Fishing Effort and Harvest of Smallmouth Bass in a Small Arkansas Ozark Stream

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Abstract: Stream fishing for black bass (*Micropterus* spp.) is a popular outdoor recreational activity in northern Arkansas. After construction of a new access area on Crooked Creek, Arkansas in 2017, anglers expressed concerns about increased fishing pressure and possible overharvest of smallmouth bass (*Micropterus dolomieu*). In 2019, we conducted a creel survey (60 sample days over six months) at five public accesses, including the new access, on a 35-km section of Crooked Creek. We also tagged 195 fish in an associated one-year exploitation study to address requests for stricter regulations and mandatory catch and release for smallmouth bass. Estimates of fishing pressure (20,521 h) and smallmouth bass catch rates (1.13 fish h^{-1}) were both high. We saw high tag reporting rates (61%) during the first two months of the exploitation study. Smallmouth bass harvest was negligible, but the results of this study indicated that anglers caught smallmouth bass multiple times per year; thus, fishing-related mortality may still affect the population. Because low harvest rates limit the ability of regulations to improve fisheries, removing two special regulation areas currently managed with more restrictive regulations may be justified for Crooked Creek. Future research looking at the effects of multiple catch-and-release events on a large portion of the population in a small stream may prove helpful in managing these fisheries.

Key words: *Micropterus*, creel, tagging, exploitation rate, angler

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Recreational fishing is both popular and economically important in Arkansas, with an estimated 368,183 days spent fishing by licensed Arkansas resident anglers in 2016 and an estimated investment of US$3.26 billion in fishing equipment by these anglers (Hunt and Westlake 2018). The smallmouth bass (*Micropterus dolomieu*) is one of the state's most sought-after stream sport fish. Besides being ecologically and recreationally important, the smallmouth bass serves as an excellent indicator of stream health, as it is typically intolerant to high turbidity, high water temperatures, and environmental alterations (Hlass et al. 1998, Port et al. 2021). Smallmouth bass inhabit clear streams and deep reservoirs of the Ozarks and Ouachita highlands within Arkansas, near the southern extent of their native distribution in the United States (Robison and Buchanan 2019). The unique physical characteristics and water chemistry found in many Ozark Highlands streams often support high abundances of smallmouth bass (Dauwalter and Fisher 2008, Sterling et al. 2019). These stream populations are significant to anglers; in 2017, Arkansas resident black bass (*Micropterus* spp.) anglers fished an average of 4.9 days per angler per year on streams, compared to 13.6 days on reservoirs (Hunt and Westlake 2019).

Fisheries managers use regulations to manipulate or protect fish populations and distribute the resource among anglers. For example, a 356-mm minimum-length limit (MLL) was implemented for the southern two-thirds of Wisconsin in 1989. Five of six regulated streams showed significantly increased smallmouth bass abundance and improved size structure, while no such changes were observed in an Illinois reference stream with no length limits (Lyons et al. 1996). In Pallette Lake, Wisconsin, fishing effort increased 62%, annual harvest of smallmouth bass declined 95%, and smallmouth bass 305–406 mm increased after implementation of a 406-mm MLL and a two-fish daily bag limit (Newman and Hoff 2000). In another study, smallmouth bass in five Missouri Ozark streams did not reach sexual maturity until age 4 (265–312 mm TL), thus making them more vulnerable to overfishing (Sterling et al. 2019). As a result, smallmouth bass size structure and angler yield in Ozark Mountain streams in Missouri improved with more restrictive length limits. Yet, the ability of managers to influence smallmouth bass through such regulations decreased as voluntary release of black bass increased dramatically throughout the United States in the late 1980s and early 1990s (Myers et al. 2008). When fishing mortality is substantially below natural mortality, regulations may have little to no impact on the fishery (Gaeta et al. 2013, Hessenauer et al. 2018, Sass and Shaw 2020).

The Arkansas Game and Fish Commission (AGFC) uses a statewide smallmouth bass management plan to manage Arkansas stream smallmouth bass fisheries to provide high-quality fishing opportunities, increase public satisfaction, and conserve Arkansas'

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unique resources (Port et al. 2021). In 1992, the AGFC adopted the Ozark Zone Blue Ribbon Stream designation to protect and promote streams and rivers with a high smallmouth bass density (>400 fish km^{-1}) and fast growth (between 308–356 mm TL in 4–5 years). The AGFC manages these streams with a daily limit of two smallmouth bass and a 356-mm MLL. Streams outside this designation have a 254-mm or 305-mm MLL and a four-fish daily limit.

Crooked Creek in north central Arkansas is recognized as an excellent smallmouth bass fishery and was designated as an Ozark Zone Blue Ribbon Stream in 1992. Before this designation, Crooked Creek had a daily limit of six smallmouth bass with a 254-mm MLL. During the same period, anglers expressed concerns about increased angling pressure, excessive harvest, and impacts from in-stream gravel mining. Thus, the AGFC conducted population and creel studies on Crooked Creek in response to these concerns and in 2001 implemented two special regulation areas (457-mm MLL and a daily limit of one smallmouth bass) and a catch-and-release-only area (Figure 1; Wagner et al. 1996). Quinn et al. (2011) evaluated these regulation changes over a 23-year period (1986–2009), finding that the Blue Ribbon Stream regulations were associated with increased size structure, angler catch rates, and population biomass of smallmouth bass and lower annual mortality and exploitation. However, they did not find noticeable improvements in stock descriptors for the two special regulation areas or the catch-and-release area compared to the segments under the Blue Ribbon Stream regulations.

Angler concerns about smallmouth bass overharvest and excess fishing pressure on Crooked Creek resurfaced in 2017 when a new AGFC access area split a 19-km section of Crooked Creek into more manageable floats (Figure 1). As a result, anglers requested more restrictive regulations be implemented, but previous research on smallmouth bass harvest in similar Ozark streams suggested a high voluntary release ethic likely exists in these streams (Williamson et al. 2015; AGFC, unpublished data). Therefore, the objective of this study was to estimate fishing pressure and harvest of smallmouth bass on Crooked Creek in northern Arkansas. With a better understanding of harvest and fishing pressure on Crooked Creek, we can evaluate current regulations and build upon existing information in the Ozark Highlands to help ensure quality, sustainable smallmouth bass fisheries.

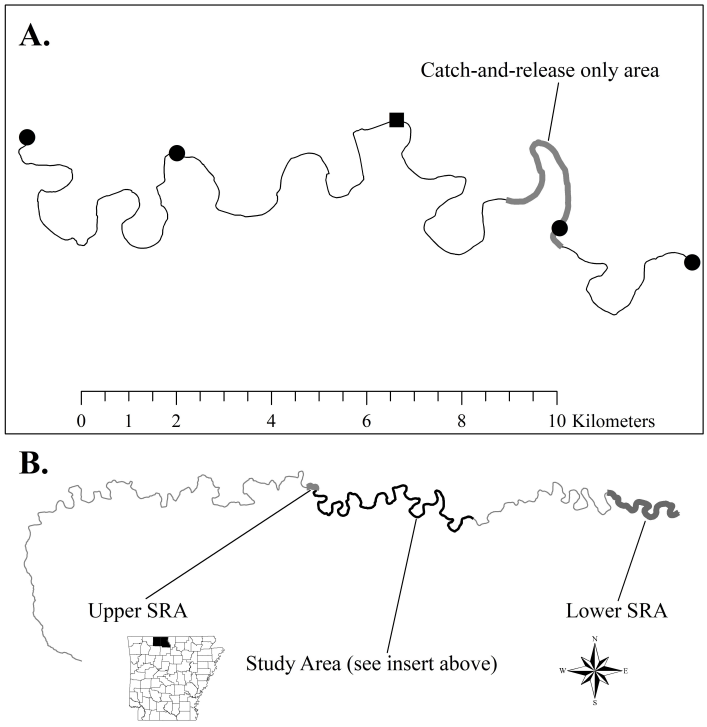

Figure 1. Map showing the 35-km study area and adjacent sections of Crooked Creek, Arkansas. A) The study area with five public accesses and the 4.4-km catch-and-release area are shown; square denotes the access area created in 2017. B) The upper (1.2 km) and the lower (11 km) special regulation areas (SRA) are shown above and below the study area. The special regulations for these areas are a 457-mm minimum-length limit and a daily limit of one smallmouth bass.

Study Area

Originating in the Springfield Plateau, Crooked Creek is a small, spring-fed tributary of the White River that flows easterly for approximately 142 km through the Ozark Highlands ecoregion in Arkansas (Figure 1). This fifth-order stream has a total watershed area of 1197 km^2 and a daily discharge range of 0.6–1011 m^3 sec^{-1} (U.S. Geological Survey Gauge 07055607). Due to unique hydrology and geomorphology, intergravel flows can begin at approximately 40 km from the White River; the stream re-emerges around 16 km from the White River during much of the dry season (July–October; Daly et al. 2002, Quinn et al. 2011).

Crooked Creek is a popular recreational area for floaters and anglers during the spring and summer. Although much of the property along Crooked Creek is privately owned, the public has a right to use the water through a prescriptive easement (State v. Sharp, case number E 97-229-1, Marion County Chancery Court, 8 June 1999). Our study was restricted to the 35.4-km section from Pyatt to Yellville, Arkansas, which has five public accesses (Figure 1), as public access to Crooked Creek above and below this section is limited. In addition, just below this section of Crooked Creek is unusable during the dry season due to the intergravel flow.

Methods

Angler Interviews

An access-point creel survey was conducted from March to August 2019 at the five public access areas on Crooked Creek. The access-point design incorporated a two-stage stratified random

sampling component (Pollock et al. 1994). Sixty total creel days (ten per month) were conducted during spring (March, April, May) and summer (June, July, August) with equal numbers of weekdays and weekends/federal holidays. We excluded fall and winter months from the survey due to low utilization based on trail camera pressure counts conducted the year before and results from Wagner et al. (1996). The access location and starting time (AM, PM) for each creel day were randomly selected based on weighted probabilities determined from pre-creel camera pressure counts. During each 6-h shift, creel clerks interviewed one angler per party who had been fishing for at least 30 min. In addition, clerks collected catch and harvest information (e.g., species and number), including the number of smallmouth bass ≥356 mm and ≥457 mm caught; all harvested fish were measured (TL, mm).

Angler Counts

Angler counts were made using time-lapse trail cameras (Day 6 Outdoors® Plotwatcher Pro HD, Model: TLC-200-C, Columbus, Georgia) on Crooked Creek. A single camera was placed at or just below each of the five public accesses. Each camera was programmed to collect an image every 10 sec during daylight hours. Photographs were stratified by day type (weekday and weekend/holidays) and season (spring and summer). During every weekend day and even-numbered weekdays, progressive angler counts (individuals possessing visible fishing gear in their hand or boat) were conducted using the digital images collected at each access. Anglers were categorized by angling type (bank/wade and boat). Bank/wade anglers included those fishing from shore or wading, whereas boat anglers fished from a canoe, flat-bottom, kayak, raft, or tube. Only boat anglers launching at an access were counted to ensure that double-counting of boat anglers did not occur.

Angling Effort and Catch

Angler counts from the camera data were expanded to estimate fishing pressure for the six-month creel period and variance of estimates (Pollock et al. 1994, Malvestuto 1996). Fishing pressure was calculated by multiplying angler counts by the average length of a completed fishing trip calculated from access-point interview data and reported as angling hours (h). We calculated average trip length separately for each angling type. In some cases, average trip lengths for specific angler types could not be estimated because no interviews occurred within a particular access/section, season, or day type. Therefore, average trip length for the same angling type from a comparable season, day type, and access/section was used. The number of fishing trips on Crooked Creek was estimated by dividing total angling pressure by the mean fishing time for completed trips (Malvestuto 1996). Catch and harvest rates were calculated from completed trip data using the ratio-of-means estimator (Pollock et al. 1994, Malvestuto 1996).

Exploitation Study

We conducted a one-year exploitation study, starting 1 June 2019, to estimate exploitation rate of smallmouth bass exceeding the 356-mm MLL. A total of 195 smallmouth bass were collected via daytime electrofishing in the same 35-km section as the concurrent creel survey and were measured (TL, mm) and tagged with brightly colored 81-mm Hallprint® nylon PDS dart tags just below the dorsal fin. These tags were imprinted with "AR GAME&FISH," a three-digit number, and a telephone number for AGFC. A combination of 98 low-reward (US$10) and 52 high-reward ($100) values were used to elicit maximum tag returns from anglers to estimate reporting rates (Meyer et al. 2012). We alternated between the two values during the tagging process to ensure equal spatial coverage of both rewards. The low-reward tags were yellow and printed with "REWARD," whereas the high-reward tags were red and labeled "$100 REWARD." Additionally, 45 smallmouth bass were double-tagged with low and high reward tags (combined $110) to estimate tag loss. For analyses, the double-tagged fish were combined with high-reward fish. Signage with information about the study was posted at the AGFC accesses, a local tackle shop, and canoe rental and shuttle services, and distributed through social, broadcast, and print media outlets to inform anglers and encourage reporting. We asked anglers who reported tags if they harvested the fish, the date, and where they caught the tagged smallmouth bass.

The estimate of the annual exploitation rate (u) was obtained by correcting for tag loss, tagging mortality, and angling reporting rates following Ricker (1975):

$$u = \frac{N_r}{[N_0(1-t)(1-m)(\lambda)]}$$

where N_r is number of tagged fish harvested, N_0 is number of tagged fish, t is proportion tag loss, m is tag-associated mortality rate, and λ is tag reporting rate. We estimated tag loss from the percentage of the double-tagged fish reported caught with only one tag. We assumed tag-associated mortality to be zero, and reporting rate of high-reward tags and double-tags was assumed to be 100% (Meyer et al. 2012). The tag reporting rate of the low-reward tags (λ) was calculated following Pollock et al. (2002):

$$\lambda = \frac{R_t/N_t}{R_r/N_r}$$

where R_t is number of low-reward tags reported by anglers, N_t is total number of low-reward tags used, R_r is number of high-reward tags reported by anglers, and N_r is number of high-reward

tags used. Upper and lower binomial confidence intervals (CI) were calculated using the Wilson Score Interval for all exploitation estimates (Agresti and Coull 1998).

Results

Angling Effort and Catch

A total of 219 angling parties representing 448 anglers were interviewed during 60 creel days over six months. Anglers spent 20,521 h (580 h km^{-1}; Relative Standard Error [RSE] = 7) angling on Crooked Creek during an estimated 4809 angling trips on the 35-km reach of Crooked Creek during the six-month creel study. The angling pressure was higher in the summer (13,936 h; RSE = 7) compared to spring (6601 h; RSE = 12), whereas pressure was similar among weekdays (10,493 h; RSE = 8) and weekends (10,444 h; RSE = 9).

Most angling parties (155; 71%) were fishing for smallmouth bass on Crooked Creek. The smallmouth bass directed catch rate was 1.13 fish h^{-1} (Table 1). The catch rate for smallmouth bass ≥356 mm and ≥457 mm was 0.17 and 0.02 fish h^{-1}, respectively (Table 1). No anglers encountered during this creel survey were observed harvesting smallmouth bass.

Exploitation Study

During 19.2 h of electrofishing, we tagged 195 smallmouth bass from 353–482 mm TL (mean = 391 mm; SE = 2; Figure 2). Three of the 21 double-tagged fish reported by anglers lost one tag; thus, we estimated tag loss to be 14%. The unadjusted return percentage for both the low-reward (n = 44) and high-reward tags (n = 44) was ~45%; thus, the low-reward reporting rate (λ) was 0.99. During the concurrent access point creel survey, the return rate of observed tags (3 of 3 fish) was similar to the reporting rate during the exploitation study.

Anglers caught 54 (61%) of the reported tagged fish within the first two months. The median number of days for a tagged smallmouth bass to be caught was 28 days and ranged from 1 to 365 days. Anglers reported harvesting eight smallmouth bass ranging from 356 to 469 mm (mean = 403 mm; SE = 15), conferring an exploitation rate estimate of 0.05 (95% CI = 0.02–0.08) during the 12-month study (Table 2).

Anglers reported catching tagged fish within an average of 0.7-km downstream of the initial tagging location. There was some movement of tagged smallmouth in and out of the catch-and-release area. Three tagged smallmouth bass moved out of the catch-and-release area and were caught then released, while two caught tagged fish had moved into the area. Only one angler reported catching a tagged smallmouth bass outside the 35.4-km study area.

Table 1. Directed catch rate (fish h^{-1}) estimates for smallmouth bass by size category for Crooked Creek, Arkansas, March to August 2019 (60 creel days). Estimates are given for all survey days (overall) and by angler type, day type, and season (spring: March–May; summer: June–August). We observed no smallmouth bass harvested during the creel.

		Angler Type		Day Type		Season	
Size	Overall	Boat	Wade/Bank	Weekday	Weekend	Spring	Summer
All	1.13	1.14	1.09	1.52	1.04	0.96	1.20
≥356 mm	0.17	0.14	0.31	0.20	0.16	0.15	0.18
≥457 mm	0.02	0.02	0.01	0.01	0.02	0.02	0.02

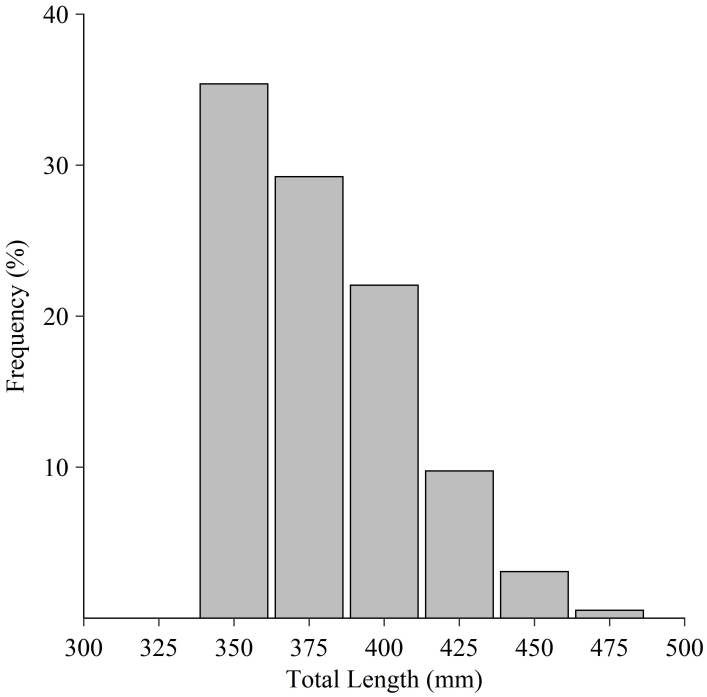

Figure 2. Length-frequency histogram for smallmouth bass tagged (n = 195) for the exploitation study on Crooked Creek, Arkansas, 2019.

Table 2. The number of smallmouth bass tagged (n) with each reward type (Low-$10; High-$100) as well as adjusted number tagged after factoring tag loss (T), number returned (R), reporting rate (λ), number kept (harvested), exploitation rate (u), and binomial CI for u for Crooked Creek, Arkansas, from 1 June 2019 to 15 June 2020. Tag loss was estimated to be 14%. Tagging mortality was presumed to be zero.

Tag Type	n	T	R	λ	Kept	u	95% CI
Low	98	83	44	0.99	5	0.06	0.02–0.11
High	97	83	44	1.00	3	0.04	0.01–0.09
Total	195	166	88		8	0.05	0.02–0.08

Discussion

Our study found high fishing pressure for this moderate-sized stream, but exploitation of smallmouth bass was negligible. High voluntary release of smallmouth bass caught by anglers is causing Crooked Creek to function like a catch-and-release fishery, thus

limiting the effectiveness of the current harvest regulations. Therefore, implementing more restrictive harvest regulations, such as the ones used in the special regulation or catch-and-release areas, would not improve or further protect the smallmouth bass fishery on Crooked Creek (Allen et al. 2008).

The notoriety of the smallmouth bass fishery, combined with being a moderately sized stream, has caused anglers to be concerned with angling pressure on Crooked Creek since the 1980s. High reporting and return rates of tags during the exploitation study confirm significant fishing pressure. However, although angling pressure was high, angling pressure and smallmouth bass harvest have declined from what was observed during a 1990s Crooked Creek creel survey (Wagner et al. 1996).

The new access site has been popular with the public and concessioners offering float trips. A small vocal group of anglers believed this would have caused angler effort to increase; however, the results suggest the opposite occurred. We speculate that increased access has resulted in higher use by recreationists. During the 2019 creel survey, 72% of the users were not fishing. Unfortunately, biologists did not determine the percentage of recreationists during the 1990s creel, so we could not assess whether changes in use had occurred over the 30 years. We hypothesize that the number of recreationists has increased due to efforts by the AGFC to promote accessibility, such as the Crooked Creek Water Trail, and the increase in the popularity of affordable kayaks. Elevated waterbody use by non-anglers has been shown to create conflict with anglers and affect their experience and use of fishing locations (Meyerhoff et al. 2019). Most anglers currently rely on public access sites to enter Crooked Creek, but that has not always been the case. In the mid to late 1990s, landowners closed popular private access points, historically open to the public, due to uncertainties from legal battles regarding instream gravel mining. As a result of increased traffic using public accesses on Crooked Creek, anglers may be seeking other Ozark streams to fish for smallmouth bass (Birdsong et al. 2021), explaining why angling pressure has decreased.

We observed no smallmouth bass harvested during the creel survey, which confirmed the low exploitation rate of the tagging study. Harvest of smallmouth bass likely has not been of concern since the early 1990s, as Quinn et al. (2011) estimated that smallmouth bass exploitation decreased to 2% on Crooked Creek following the Blue Ribbon Stream designation regulation change. Additionally, by the early 1990s, catch-and-release ethics gained popularity nationwide for black bass (Long et al. 2015). A Buffalo River creel survey conducted in 1991–1992 reported a harvest rate of 0.06 smallmouth bass per hour and indicated that harvest was not likely affecting the population (Johnson 1995). Similar evidence of zero to low smallmouth bass harvest has been observed in recent Ozark stream studies in Arkansas, Oklahoma, and Missouri and studies have concluded that more restrictive regulations would not increase smallmouth bass numbers (Williamson et al. 2015, Stein et al. 2020, Chapagain et al. 2021).

Our results from the 2019 creel survey and the reporting and return rates observed during the exploitation study suggest high smallmouth bass angling pressure (Risley et al. 2021). We observed no difference in reporting rate of low and high reward tags. Reporting rate can vary based on angler demographics and satisfaction with the fishery or the agency conducting the study (Meyer et al. 2012). Specialized fisheries such as Crooked Creek, where 71% of anglers were targeting smallmouth bass, have been shown to have high reporting rates (Taylor et al. 2006). Thus, utilizing high monetary rewards may not be crucial for small-directed fisheries like Crooked Creek.

During our tagging study, we instructed anglers to clip the tags off and return them for rewards; however, anglers reported catching and releasing seven fish with the tag(s) still attached. Of these fish, anglers reported catching five (71%) a second time. From this, we hypothesize that anglers catch a large portion of the population multiple times yearly. Additionally, angler catch rates of smallmouth bass on Crooked Creek were considerably greater than the last population estimate, indicating that fish are likely caught and released multiple times per year (Quinn et al. 2011). Martin and Fisher (2008) reported that nearly one-fifth of the smallmouth bass population was caught yearly in fisheries where catch-and-release was substantial. Isermann et al. (2013) saw regional trends in release rates of black bass varying between northern and southern regions of Minnesota, indicating that it remains important to estimate exploitation for individual bodies of water even if regional harvest is low. In a catch-and-release dominant fishery, managers should realize that fishing-related mortality may still affect the population. Hessenauer et al. (2018) reported that even when catch-and-release mortality is low, it may still be a dominant source of mortality and can suppress the size structure of a fishery when compounded over multiple catch events and seasons.

The creel survey and exploitation study on Crooked Creek demonstrated that angler concerns about excessive fishing pressure and the overharvest of smallmouth bass were unwarranted. Voluntary release of smallmouth bass has been shown to be common among Ozark streams dating back to the 1980s. Knowing the exploitation rate improves our understanding of the dynamic rate functions (i.e., growth, mortality, and recruitment) of smallmouth bass on Crooked Creek and is crucial for determining whether regulatory changes are warranted. We found that more restrictive harvest regulations would not improve the fisheries. Additionally,

our data do not support the two special regulations currently in place on Crooked Creek; thus, removing these regulation areas may be biologically justified. Future studies should explore the effects of multiple hooking events on fish mortality and population size structure.

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