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Assessing the Potential for Rainbow Trout Reproduction in Tributaries of the Mountain Fork River below Broken Bow Dam, Southeastern Oklahoma

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Cover photographs: pirate perch (top left), orangebelly darter (bottom left), Cooper Creek (center), rainbow trout (top right), and highland stoneroller (bottom right) of the lower Mountain Fork River system below Broken Bow Dam, southeastern Oklahoma. (photographs by Trevor Starks except the rainbow trout, taken by Tyler Farling)

PRODUCT DISCLAIMER

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Abstract

Stocked trout (Salmonidae) in reservoir tailwater systems in the Southern United States have been shown to use tributary streams for spawning and rearing. The lower Mountain Fork of the Little River below Broken Bow Dam is one of two year-round tailwater trout fisheries in Oklahoma, and the only one with evidence of reproduction by stocked rainbow trout (*Oncorhynchus mykiss*). Whether stocked trout use tributaries in this system for spawning is unknown. Furthermore, an inventory of the resident fish communities in these tributaries is lacking. To address these gaps, we surveyed 10 tributaries, from intermittent through third order, for fishes during presumed spawning periods of rainbow trout; we used backpack electrofishing in February and April 2015 and 2016 to determine the composition of the fish assemblages and whether trout were present. Stocked adult trout were found in three tributaries in 2015; wild juvenile rainbow trout were found in Bee Branch in 2015 and in an intermittent tributary of Spillway Creek, just above the "Cold Hole," in 2016. Fish assemblages were dominated by highland stonerollers (*Campostoma spadiceum*) in larger, wider systems and by orangebelly darters (*Etheostoma radiosum*) in smaller, narrower streams. These data fill an information gap in our understanding of small streams in the Ouachita Mountains, and they demonstrate that some streams are suitable for rainbow trout reproduction.

Keywords: Highland stoneroller, Mountain Fork River, orangebelly darter, Ouachita Mountains, rainbow trout, river continuum.

INTRODUCTION

Small streams (second order or less) are relatively understudied, and thus there is little knowledge about their resident fish assemblages. Previous studies have found variable numbers of fish species in small systems. For example, two first-order streams in North Carolina contained 1 to 13 fish species depending on location and season (Long 2010), and up to 21 species were found in second-order and smaller streams in the Coastal Plain of South Carolina (Paller 1994). In general, however, fish assemblages in these systems appear to be deterministically structured, with high stability among years but differences among seasons that align with fish migrations; associated spawning activities may influence these assemblages (Gorman and Karr 1978, Lienesch and others 2000, Moyle and Vondracek 1985).

The tailwater trout fishery in the Mountain Fork of the Little River below Broken Bow Dam is one of only two year-round trout streams in Oklahoma; spawning migrations from stocked trout, particularly rainbow trout (*Oncorhynchus mykiss*), could be adding to the diversity of tributary streams, at least seasonally. Natural reproduction of rainbow trout has been documented in this system since 2006,[1] but it is unknown if this species uses tributaries for spawning. Rainbow trout have been shown to spawn in small, warmwater tributaries of other tailwater trout fisheries, such as the Chattahoochee River tailwater in Georgia below Buford Dam (Long and others 2007). In one of these tributaries, natural reproduction of rainbow trout occurred for at least 3 consecutive years, with juvenile fish persisting through the summer (Lee and others 2012, Long and others 2008); this suggests that these small streams can be residences for this nonnative species.

The objectives of this study were to survey the fish community in several tributaries of the lower Mountain Fork below Broken Bow Dam and determine the presence or absence of rainbow trout (stocked adults or wild-spawned juveniles).

[1] Oklahoma Department of Wildlife Conservation [ODWC]. Unpublished data. On file with: Kyle James, Southeast Region Fisheries Biologist, 673 SW Highway 1, Wilburton, OK 74578.

STUDY AREA

The lower Mountain Fork and its tributaries lie within the Ouachita Mountains ecoregion; this area comprises sandstone and shale strata, with topographic relief from 90 to 213 m and annual precipitation of 127–140 cm (USDA Forest Service 1999). Since 1989, the lower Mountain Fork mainstem has been a designated tailwater trout fishery for 19.3 km below Broken Bow Dam in southeastern Oklahoma; this section of the river receives hypolimnetic discharge of cold water from Broken Bow Reservoir (Harper 1994) with a mean annual discharge of 40.3 m^3/s (USGS 2016a). The tributaries to the Mountain Fork within the designated trout area are generally small, ranging from intermittent to third order.

METHODS

We sampled for fishes in 10 tributary streams of the designated trout area of the lower Mountain Fork below Broken Bow Lake, Oklahoma (fig. 1). Eight streams were surveyed in 2015 and three in 2016; only one stream (Bee Branch) was sampled both years. Samples were conducted with backpack electrofishing, moving upstream from just above the mouth of the tributary, and consisted of 30 minutes of on-power time. All fish captured were identified and released back to the environment alive or preserved and identified in the laboratory. We conducted surveys in February and April to coincide with rainbow trout spawning (Long and others 2008).

We obtained a variety of environmental measurements in 2015 to correlate with fish assemblages. During the February sampling, we made several measurements of wetted width and water depth, and we averaged them for each stream. At these measurement transects, we calculated cross-sectional area (CS = depth × width) and averaged them for each stream. Using National Hydrography Dataset Plus (NHDPlus v2: http://www.horizon-systems.com/nhdplus/) in ArcGIS, we calculated total stream length, stream order, stream gradient, and watershed area.

We summarized and analyzed fish assemblages and environmental variables among streams with a variety of methods. For assemblage data, we counted number of species (species richness) in each system, calculated proportional abundance, and then calculated expected number of species (ENS). Expected number of species is a measure of species diversity that is linearly scaled (e.g., a stream with twice the diversity = 2 × ENS), as opposed to the traditional measure of Shannon entropy as diversity (Jost 2006); it is calculated as:

$$\left(\exp -\sum_{i=1}^{S} p_i \ln p_i\right)$$

where

S = number of species

p = the proportional abundance of species i.

Cooper Creek. (photograph by Trevor Starks)

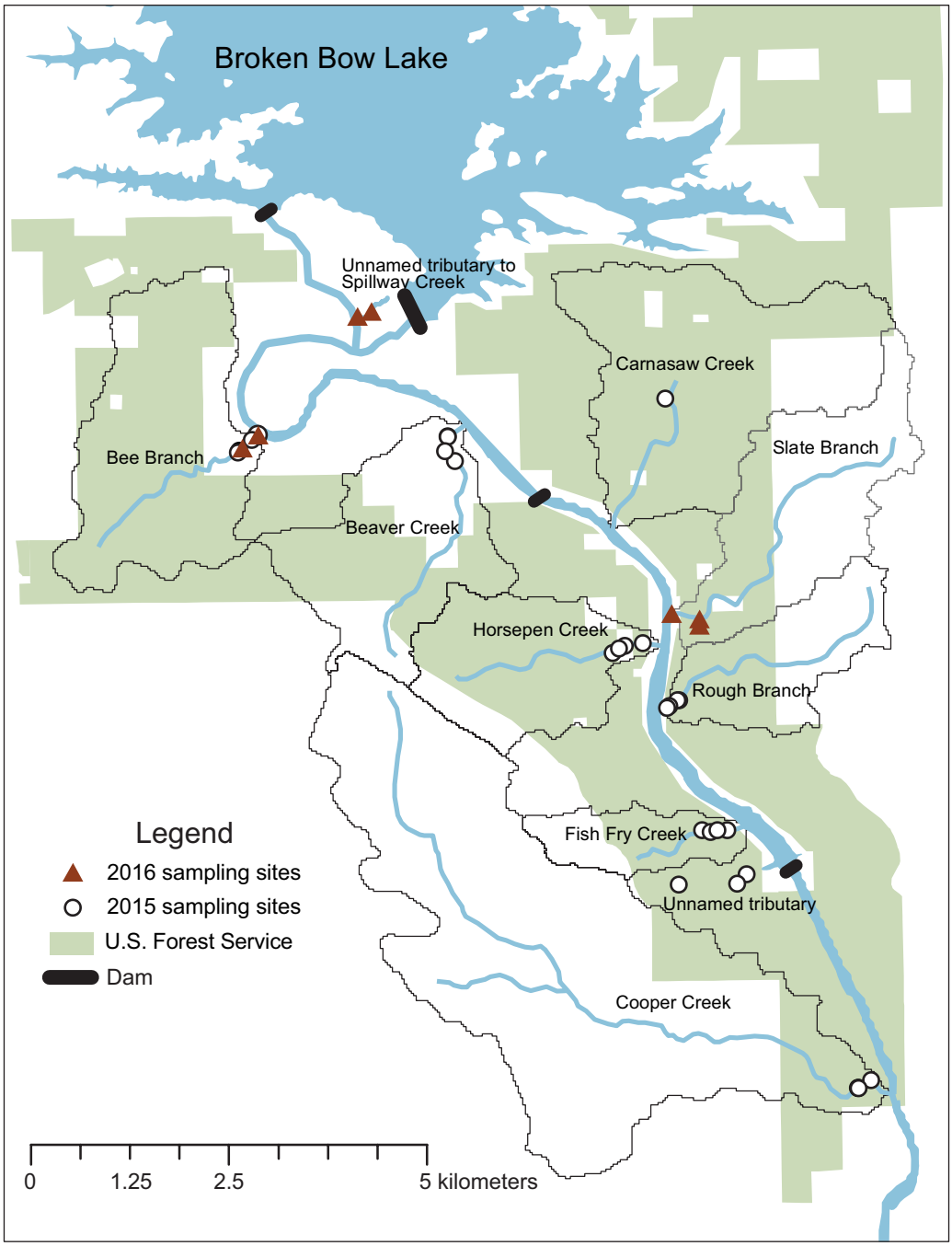

Figure 1—Tributaries to the Mountain Fork of the Little River below Broken Bow Dam, southeastern Oklahoma, sampled for fish in 2015 and 2016. Tributary watersheds as available in NHDPlus v2.0, and Ouachita National Forest boundaries are shown.

To examine similarities among streams in 2015, we conducted a nearest-neighbor cluster analysis based on Bray-Curtis dissimilarity using PC-ORD (v6.0) software. Finally, to examine relationships among environmental variables and fish assemblages in 2015, we calculated Pearson correlation coefficients using SigmaPlot (v12.5) software. For Bee Branch, which was the only stream sampled in both years, we calculated the Bray-Curtis similarity (0 [no similarity] to 1 [complete similarity]) between years using PC-ORD (v6.0) software.

RESULTS

A total of 2,229 individuals (1,747 in 2015 and 482 in 2016) representing 23 species and 10 families were captured (tables 1–3). We found two species of fish in Carnasaw Creek; however, we were only able to sample once in the upper portion of the watershed, so we removed samples from this system from further analyses. In 2015, the number of species ranged from 3 to 18, with a mode of 8, but these communities were usually dominated by such a few species that ENS values were much lower than the observed number of species (i.e., low evenness) (table 2).

Table 1—Common and scientific names of fishes captured from lower Mountain Fork tributaries in 2015 and 2016

Family and common name	Scientific name
Aphrododeridae	
Pirate perch	*Aphredoderus sayanus*
Catastomidae	
Creek chubsucker	*Erimyzon oblongus*
Centrarchidae	
Green sunfish	*Lepomis cyanellus*
Longear sunfish	*Lepomis megalotis*
Orangespotted sunfish	*Lepomis humilis*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
Cyprindae	
Highland stoneroller	*Campostoma spadiceum*
Bigeye shiner	*Notropis boops*
Striped shiner	*Luxilus chrysocephalus*
Creek chub	*Semotilus atromaculatus*
Redfin shiner	*Lythrurus umbratilis*
Esocidae	
Redfin pickerel	*Esox americanus*
Fundulidae	
Blackstripe topminnow	*Fundulus notatus*
Ictaluridae	
Yellow bullhead	*Ameiurus natalis*
Slender madtom	*Noturus exilis*
Percidae	
Creole darter	*Etheostoma collettei*
Orangebelly darter	*Etheostoma radiosum*
Orangethroat darter	*Etheostoma spectabile*
Logperch	*Percina caprodes*
Poeciliidae	
Western mosquitofish	*Gambusia affinis*
Salmonidae	
Brown trout	*Salmo trutta*
Rainbow trout	*Oncorhynchus mykiss*

Highland stoneroller. (photograph by Trevor Starks)

Highland stoneroller (*Campostoma spadiceum*) dominated the fish assemblages in Bee Branch, Beaver Creek, and Cooper Creek (>50 percent), whereas orangebelly darter (*Etheostoma radiosum*) was the dominant species in the remaining tributaries. Systems dominated by highland stoneroller (i.e., Bee, Breaver, and Cooper) clustered with each other and apart from the systems dominated by orangebelly darter (i.e., Horsepen, Rough, Fish Fry, and unnamed) (fig. 2). In 2016, fish diversity was more even than observed in 2015, with ENS values from 3.8 to 4.5, although observed number of species (from 6 to 8) was similar (table 3).

The fish assemblage in Bee Branch, which was the only tributary sampled both years, had the same number of species (8) both years, but the ENS value in 2016 was more than double the value in 2015. Moreover, no species of fish made up more than 50 percent of the total number in 2016. Ten species of fish were found total, but only eight in each year (tables 2 and 3). Rainbow trout and redfin pickerel (*Esox americanus*) were found in 2015 but not in 2016, whereas logperch (*Percina caprodes*) and slender madtom (*Noturus exilis*) were found in 2016 but not in 2015. Fish assemblage similarity was 0.62 (Bray-Curtis) between years.

Trout were found in four streams in 2015 (rainbow trout in Bee Branch [N = 2], Horsepen Creek [N = 1], and Rough Branch [N = 1]; brown trout (*Salmo trutta*) in Cooper Creek [N = 1]), but only those found in Bee Branch were small enough (<200 mm total length) and with morphology indicative of wild production (e.g., complete, non-eroded paired fins) (table 4). In 2016, trout were only found in the unnamed tributary to Spillway Creek (N = 16), and these were rainbow trout indicative of wild production.

Table 2—Proportional abundance and community structure metrics of fish assemblages among tributary streams (ordered from upstream to downstream) of the lower Mountain Fork below Broken Bow Dam, Oklahoma in 2015

	Tributary stream							
Common name	Bee	Beaver	Carnasaw[a]	Horsepen	Rough	Fish Fry	Unnamed (Mtn. Fork)	Cooper
Pirate perch	—	—	—	—	—	—	—	0.01
Creek chubsucker	<0.01	0.03	—	—	—	—	—	0.01
Green sunfish	—	<0.01	—	0.02	0.15	0.30	0.06	0.04
Longear sunfish	—	—	—	—	—	—	—	<0.01
Orangespotted sunfish	—	—	—	—	—	0.01	—	0.01
Bluegill	—	—	—	—	—	—	—	<0.01
Largemouth bass	—	—	—	—	0.03		—	—
Highland stoneroller	0.87	0.57	0.93	0.17	0.08	—	—	0.64
Bigeye shiner	0.01	—	—	—	—	—	—	0.07
Striped shiner	—	—	—	—	—	—	—	0.09
Creek chub	0.02	0.17	—	0.01	0.03	—	—	—
Redfin shiner	—	—	—	—	—	—	—	0.01
Redfin pickerel	<0.01	0.04	—	—	—	0.04	0.02	0.01
Blackstripe topminnow	—	—	—	0.01	0.03	0.01	—	<0.01
Yellow bullhead	0.01	0.02	—	—	—	—	—	0.02
Slender madtom	—	0.00	—	—	—	—	—	<0.01
Creole darter	—	—	—	—	0.03	—	—	<0.01
Orangebelly darter	0.08	0.16	0.07	0.77	0.65	0.63	0.90	0.06
Orangethroat darter	—	—	—	—	—	—	—	0.02
Western mosquitofish	—	—	—	0.02	—	—	0.02	—
Brown trout	—	—	—	—	—	—	—	<0.01
Rainbow trout	0.00	—	—	0.01	0.03	—	—	—
Total individuals (N)	456	587	27	133	40	71	50	383
Number of species	8	8	2	7	8	5	3	18
Expected number of species (ENS)	1.6	2.8	1.3	2.2	3.4	2.5	2.5	3.8

— = species not captured.
[a]We were only able to sample the upper portion of this tributary once, so these data were not used in further analyses.

Although all the tributary streams sampled were relatively small (≤ third order), they ranged in size from intermittent with narrow widths (<2 m) to third order and fairly wide (~9 m) (table 5). Measures of stream size (width, depth, length, etc.) all correlated with each other, but the best correlation (r = 0.99) was stream length with mean cross-sectional area (table 6). Orangebelly darter was the only species found in all streams, and its relative abundance correlated best with mean stream width in a negative direction (r = -0.86) (table 6; fig. 3). Highland stoneroller, the only other species to exhibit predominance (>50 percent) in any of the tributaries, was negatively correlated with relative abundance of orangebelly darter (r = -0.93) (table 6; fig. 4).

Orangebelly darter. (photograph by Trevor Starks)

Table 3—Proportional abundance and community structure metrics of fish assemblages among tributary streams (ordered from upstream to downstream) of the lower Mountain Fork below Broken Bow Dam, Oklahoma in 2016

	Tributary stream		
Common name	Unnamed (Spillway)	Bee	Slate
Creek chubsucker	0.19	0.12	0.07
Green sunfish	—	—	0.04
Highland stoneroller	0.23	0.52	0.14
Bigeye shiner	0.01	0.07	
Creek chub	0.46	<0.01	0.02
Redfin pickerel	—	—	0.04
Yellow bullhead	—	0.03	—
Slender madtom	—	0.07	—
Creole darter	—	—	0.30
Orangebelly darter	0.02	0.19	0.39
Logperch	—	<0.01	—
Western mosquitofish	—		—
Rainbow trout	0.10	—	—
Total individuals (N)	166	260	56
Number of species	6	8	7
Expected number of species (ENS)	3.8	4.1	4.5

— = species not captured.

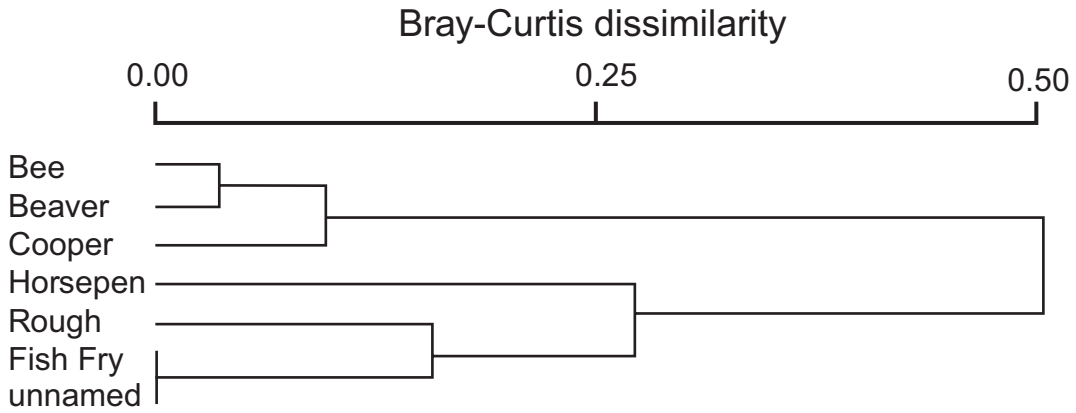

Figure 2—Cluster analysis depicting dissimilarity in fish communities in 2015 among tributaries to the Mountain Fork of the Little River below Broken Bow Dam, southeastern Oklahoma. The streams with the most dissimilar fish assemblages are grouped into pairs hierarchically until all streams are incorporated. In this graph, the most dissimilar pair (0.50) is the group of streams at the bottom (i.e., Horsepen, Rough, Fish Fry, and unnamed) and the group of streams at the top of the graph (i.e., Bee, Beaver, and Cooper). [Note: data from Carnasaw Creek are not included in this analysis because we were only able to sample once in the upper portion of the watershed.]

Table 4—Number and total length of trout captured in tributary streams of the lower Mountain Fork below Broken Bow Dam, 2015–16

	Brown trout				Rainbow trout			
Stream	N	Min TL	Mean TL	Max TL	N	Min TL	Mean TL	Max TL
		- - - - - - - - - *mm* - - - - - - - - -				- - - - - - - - - *mm* - - - - - - - - -		
				2015				
Bee	—	—	—	—	2	38	85.5	133
Cooper	1	156	156	156	—	—	—	—
Horsepen	—	—	—	—	1	229	229	229
Rough	—	—	—	—	1	230	230	230
				2016				
Unnamed (Spillway)	—	—	—	—	16	37	41.7	45

— = species not captured.

N = number; TL = total length.

Table 5—Summary of variables indicative of stream size for tributaries of the lower Mountain Fork below Broken Bow Dam that were sampled for fish 2015 and 2016

Stream	Mean width	Mean depth	Mean cross-sectional area	Stream length[a]	Stream order[a]	Stream gradient[a]	Watershed area[a]
	m	*m*	m^2	- *km* -			- - km^2 - -
Unnamed (Spillway)	2.34	NA	NA	NA	NA	NA	NA
Bee	5.12	0.12	0.62	2.68	2	0.01	7.00
Beaver	5.08	0.13	0.68	3.47	2	0.01	5.46
Carnasaw[b]	5.43	1.31	0.24	2.15	1	0.02	8.69
Slate	NA	NA	NA	4.40	2	0.02	5.28
Horsepen	2.78	0.20	0.55	2.68	2	0.01	4.23
Rough	3.96	0.27	1.06	3.53	2	0.03	3.29
Fish Fry	2.30	0.14	0.33	1.42	1	0.02	1.75
Unnamed (Mtn. Fork)	1.67	0.14	0.23	NA	NA	NA	NA
Cooper	8.68	0.30	2.61	11.39	3	0.01	18.29

NA = not applicable (data not taken).

[a] From NHDPlus v2.

[b] We were only able to sample the upper portion of this tributary once, so these samples were not used in further analyses.

Table 6—Correlation matrix among variables indicative of stream size and proportion of orangebelly darter and highland stoneroller for tributaries of the Mountain Fork below Broken Bow Dam that were sampled for fish in 2015

	Mean width (*m*)	Mean CS area (m^2)	Mean depth (*m*)	Stream length (*km*)	Stream order	Stream gradient	Watershed area (km^2)	Prop. ETHRAD	Prop. CAMSPA
Mean width (*m*)	1	**0.90**	0.57	**0.92**	**0.88**	-0.60	**0.95**	**-0.86**	0.60
Mean CS area (m^2)	—	1	**0.83**	**0.99**	**0.86**	-0.41	**0.93**	-0.57	0.18
Mean depth (*m*)	—	—	1	0.74	0.66	0.03	0.57	-0.11	-0.44
Stream length (*km*)	—	—	—	1	**0.87**	-0.54	**0.96**	-0.54	0.26
Stream order	—	—	—	—	1	-0.59	**0.88**	-0.56	0.29
Stream gradient	—	—	—	—	—	1	-0.69	0.63	-0.64
Watershed area (km^2)	—	—	—	—	—	—	1	-0.69	0.50
Prop. ETHRAD	—	—	—	—	—	—	—	1	**-0.93**
Prop. CAMSPA	—	—	—	—	—	—	—	—	1

— = data is redundant with upper portion of matrix and thus omitted.
CS = cross-sectional (width x depth); prop = proportion; ETHRAD = orangebelly darter (*Etheostoma radiosum*); CAMSPA = highland stoneroller (*Campostoma spadiceum*).
Bold numbers mean correlation coefficients are significantly different from 0 at the P ≤0.05 level of significance.

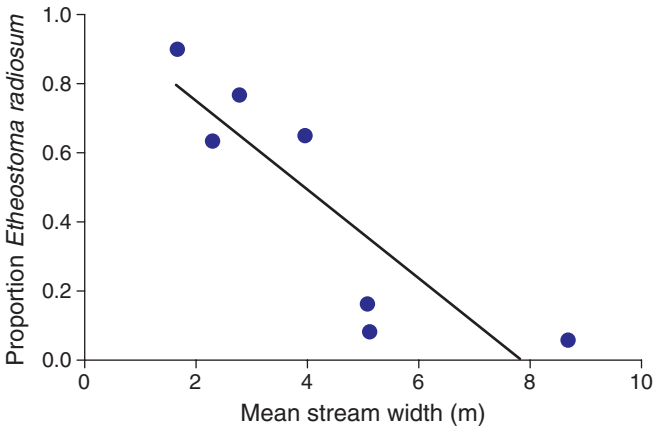

Figure 3—Relationship of proportion orangebelly darter (*Etheostoma radiosum*) in fish community to mean stream width for tributaries of the Mountain Fork of the Little River below Broken Bow Dam in 2015.

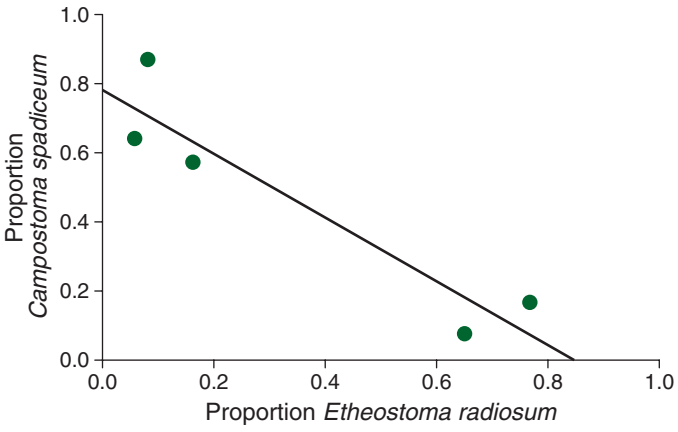

Figure 4—Relationship of proportion highland stoneroller (*Campostoma spadiceum*) in relation to proportion orangebelly darter (*Etheostoma radiosum*) in tributaries of the Mountain Fork of the Little River below Broken Bow Dam in 2015.

DISCUSSION

The fish assemblages of the tributaries to the lower Mountain Fork appear to be driven by size, with the smallest systems dominated by orangebelly darters and the larger ones by highland stonerollers. These results are in keeping with the general predictions of the river continuum concept (Vannote and others 1980), although applied across systems instead of along a linear gradient of one system (i.e., from headwater to mouth). Larger, wider streams have less riparian canopy cover and more sunlight, allowing for increased primary production through photosynthesis (i.e., autochthonous system) and increased algae, the primary food source for stonerollers (Cashner and others 2010). Smaller systems, conversely, have more shading, thus reducing the production of algae. In the systems we studied, streams wider than about 4 m had reduced numbers of orangebelly darters and were dominated by stonerollers, suggesting differences in production between these systems, although we did not specifically measure primary production in any system.

The orangbelly darter is a benthic invertivore, consuming larval mayflies, dipterans, and caddisflies (Jones and Maughan 1989, Scalet 1972), but most of the biology and ecology of this species is known from studies in large rivers [e.g., Blue River, OK (Scalet 1972, 1973a, 1973b) and Glover River, OK (Jones and Maughan 1989)], where sources of production are more likely to be autochthonous than allochthonous. Whether orangebelly darters inhabiting small, headwater streams of the Little River basin in our study area exhibit feeding ecology different from the populations in these larger systems is unknown and worth investigating.

Although we focused on the downstream stretches of these tributaries, we believe we captured the entire complement of likely species. Longitudinally, species richness increases downstream largely through species additions (Evans and Noble 1979, Meyer and others 2007), although replacements also occur (Paller 1994). Moreover, species diversity in tributaries may be influenced by immigration from the receiving river (Meyer and others 2007), making the lower reaches most likely to contain the maximum number of species in the tributary.

Trout immigration from stockings in the lower Mountain Fork added to the species assemblage pool in 5 of the 10 sampled tributaries, although numbers were often less than 2 individuals. The wild trout found in two of the tributaries were assumed to be the result of spawning *in situ* (i.e., stocked fish migrating into tributaries and spawning). Curiously, wild trout have only been observed in the upmost section (including tributaries) of the lower Mountain Fork, above the dam between the mouths of

Rainbow trout. (photograph by Tyler Farling)

Beaver and Carnasaw Creeks, in spite of stocked fish residing throughout the entire 19.3 km of river. Differences in habitat (e.g., substrate composition, temperature) among these sections that would differentially affect trout reproduction are unknown.

Interannual differences in fish assemblages, including captures of trout, were likely influenced by an extreme rain event in December 2015 that caused extensive and prolonged flooding. The rain event on December 28, 2015, was the most extreme on record for the month since 1971; 164 mm of precipitation compared to 175 mm in 1971 (Oklahoma Climatological Survey 2016). This rain event resulted in the largest mean December river discharge on record (192 m^3/s) (USGS 2016b); nearly double that in December 1971 (mean = 92 m^3/s). The most notable change in Bee Branch, the only tributary sampled in both years, was a decline in relative abundance of highland stonerollers (87 percent in 2015 compared to 52 percent in 2016), which resulted in a more even fish community (ENS = 1.6 in 2015 compared to ENS = 4.1 in 2016). We speculate that scouring from the flood reduced algae in the system, leading to a reduction in stoneroller abundance, although quantification of food resources was not attempted in either year and additional studies would be required to test this as a hypothesis.

Several tributaries of the lower Mountain Fork appear suitable for trout habitation, but only two (Bee Branch and unnamed tributary to Spillway Creek) indicated supporting reproduction. Both of these tributaries were located between Broken Bow Dam and the next downstream dam; these tributaries are closest to the coldwater discharge from Broken Bow Lake, suggesting a role of water temperature and connectivity to the mainstem. The importance of these tributaries for spawning and rearing by rainbow trout to the entire lower Mountain Fork fishery is unknown, but results of this study suggest the potential for wild contribution exists.

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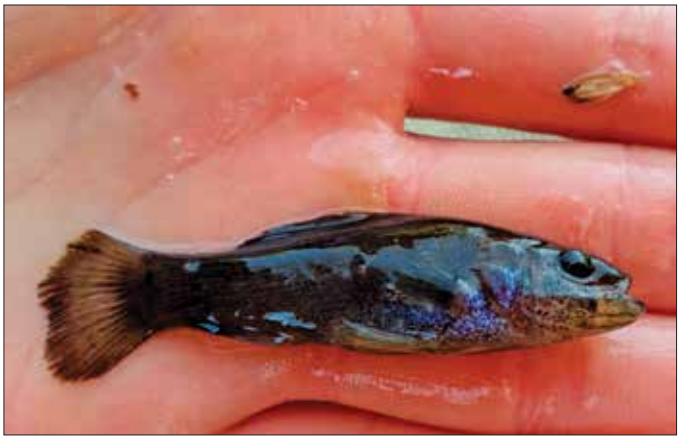

Pirate perch. (photograph by Trevor Starks)

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Stocked trout (Salmonidae) in reservoir tailwater systems in the Southern United States have been shown to use tributary streams for spawning and rearing. The lower Mountain Fork of the Little River below Broken Bow Dam is one of two year-round tailwater trout fisheries in Oklahoma, and the only one with evidence of reproduction by stocked rainbow trout (*Oncorhynchus mykiss*). Whether stocked trout use tributaries in this system for spawning is unknown. Furthermore, an inventory of the resident fish communities in these tributaries is lacking. To address these gaps, we surveyed 10 tributaries, from intermittent through third order, for fishes during presumed spawning periods of rainbow trout; we used backpack electrofishing in February and April 2015 and 2016 to determine the composition of the fish assemblages and whether trout were present. Stocked adult trout were found in three tributaries in 2015; wild juvenile rainbow trout were found in Bee Branch in 2015 and in an intermittent tributary of Spillway Creek, just above the "Cold Hole," in 2016. Fish assemblages were dominated by highland stonerollers (*Campostoma spadiceum*) in larger, wider systems and by orangebelly darters (*Etheostoma radiosum*) in smaller, narrower streams. These data fill an information gap in our understanding of small streams in the Ouachita Mountains, and they demonstrate that some streams are suitable for rainbow trout reproduction.

Keywords: Highland stoneroller, Mountain Fork River, orangebelly darter, Ouachita Mountains, rainbow trout, river continuum.

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