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Growth and mortality of Ozark bass (Ambloplites constellatus) in streams of the Ozark Highlands

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ABSTRACT

The Ozark bass (*Ambloplites constellatus*) is endemic to the Upper White River Basin, and a limited amount of information exists on the Ozark bass population, including growth and mortality characteristics. The purpose of this study was to determine growth and mortality of Ozark bass in the Upper White River Basin, compare growth of Ozark bass to other *Ambloplites* species, and compare growth and mortality of Ozark bass between sample sites. Sampling occurred in Crooked Creek and in the Lower Wilderness Area (LWA) of the Buffalo River, with multiple collections from each body of water. Sampling occurred during summer 2013 via electroshocking from a boat. Length and weight data were recorded while sampling, and fish ages were determined through otolith retrieval. Ozark bass exhibited similar growth patterns to Shadow bass (*Ambloplites ariommus*); however, Rock bass (*Ambloplites rupestris*) grew faster and larger. Growth of Ozark bass appeared to be similar between Crooked Creek and the LWA of the Buffalo River until 5 years of age. After age 5, the growth of fish collected from the LWA of the Buffalo River slowed compared to 5 and older fish collected from Crooked Creek. Ozark bass of the LWA of the Buffalo River had an overall greater mortality rate than those in Crooked Creek; however, one of two sites sampled on Crooked Creek had a comparable fish mortality rate to that measured in the LWA of the Buffalo River. Results indicated that size-selected mortality may have occurred in the LWA of the Buffalo River and at least one location sampled in Crooked Creek, possibly due to fishing mortality and angler popularity at the sites. Data collected in this study were part of a long-term attempt by the Arkansas Game and Fish Commission to gather baseline data on the Ozark bass population and to determine the efficacy of current harvest regulations for that species in the Upper White River Basin. Baseline data will be used in the future to determine whether local fish populations respond to climate change or other impacts to the watershed.

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MEET THE STUDENT-AUTHOR

Ashley Rodman

Working in Yellowstone National Park the summer after graduating from Viola High School sparked my interest in environmental issues. Becoming a charter member and president of an Arkansas Game and Fish Commission Stream Team while attending Arkansas State University-Mountain Home (ASUMH) contributed to my decision to focus my education on water quality. After receiving my Associate of Arts Degree from ASUMH, I transferred to the University of Arkansas into the Crop, Soil, and Environmental Sciences (CSES) Department to pursue a Bachelor of Science (B.S) in Environmental, Soil, and Water Science. Through the CSES Department, I have been able to compete in national competitions, become involved in the CSES Club, as well as receive college credit and research experience through an internship with the Arkansas Game and Fish Commission. I will graduate with my B.S. this summer after returning from a study abroad trip to Mozambique, Africa where I will be conducting water quality analyses to aid a local poultry operation. Soon after returning from Africa, I will begin my graduate studies in the CSES Department with Thad Scott, focusing on stream water quality.

Numerous people have given me the guidance and encouragement to allow me to be where I am today, and I am truly grateful to each and every one of them.

INTRODUCTION

Prior to 1977, the Ozark bass, Rock bass, and Shadow bass were classified as a single fish species, *Ambloplites rupestris*. In 1977, *Ambloplites rupestris* was split into three different species, and the Ozark bass was renamed *Ambloplites constellatus* (Cashner and Suttkus, 1977). Minimal published data exist on growth or other population characteristics due to the relatively recent species split and the limited range of the Ozark bass. Whisenant and Maughan (1989) have reported some of the only available information for the Ozark bass, including mean size at age. One of the objectives of the Whisenant and Maughan (1989) study was to collect baseline data for the Ozark bass to see if increased recreational pressures and angling effort had impacted the sport fisheries of the Buffalo River. The Arkansas Game and Fish Commission (AGFC) has collected electroshocking data on Ozark bass since 1992; however, to date, no age data have been collected (Stan Todd, Arkansas' District 2 Fisheries Management Biologist, pers. comm.).

Growth and mortality rates are important metrics of any fish population and are useful for comparing different fish populations and evaluating harvest regulations (Ricker, 1975). Age distribution data are collected to aid in the determination of length-at-age, which is required for the calculation of growth and mortality rates (Ricker, 1975). Length-at-age is an estimate of mean size of fish at annual increments. Sagittal otoliths have been used to determine the age of fish species due to ease of readability and accuracy compared to other aging methods (Maceina et al., 2007). Otoliths increase in size with fish size and leave dense rings during periods of slow growth. These annular rings can be used to determine fish age (Jearld, 1985).

Conductivity, pH, water temperature, and dissolved oxygen are often measured in association with electroshocking data collection. If differing growth or mortality rates occur between sampled sites, measured water quality indicators could potentially disclose reasons for conflicting results. Conductivity correlates with total dissolved solids and nutrient availability (Uwidia and Ukulu, 2013). Nutrient availability is a determining factor in fish growth (Keller et al., 1990). Temperature also impacts growth rates due to the direct relationship between temperature and chemical reaction rates (Whiteledge et al., 2006). Extreme levels of dissolved oxygen and pHs that are too acidic or too basic can cause stress to fish, causing more energy expenditure and less energy available for growth (Breitburg et al., 1997; Magnuson et al., 1984).

According to Buchanan and Robison (1988), the Ozark bass is endemic to the Upper White River Basin. However, the Upper White River Basin Foundation (UWRBF, 2012)

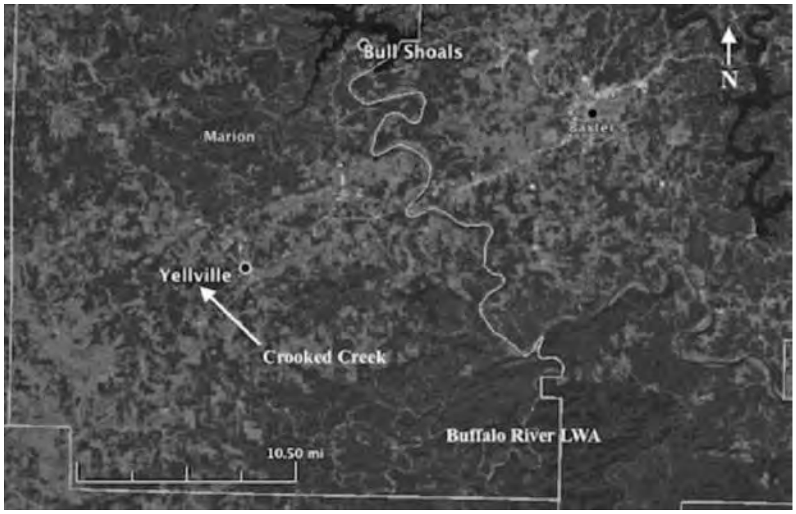

Fig. 1. Location of Crooked Creek and the Lower Wilderness Area of the Buffalo River in Marion County, Ark.

points out several concerns in the White River watershed, including the ease of groundwater contamination in the karst geology of the area, increased urbanization and alteration of watershed hydrology, and increasing confined animal feeding operations. Climate change models for the southeastern United States predict an increase in number and duration of droughts, greater mean annual temperature, as well as heavy rain events with shorter durations (USEPA, 2013). Changes in watershed hydrology, whether from increased urbanization or climate change, could potentially alter stream morphology, and therefore impact habitat of the Ozark bass and other endemic fish species.

Population data aid fisheries biologists in evaluating current regulations to ensure that overfishing does not occur. Recent limitations on harvest pertaining to other sport fishes in Ozark Highland waterways may have increased harvest of the Ozark bass in some streams. Currently, there is a creel limit of 10 fish and no size limit for Ozark bass, Rock bass, and Shadow bass combined (AGFC, 2013). Since the Ozark bass has a limited range, monitoring current population characteristics of the Ozark bass will be beneficial in evaluation of current and potential future impacts on the Ozark bass population. Therefore, the objective of this study was to determine population information and growth and mortality rates for Ozark bass in the Upper White River Basin. Growth rates were compared to that for other *Ambloplites* species and mortality rates were compared among sample locations. It was hypothesized that growth rates would be similar among *Ambloplites* species and mortality rates would be similar among sampled streams in the Ozark Highlands.

METHODS AND MATERIALS

Upper White River Basin Characteristics

The Upper White River Basin is located in southern Missouri and in north central and northwestern Arkansas over karst topography (UWRBF, 2012). Ozark bass generally inhabit stream pools that have high dissolved oxygen, continuous flow, and low turbidity (Buchanan and Robison, 1988), all of which are characteristics present in the Upper White River Basin.

The mean annual precipitation throughout northwest Arkansas is 126.6 cm (USGS, 2005; Climate Zone, 2013). The mean annual air temperature is 16.6 °C, with mean summer-month temperatures as follows: 25.8 °C in June, 27.7 °C in July, and 27.0 °C in August (USGS, 2005; Climate Zone, 2013).

Fish Collection

Ozark bass were collected by boat electroshocking in the Upper White River Basin, including in the Lower Wilderness Area (LWA) of the Buffalo River and in Crooked Creek (Fig. 1). Six runs (i.e., the length of actual shocking time between measuring fish) occurred near Middle Creek, five above Leatherwood Creek, and five below Leatherwood Creek in the LWA of the Buffalo River for a total electroshocking time of 257 minutes (Fig. 2a). In Crooked Creek, five runs occurred at both the Education Center location and at the Pyatt site for a total electroshocking time of 61 and 47 minutes, respectively (Fig. 2b).

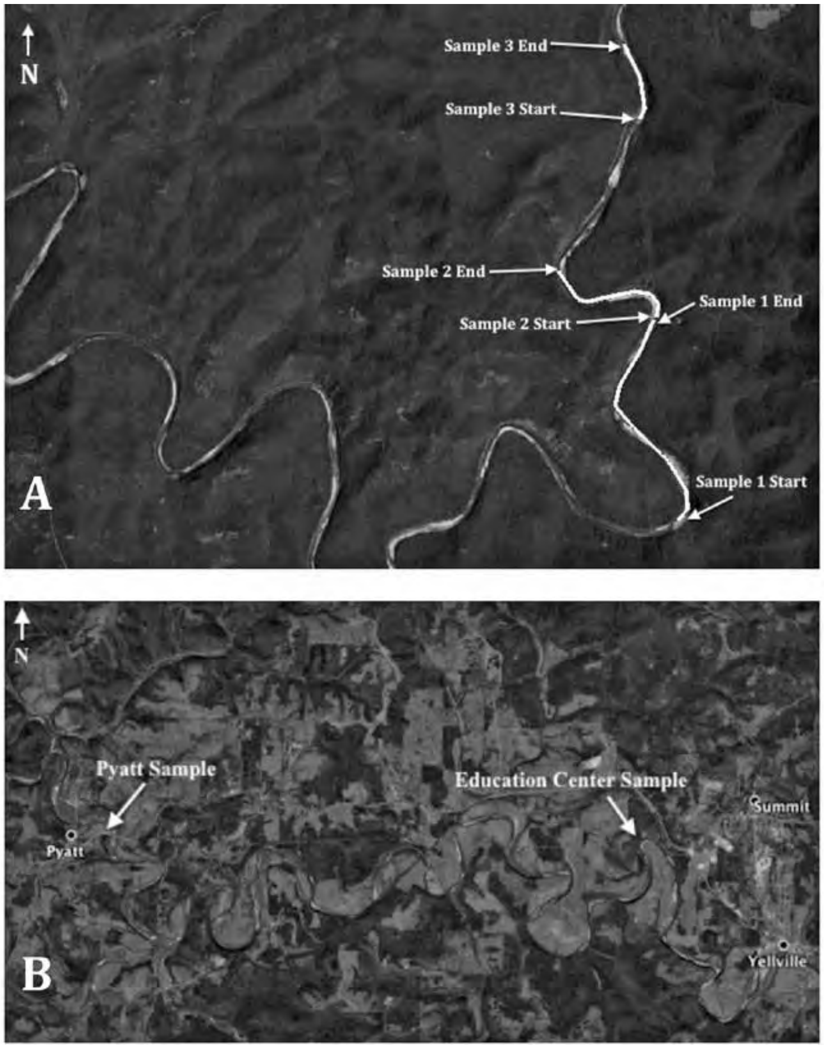

Fig. 2. Sample sites on the Lower Wilderness Area of the Buffalo River (A) and Crooked Creek from 2013 (B).

During the electroshocking process, pulsed direct current (DC) electricity was directed through the water via cathodes and anodes (Kolz et al., 2000). The cathode can either be a metal boat hull or separate electrodes used near the boat when using a fiberglass hull (Kolz et al., 2000). With DC electroshocking, the cathodes repel the fish, while the anodes attract the fish causing temporary electro-narcosis when the fish encounters the current (Kolz et al., 2000). While the fish are temporarily disoriented, they float to the surface where they can be more easily collected with nets.

Ozark bass collections took place during summer 2013 when the water flow was at a level that permitted safe sampling. The Buffalo River was sampled on June 10, 11, and 12, while Crooked Creek was sampled on June 21 and 24. Water levels had to be less than the 1.5-m (~5 ft) stage at Highway 65 in the LWA of the Buffalo River and less than the 3-m (~10 ft) stage at Kelly's Crossing on Crooked Creek for safe sampling to occur. Summer was chosen for the study because water levels are generally lower and fish are more concentrated, more active, and easily caught during the warmer months of the year.

Ozark bass sampling was conducted in pools and other deep habitat reachable by boat. Each run was conducted for approximately 10 minutes. Weights, to the nearest ±2 grams, and total lengths, to the nearest millimeter, of each fish collected were recorded in the field. Ten fish per size class, if available, were saved for otolith retrieval. Size classes ranged from 0 to 270 mm with 10-mm intervals. If the maximum of 10 fish in any given size class were collected, extra fish collected in the same size class thereafter were weighed, measured, and released. The gender of each Ozark bass collected from the Buffalo River was also recorded so that comparisons of growth rates by sex could be made. Since fish growth can be affected by water quality, a suite of water quality indicators, including pH, conductivity, water temperature, and dissolved oxygen, were measured and recorded in the field. These data were used to help explain results if there were dramatic conflicts in results or unexpected results from stream to stream.

Once fish numbers, lengths, and weights had been recorded, numerous additional calculations were made. The catch-per-unit-effort (CPUE; i.e., fish per hour) was calculated from the number of Ozark bass collected on the Buffalo River and Crooked Creek. The relative stock density (RSD) was determined by grouping fish into various size classes based on the length of the current world record fish. Since there are minimal data for Ozark bass, the RSD size classes for Rock bass were used and included Stock (≥100 mm in length), Quality (≥180 mm), Preferred (≥230 mm), Memorable (≥280 mm), and Trophy (≥330 mm). The relative weight (Wr) was also calculated to compare Ozark bass collected from the two main waterways. Relative weight is a comparison between the weight of a sampled fish compared to a standard weight generated from a standard weight equation for that species. Relative weight gives an index of condition or plumpness for the sampled fish. Relative weight was calculated using the following equation from Anderson and Gutreuter (1983):

$$W_r = \left(\frac{\text{weight of fish}}{\alpha * \text{length of fish}^{\beta}} \right) * 100 \qquad \text{Eq. 1}$$

A Shadow bass standard weight equation was used due to the unavailability of standards for Ozark bass. The parameters used were α = -5.1461 and β = 3.2110 (Mareska and Jackson, 2002). The Shadow bass are a different species of fish, and the Ozark bass may not have the exact same standards; however, Shadow bass and Ozark bass are in the same genus. Thus, the Shadow bass data were assumed sufficient as a comparison tool between the two sampled areas.

Sagittal otoliths, which are two disc-shaped bones in the heads of boney fish that are used to estimate age, were collected from the brain cavities of the Ozark bass (UAF, 2013). Although the goal for collecting otoliths was up to 10 fish per size class, in some instances, 10 fish were not possible in each size class due to a lack of availability during collection. Otoliths were transported to an AGFC laboratory for aging. Otoliths were glued to glass slides and, if needed, sectioned with a low-speed saw. Age data were recorded after microscopic observation and counting of the number of annuli present on each otolith. The population age distribution was estimated based on population length frequency and an age-length key generated from fish with known lengths and ages based on previous otolith observation (Quist et al., 2012). Growth and mortality rates were estimated from the population age distribution (Ricker, 1975). Lengths-at-age were estimated using the von Bertalanffy equation and growth rates were then calculated from those estimates. The von Bertalanffy equation is as follows:

$$L_t = L_{\infty}\left[1 - e^{-k(t-t_o)}\right] \qquad \text{Eq. 2}$$

where L_t is the length at a certain age, L_{∞} is the longest length that fish in the population will ever attain, k is a growth constant, t_o is the hypothetical age of the fish at a length of 0, and t is the age of the fish (Pine et al., 1983). Mortality rates for the LWA of the Buffalo River and Crooked Creek were calculated using the Chapman-Robson method (Robson and Chapman, 1961).

Data Analyses

Mortality rates were compared with similar data from different locations and growth rates were compared among species. A Student's t-test was performed using Microsoft Excel to evaluate whether the slope of the relationship between the log-transformed lengths and weights for the Ozark bass differed between locations (i.e., Buffalo River and Crooked Creek). A Student's t-test was also performed to evaluate the effect of sample location (i.e., Buffalo River and Crooked Creek, combined across the two locations and separately by location) on calculated mortality rates in each age category. The threshold at which significance was judged was α = 0.05.

RESULTS AND DISCUSSION

Ozark bass were present in both Ozark Highland waterways sampled. One hundred and thirty-nine Ozark bass were collected in the LWA of the Buffalo River, 57 near Middle Creek, 45 above Leatherwood Creek, and 37 below Leatherwood Creek. A total of 188 Ozark bass were collected in Crooked Creek, 86 at the Education Center site and 102 at the Pyatt site.

Mean CPUE of Ozark bass in the Buffalo River was 31.2 fish per hour, with the 95% confidence interval of 26.3 to 36.2 fish per hour (Fig. 3). The shortest fish collected from the Buffalo River was 61 mm long, while the longest fish was 256 mm long. There was a noticeable decline in the number of fish from the Buffalo River caught per hour over 220 mm long, with no fish collected in the 240-mm to 249-mm size class.

The mean CPUE of Ozark bass in Crooked Creek was 101.5 fish per hour (Fig. 3). The 95% confidence interval

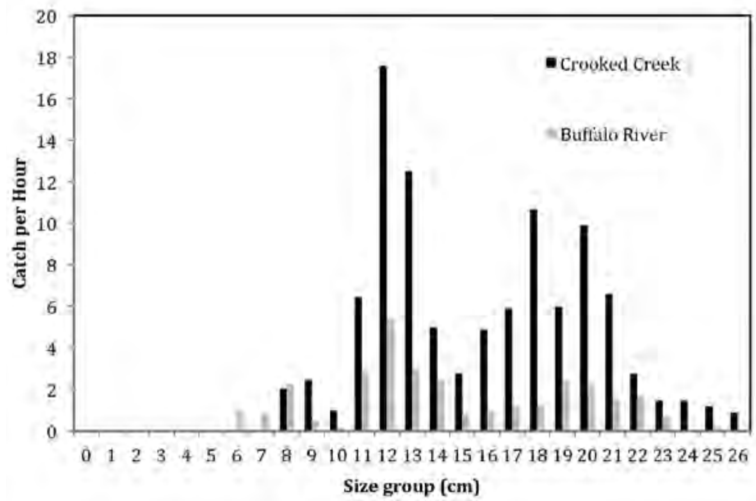

Fig. 3. Catch-per-unit-effort (CPUE, catch per hour) per size group of Ozark bass for the Lower Wilderness Area of the Buffalo River and Crooked Creek, June 2013.

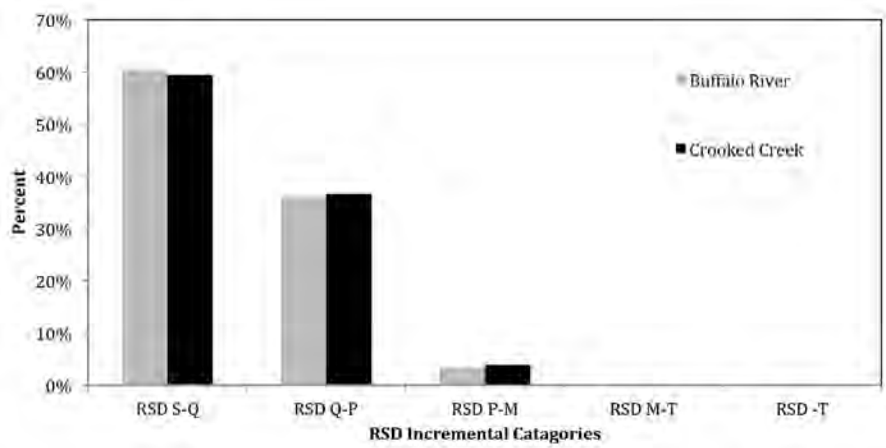

Fig. 4. Relative stock density (RSD) for Ozark bass in the Lower Wilderness Area of the Buffalo River and Crooked Creek, June 2013. S-Q = 100-179 mm, Q-P = 180-229 mm, P-M = -230-279 mm, M-T = 280-329 mm, T = ≥330 mm.

for the population's mean was 71.9 to 131.1 fish per hour. Sizes of fish collected from Crooked Creek ranged from a minimum of 88 mm to a maximum of 260 mm long. There was also a decrease in the number of fish caught per hour above 210 mm long in Crooked Creek. Figure 3 clearly depicts that there was a greater number of fish caught per hour from Crooked Creek than the Buffalo River. Since CPUE is directly related to density, there was also a greater density of fish in Crooked Creek than in the Buffalo River.

The relative stock density (RSD; Fig. 4) offers a different way to represent the size distribution of the Ozark bass that were collected than simply the length of fish collected. Fish under Stock size (<100 mm long) were not included in Fig. 4 because those fish were not significant when considering the impacts of angling pressure on the Ozark bass population. The mean length of Ozark bass greater than Stock size collected from the LWA of the Buffalo River was 164 mm, with a 95% confidence interval of 156 mm to 171 mm. The minimum length of fish greater than Stock size was 107 mm, while the maximum length over Stock size was 256 mm. The mean length of Ozark bass in Crooked Creek that were greater than Stock size was 164 mm, with a 95% confidence interval of 158 mm to 169 mm. The smallest-sized fish greater than Stock size was 103 mm long, while the largest fish was 260 mm long in Crooked Creek.

According to Fig. 4 and Table 1, the percentage of fish present in each size category decreased with increasing size category in the Buffalo River and Crooked Creek. The RSD graph depicts that there is a similar size dis-

Table 1. Relative stock density (RSD) for the Buffalo River and Crooked Creek.

	Buffalo River		Crooked Creek	
RSD Size Category	Relative Abundance (%)	95% Confidence Interval (%)	Relative Abundance (%)	95% Confidence Interval (%)
Stock size (< 100 mm)	14.4	13.9 to 14.9	4.3	4.0 to 4.5
Stock to Quality (100 mm to 179 mm)	60.5	59.7 to 61.3	59.4	58.9 to 60.0
Quality to Preferred (180 mm to 229 mm)	36.1	35.3 to 36.9	36.7	36.1 to 37.2
Preferred to Memorable (230 mm to 279 mm)	3.4	3.1 to 3.7	3.9	3.7 to 4.1
Memorable to Trophy (280 mm to 329 mm)	-[a]	-	-	-
Trophy (≥330 mm)	-	-	-	-

[a] No fish collected in size class.

Table 2. Growth data for Ozark bass in the Buffalo River and in Crooked Creek.

	Water Body/Growth Parameter					
	Buffalo River			Crooked Creek		
Fish Age (years)	Mean Length	Variance	Number of Fish	Mean Length	Variance	Number of Fish
1	76.3	109	21	83.6	14.8	5
2	130	189	46	128	156	40
3	183	117	20	173	81.9	32
4	207	117	9	195	76.7	8
5	216	81.3	16	205	60.3	23
6	214	443	3	206	124	3
7	208	-[a]	1	230	113	2
8	-	-	0	238	32	2
9	258	-	1	253	40.5	2

[a] No data.

tribution of fish between the Buffalo River and Crooked Creek (Fig. 4).

Differential growth patterns between sexes have been observed in some fish, such as long-eared sunfish (*Lepomis megalotis*) present in the Buffalo River (S. Todd, pers. comm.). However, both genders of Ozark bass appeared to grow at a similar rate (data not shown); thus, the subsequent results for fish size characteristics are combined across genders. As the length of Ozark bass increased, the weight of Ozark bass increased logarithmically. Since there was a similar logarithmic relationship between the weight and length of Ozark bass from both the Buffalo River and Crooked Creek, all data were combined to determine a single weight-length relationship for Ozark bass in Ozark Highland waterways. In this study, 99% of the variability in length of Ozark bass was explained by weight variations.

The mean relative weight (Wr) of Ozark bass in the Buffalo River was 85, with a variance of 36.0. Crooked Creek's relative weight was 92, with a variance of 50.4. The minimum relative weight of Ozark bass in the Buffalo River was 70, with a maximum of 100. The minimum relative weight of Ozark bass in Crooked Creek was 72, with a maximum of 114.

Based on the relative weight results, Ozark bass in Crooked Creek appeared to be in slightly better condition than those in the Buffalo River. This would suggest that food availability was greater in Crooked Creek than in Buffalo River, which may partially explain the greater density of Ozark bass in Crooked Creek than in the Buffalo River.

Otoliths were retrieved and aged from 117 Ozark bass from the Buffalo River and from 127 Ozark bass from Crooked Creek. From the age data collected, an age-length key was derived, which allowed for the calculation of the age of sampled fish that were not kept for otolith retrieval. Then, the lengths of fish in each individual age category were averaged. Table 2 summarizes the mean length, variance, and number of fish in each age category from both streams sampled in this study. Comparing our

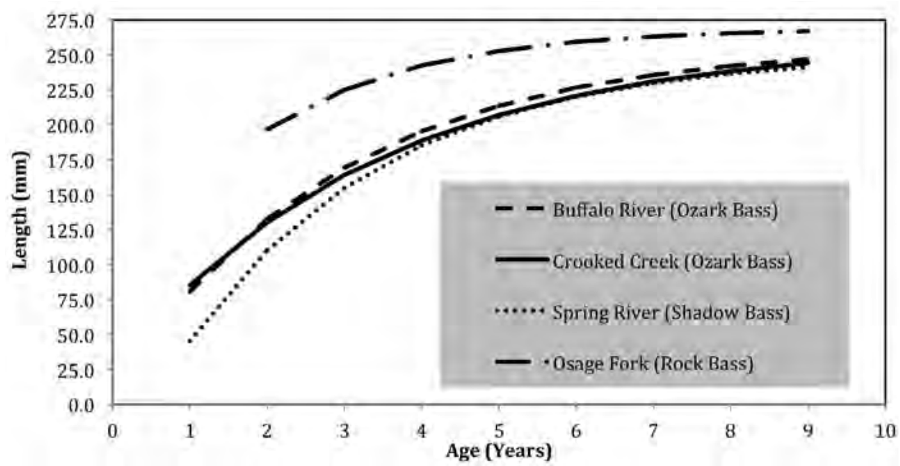

Fig. 5. von Bertalanffy growth curves for Ambloplites sp. (i.e., Ozark bass, Shadow bass, and Rock bass) in the Buffalo River, Crooked Creek, Osage Fork, and the Spring River.

results to data from Whisenant and Maughan (1989), their length data appear to be classified under the wrong age classes. For example, if all of length data from the Whisenant and Maughan (1989) study were shifted one age class older, then both data sets would show similar growth among Ozark bass. Fish scales were used to determine age of Ozark bass reported in Whisenant and Maughan (1989), which could be the reason for a potentially inaccurate age classification. The number of Ozark bass collected in the Whisenant and Maughan (1989) study was drastically greater (n = 1090 in 1980 sampling) than that collected in this study. Therefore, it appears that there were fewer Ozark bass in the Buffalo River in 2013 than in the early 1980s. The National Park Service has reported that the number of visitors to the Buffalo River has doubled since the early 1980s (unpublished data, S. Todd, pers. comm.) when the Whisenant and Maughan (1989) study was conducted. This observation suggests that increased visitation to the Buffalo River may have led to a decrease in the number of Ozark bass in the river.

The length-at-age data for both sampled water bodies depicted similar trends (Fig. 5). The terms in the von Bertalanffy equation for the Buffalo River were 258 mm for maximum attainable length (L_∞), 0.346 for the growth constant (k), and -0.087 for the length-at-age 0 (t_o). The terms in the equation for Crooked Creek were 260 mm for maximum attainable length (L_∞), 0.299 for the growth rate (k), and -0.328 for the length at zero 0 (t_o). Figure 5 portrays that as the age of Ozark bass increased, the growth rates slowed and became more similar in both sample waterways; therefore, growth rates between Crooked Creek and Buffalo River sample sites were comparable.

Growth data for Rock bass collected from Osage Fork by the Missouri Department of Conservation and for Shadow bass collected from the Spring River by the AGFC were compiled and presented in Fig. 5 to compare growth among species (Johnson et al., 2010; unpublished data). Shadow bass were depicted as initially growing slower; however this might have been due to errors in measurement of small fish or time of year fish were collected. As age increased, the growth rate of Shadow bass became more analogous to that of Ozark bass. Rock bass, however, grew faster and larger than both Ozark bass and Shadow bass (Fig. 5).

The growth models for the Buffalo River and Crooked Creek indicated that growth rates for Ozark bass were similar between water bodies; however, Ozark bass in the Buffalo River initially grew faster than those in Crooked Creek (Table 3). Growth rates slowed in both water bodies at approximately age 5; and the growth rate of Crooked Creek fish slightly surpassed that of the Buffalo River fish after age 5. Size-selective mortality (i.e., angling) might have been a factor in the slower growth rate estimates of the older fish in the Buffalo River, as anglers tend to keep the faster growing, better conditioned fish, leaving only the slower growing fish in the larger sizes. Growth rates between the Pyatt and Education Center sampling sites on Crooked Creek were also compared, and, like the growth rates estimated for Ozark bass in Crooked Creek and in the Buffalo River, the estimated growth rates for Ozark bass were similar between the two Crooked Creek sample sites. In addition, water quality indicators measured in the Buffalo River and Crooked Creek were similar between locations.

Mortality rates were calculated for three different age categories: 2 to 9 year olds, 2 to 5 year olds, and 5 to 9 year olds. The population was divided into different age groups due

Table 3. Length-at-age and growth rates for Ozark bass in the Buffalo River and in the combined Crooked Creek sample sites for 2012-2013.

Fish Age (Years)	Buffalo River Length-at-age (mm)	Buffalo River Growth Rate (mm/year)	Crooked Creek Length-at-age (mm)	Crooked Creek Growth Rate (mm/year)
1	80.8	51.8	86.2	44.1
2	132.6	36.7	130.3	32.9
3	169.3	25.9	163.2	24.6
4	195.2	18.4	187.8	18.3
5	213.6	13	206.1	13.7
6	226.6	9.2	219.8	10.2
7	235.8	6.5	230.0	7.6
8	242.3	4.6	237.6	5.7
9	246.9	-[a]	243.3	-

[a] No data.

to the Buffalo River's length-at-age relationship indicating a deviation from the von Bertalanffy growth model after age 5. One-year-old fish were not included in the calculations since fish younger than age 2 were not fully recruited to the sampling gear, and therefore their numbers were probably underestimated. Table 4 shows the mortality rate, variance, and number of fish sampled for each age category at both sampled areas. The two sampling sites on Crooked Creek were further broken down to show individual site mortality rates because there were differences in size distribution at the two sampling sites. More and larger fish were collected at the Pyatt site, implying that there was a greater mortality rate at the Education Center site on Crooked Creek. It was suspected that the Education Center site on Crooked Creek had greater angling pressure than at the Pyatt site.

There was a significant difference between mortality rates in all age categories on the Buffalo River and Crooked Creek, between the Pyatt site and Education Center site on Crooked Creek, and between the Buffalo River and the Pyatt site. Comparison between the Buffalo River and the Education Center site on Crooked Creek revealed no difference in mortality rate of Ozark bass in the 2 to 5 year old age category. A significant difference existed in the other age categories when comparing the Buffalo River and the Education Center site on Crooked Creek.

The lowest overall mortality rate of Ozark bass observed among the sampled areas was at the Pyatt sample site on Crooked Creek. The Education Center site on Crooked Creek had the greatest mortality rate, except when comparing the site's 2 to 5 year old age category to that from the Buffalo River. The Buffalo River's mortality rate was intermediate between that estimated at the Education Center and the Pyatt sites on Crooked Creek, except in the 2 to 5 year old age category when compared to that at the Education Center site. The mortality rates for the Buffalo River and the Education Center site on Crooked Creek in the 2 to 5 year old age category did not differ. Mortality rates were greater at all sites in the >5 year old age category compared to the other age categories.

Total mortality is made up of fishing mortality (e.g., anglers harvesting fish and fish death due to hooking) and natural mortality (e.g., predators, disease, and water quality issues). A possible reason for low mortality at the Pyatt sample site on Crooked Creek was less total mortality than at the other sampled areas, which could be due to lower angling pressure. Greater mortality at the Education Center site on Crooked Creek might have been due to greater levels of fishing mortality (e.g., angling pressure) due to the ease of accessibility and popularity of the site among anglers. Increased mortality in the >5 year old age category at all sampled areas indicated that anglers are harvesting larger, better conditioned fish. There has been a two-fold increase in visitors to the Buffalo River since 1980, and the number of Ozark bass has likely decreased since the Whisenant and Maughan (1989) study. Hence, angling pressure is likely responsibility for the elevated mortality of the >5 year old fish. Since little data have been collected to know for certain that anglers are the main cause for differing mortalities between streams and increased mortality in the >5 year old age category, creel surveys are planned for the Buffalo River and possibly for Crooked Creek in the near future to assess angler impacts to the fisheries. The creel surveys will gather data about the number of anglers utilizing the water bodies and other valuable data when considering angling pressures.

In this study, the growth of Ozark bass were compared to existing data for Shadow bass and Rock bass and mortality rates were compared between sampled sites on the Buffalo River and on Crooked Creek. Data collected in

Table 4. Mortality rates, variance and number of fish for Ozark bass sampled in the Lower Wilderness Area of the Buffalo River, in Crooked Creek combined across sample locations, and in each Crooked Creek sample location.

Water Body/Age Range (Years)	Mortality (%)	Variance	Number of Fish
Buffalo River			
2 to 9	49.3	0.001	119
2 to 5	47.0	0.003	111
5 to 9	65.0	0.007	23
Crooked Creek (sample sites combined)			
2 to 9	45.8	0.001	184
2 to 5	41.0	0.002	172
5 to 9	60.6	0.003	43
Crooked Creek at Education Center site			
2 to 9	51.7	0.002	80
2 to 5	47.0	0.004	78
5 to 9	77.1	0.008	18
Crooked Creek at Pyatt site			
2 to 9	39.6	0.001	79
2 to 5	23.0	0.007	72
5 to 9	57.0	0.008	19

Notes: There was a significant difference between mortality rates in all age categories on the Buffalo River and Crooked Creek, between the Pyatt site and Education Center site on Crooked Creek, and between the Buffalo River and the Pyatt site. The Buffalo River and Education Center site on Crooked Creek had a significant difference in the 2 to 9 age range as well as the 5 to 9 range.

this study were part of a long-term attempt by the AGFC to gather baseline data on the Ozark bass population and to determine the efficacy of current harvest regulations for that species in the Upper White River Basin. Baseline data will be used in the future to determine whether local fish populations respond to climate change or other impacts to the watershed.

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