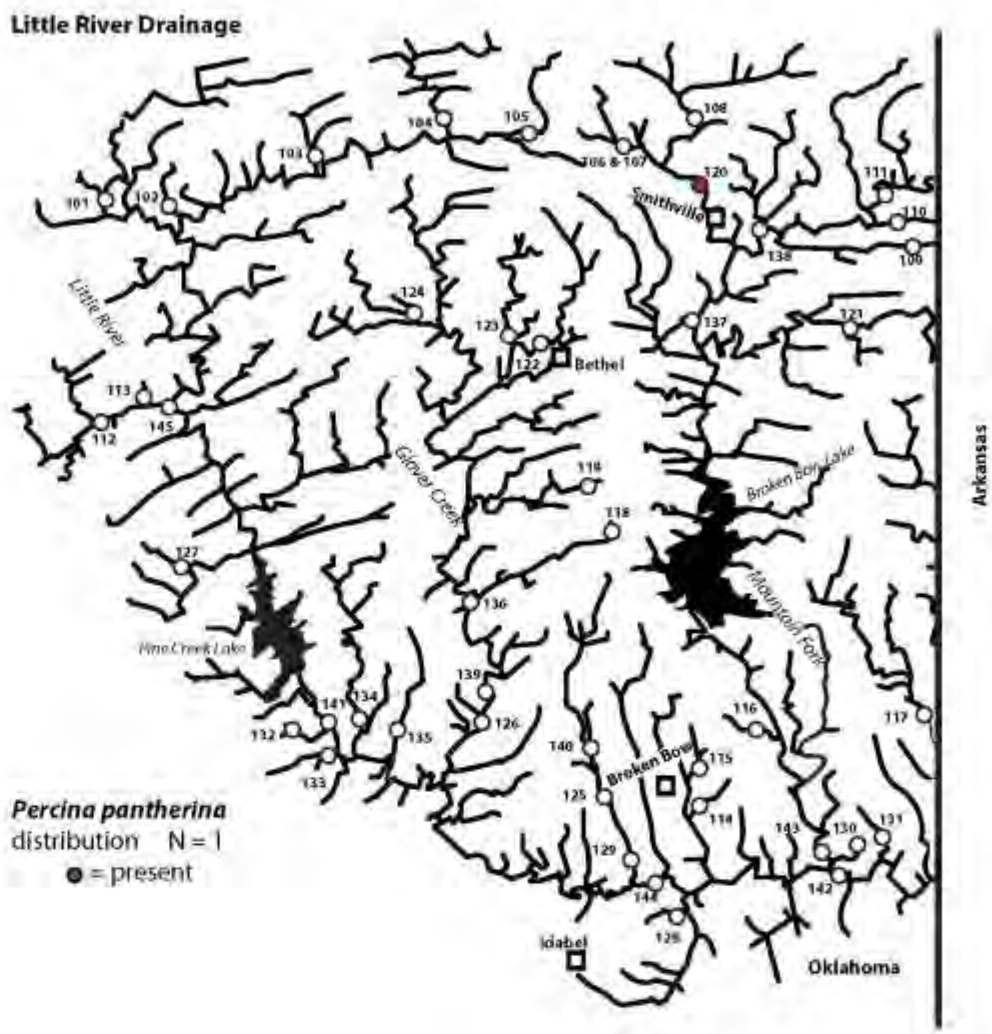


Fig. 9. Capture and release of Leopard Darter (*Percina pantherina*) from a single site in the Little River drainage based on collections made summer 2015.

Orangebelly Darter (*Etheostoma radiosum*) was widespread throughout the study area and occurred at 36 sites in the Muddy Boggy River drainage (Fig. 10A), 18 sites in the Kiamichi River drainage (Fig. 10B), and 26 sites in the Little River drainage (Fig. 10C).

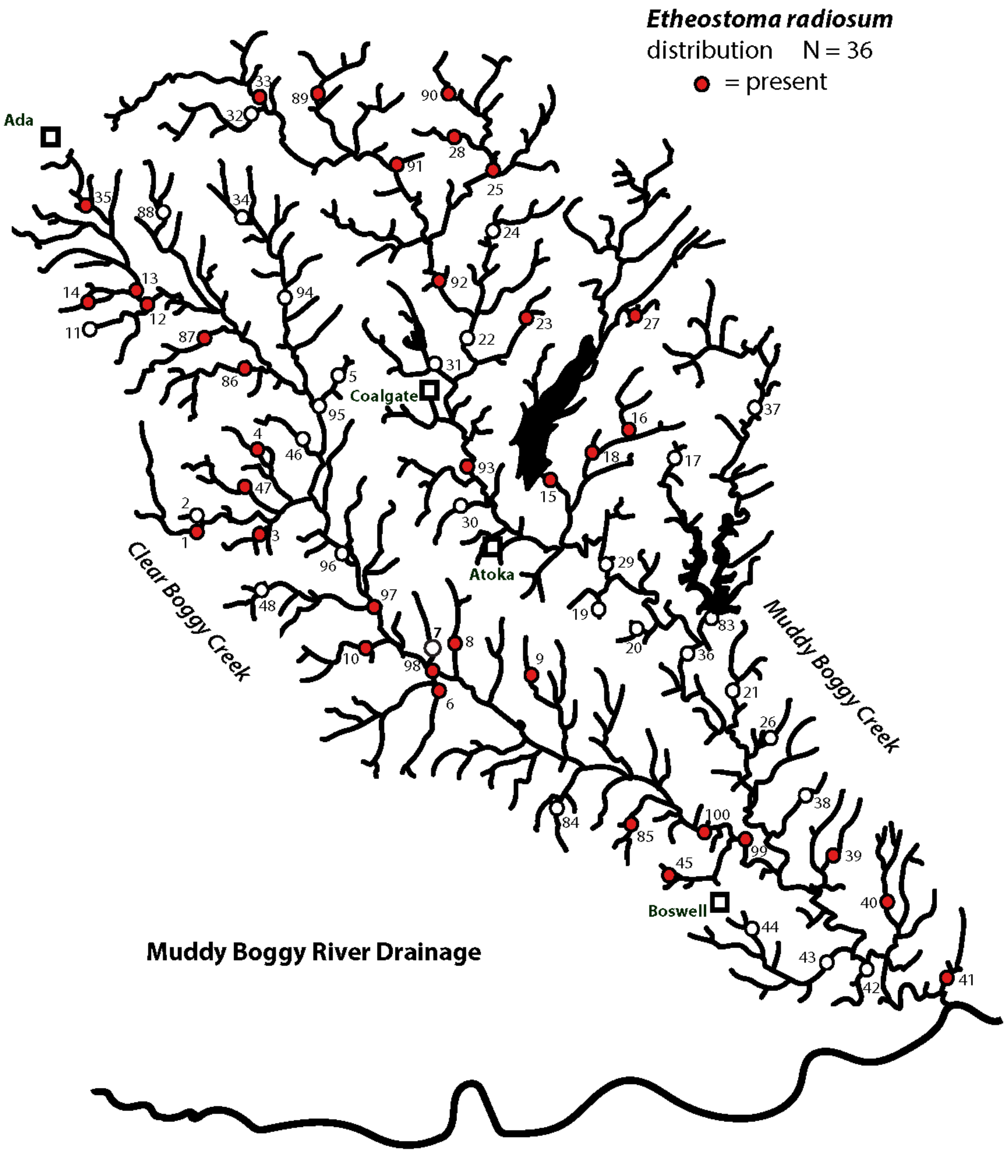


Fig. 10A. Distribution of Orangebelly Darter (*Etheostoma radiosum*) in the Muddy Boggy River drainage based on collections made summer 2014.

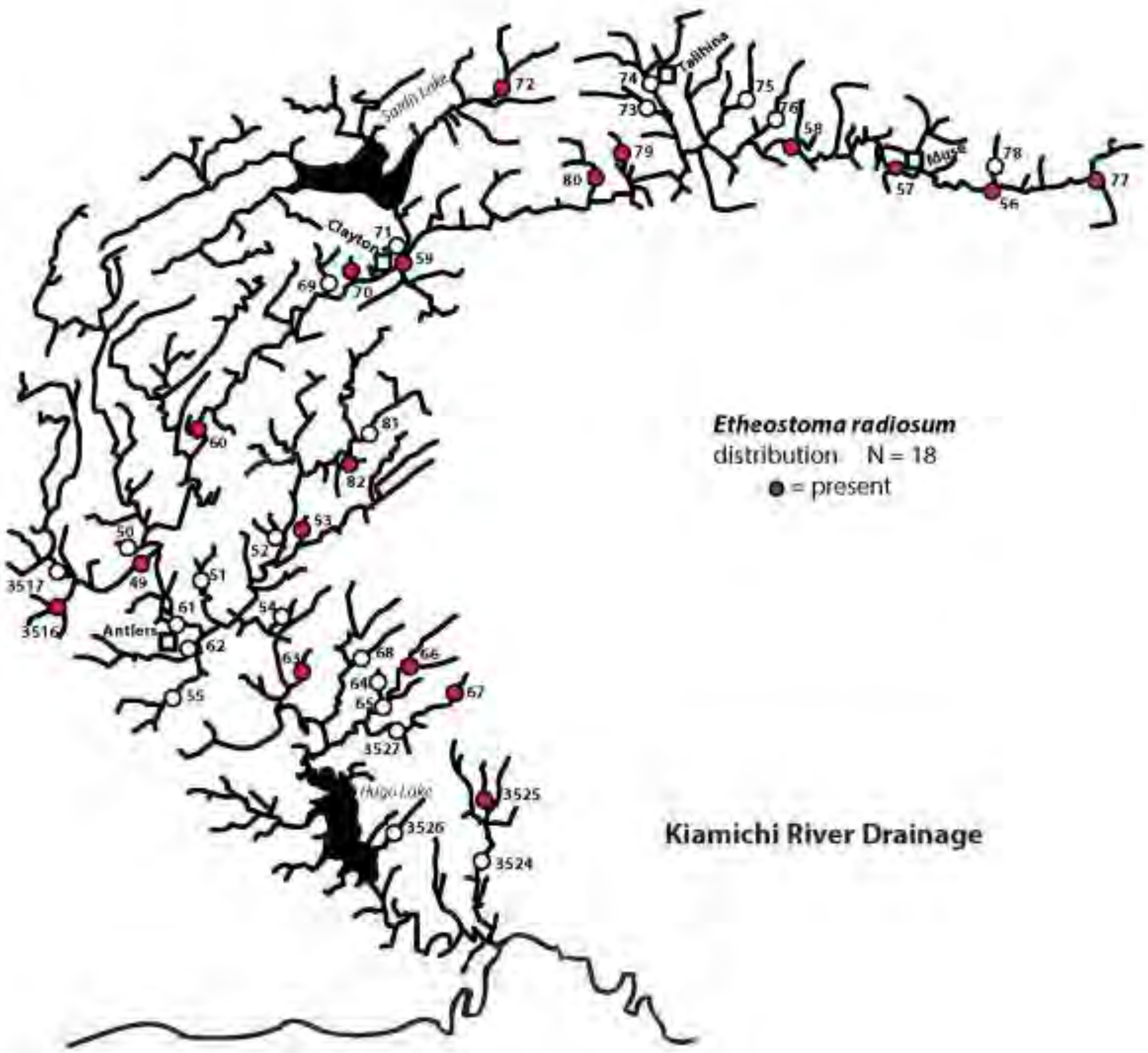


Fig. 10B. Distribution of Orangebelly Darter (*Etheostoma radiosum*) in the Kiamichi River drainage based on collections made summer 2014.

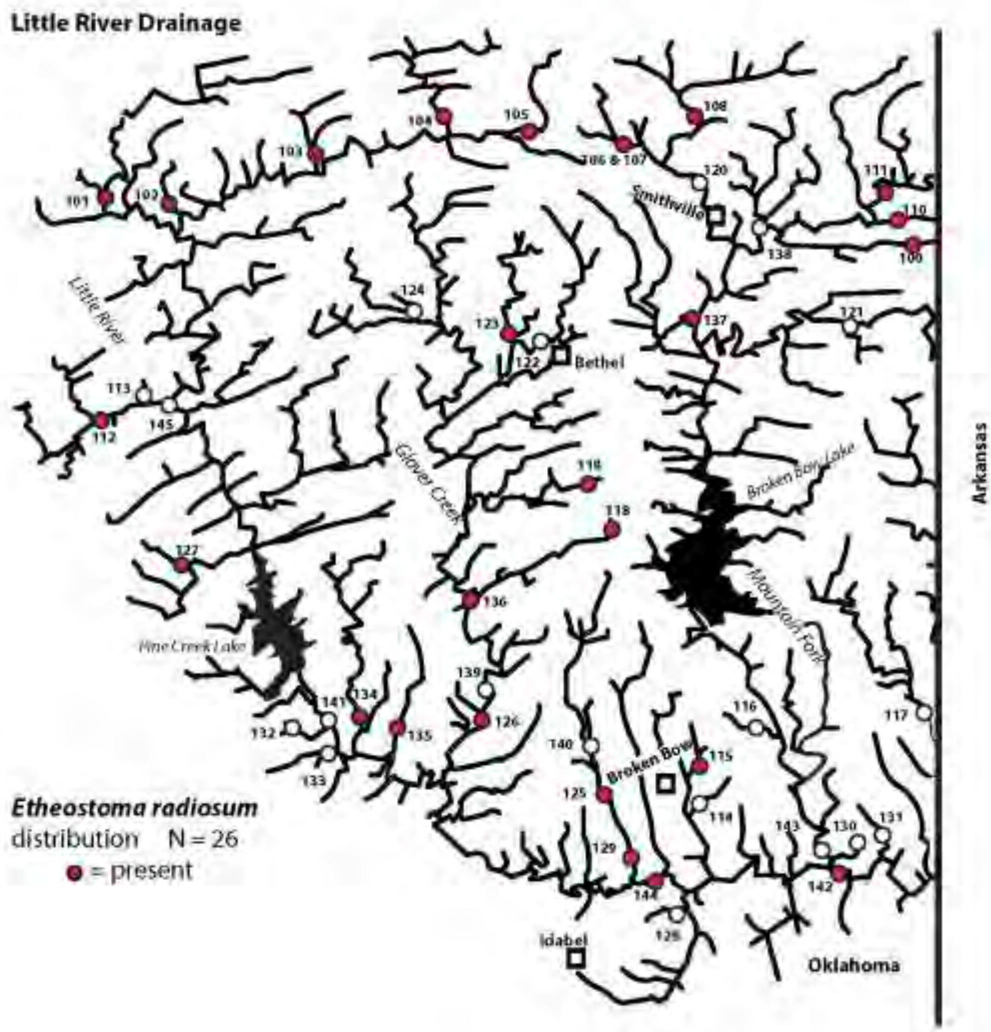


Fig. 10C. Distribution of Orangebelly Darter (*Etheostoma radiosum*) in the Little River drainage based on collections made summer 2015.

Ouachita Mountain Shiner (*Lythrurus snelsoni*) was found only in the Little River drainage but was widespread in the headwater regions, occurring at 17 sites (Fig. 11).

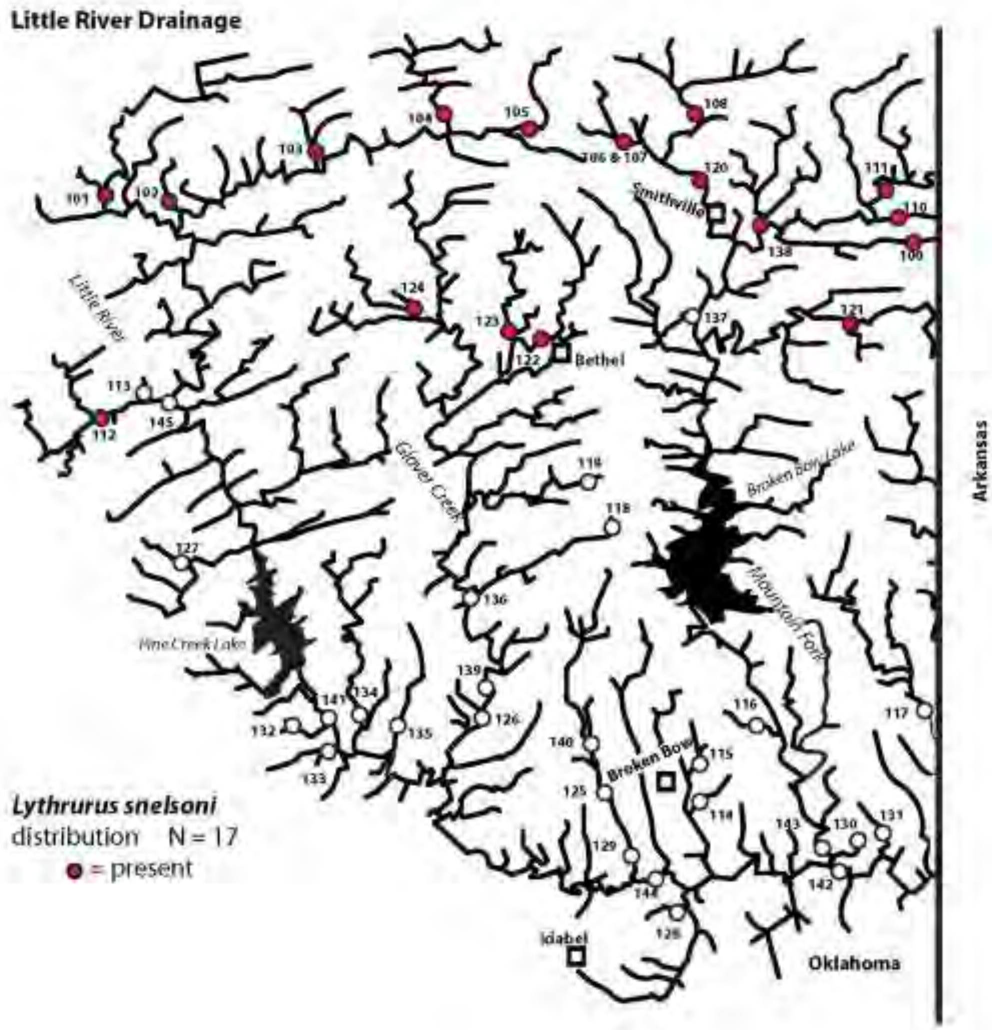


Fig. 11. Distribution of Ouachita Mountain Shiner (*Lythrurus snelsoni*) in the Little River drainage based on collection in summer 2015.

Pallid Shiner (*Hybopsis amnis*) was found at only one site in the Muddy Boggy River drainage (Fig. 12).

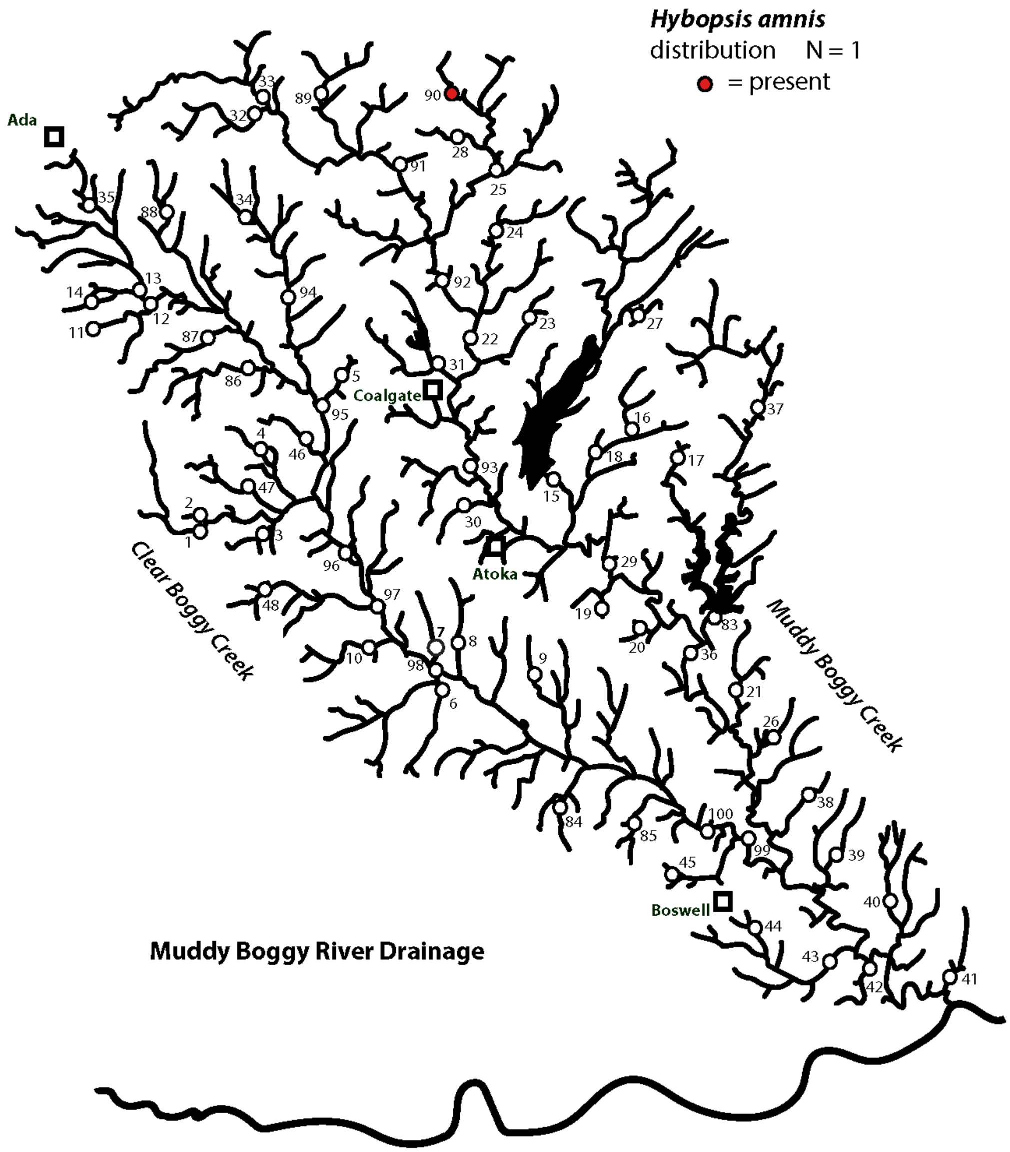


Fig. 12. Occurrence of Pallid Shiner (*Hybopsis amnis*) at only one site in the Muddy Boggy River drainage.

Rocky Shiner (*Notropis suttkusi*) was collected from 11 sites in the Muddy Boggy River drainage (Fig. 13A), 6 sites in the Kiamichi River drainage (Fig. 13B) and 6 sites in the Little River drainage (Fig. 13C).

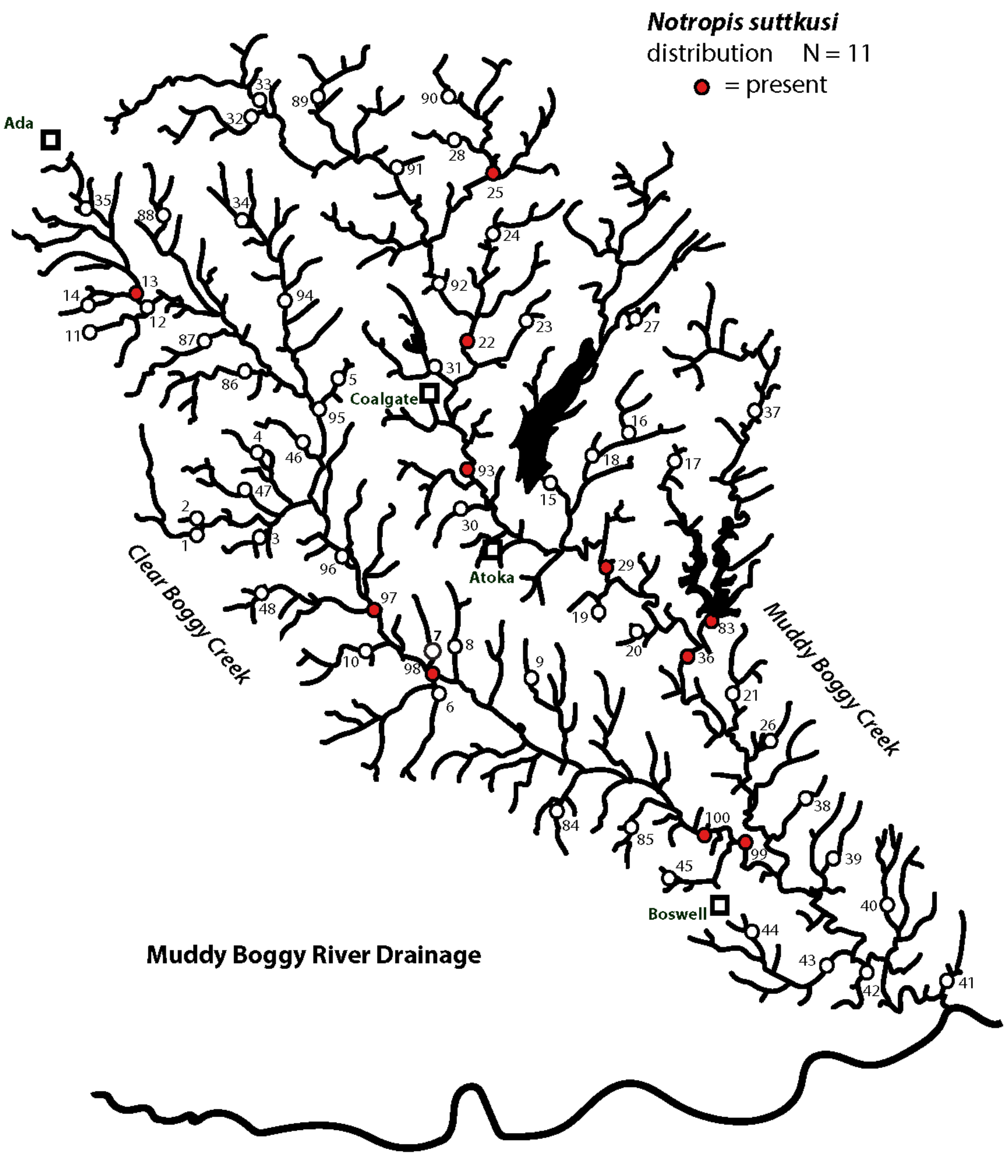


Fig. 13A. Distribution of Rocky Shiner (*Notropis suttkusi*) in the Muddy Boggy River drainage based on collections made summer 2014.

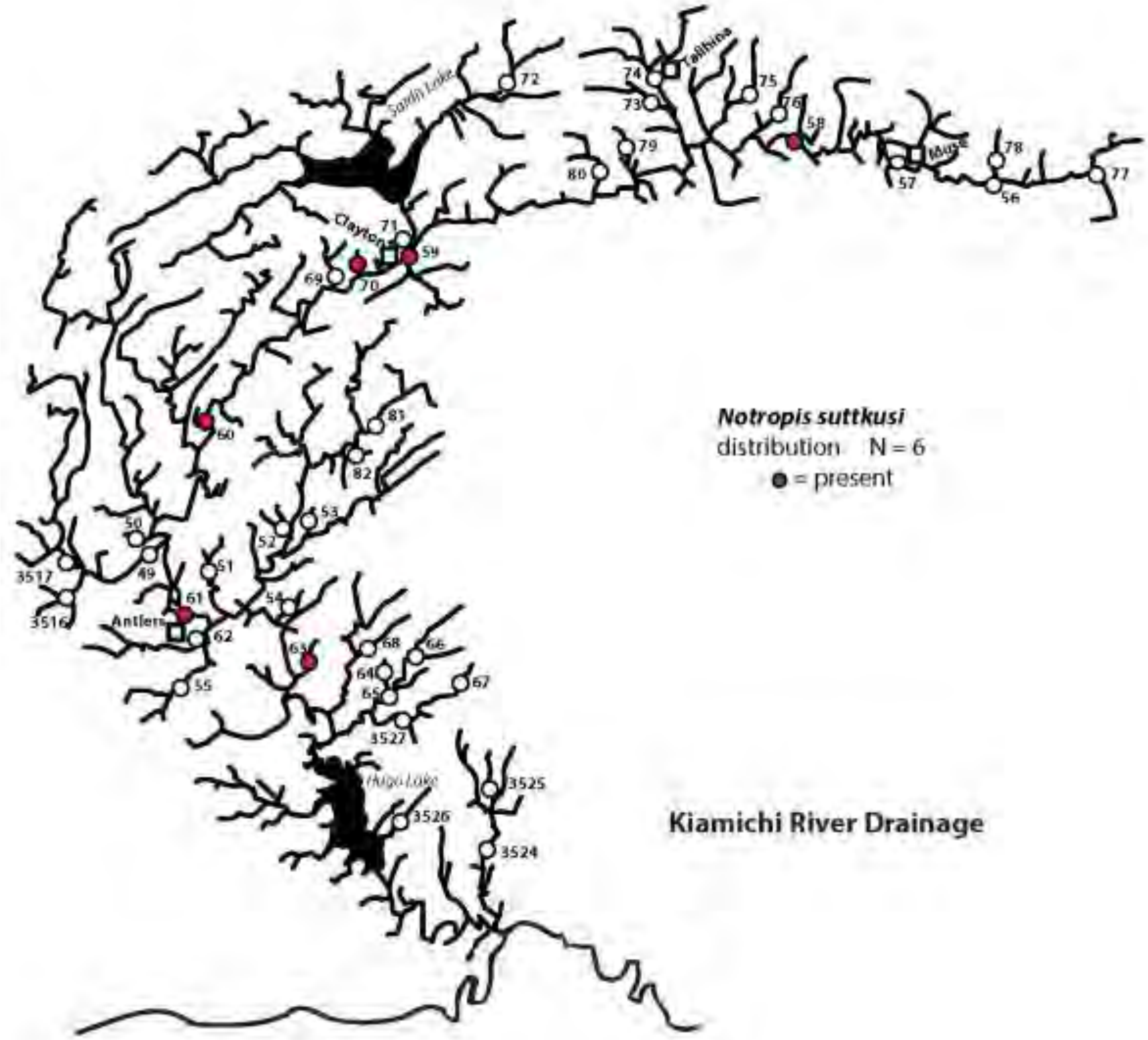


Fig. 13B. Distribution of Rocky Shiner (*Notropis suttkusi*) in the Kiamichi River drainage based on collections made summer 2014.

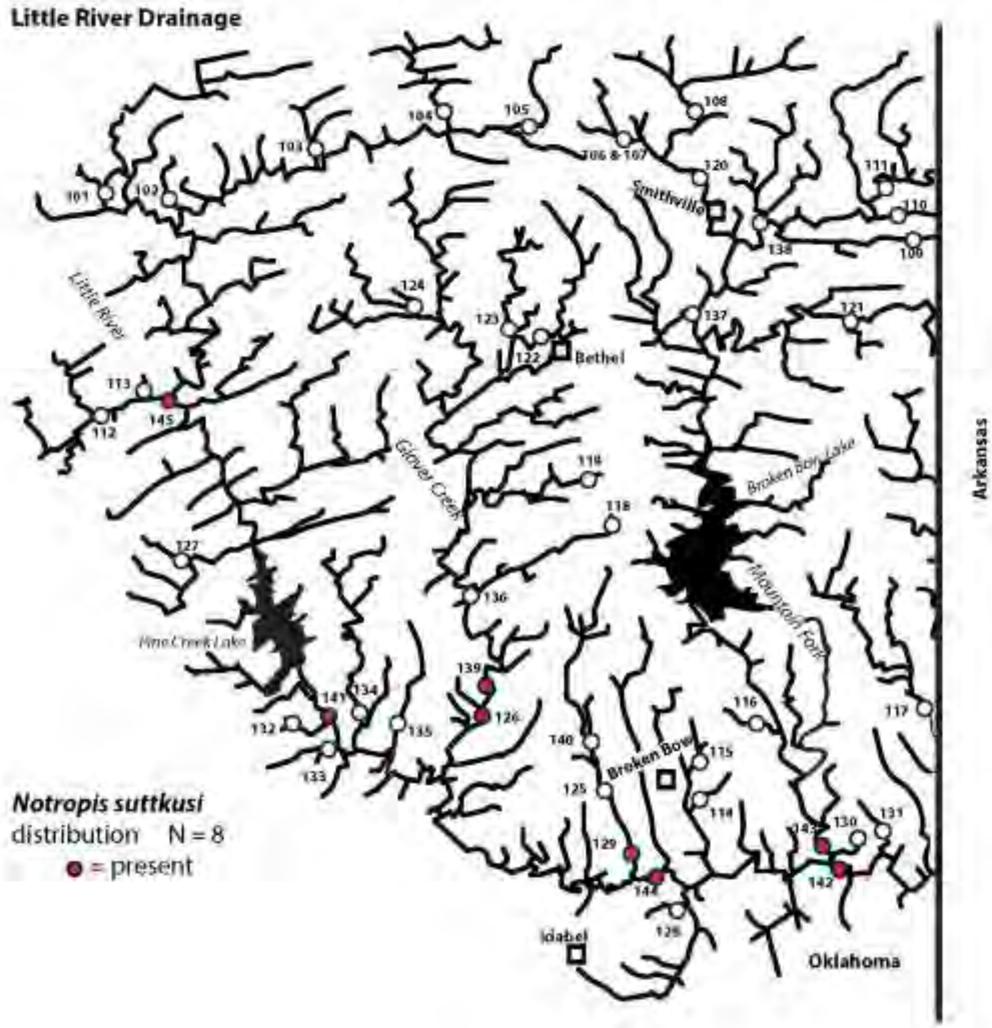


Fig. 13C. Distribution of Rocky Shiner (*Notropis suttkusi*) in the Little River drainage based on collections made summer 2015.

An ammocete (larval lamprey) was collected at a single site in the Kiamichi River (Fig. 14). This specimen could not be identified to species but could be either Southern Brook Lamprey (*Ichthyomyzon gagei*) or Chestnut Lamprey (*I. castaneus*)

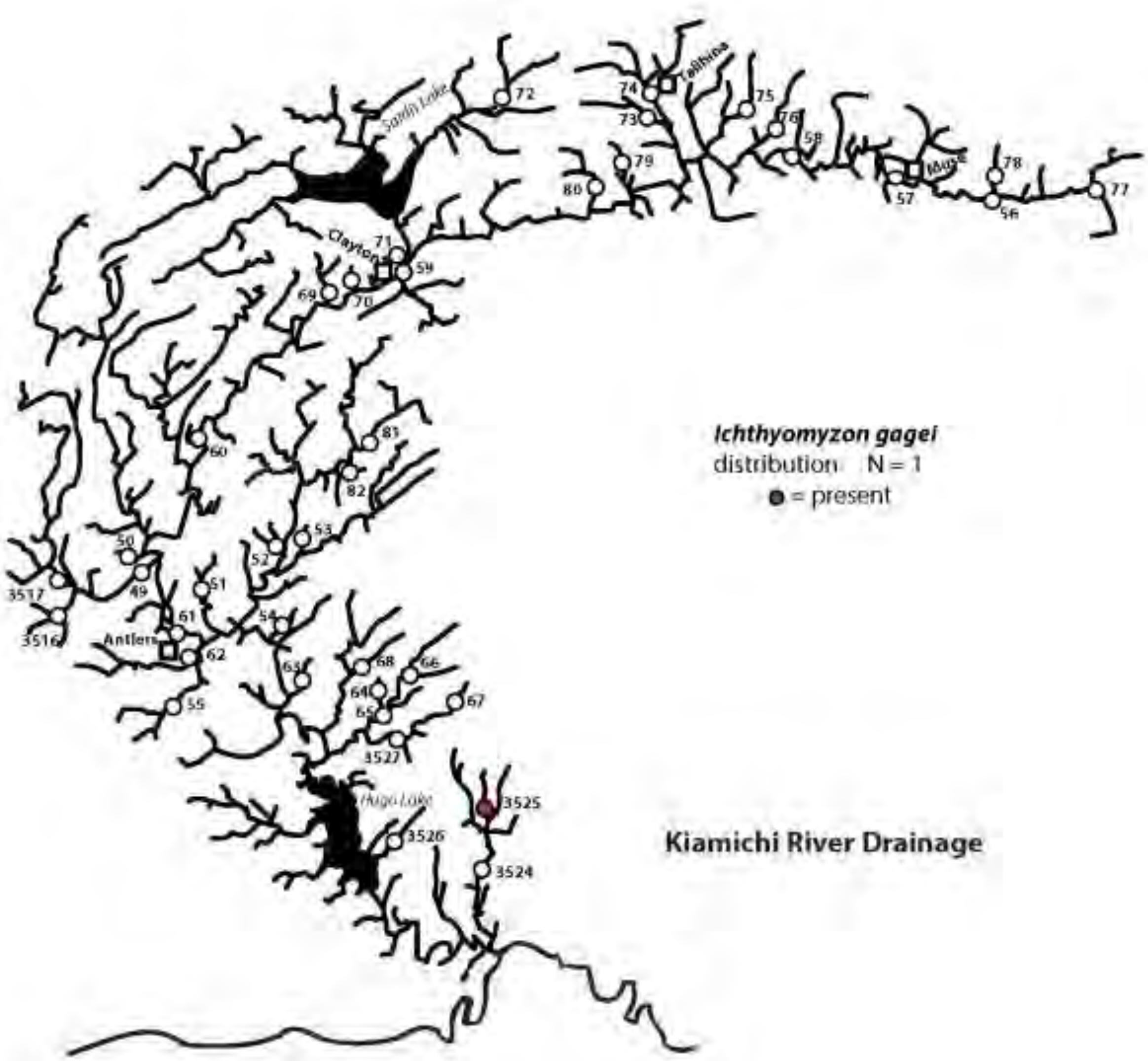


Fig. 14. A larval lamprey, possibly a Southern Brook Lamprey (*Ichthyomyzon gagei*) was collected at a single site in the Kiamichi River Drainage.

Summary of SCGN Distribution Across Drainages

Table 2 below indicates the distribution of SGCN species across the drainages that were sampled in 2014 and 2015. The Little River drainage had the highest proportion (84.4%) of sites that contained at least one SGCN species, if the widespread Orangebelly Darter is included (Table 2A). The Muddy Boggy River drainage had the second highest percentage of sites with SGCN species.

Table 2A. Number of sites with SGCN species in each of the three river drainages sampled in this study.

SGCN ACROSS DRAINAGES		
Drainage	**Sites With SGCN**	**Proportion**
All Drainages (151)	108	71.5%
Muddy Boggy (66)	46	69.7%
Kiamichi (40)	24	60.0%
Little River (45)	38	84.4%

If the Orangebelly Darter was excluded from the SGCN species group (which we address in "recommendations"), the Little River drainage again had the greatest proportion of sites containing at least one SGCN species, but the relative numbers of sites with SGCN species in the Muddy Boggy River drainage and the Kiamichi River drainage were reversed (Table 2 B). Protection of the Little River drainage would appear to afford the greatest protection of SGCN species in southeastern Oklahoma.

Table 2B. Number of sites with SGCN species (not including Orangebelly Darter) in each of the three river drainages sampled in this study.

SGCN ACROSS DRAINAGES (*E. radiosum* NOT Considered)		
Drainage (Total Sites)	**Sites With SGCN**	**Proportion**
All Drainages (151)	62	41.1%
Muddy Boggy (66)	20	30.3%
Kiamichi (40)	14	35.0%
Little River (45)	28	62.2%

Sites with Multiple SGCN Species

Of the 151 sites collected by seining, 72 sites had a single SGCN species (with Orangebelly Darter included) and 26 sites had two SGCN species. There were nine sites that had three SCGN species and one site that had four. Sites with three or four species are described in detail (latitude-longitude; physical description) in Table 3 and mapped in Figs. 15-17.

Table 3. Detailed description of sites with three or four SGCN species.

FIELD ID	Drainage	Name	Latitude	Longitude	Description	SGCN Species
ZDZ103	Little	Wildhorse Creek	34.51863	-95.05679	Wide and rocky stream with fast flowing riffles and lots of in-stream structure	*L. snelsoni* *N. chalybaeus* *N. ortenburgeri* *E. radiosum*
WJM3525	Kiamichi	Tuttle Branch of Bull Creek	34.43821	-95.15020	Small woodland creek, pool with undercut and vegetated banks	*I. gagei (?)* *N. atrocaudalis* *E. radiosum*
ZDZ63	Kiamichi	Mill Creek	34.20023	-95.46191	Narrow, rocky channel with good depth and in-stream structure	*N. atrocaudalis* *N. suttkusi* *E. radiosum*
ZDZ70	Kiamichi	Un-named Trib.	34.56547	-95.39822	Woodland creek with high, eroded banks and good riffle--run--pool development	*N. atrocaudalis* *N. suttkusi* *E. radiosum*
ZDZ93	Muddy	Muddy Boggy Creek	34.44740	-96.16911	Rocky, muddy, and sluggish with heterogeneous habitat	*N. atrocaudalis* *N. suttkusi* *E. radiosum*
ZDZ100	Clear	Clear Boggy Creek	34.10006	-95.88593	Secluded woody stream with shallow riffles feeding into deep pool	*C. elongatus* *N. suttkusi* *E. radiosum*
ZDZ105	Little	Little River	34.53963	-94.84777	Shallow, rocky woodland headwater stream	*L. snelsoni* *N. ortenburgeri* *E. radiosum*
ZDZ112	Little	Cloudy Creek	34.31009	-95.27246	Wide riffle and boulder filled channel with vegetated banks	*L. snelsoni* *N. ortenburgeri* *E. radiosum*
ZDZ142	Little	Little River	33.94763	-95.56573	Wide, shallow riffles and runs with rocky instream structure and edge habitat	*N. atrocaudalis* *N. suttkusi* *E. radiosum*
ZDZ144	Little	Little River	33.94863	-94.73422	Wide, shallow riffles and runs with large isolated cold backwater habitat	*N. atrocaudalis* *N. suttkusi* *E. radiosum*

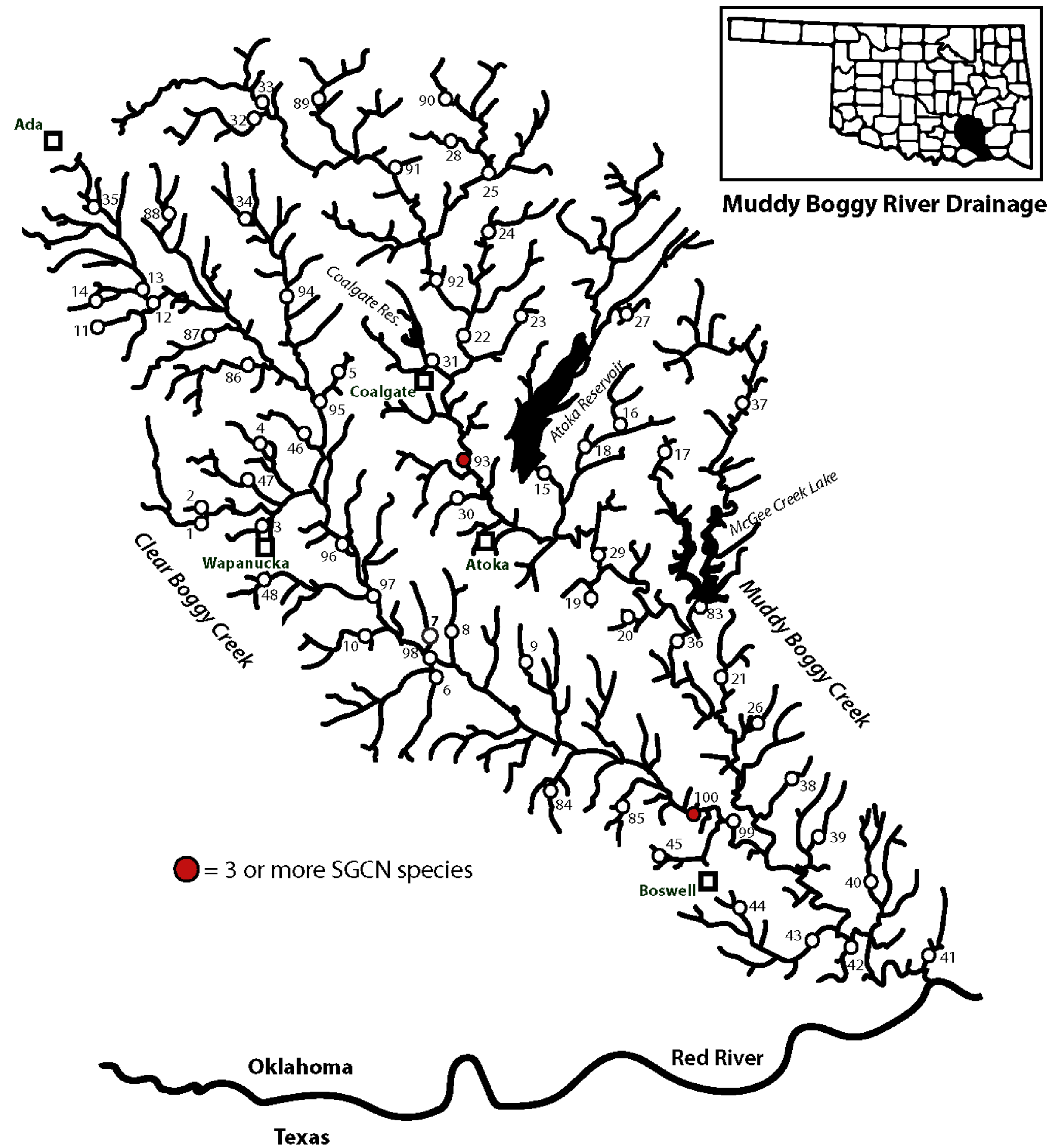


Fig. 15. Locations of sites with 3 or more SGCN species in the Muddy Boggy River Drainage.

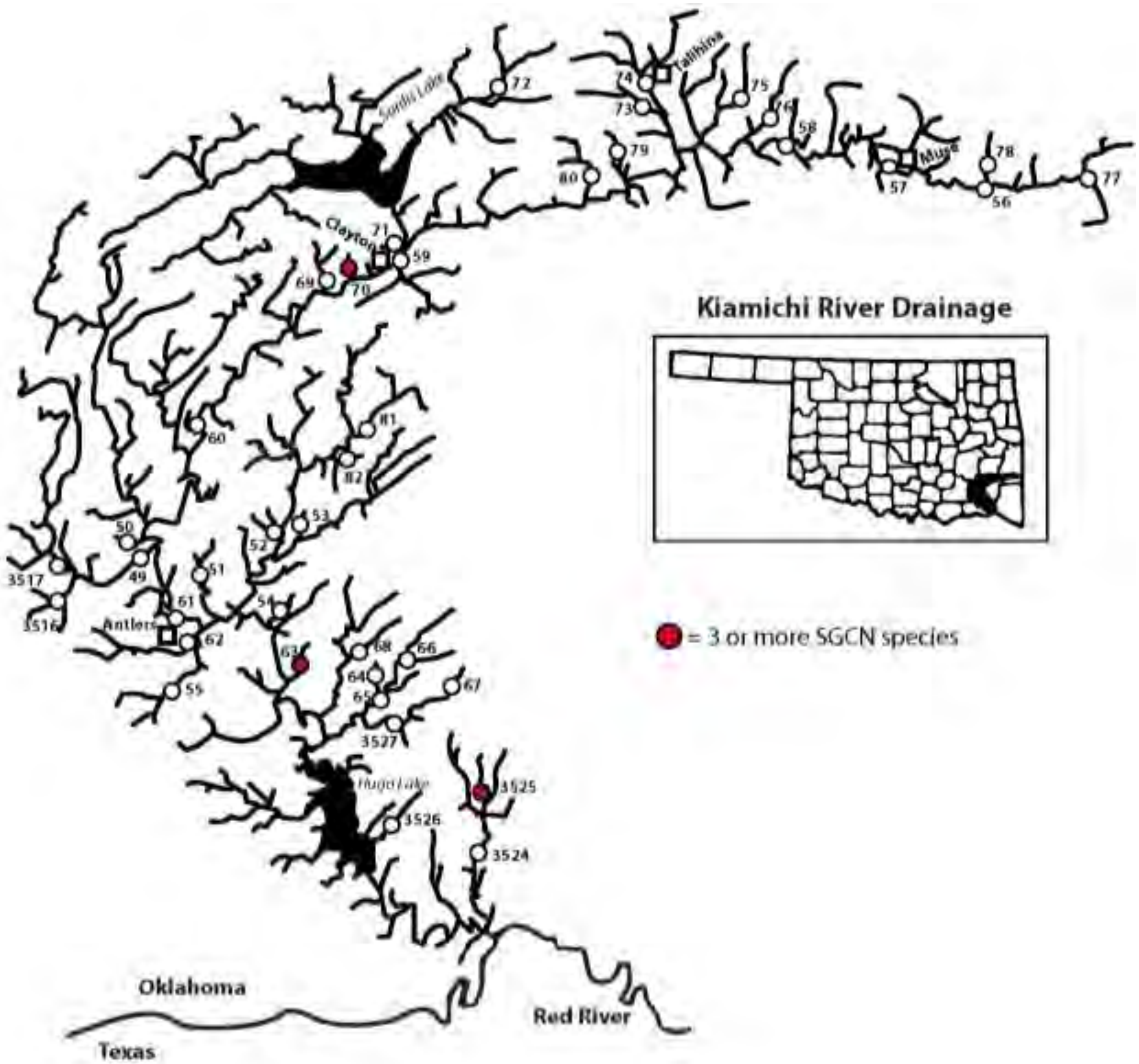


Fig. 16. Locations of sites with 3 or more SGCN species in the Kiamichi River drainage.

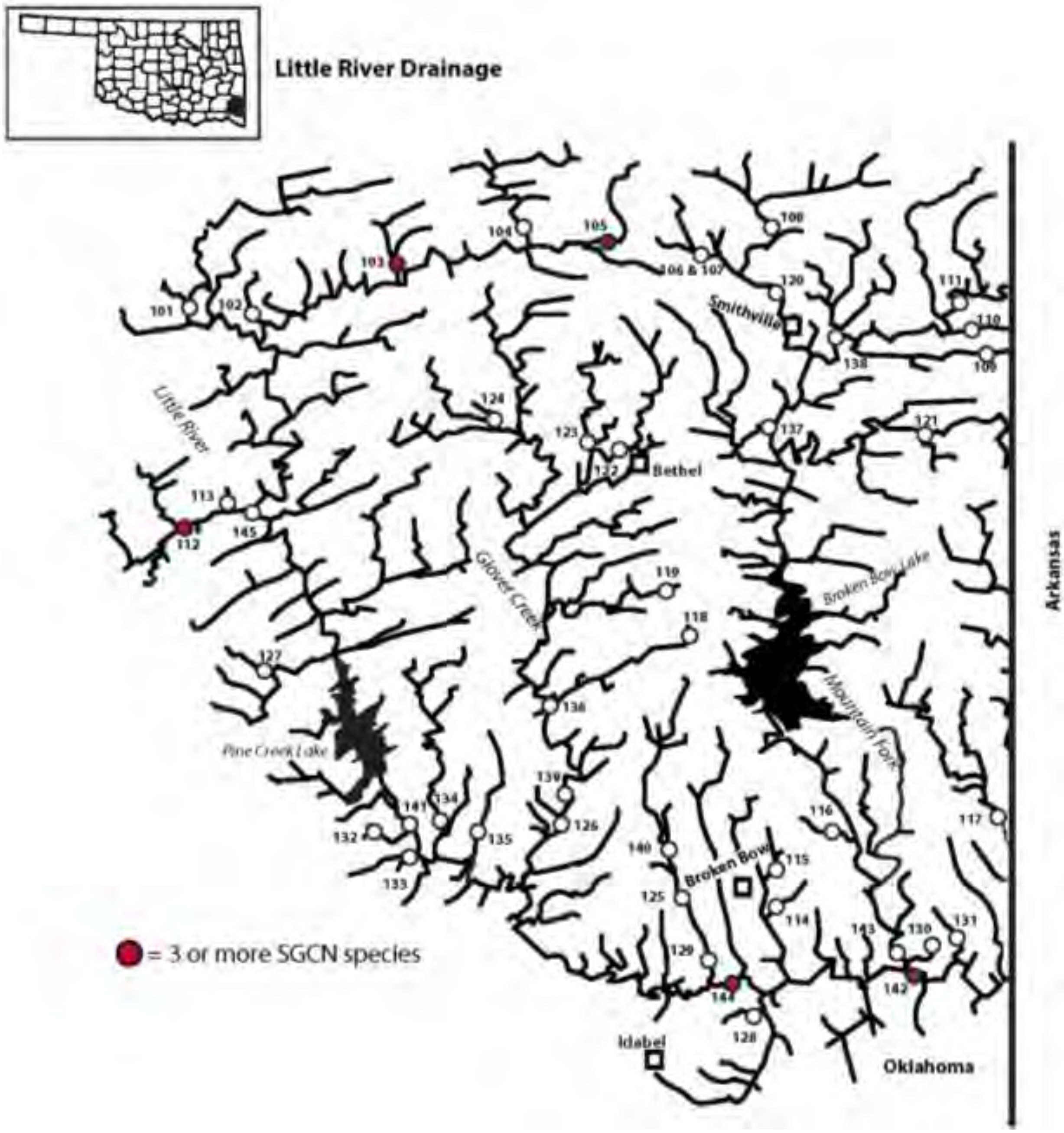


Fig. 17. Locations of sites with 3 or more SGCN species in the Little River drainage.

The number of SGCN species at a site was significantly positively related ($R^2 = 0.223$, $p < 0.00001$) to the total number of species captured at that site (Fig. 18). We interpret this to mean that across the region in general, protection of speciose stream reaches provides a significantly enhanced chance of also protecting SGCN species.

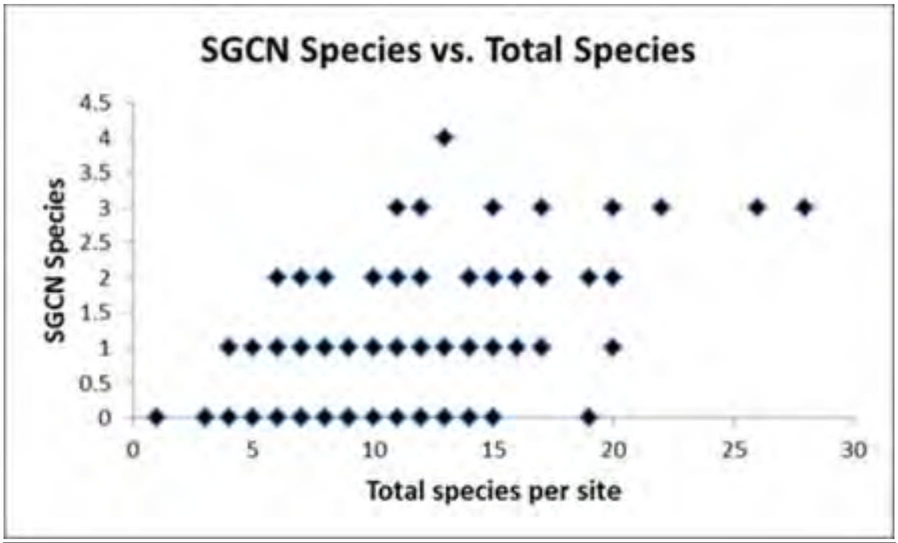


Fig. 18. Number of SGCN species captured at a site as a function of total number of species captured at that site. Note that there are multiple points on this plot that represent more than one site because of identical values for both variables. The graph is provided to illustrate the overall relationship between the two variables but should not be used to reconstruct the raw data.

Results: Fish Community Structure

General condition and diversity of fish communities

Across the region native fish communities generally remained in good condition relative to historical information from the 1920s through the 1970s, with numbers of species per site typical of the diversity we have found in previous sampling in the region from the mid-1970s to now (Matthews, unpublished data). This also is commensurate with findings for fish communities across most of Oklahoma, in which we compared contemporary samples to historical samples from the 1920s (Matthews and Marsh-Matthews, 2015), Across all our samples, the mean number of species per site in this project was 11.1, with a median of 11 and the third quartile (= 75% of the sites) of 14 species. Thus, sites with more than 14 species might be considered priority sites for conservation of intact, complex local fish communities, as addressed below. Appendix B to this report includes species and numbers of fish in all of our samples in the three drainages in 2014 and 2015).

Gill netting in 2016 added one species previously undetected by seining: two adult Shortnose Gar (*Lepisosteus platostomus*), taken in the Muddy Boggy River mainstem near Lane, Oklahoma.

Figure 19 indicates that many of the local fish communities range from about 8 to 16 species, with a few sites having in excess of 20 species. This compares well with historical samples in the region, dating to collections in the 1920s by A. I. Ortenburger and colleagues (Hubbs and Ortenburger 1929a,b). Sites with fewer than five species were typically in very small locations, such as spring runs that usually have a limited fish community. We found no evidence in the field of any obvious or gross pollution or other factors that would have lowered species richness, and the low numbers of species at a few sites are probably natural. No evidence was found of any potentially harmful invasive fish species.

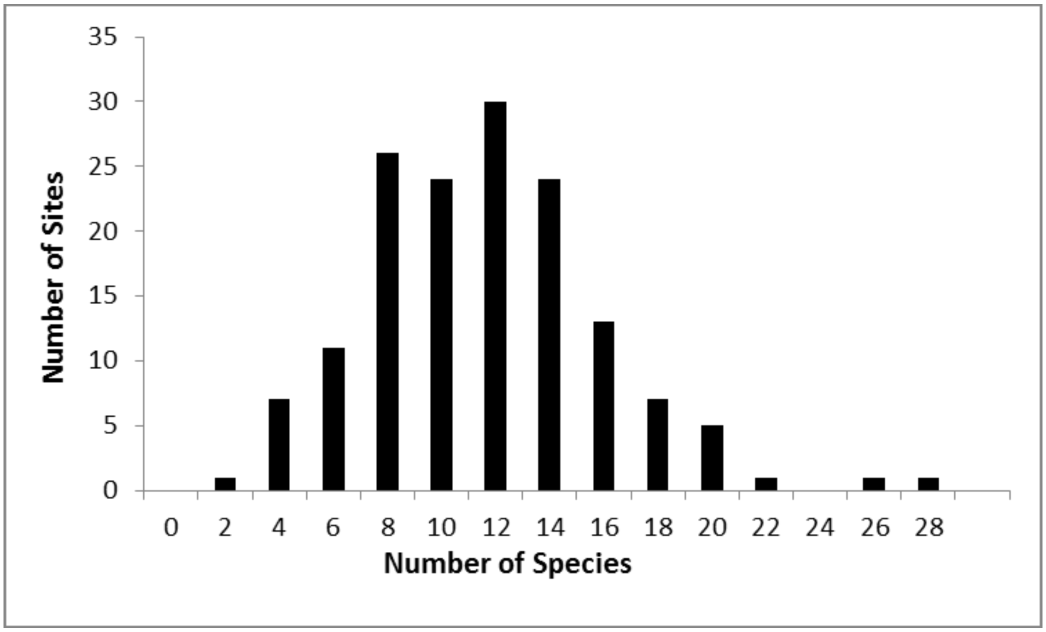


Fig. 19. Number of sites collected in this project versus number of fish species per site.

Maps [Figs. 20-22] below indicate locations of sites with high native fish diversity, with 15 (> 75th percentile of species richness) or more and 19 or more (>90th percentile of species richness) species, which could be considered "priority" or "high priority" sites, respectively, for conservation of native fishes. Numbered sites on maps correspond to original field numbers of survey crews and match Appendix A of this report, with details on locations and environmental conditions at all sites.

In the Muddy Boggy River drainage, there were 11 sites with 15-18 species, and 5 sites with 19 or more species, with both kinds of priority sites occurring throughout the watershed, from lower mainstems to headwaters (Fig.20). The Muddy Boggy portion of the drainage had more of the highest priority sites with 19 or more species than the Clear Boggy branch of the drainage, and more of the 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.

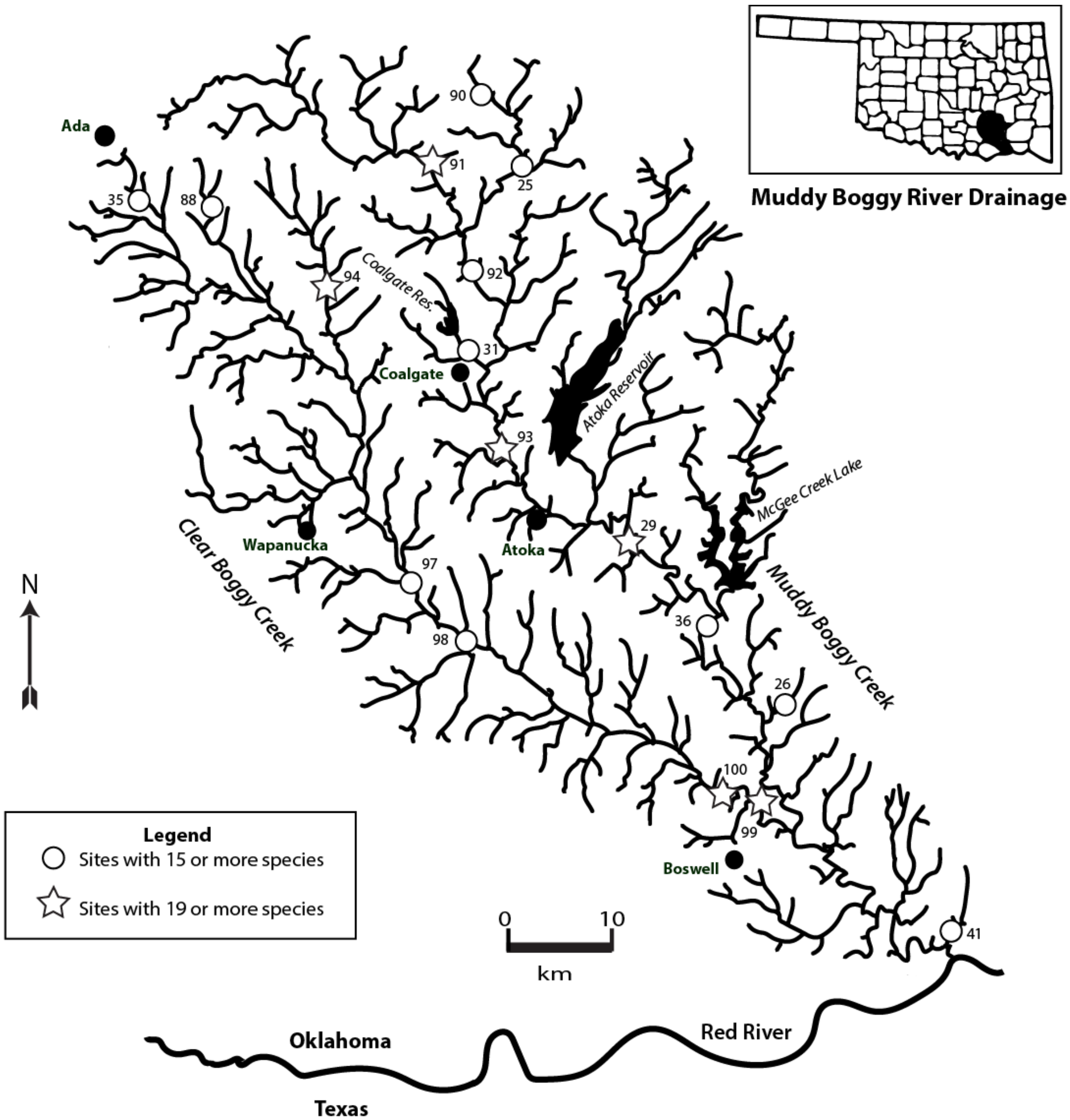


Fig. 20. Sites in the Muddy Boggy River drainage with 15 or more species.

In the Kiamichi River drainage (Fig. 21) there were 3 sites with 15-18 species, and 2 sites with 19 or more species, all in the lower part of the watershed from near Clayton, Oklahoma, downstream.

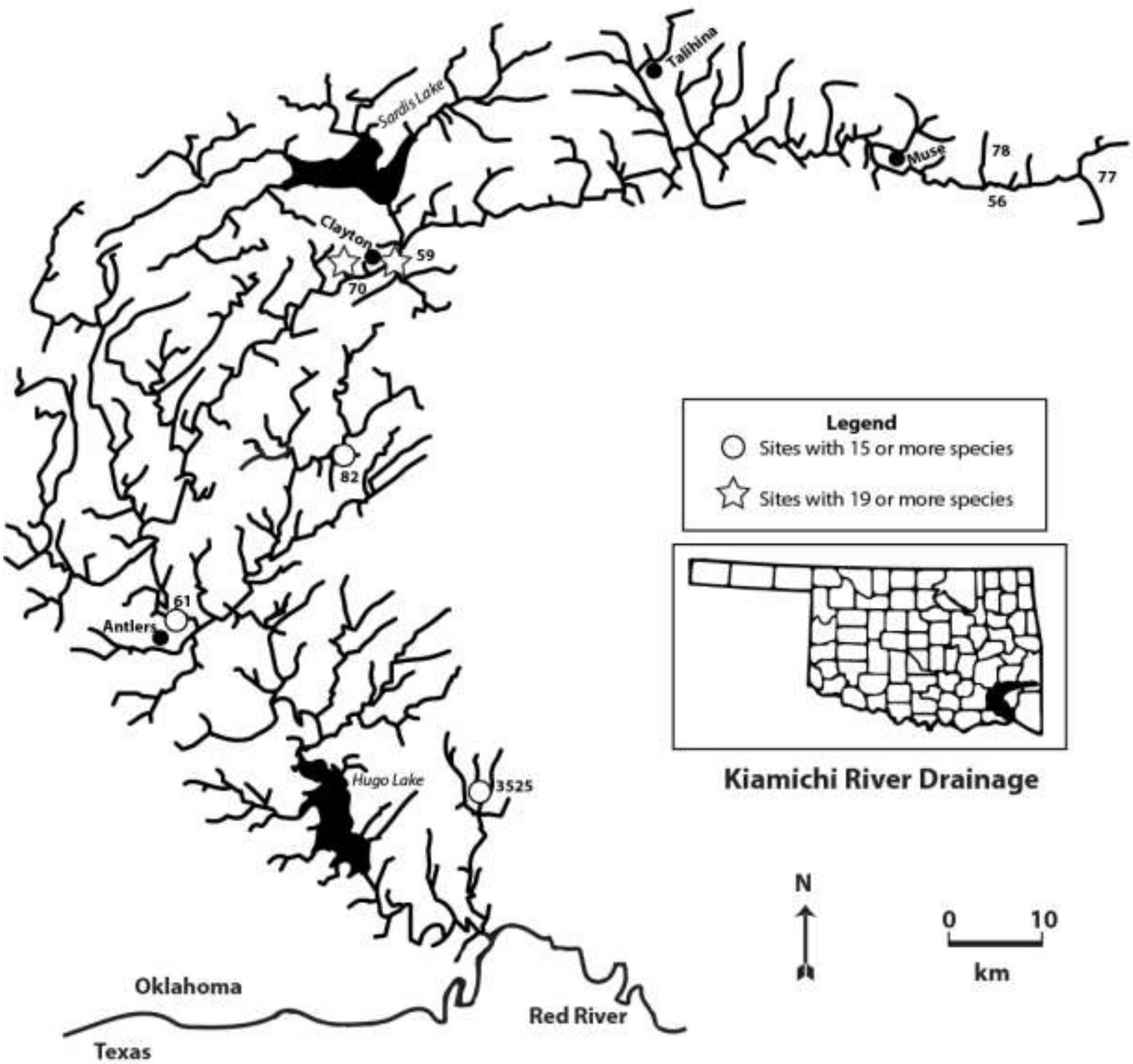


Fig. 21. Sites in the Kiamichi River drainage with 15 or more species.

In the Little River basin (Fig. 22) there were 5 sites with 15-18 species, and 3 sites with 19 or more species, with both kinds of priority sites occurring lower in the basin.

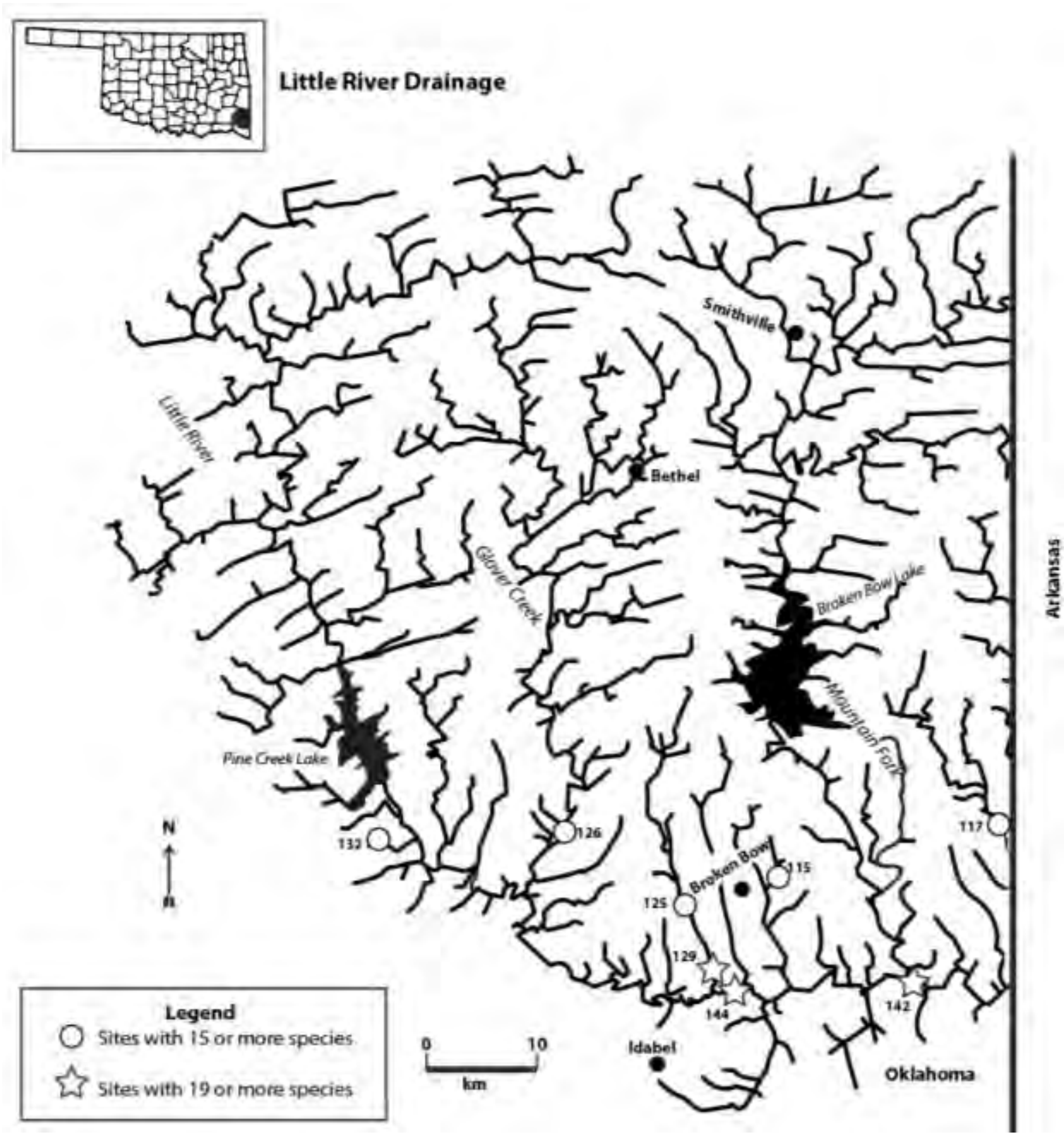


Fig. 22. Sites in the Little River drainage with 15 or more species.

Prediction of Potential Future Changes in the Fish Communities

Several approaches were taken to estimate the potential for future change in local fish communities in the region, with emphasis on sites that had SGCN species. As an overview, we examined sites (in addition to this project) within southeastern Oklahoma at which we had four or more collections of the stream fish community over time (years to decades), to determine a general magnitude of baseline variation in native fish communities in Oklahoma.

Loose Equilibrium.--The variation in the example fish communities, below, was interpreted in the context of our recent published work that emphasizes the tendency of native stream fish communities in the central United States to vary from time to time, yet remain within the boundaries of a "loose equilibrium" (DeAngelis et al. 1985; Taylor 2010; Matthews et al. 2013, 2014; Matthews and Marsh-Matthews 2016, 2017). According to the "loose equilibrium concept" (LEC) native communities may change substantially in composition from one time to the next (e.g., year to year), yet tend over longer periods of time to return toward an average community composition. The LEC, suggesting a lack of overall change over long periods of time, is in contrast to models in which communities change permanently from one state to another (i.e., that they might consistently or persistently move from one community structure to another, without any tendency to return toward a long-term average).

Our published work on the two Midwestern streams for which we have data spanning 40 years (Piney Creek, Arkansas, and Brier Creek, Oklahoma) strongly suggests that these streams may vary markedly in composition from one time to the next, yet return toward an average condition over longer periods of time, and thus are in what is considered loose equilibrium (Matthews et al. 2013, 2014; Matthews and Marsh-Matthews 2016), even in spite of major natural disturbances like floods or droughts. Taylor (2010) also showed examples of Oklahoma streams being in loose equilibrium, in spite of water withdrawal. Our book in press (Matthews and Marsh-Matthews 2017) provides further examples from streams throughout Oklahoma or the Midwest indicating that many stream fish communities remain in loose equilibrium, barring major human disturbance. Thus, as a first approximation for native stream fish communities in the region, "loose equilibrium" should be considered the default expectation for dynamics of the community. In other words, change in community structure from one year to the next is to be expected, or is "normal", but the longer-term expectation is that fish communities should not change directionally or to a different community state, unless some external forcing factor (like human disturbance) grossly alters them.

Percent Similarity between Samples.--In the context of loose equilibrium we first examined the average magnitude of similarities or differences between consecutive samples for nine local native stream fish communities and for one "global" (six sites on Kiamichi River mainstream, summed for each survey) fish community in southeast Oklahoma. Similarities or differences from time to time in each community were based on a "percent similarity index" (PSI) which indicates the minimum percentage of the total community that is similar, based on proportional abundance of each species in each sample. Operationally, the PSI is based on taking for each species in two consecutive samples the lesser of its proportion in either community, and summing those minima across all species. The PSI has had wide use in community ecology, and provides results very similar to more complex measures like the Morisita Index or the Morisita-

Horn Index, but for this report we opted to use the PSI because of its straightforward interpretation as the "minimum similarity" between samples for the community at any two consecutive times.

For these ten native fish communities average PSI values were as in Table 4, with a grand average PSI of 61.2%. Thus, for native stream fishes throughout the Muddy-Clear Boggy, Kiamichi, or Little River drainages the most likely prediction of community dynamics, based on relative abundances of all species, would be for the communities to be approximately 61% similar from one sample to the next (= a change from time to time of about 39%, based on species abundances).

Table 4: Average PSI for eleven stream sites in or west of the State Wildlife Grant study region.

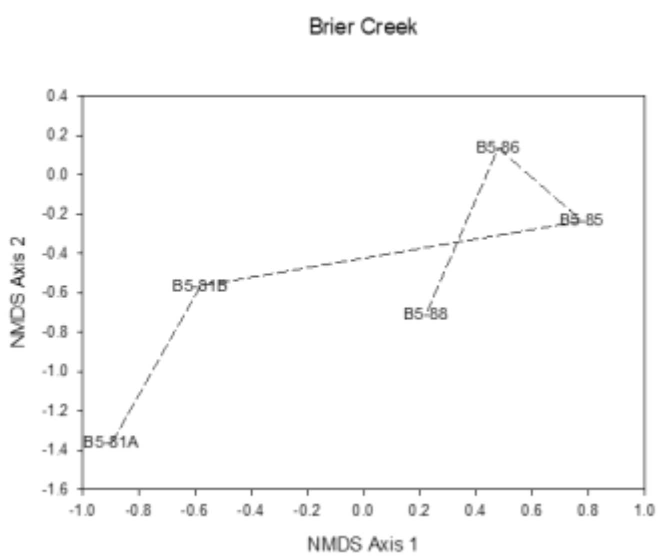
AVERAGE PERCENT SIMILARITY BY SITE		
Site	**Drainage**	**Avg PSI**
Brier Creek Site 5	Red	54.7
Little Glasses Creek	Washita	51.8
Blue River-Connorville	Blue	62.2
Byrd Mill Ck Site 3	Clear Boggy	63.2
Byrd Mill Ck Site 5	Clear Boggy	60.3
Kiamichi 2-Moyers	Kiamichi	55.1
Kiamichi 6-Whitesboro	Kiamichi	69.9
Kiamichi 8-Big Cedar	Kiamichi	67.8
Kiamichi Global (N=6)	Kiamichi	66.0
Glover at Hwy 3	Little	61.0
Grand Average	All	61.2

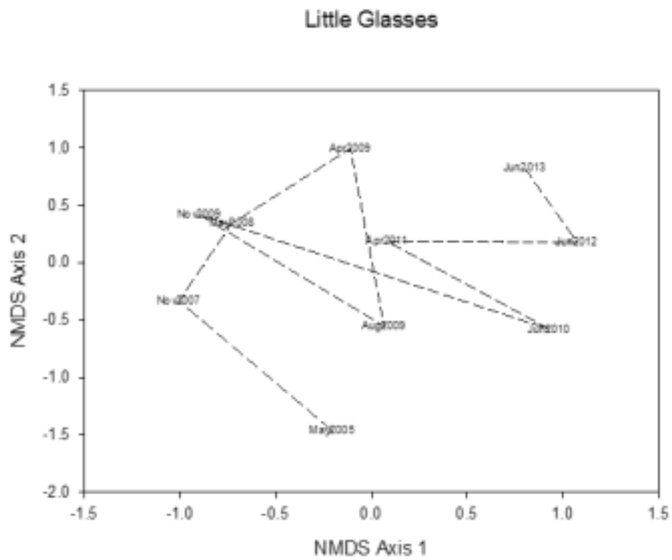
Note that two of the sites outside the study area for the current project (Brier Creek and Little Glasses Creek) had the lowest average PSI across times. These streams are environmentally harsh and highly variable, and subject to the influence of back-flooding from Lake Texoma (Ross et al. 1985; Matthews and Marsh-Matthews 2007; Matthews et al. 2013). Thus their relatively low similarity from time to time is not surprising. The other site with PSI lower than 60% was Kiamichi River Site 2, north of Moyers, and in a reach of the Kiamichi River for which discharge has been substantially modified as the result of construction and of Sardis Lake since the 1980s, with particularly harsh no or low-flow conditions in the period 2004-2011 (Table 2 of Vaughn et al. 2015). The other sites within the present study area that we resampled in 2014 or 2015 with average PSI values greater than 60% were two sites on Byrd Mill Creek (Clear Boggy drainage); two sites on the upper Kiamichi River near Whitesboro and Muse, above the influence of Sardis Lake; and the site on the Glover River at Hwy 3. All of these sites are in streams that are at least partially spring-fed, with more consistent flow, than the sites toward the west with average PSI less than 60%.

Community Trajectories in Multivariate Space.--Percent similarity (PSI) values provide an indication of the tendency for a stream fish community to remain similar or to change from one time to the next, but do not provide an indication of the long-term trends in community structure within a site. To determine long-term trends for a community it is useful to examine the trajectory of the community across multiple collections. For a given community, the PSI values comparing all possible pairs of samples (not just the consecutive samples) can be used in a synthesis by Non-Metric Multidimensional Scaling (NMDS) that produces a biplot of the position of the community within NMDS axis space. This approach is commonly used in community ecology to track changes in the composition of a community over time (Matthews et al. 2013; Matthews and Marsh-Matthews 2016, 2017).

For each of the communities above for which we had five or more samples, an NMDS was based to produce the biplots in the figures below. Within each biplot, dashed lines were added to connect consecutive samples, providing a view of the trajectory of the community across time. These trajectories were inspected using guidelines in Matthews and Marsh-Matthews (2016) to determine whether each community appeared to be in loose equilibrium, as evidenced by frequent changes in direction with the trajectory, or, alternatively, if there was evidence of persistent long-term change from one community state to another.

For three of the examples just west of the current State Wildlife Grant study area, the patterns in Figure 23 suggested that although there was change in the community from time to time there was a tendency for the community to reverse direction and return toward an average community condition. This suggested that these three sites were in loose equilibrium (as we had documented previously for these sites, using a slightly different similarity measure: the Morisita-Horn Index; Matthews et al. 2013; Matthews and Marsh-Matthews 2017). Note that this finding also substantiates that the detection of loose equilibrium is robust, regardless of which similarity index (Morisita-Horn or PSI) is used.





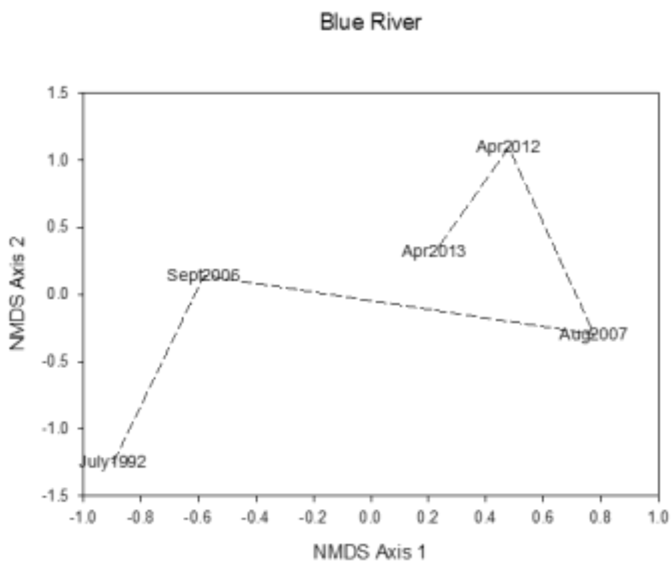


Fig. 23. NMDS biplots based on PSI matrices for Brier Creek Site 5 (only showing 1981 to 1988 as the example), Little Glasses Creek, and Blue River.

Our long-term study site on the Glover River at State Hwy 3 west of Broken Bow showed a strong tendency for the trajectory in NMDS space to change, yet over the long term (1978 to 2015) to revert to an earlier condition, showing loose equilibrium. In Figure 24, the samples in July 1982 and in July 2015 are in virtually an identical position, overlapping in the upper left corner. These two samples were similar in being strongly dominated numerically by Bigeye Shiner (*Notropis boops*), Steelcolor Shiner (*Cyprinella whipplei*), and Longear Sunfish (*Lepomis megalotis*), with these three species comprising 78.7 and 93.5% of the communities at this site during those two samples. And in both these samples there were low numbers of darters. The sample most divergent from the original 1976 sample was in April 2000 (upper right corner of biplot), when the previous three species were also abundant, but we additionally took 164 Brook Silversides (*Labidesthes sicculus*), 158 Orangethroat Darters (*Etheostoma spectabile*) and 85 Orangebelly Darters (*E. radiosum*).

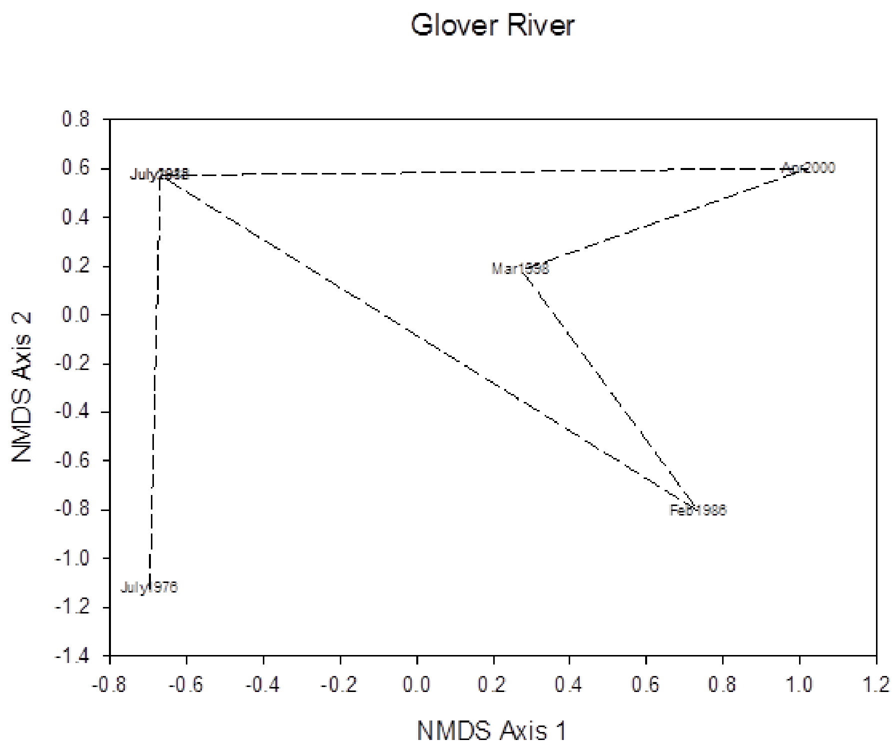


Fig. 24. NMDS biplot based on PSI values for Glover River at State Highway 3. Note that July 1982 and July 2015 are in identical positions in the upper left corner of the biplot.

Finally, NMDS biplots (Figs. 25 - 26) were produced for three local sites on the Kiamichi River, and for the "global" Kiamichi River based on pooling of six mainstream sample sites, for all of which we had samples in 1981, 1985, 1986, 1987, and 2014 (this project). The most downstream site, Kiamichi Site 2, has had disturbance in flow conditions, particularly in recent years (Vaughn et al. 2015). This site did exhibit frequent divergence from average community structure, but with substantial "return" toward average after excursions away from average, with the exception of the most recent sample. That sample was unique for the site in that we found an order of magnitude more Rocky Shiners (*Notropis suttkusi*) (N = 553) than in any previous collection. Many of the Rocky Shiners were males in peak breeding coloration. One other noteworthy difference between the 2014 sample and most previous was a low number of darters (Percidae), which might be related to the vagaries of flow in recent decades that might have stranded riffle habitat during low-water episodes (Vaughn et al. 2015). It remains to be seen in the future if Kiamichi Site 2 will revert back toward a long-term average. Regardless, the overall pattern in the figure below suggests that this site is in a long-term loose equilibrium.

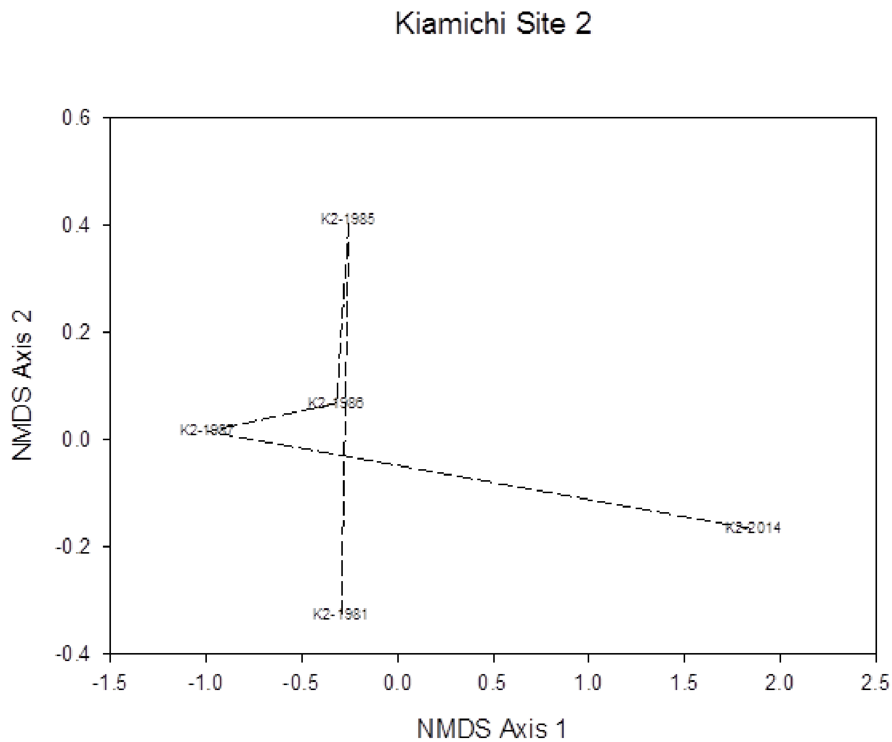


Fig. 25. NMDS of PSI for Kiamichi River Site 2.

The other two Kiamichi River sites (Sites 6 and 8) are upstream from the influence of flow control by Sardis Dam, and have had more consistent flow than the downstream site (Vaughn et al. 2015). They appeared to be partially (Site 6) or highly (Site 8) consistent with the loose equilibrium concept. Kiamichi Site 6 moved substantially to the right on Axis 1 of the biplot in the 2014 sample, when relative abundance of Redfin Shiner (*Lythrurus umbratilis*) and Brook Silversides (*L. sicculus*) increased markedly, and the relative abundance of Bigeye Shiner (*Notropis boops*) was lower than in the past. As a result, we consider Kiamichi Site 6 to be partially in loose equilibrium.

Kiamichi Site 8 (Fig. 26) showed strong evidence of being in long-term loose equilibrium, with frequent changes in direction of the trajectory, and several reversals of the community back toward a long-term average.

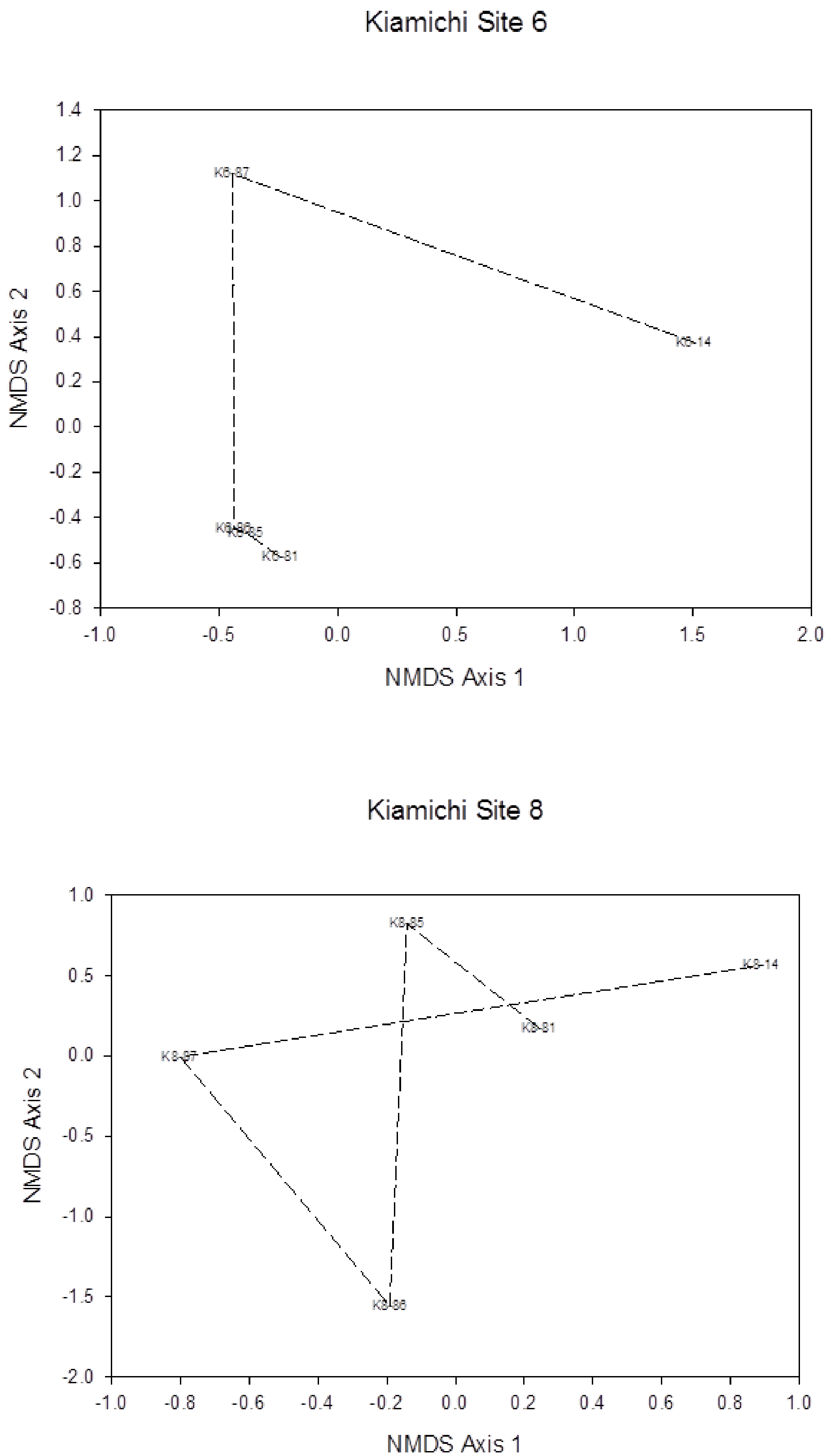


Fig. 26. NMDS of PSI for Kiamichi River sites 6 and 8.

For the global community of the mainstem Kiamichi River (Fig. 27), based on pooling of six permanent sampling sites during each survey, all evidence from the NMDS biplot below suggested long-term loose equilibrium, as the trajectory changed directions sharply on two occasions, and the final sample (2014) was very near the first sample (1981) in overall NMDS biplot space.

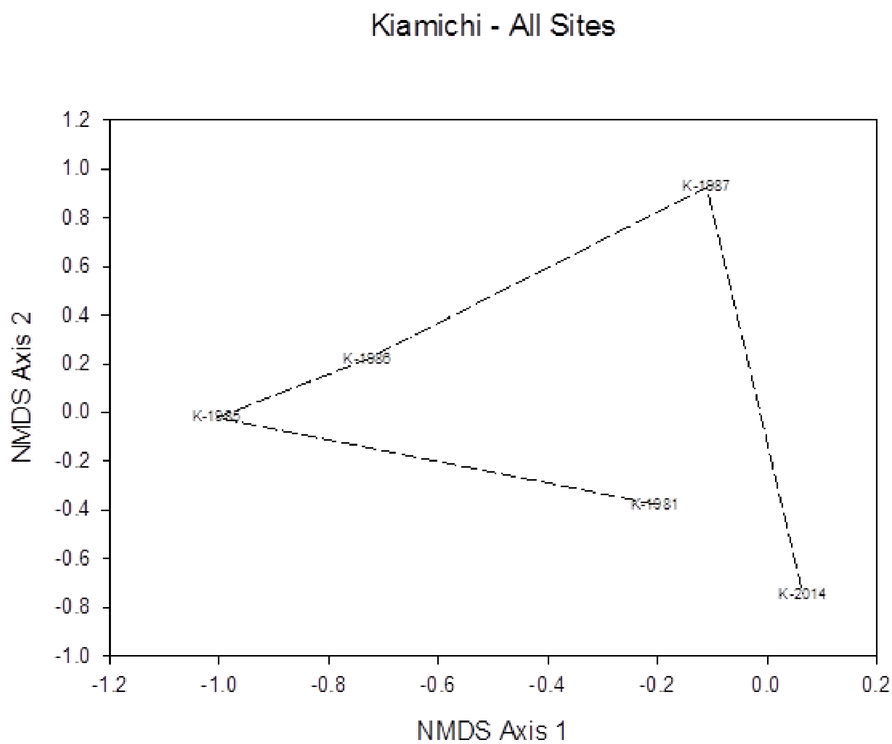


Fig. 27. NMDS biplot of PSI values for global Kiamichi River.

Differences between Years for Sites Sampled in 2014 and 2015.—After the initial sampling in the Muddy Boggy River drainage in 2014, 16 sites were selected for re-sampling in early September of 2015. Four creek and four mainstem sites were randomly selected for both Muddy Boggy and Clear Boggy Creeks. Every effort was made to keep sampling identical to the previous year. Change in the composition of fish communities from 2014 and 2015 were assessed using percent similarity index which assigned a value ranging from 0 to 1, i.e., no similarity to completely similar. Change in stream reach environment was determined by assessing three factors: depth, stream composition, and substrate composition. For each site the number of changes was counted and ranged from 0 to 3 total changes to stream reach environment.

Table 5 indicates a substantial relationship between the subjectively judged number of changed environmental factors per site and the percent similarity in the fish community samples between years. For sites where none or only one of the scored environmental factors were judged to have changed, the mean PSI of 0.61 is consistent with the predictions in the previous section, i.e., that, barring environmental change, local stream fish communities might be expected to be approximately 60% similar in species abundances from time to time. In contrast, at five sites where there were apparent interyear changes in all three scored factors, the mean PSI was much lower (= 0.37), indicating a more than 60% change in abundance of the species in the community.

Table 5. Mean and standard error for PSI values comparing samples in 2014 and 2015, relative to score for environmental change between years, for 16 sites resampled in 2015.

	Environmental Change Score		
	0 to 1	2	3
mean PSI	0.61	0.55875	0.37
SE	0.03	0.03	0.07
n	7	4	5

Examined graphically (Fig. 28), the magnitude of change in fish abundances in local communities was clearly related to the number of changed environmental factors from one year to the next, as illustrated below.

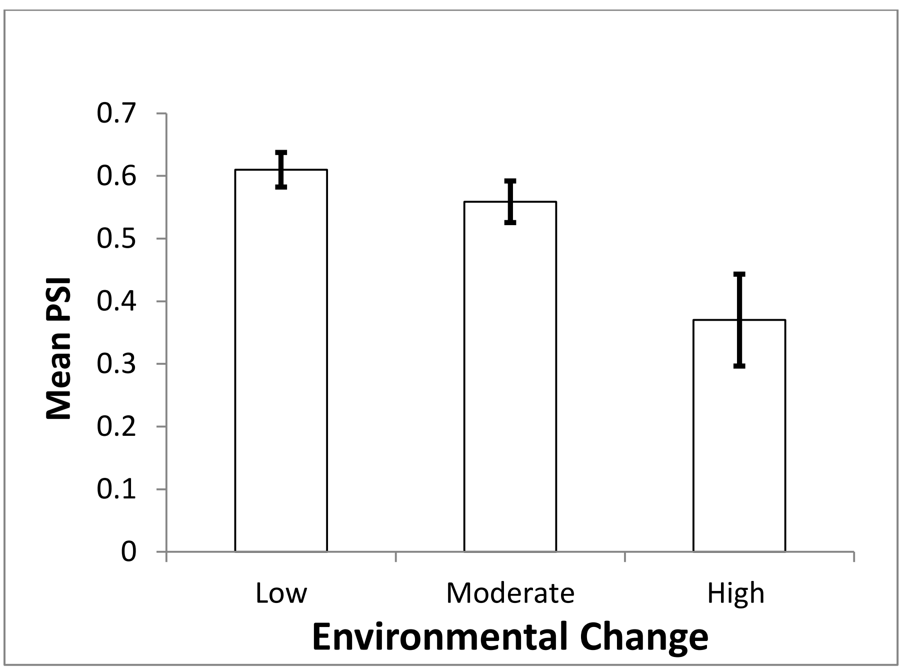


Fig. 28. Mean and standard errors of PSI scores compared to environmental change between 2014 and 2015.

Summarizing Expected Normal Variation in Stream Fish Communities.--The combination above of percent similarity for fish communities at long-term sites, the temporal trajectories of those sites in multivariate community space, and the comparison of fish communities at 16 sites sampled in two years each in the present study collectively suggest that the baseline for stream fish communities in southeastern Oklahoma is that they can be expected, without any major human modifications to the streams, or extreme environmental perturbation, to be approximately 60% similar in species relative abundances from time to time, but that most sites will not show any persistent trajectory away from their first samples. In other words, while we can expect individual sites to exhibit normal variation from time to time, we can also expect that the stream fish communities should not change in any persistent direction. If long-term study sites do show evidence of persistent change away from their baseline structure, then special effort should be exerted by managers to determine if human-related activities could be causing substantial changes in the stream environment, or if any persistent impacts (pollutants, gravel mining, stream crossings, other human disturbances) may be related to changes in the fish community and therefore if such impacts could be abated.

Coefficients of Variation in Individual Species and Community Vulnerability.—For long-term samples at six sites on the Kiamichi River mainstem from 1981 to 2014 (2014 collected as part of this project) we calculated a coefficient of variation (CV) for 21 common species for which more than 30 individuals had been collected across all surveys (Table 6). The only SGCN species included was Orangebelly Darter (*Etheostoma radiosum*), as no other SGCN species was sufficiently common or abundant in the Kiamichi River mainstem samples to allow calculating a CV. The CV for each species equals the standard deviation of its abundance divided by its mean abundance. For this purpose we pooled all six samples within each of five surveys and calculated the individual species CVs. As indicated in the table below, the common species in the Kiamichi River ranged from having very low variation in abundance (e.g., Orangebelly darter, with CV = 0.090) to being highly variable with a CV > 1.00 (including Rocky Shiner, Emerald Shiner, and Gizzard Shad).

Grossman et al. (1990) evaluated CV for many fish species in the eastern United States, and considered species with CV below 0.25 to be “highly stable”, 0.25-0.50 “moderately stable”, 0.50-0.75 “moderately fluctuating”, and > 0.75 to be “highly fluctuating”. By those criteria, species we analyzed from the Kiamichi River would have included seven species as stable to moderately stable, seven to be moderately fluctuating, and seven to be highly fluctuating.

It is noteworthy that Orangebelly Darter, which has been considered an SGCN species, is not only widely distributed and abundant in southeast Oklahoma (as noted earlier), is also rather persistent in its abundance in a river from time to time, and its populations would by the Grossman et al. (1990) criteria be “highly stable”. This further supports our recommendation (below) that the Orangebelly Darter be removed from the SGCN list, as it is widespread, abundant, and appears to have stable populations (barring habitat destruction, see below).

Table 6. Coefficients of Variation (CV) for 21 common species in the Kiamichi River mainstem.

COEFFICIENTS OF VARIATON – KIAMICHI RIVER SPECIES	
SPECIES	**CV**
Orangebelly Darter	0.090
Redfin Shiner	0.371
Topminnows (2 Spp)	0.383
Bigeye Shiner	0.415
Steelcolor Shiner	0.416
Largemouth Bass	0.447
Brook Silverside	0.480
Bluegill	0.517
Dusky Darter	0.625
Bluntnose Minnow	0.641
Western Mosquitofish	0.641
Longear Sunfish	0.653
Spotted Bass	0.738
Channel Darter	0.745
Highland Stoneroller	0.762
Mimic Shiner	0.835
Kiamichi Shiner	0.878
Blacktail Shiner	0.915
Rocky Shiner	1.248
Emerald Shiner	1.435
Gizzard Shad	1.606

Overall, there was no evidence in Table 6 of a taxonomic influence on CVs for individual species in the Kiamichi River mainstem, as species within families including minnows (Cyprinidae), sunfish and bass (Centrarchidae), and darters (Percidae) varied widely in their CV values. Thus CV values may be of interest in predicting likelihood for individual species to change in abundance within a site or sites, but CV values for these common species provided no strong insight into how much a whole community might be predicted to vary over time. We examined the abundance of species with low, medium, or high CV values in local communities from this project that contained two or more SGCN species to ask if sites with SGCN species were characterized by highly variable species, but there was no discernable pattern. We thus suggest that evaluating CV for species within communities with SGCN species may not be a particularly useful way to predict potential for future changes in those locations. Matthews (1998, pages112-122) also pointed out some of the difficulties in using CV of species to predict stability of whole communities, so this approach was considered but ultimately not used as a predictor in the present project.

Tolerances of Species and Communities for Water Quality or Habitat Degradation.—A more useful approach to predicting the potential for local stream fish communities, particularly those with SGCN species, to change in the future is to consider the degree to which a community consists of species that are tolerant versus intolerant of degradation of water quality or of habitat. Jester et al. (1992) used "expert opinion" by six experienced Oklahoma fisheries biologists (including William Matthews) to estimate the tolerance of all fish species in Oklahoma for degradation of water quality and, separately, for degradation of habitat. Each participant individually rated each species for their tolerance of (or sensitivity to) water quality and habitat changes, based on their own individual experience in Oklahoma field work. The results (Table 1 of Jester et al. 1992) provide a mean value (calculated across all participant ratings) for each Oklahoma species from 1.0 (least tolerant) to 4.0 (most tolerant) for changes in water quality or changes in habitat. According to Jester et al. (1992) this list was intended to "become the official tolerance classification for regulatory purposes in Oklahoma".

The tolerance values in Table 1 of Jester et al. (1992) were used to calculate a weighted average tolerance (Table 7) for all local stream fish communities sampled in the current project. For water quality tolerance, and separately for habitat degradation tolerance, the Jester tolerance score for each species was multiplied by the abundance of each species, and the total tolerance score for the community, adjusted for total abundance of all species in the community, provided a community tolerance score. In this weighted average tolerance score, communities with a low average would indicate that the community as a whole would be intolerant of change or habitat degradation, and a high average would indicate a community dominated by tolerant species. The community average score can be used to predict whether or not a community as a whole might be expected to change in the event of human-induced changes in water quality, habitat availability, or both.

There was a substantial gradient from community tolerance to intolerance from west to east (Table 7), with highest mean community tolerances for sites in the Clear Boggy drainage, and least community tolerances for sites in the Little River drainage.

Table 7. Grand mean of tolerances for individual sites in four southeast Oklahoma river drainages.

AVERAGE COMMUNITY TOLERANCES ACROSS DRAINAGES		
Drainage	**For Degradation of Water Quality**	**For Habitat Degradation**
Clear Boggy	3.12	3.00
Muddy Boggy	2.87	2.64
Kiamichi	2.58	2.41
Little River	2.34	2.06

Communities in all drainages averaged less tolerant for habitat degradation than for degradation of water quality (Table 7). The three maps in Figures 29 -31 show the distribution of tolerant to intolerant local communities within the study areas of this project. Following designations in Jester et al. (1992) sites with average tolerance values of 2.5 or lower were considered "moderately intolerant", and sites with values of 1.7 or below were considered "intolerant". In the colored maps below dark green = sites with averages of "tolerant" or "moderately tolerant" for both factors; light green = sites averaging "moderately intolerant" for either water quality or habitat changes but not both; yellow = sites "moderately intolerant" for both water quality and habitat changes; orange = sites averaging "intolerant" for either water quality or habitat changes; and red = sites averaging "intolerant" for both water quality and habitat changes. In summary, sites exhibited progressive lack of tolerance for water quality or habitat changes on the gradient from dark green (= most tolerant) to red (= least tolerant).

In the Muddy Boggy River drainage (Fig. 29), the majority of sites tended toward having tolerant species, and thus local communities relatively resistant to change in the event of water quality or habitat degradation. Only two sites (ZDZ40 and ZDZ43) located downstream in the drainage had communities with lack of tolerance for changes. In the middle to upper parts of the basin, eleven sites averaged moderately intolerant for both water quality and habitat changes, and one site (ZDZ 16) was rated "intolerant" for habitat degradation. But note that in the uppermost Muddy Boggy drainage, in the higher-gradient gravel-bottomed streams, most sites were tolerant of potential changes.

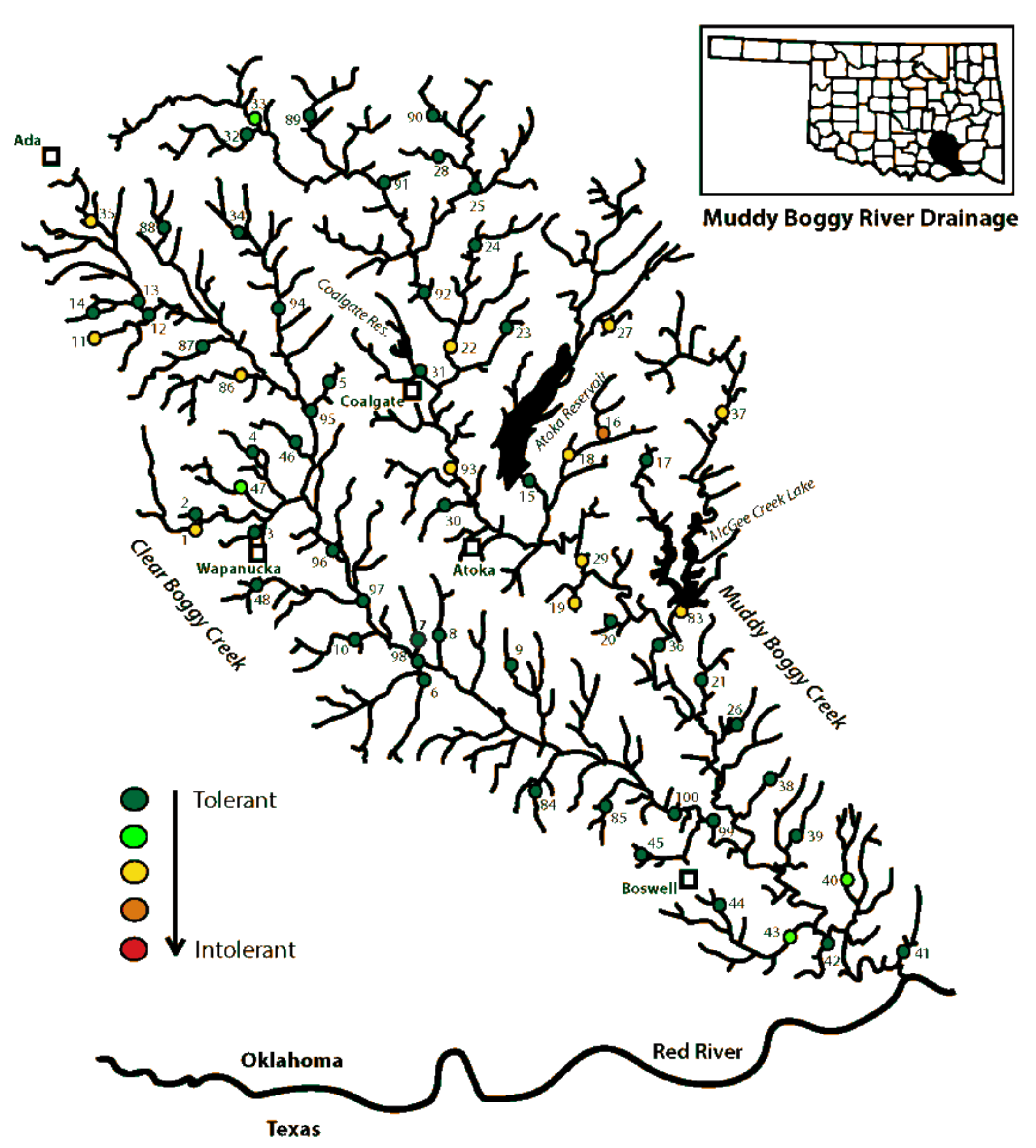


Fig. 29. Average tolerances of the fish communities in the Muddy Boggy River drainage.

In the Kiamichi River basin (Fig. 30), sites in general tended more toward being less tolerant for environmental changes than were sites in the Muddy Boggy-Clear Boggy basin. In the Kiamichi basin, 18 sites averaged tolerant or moderately tolerant for either kind of environmental change, and four other sites were moderately intolerant (of habitat degradation only). But 16 sites where classified as moderately intolerant for both kinds of changes, including seven lower in the basin and nine in the uppermost parts of the basin. The fish community at one site (ZDZ60) was intolerant of habitat degradation (and moderately intolerant of water quality changes), and the uppermost site in the basin (ZDZ77) averaged "intolerant" of both water quality and habitat degradation. The ZDZ77 site was Little Pigeon Creek, an extreme headwaters site 7 meters wide, characterized by riffle-pool structure and gravel-cobble bottom. It was dominated numerically by a large number of Kiamichi Shiners (*Notropis ortenburgeri*), considered by Jester et al. (1992) to be intolerant of either water quality or habitat degradation. Note that all sites in the upper Kiamichi basin above Talihina, Oklahoma, had fish communities that were moderately intolerant to intolerant of both kinds of environmental changes.

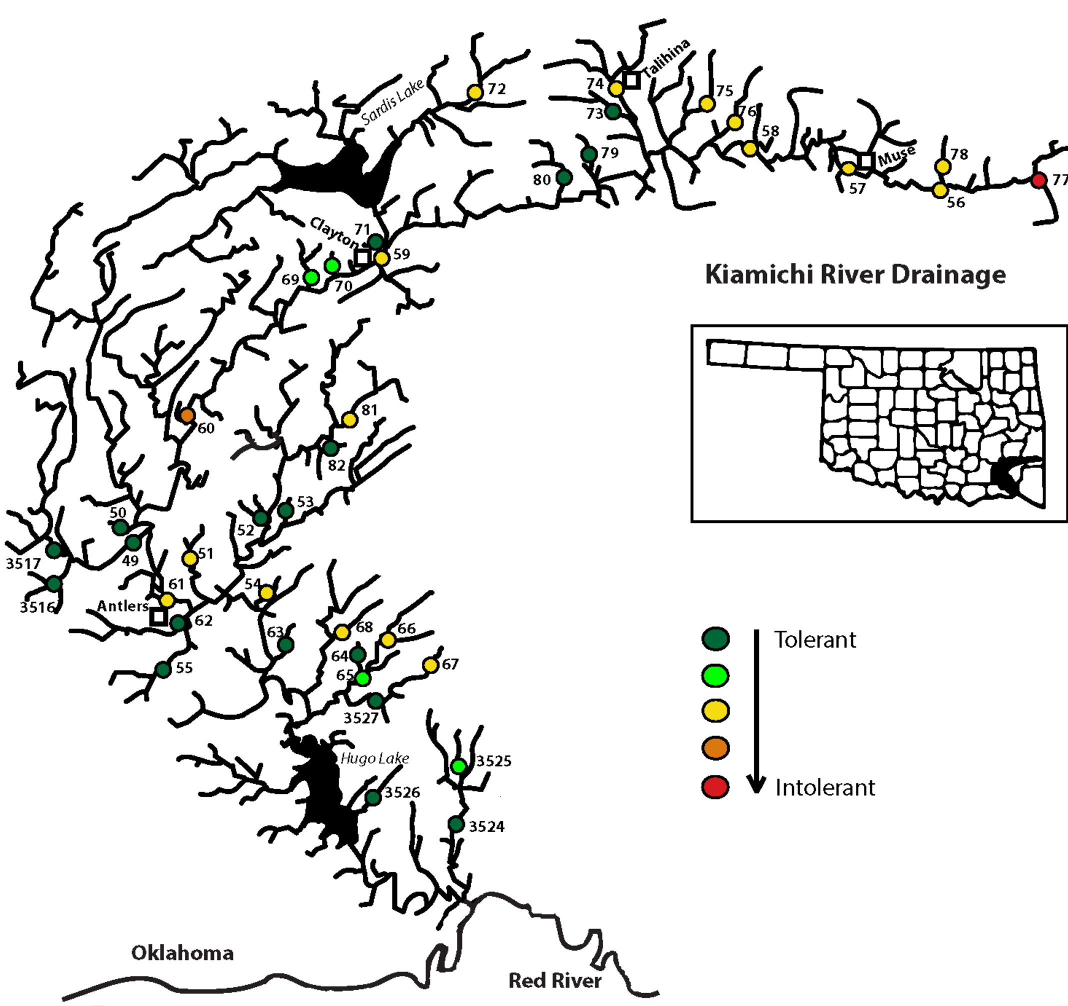


Fig. 30. Average tolerances of the fish communities in the Kiamichi River River drainage.

The Little River basin (Fig. 31) was characterized by fish communities that on average were markedly less tolerant of environmental change that those in the Boggy or Kiamichi basins. In the Little River basin, only 7 of the 45 sites were tolerant or moderately tolerant of changes in water quality or habitat. All the rest varied from moderately intolerant to tolerant for both water quality and habitat degradation. Ten sites in the upper parts of the Little River basin (in Little River, Glover, and Mountain Fork drainages) had local fish communities rated as “intolerant” of habitat degradation. One site (ZDZ120) on Big Eagle Creek northwest of Smithville, OK, had a fish community rated “intolerant” of either water quality change or habitat degradation. That site was dominated numerically by Ouachita Mountain Shiner (*Lythrurus snelsoni*), rated as intolerant for both kinds of changes by Jester et al. (1992), and many of the other sites rated as intolerant for habitat degradation also had relatively large numbers of Ouachita Mountain Shiners.

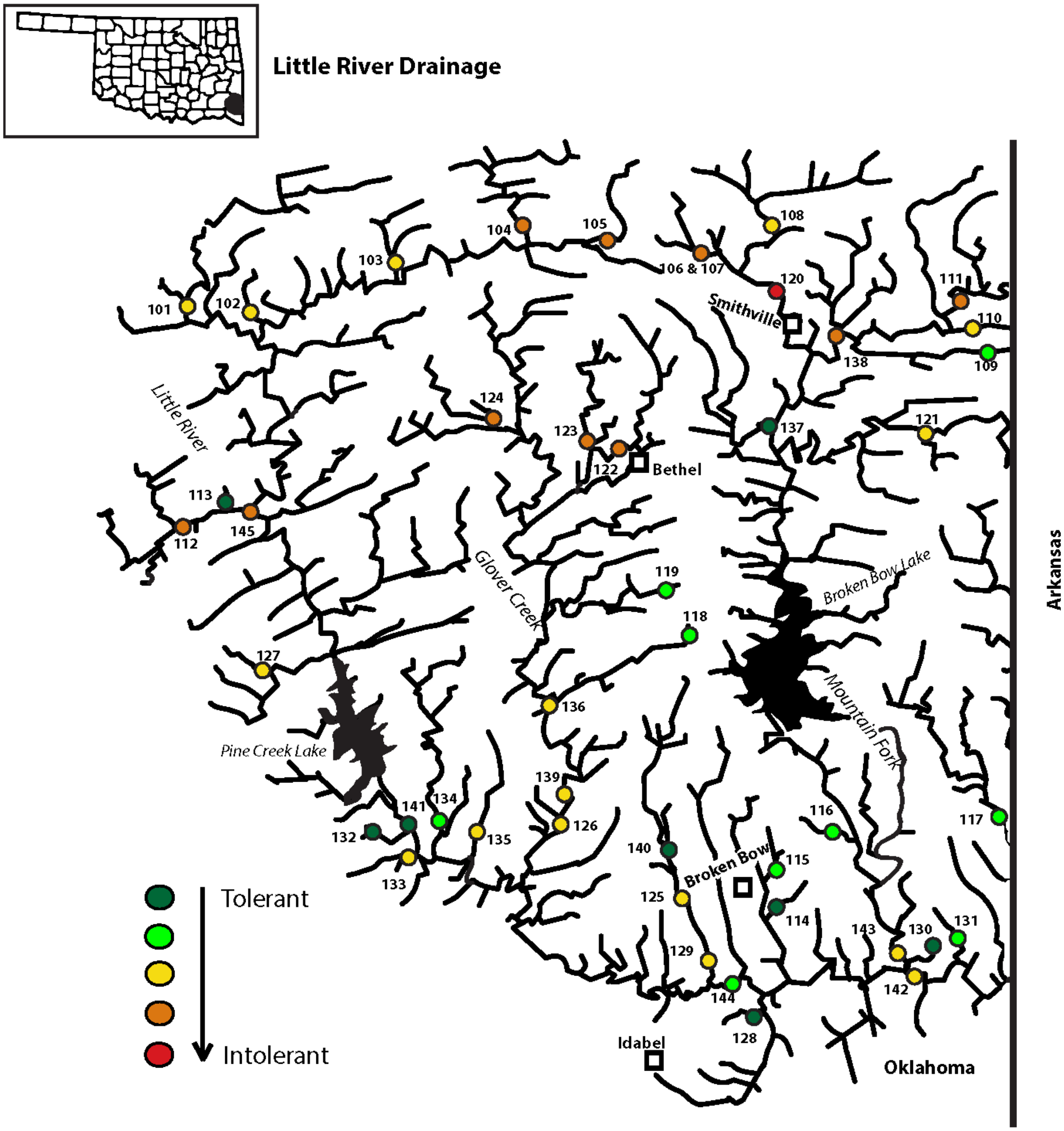


Fig. 31. Average tolerances of fish communities in the Little River drainage.

In summary, the evidence from assessment of tolerance of the local fish communities following the Jester et al. (1992) ratings indicated that of the three major basins, the Little River had many more sites characterized by intolerance of the fish communities for environmental change. Additionally, in the Kiamichi River and Little River basins fish communities with lower average tolerance by the Jester et al. ratings were located mostly in the upper portions of the drainages, in river headwaters or in tributary creeks. There is substantial opportunity to protect stream reaches characterized by potentially vulnerable species, as outlined in the section below.

Results: Opportunities for Protection of SGCN Species and High Diversity Communities

High Diversity Local Communities, and Stream Reaches Characterized by Fish Species with Low Tolerance for Environmental Change

Results from this project suggest many opportunities for current or future protection of stream areas with a focus on diversity of native species, SGCN species, and tolerances of local fish communities for environmental changes (in water quality or in habitat quality). For this purpose each basin is considered separately, with areas identified on the basis of the traits above, overlaid on areas that are already protected or have potential for protection by virtue of being public lands managed by the ODWC in Wildlife Management Areas (WMA), the USFWS Little River Wildlife Refuge, or the Ouachita National Forest (ONF) of the USDA Forest Service.

Potential protected areas.-- The maps that follow provide approximate outlines (gray areas within dotted boundary lines) of areas in the three basins where streams and stream fishes could be protected by virtue of ownership or agreements that provide state or federal control of the lands. The maps are intended for general indications of protected areas only; for each indicated area more detailed maps by the controlling agency should be consulted for specific boundaries.

Muddy Boggy River Drainage.--In the Muddy Boggy River drainage (Fig. 32), including Clear Boggy Creek, the primary protected areas are east of Atoka Reservoir to upper McGee Creek, including the Atoka WMA, Stringtown WMA, and McGee Creek WMA (see map). 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 species, but not within the protected areas. We did find one site with a fish community rated as intolerant of habitat change, and that site (ZDZ16) was in or near the protected areas. At present, federal or state protected are relatively limited in area within the Muddy Boggy River drainage, and protection of high diversity sites, sites with SGCN species, or sites with native fish communities potentially vulnerable to environmental change will depend on education and landowner cooperation, as much of the basin is in private lands.

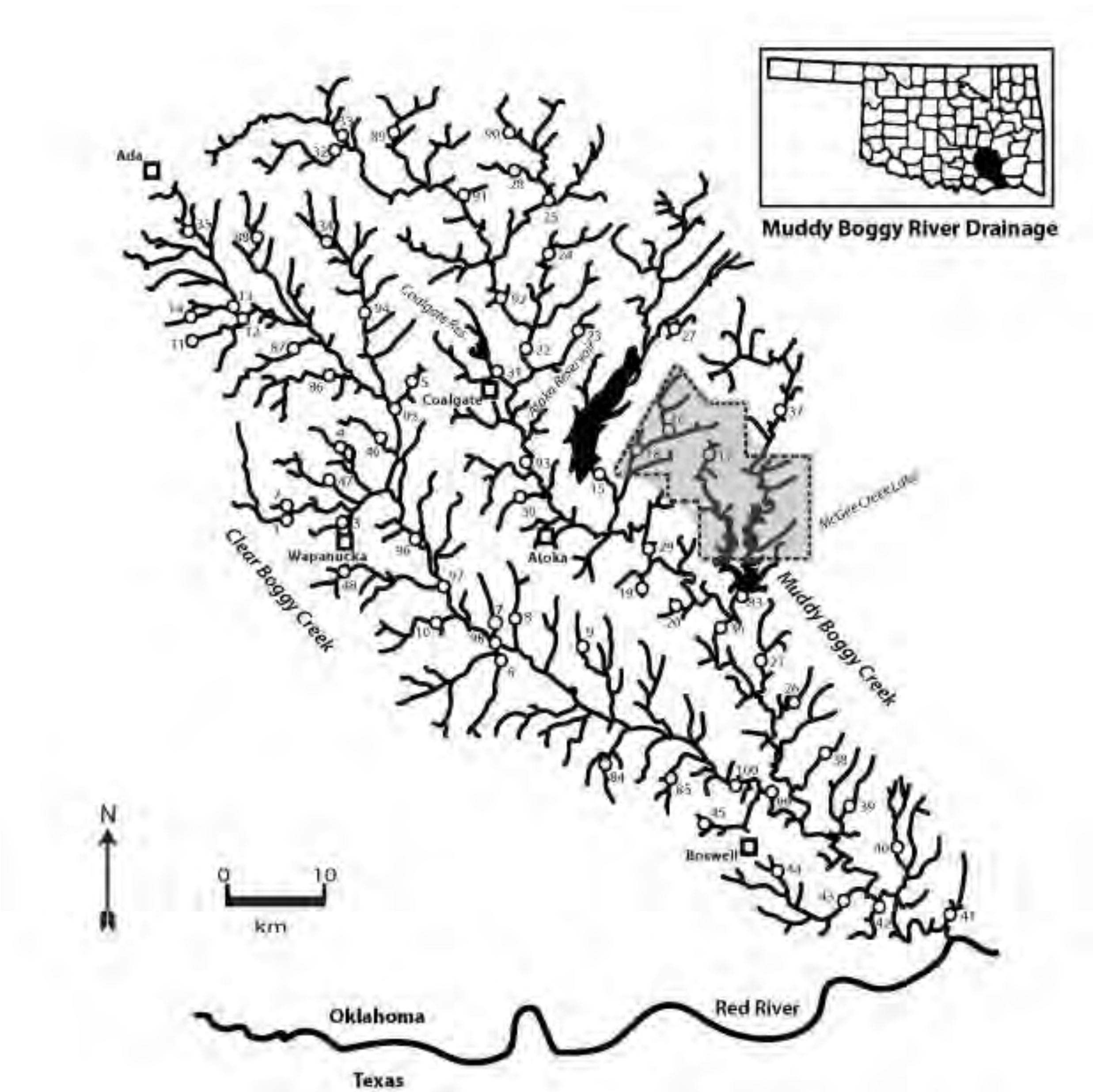


Fig. 32. Protected areas in the Muddy Boggy River drainage.

Kiamichi River Drainage.—The upper reaches of the Kiamichi River drainage (Fig. 33) have substantial protection with headwaters of the river and some tributary creeks on in the Ouachita National Forest or the Leflore Unit of the Ouachita WMA (see map). At midreach in the drainage 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 parts of the Kiamichi River basin are in private ownership, so that protection of streams and native fishes will depend on education and landowner cooperation. In the Kiamichi River basin, only five of our samples had 15 or more species, but the most speciose site, near Clayton, Oklahoma, are near but not within the Pushmataha WMA. That site also had three SGCN species. Numerous sites in the river or tributaries upstream from Talihina had low community average tolerance for environmental change, with ZDZ77 (Little Pigeon Creek) being intolerant for change in either water quality or habitat. Those sites with low fish community tolerances are largely within areas protected by the ONF or the Ouachita WMA. Further downstream near and east of Antlers, eight sites also had native fish communities with low tolerance for environmental change, in an area lacking federal or state protected areas. However, this area is characterized by being rural and remote with rugged topography, and with landowner cooperation may enjoy relatively good protection for native fish communities.

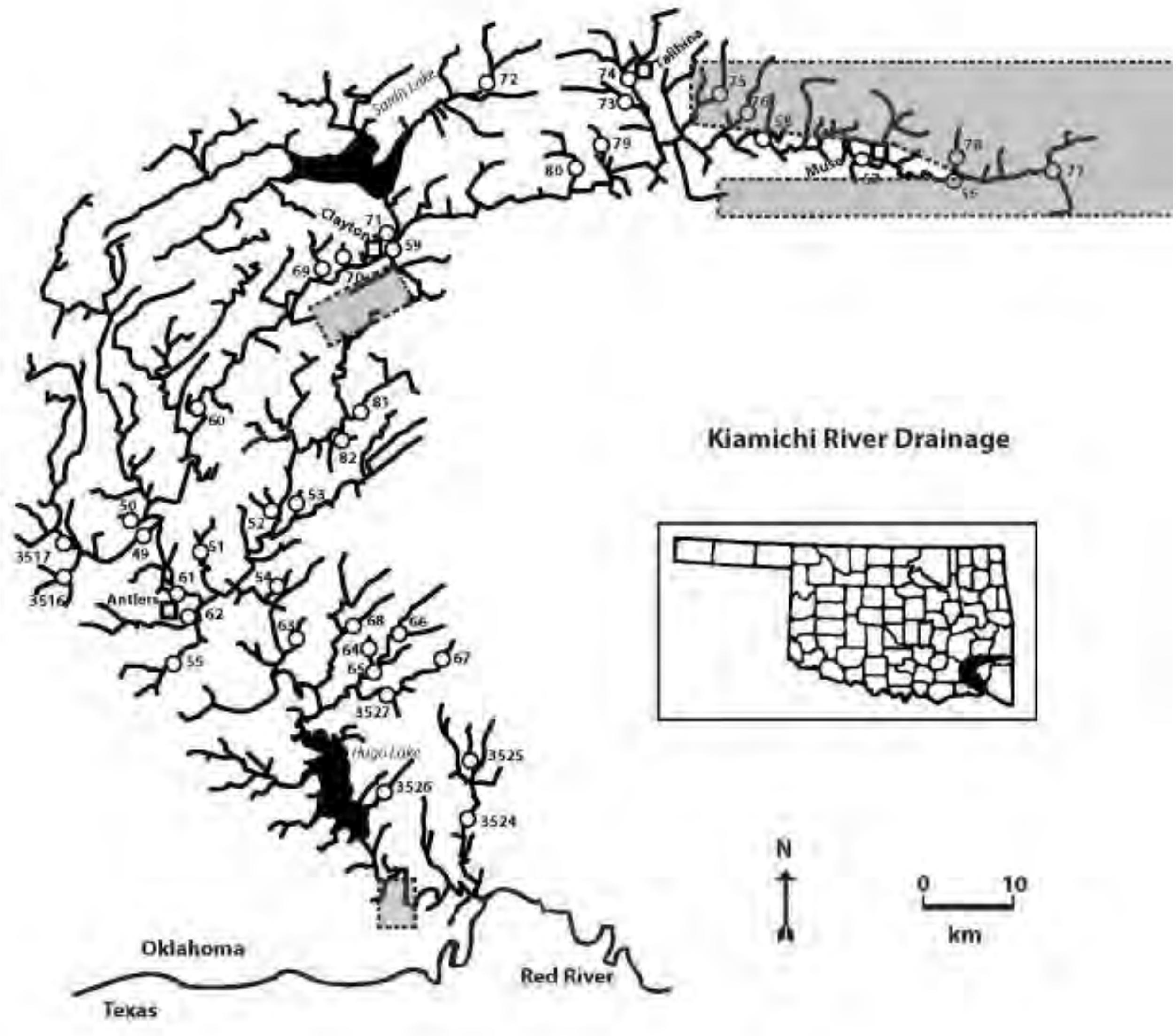


Fig. 33. Protected areas in the Kiamichi River drainage

Little River Drainage.—The Little River drainage, include(Fig. 34)ng Little River proper, Glover River, and Mountain Fork River in Oklahoma, has by far the most governmentally protected areas out of the three basins in the present project. Combinations 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, much of 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, Oklahoma, to the Arkansas state line (see map). The Little River basin has numerous sites downstream, 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 also provides protection for two sites where we detected three SGCN species, but three others sites, upstream in Little River, where we detected three SGCN species are not within governmentally protected areas. In the Little River basin, there were eleven sites in the upper Little River, Glover River, or Mountain Fork drainages that had fish communities with low tolerance for environmental change, particularly for degradation of habitat. None of those sites are within areas currently afforded protection by governmental ownership, as most of that area is in private ownership. Whereas much of the lower part of the Little River basin has protection from federal or state ownership, such protection is lacking in the upper parts of the basin. Thus, landowner education and cooperation, and land use practices, will continue to be crucial for protection of native fish communities in the upper parts of the Little River basin. Consideration should also be given to opportunistically expanding ODWC ownership of areas for potential protection of streams and native fishes in the upper Mountain Fork, Little, and Glover rivers. (See “Recommendations” section below).

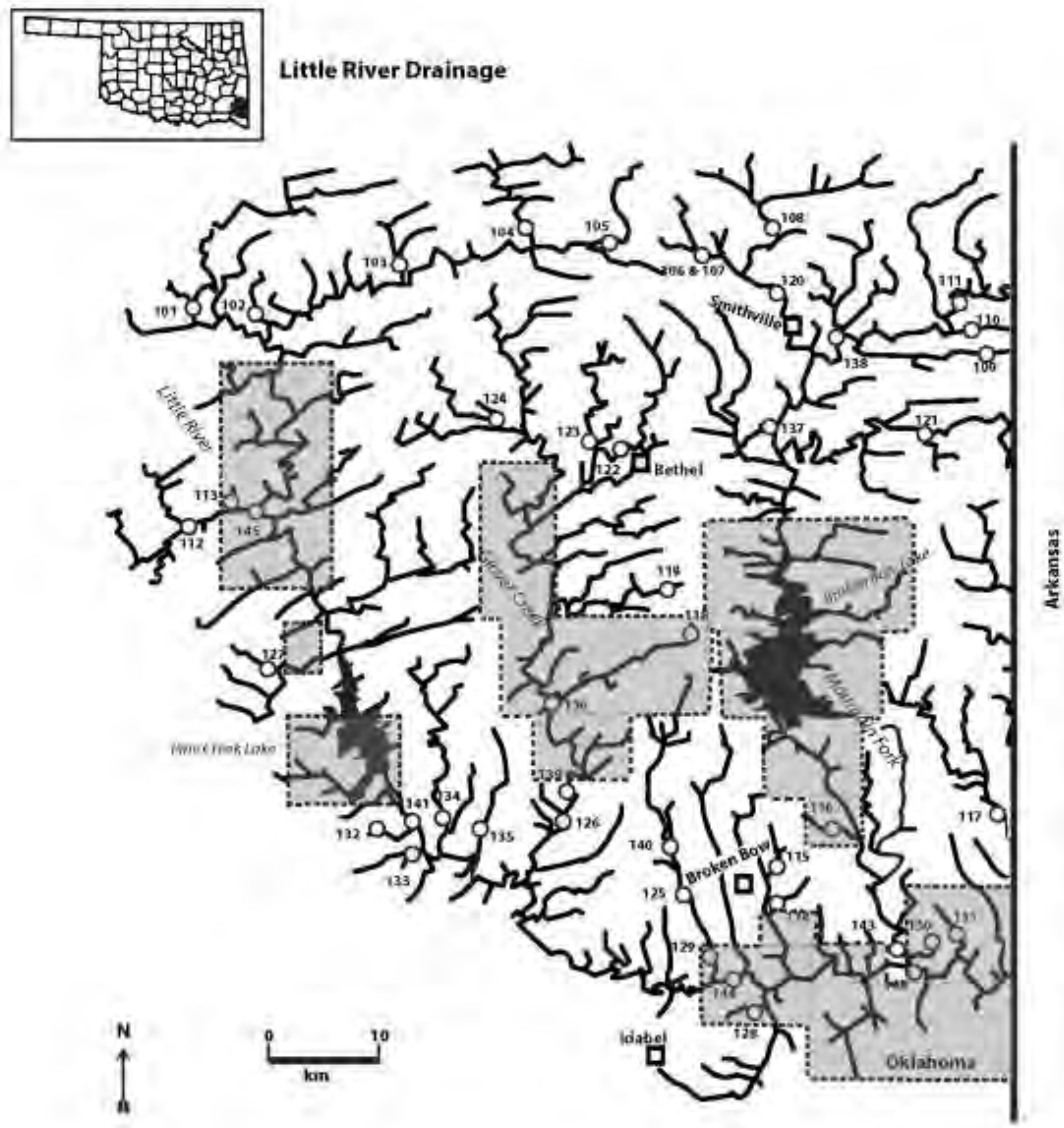


Fig. 34 Protected areas in the Little River drainage.

Products

Zbinden, Z.D. 2016. Beta diversity of stream fish communities: partitioning variation between spatial and abiotic factors. – *To be submitted to the journal "Ecography".*

Zbinden, Z.D., W.J. Matthews, and E. Marsh-Matthews. 2016. A comparison of fish community structure between Clear Boggy and Muddy Boggy Creeks. – *Talk given at the Oklahoma Natural Resource Conference, Oklahoma City, Oklahoma.*

Zbinden, Z.D., A.D. Geheber, W.J. Matthews, E. Marsh-Matthews. 2015. A contemporary fish survey of the Muddy Boggy River drainage, Southeast Oklahoma, U.S.A. *– Poster given at the Joint meeting of Ichthyologists and Herpetologists, Reno, Nevada.*

Zbinden, Z. D., W. J. Matthews, and E. Marsh-Matthews. Changes in stream fish communities in southeast Oklahoma for the 1970s to now. *– To be submitted to the journal "Copeia" or to "Transactions of the American Fisheries Society*".

III. RECOMMENDATIONS

Based on all field sampling, quantification of fish species per site, and data analyses, the following recommendations are made.

Recommendation 1: High priority sites with 15 or more native species, and very high priority sites with 19 or more native species, should be clearly identified for ODWC regional biologists and game wardens for special attention or protection, and landowners or river regulation authorities should be so advised. These sites may be on private property, and special efforts should be made to educate landowners and to work cooperatively with them to assist in protection of local fish communities in streams on their land. Landowners encountered by field crews on this project were uniformly amenable to the surveys, and seem to take genuine interest in integrity of the fish or of "their" streams. Most should be receptive to coordinated opportunities to aid in fish conservation.

Recommendation 2: High priority sites with 3 or more SGCN species, or very high priority sites with one or more of the rarest SGCN species, should be clearly identified for ODWC regional biologists and game wardens for special attention or protection, and landowners or river regulation authorities should be so advised. These sites may be on private property, and special efforts should be made to educate landowners and to work cooperatively with them to assist in protection of localities with SGCN fish species. Special care should be taken to not raise any landowner concerns about having SGCN species on their property, and, instead, to enlist their cooperation in non-threatening measures to help assure integrity of stream habitats that contain SGCN species. Measures might be developed to assist landowners with incentives to maintain high quality waters on their property.

Recommendation 3: Survey of fish in streams of the region should be continued on a regular basis, more frequently than in the past. The surveys in 2014-2015 represent the first comprehensive surveys in the region since the 1960s or 1970s, and more frequent assessment of status of SGCN species and of entire native fish communities would be advisable, at least once per decade, and more frequently at key locations with known populations of SGCN species or with high diversity of native species. Long-term sampling will help to identify trends in local and regional fish communities, to determine if they remain in loose equilibrium in spite of short-term dynamics, and to continue to provide a baseline against which managers can assess future changes in the communities.

Recommendation 4: Surveys should include streams of all sizes in these three drainages, as both headwaters and lower mainstem sites have fish communities that would benefit from protection. Long-term monitoring has been carried out at some sites in the region by personnel of the Oklahoma Department of Environmental Quality, but many of those efforts have been on larger mainstems. The most recent comprehensive surveys of the three drainages, including small streams as well as mainstems, before the present survey were by Mr. Jimmie Pigg, in the 1970s (Pigg and Hill 1974; Pigg 1977, 1978) More focus on stream fish communities in small, headwaters streams would be desirable in future monitoring.

Recommendation 5: Our study was by seining and a limited amount of gill netting in wadeable stream reaches, which provided excellent assessment of smaller-bodied SGCN species, but may underrepresent large-bodied SGCN species such as Alligator Gar, Blue Sucker, or Alabama Shad that are less likely to be detected by seining. It would be desirable in the future for ODWC to focus efforts to survey lower the mainstems of the Little, Kiamichi, and Muddy Boggy rivers, by boat gill netting or electrofishing to better ascertain status of some "big-water" SGCN species.

Recommendation 6: The Orangebelly Darter (*Etheostoma radiosum*) is 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 our region of study that we recommend it be considered for removal from the state list of species of "greatest conservation need". However, the species is currently under molecular study by Dr. Thomas Turner of the University of New Mexico, and his work and previous taxonomic work on Orangebelly Darter by Matthews all suggest that the form currently known as "*Etheostoma radiosum*" from the Blue River is a distinctive form, probably warranting elevation to status as a full species. Thus our recommendation is to consider removing the *Etheostoma radiosum* from southeastern Oklahoma from the SGCN list, but to modify the SGCN list to specify the "Orangebelly Darter species in Blue River" as an SGCN taxon.

Recommendation 7: The Rocky Shiner (*Notropis suttkusi*) occurred in 25 of our sampling sites in all three major drainages, and was extremely abundant in some locations. With its wide distribution in Oklahoma it might be considered for removal from the SGCN list, although as a regional endemic its abundance should be monitored in the future. Potentially lower its rating from Tier 1 to Tier 2.

Recommendation 8: The Ouachita Mountain Shiner (*Lythrurus snelsoni*) 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 its continued monitoring, but we envision no outright threats to this species so long as an abundance of high quality water continues to flow in the Little River uplands. Potentially lower its rating from Tier 1 to Tier 2.

Recommendation 9: All other Tier 1 and Tier 2 fish species in southeastern Oklahoma should remain as SGCN species because their status remains in doubt. Particular effort should be directed toward sampling more locations for presence of Peppered Shiner (*Notropis perpallidus*) and Crystal Darter (*Crystallaria asprella*), because we formerly found these occasionally in a few locations in the Little River basin (Matthews, unpublished data) but they were not detected in the present surveys.

Recommendation 10: Fish communities in southeastern Oklahoma streams in general seem to be in good condition, relative to expectations from historical surveys, and expectations of the loose equilibrium concept. No invasive species were encountered, but continued vigilance in southeastern Oklahoma streams should be maintained for any evidence of encroachment of the region by Asian carps, Northern Snakehead, or other potentially harmful species. Future monitoring should include efforts comparable to those in the current project, and appropriate multivariate assessment of community trajectories should be used to continue to assess the structure of the communities relative to loose equilibrium. Managers might adopt a "yellow light – red light" approach, based on expectations of loose equilibrium. For example, once there is minimum number of surveys for the fish community of a local site or of a whole drainage to be assessed with multivariate trajectories (we recommend a minimum of five surveys across time for this to be effective), managers could then consider one "excursion" of the community outside the multivariate boundaries established by of previous surveys to be a cautionary or "yellow light", requiring increased vigilance, and continued (two or more) excursions outside previous community boundaries to be a "red light", potentially triggering more aggressive monitoring or actions to ameliorate changes in native fish communities.

Recommendation 11: Emphasis should be placed on conservation actions within these river basins that continue to assure the availability of strong flows of high quality water. Any reduction in availability 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 very carefully to assure that habitat needs of all the diverse native species in these basins are maintained in their present high quality form. Any dam operations that limit availability of downstream waters, especially in summer or during droughts, should be avoided or modified to assure adequate flow of water 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.

Recommendation 12: Although there are stream reaches in all three drainages that can protect fish communities by virtue of state or federal ownership or cooperative agreements with NGOs or industry, managers should seek opportunities for expansion of protected areas for streams and stream fish communities. Particular efforts should be made to secure protection for sensitive native species in headwaters of the Little River drainage.

IV. SIGNIFICANT DEVIATIONS

There were no significant deviations.

V. PREPARED BY:

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DATE: August 15, 2016

APPROVED BY: ______________________________
Fisheries Division Administration
Oklahoma Department of Wildlife Conservation

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Andrea Crews, Federal Aid Coordinator
Oklahoma Department of Wildlife Conservation

VII. REFERENCES:

DeAngelis, D. L., J. C. Waterhouse, W. M. Post, and R. V. O'Neill. 1985. Ecological modelling and disturbance evaluation. Ecological Modelling 29:399-419.

Grossman, G. D., J. F. Dowd, and M. Crawford. 1990. Assemblage stability in stream fishes: a review. Environmental Management 14:661-671.

Hubbs, C. L. and A. I. Ortenburger. 1929a. Further notes on the fishes of Oklahoma with descriptonis of new species of Cyprinidae. Publications of the University of Oklahoma Biological Survey 1:17-43.

Hubbs, C. L. and A. I. Ortenburger. 1929b. Fishes collected in Oklahoma and Arkansas in 1927. Publications of the University of Oklahoma Biological Survey 1: 47-112, with Plates I-XIII.

Jester, D. B., A. A. Echelle, W. J. Matthews, J. Pigg, C. M. Scott, and K. D. Collins. 1992. The fishes of Oklahoma, their gross habitats, and their tolerance of degradation in water quality and habitat. Proceedings of the Oklahoma Academy of Science 72:7-19.

Matthews, W. J. 1998. Patterns in freshwater fish ecology. Chapman and Hall, New York.

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

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

Matthews, W. J., and E. Marsh-Matthews. 2017. Stream Fish Community Dynamics: A Critical Synthesis. Johns Hopkins University Press. In press.

Matthews, W. J., E. Marsh-Matthews, G. L. Adams, and S. R. Adams. 2014. Two catastrophic floods: similarities and differences in effects on an Ozark stream fish community. Copeia 2014:682-693.

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

Pigg, J. 1977. A survey of the fishes of the Muddy Boggy River in south central Oklahoma. Proceedings of the Oklahoma Academy of Science 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., and L. G. Hill. 1974. Fishes of the Kiamichi River, Oklahoma. Proceedings of the Oklahoma Academy of Science 54:121-130.

Ross, S. T., W. J. Matthews, and A. A. Echelle. 1985. Persistence of stream fish assemblages: effects of environmental change. American Naturalist 126:24-40.

Taylor, C. M. 2010. Covariation among plains stream fish assemblages, flow regimes, and patterns of water use. Pages 447 to 460 in: K. B. Gido and D. A. Jackson, editors. Community Ecology of Stream Fisehs: Concepts, Approaches, and Technques. American Fisheries Society Symposium 73, Bethesda, MD.

Vaughn, C. C., C. L. Atkinson, and J. P. Julian. 2015. Drought-induced changes in flow regimes lead to long-term losses in mussel-provided ecosystem services. Ecology and Evolution 5:1291-1305.

Appendix A: Excel file (provided to ODWC) of environmental conditions at all 167 seining collections.

Appendix B: Excel file (provided to ODWC) of species abundances at all 167 seining collections.