INITIAL EVALUATION OF SMALLMOUTH BASS STOCKING IN GREEN RIVER (2013–2016)

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Abstract.—The Green River in Polk and Henderson counties, North Carolina is heavily influenced by hydropower operations. The Lake Summit hydropower operation artificially cools the water, which makes it suitable for stocked trout management in the North Carolina Wildlife Resources Commission's (NCWRC) Public Mountain Trout Waters program. However, Hatchery Supported and Delayed Harvest trout stockings only occur in cooler months and there are no abundant sport fishes in the Green River to provide angling opportunity in summer months. We stocked fingerling-sized OTC-marked Smallmouth Bass *Micropterus dolomieu* in the Polk County Hatchery Supported section of the Green River in May–June 2013–2016 to determine if fingerlings would survive and recruit to sizes that anglers could catch. We evaluated the stocking by collecting Smallmouth Bass from seven sample reaches with backpack electrofishing and angling in the fall. Ninety-six percent of the Smallmouth Bass we collected were marked and thus stocked by the NCWRC. They were collected throughout the Hatchery Supported section, suggesting that this reach contains adequate Smallmouth Bass habitat. Smallmouth Bass fingerlings survived and recruited to sizes that were vulnerable to angling gear and grew at a rate comparable to other North Carolina stream populations. This experiment has successfully created a Smallmouth Bass population in the Green River and it's reported that anglers are now fishing there in the summer and fall to target the new Smallmouth Bass population.

The Green River is the western-most tributary of the Broad River watershed. It begins in Henderson County, North Carolina and flows through two impoundments, Lake Summit and

Lake Adger, before it's confluence with the Broad River at the Polk/Rutherford County border (Figure 1). The hydropower operations of these impoundments substantially alter and regulate the Green River with flow pulses. In addition, Lake Summit's outflow from the remote Tuxedo Hydropower Plant is artificially cool.

Hydropower operations are regulated by the Federal Energy Regulatory Commission (FERC). The FERC requires these operations to be re-licensed periodically (typically every 30–45 y). During the relicensing process, the North Carolina Wildlife Resources Commission (NCWRC) often requests flow regime improvements that benefit aquatic organisms, such as higher base flows, moderated peaking pulse flows, and more natural seasonally adjusted flows. However, in 1989, the FERC ruled that the Lake Summit and Lake Adger hydropower projects did not require a license because the Green River does not meet the federal definition of a navigable waterway and no construction has occurred on the hydropower facilities since 1935 (C. Goudreau, NCWRC, personal communication). Therefore, we have had no mechanism to influence the regulation of the Green River towards more natural thermal and flow conditions.

The artificially cold water in the Green River is conducive to trout management and nearly the entire distance between the Tuxedo Hydropower Plant and Lake Adger is managed as Public Mountain Trout Waters. The NCWRC stocks catchable-sized (>254 mm TL) Rainbow Trout *Oncorhynchus mykiss*, Brook Trout *Salvelinus fontinalis*, and Brown Trout *Salmo trutta* in three sections of the Green River: (1) a 4.0-km Delayed Harvest section between Fishtop Access Area and Cove Creek, (2) a short 270-m Hatchery Supported section between the Tuxedo Hydropower Plant and the Green River Game Land boundary, and (3) a longer 6.4-km Hatchery Supported section between Cove Creek and the subterranean natural gas pipeline above Lake Adger (Figure 1). In addition, the poorly-accessible "gorge" section between the upstream NCWRC Green River Game Land boundary and Fishtop Access Area is classified as Wild Trout. The stocked trout fisheries in the Green River are popular with anglers; however, the Hatchery Supported and Delayed Harvest reaches are only stocked in cool months and provide little angling opportunity in summer.

Black bass *Micropterus* spp. are the most popular sport fishes in North Carolina (Linehan 2013) and the United States (USFWS and USCB 2018). Largemouth Bass *Micropterus salmoides* are native to the Broad River watershed, as they are to all North Carolina Atlantic slope watersheds south of the Tar River (Jenkins and Burkhead 1994). However, Largemouth Bass have been widely introduced throughout North America and the world (Jenkins and Burkhead 1994), and although their native range includes the Broad River watershed, it may not have extended upstream to the Green River.

Recent genetics work is revealing that many of the presumed Largemouth Bass populations in North Carolina are intergrades with Florida Bass *M. floridanus* (S. Loftis, NCWRC, personal communication). The presumed Largemouth Bass in the Green River watershed have yet to be evaluated. Historically (≤2010), Largemouth Bass were the only black bass species known from the Green River watershed. Surveys by Duke Power and NCWRC collected Largemouth Bass in Lake Adger and Lake Summit (Messer 1966; S. R. Johnson, 1982 letter to R. B. Hamilton, Duke Power Company), in the Green River between the Tuxedo Hydropower Plant and Lake Adger (Bonner 1972; Duke Power Company, 1989 unpublished report), and below Lake Adger (Messer et al. 1966). More recently, since 2010, unidentified black bass are occasionally encountered in the Green River near the Tuxedo Hydropower Plant (T. Russ, NCWRC, personal

correspondence). These unidentified micropterans are always small (<100 mm TL) and were suspected non-native Redeye Bass *M. coosae*. However, in 2018 genetic techniques classified four of these individuals as intergrades between Alabama Bass *M. henshalli* and Bartram's Bass (*Micropterus* sp.; E. Peatman, Auburn University, personal correspondence). Neither Alabama Bass, Bartram's Bass, or Redeye Bass are native to the Broad River watershed (Baker et al. 2013).

Largemouth Bass are lentic specialists and are poorly adapted to the relatively small and high gradient North Carolina mountain region streams. Therefore, it is unsurprising that the Green River watershed surveys commonly found them in the reservoirs (Messer 1966; Johnson, letter), but rarely in lotic environments (Messer et al. 1965; Bonner 1972; Duke Power Company, unpublished report). In contrast, Smallmouth Bass, are well-adapted to similar environments and commonly provide sportfishing opportunity in warmwater streams throughout the mountain and piedmont regions of North Carolina (Goodfred et al. 2012). Although Smallmouth Bass are not native to the Atlantic slope, they are introduced and widespread and found anywhere that relatively shallow rocky habitat occurs (Goodfred et al. 2012; T. Russ, NCWRC, personal correspondence) in the Broad River watershed. In addition, a recent survey encountered them in Green River below Lake Adger (Bushon and Wheeler 2019; Figure 1).

Although we have no historical stocking records, considering their widespread introductions in the Broad River and other Atlantic slope watersheds, it seems probable that Smallmouth Bass have been introduced to the Green River above Lake Adger, but failed to establish a self-sustaining population. If the hydropower operations negatively affect Smallmouth Bass by disrupting their reproduction or early life stages, it's possible that we can create and maintain a fishery for them in the Green River with annual fingerling stockings.

The goal of this research is to create a coolwater fishery in the Green River which provides angling opportunity in summer months when the river is too warm for trout management. The specific objective of this study is to determine if Smallmouth Bass fingerlings stocked into the Green River can survive and recruit to sizes that can be caught by anglers.

Methods

Culture, marking, and stocking.—From 2013 until 2016, we conducted an experimental annual stocking of 1,000 fingerling-sized (approximately 30 mm TL) Smallmouth Bass in the Green River. Adult broodfish were collected from the North Toe River (D. Goodfred, personal conversation) and kept in a 0.2 ha pond at Table Rock State Fish Hatchery in Morganton, North Carolina. The broodfish typically spawned in mid-April and were seined from the pond after spawning when they began guarding nests. Afterwards, the juvenile Smallmouth Bass remained in the pond until late May or mid-June when they attained a mean TL ≥ 38 mm. Immediately before stocking, the juvenile Smallmouth Bass were harvested and transferred to an indoor tank where they were marked by 6 h of immersion in a solution of 500 mg/L of OTC and 1,000 mg/L of sodium chloride while the pH was buffered to 6.8–6.9 with tris.

Our study area was the Hatchery Supported section of the Green River in Polk County which stretches from the Cove Creek confluence to the subterranean natural gas pipeline crossing (Figure 2). We chose this reach because it is characterized by the shallow, rocky habitat

which is commonly inhabited by Smallmouth Bass. In addition, we wished to minimize the thermal effect of the Tuxedo Hydropower Plant; therefore, we stocked as far downstream as possible.

Population survey.—We used backpack electrofishing to collect Smallmouth Bass from the Green River between September 6 and October 6, 2013–2016. We chose seven sample reaches spread throughout study area for electrofishing (Table 1; Figure 2). These sample reaches were selected because they contained shallow water that could be sampled with backpack electrofishing gear. Each sample was staffed with one person (the shocker) carrying a Smith-Root model 12-B backpack electrofisher set to J-6 (pulses at 70 Hz and 8 ms wide) and the output V was adjusted as high as possible without overloading the unit. In addition to the shocker, 2–3 dipnetters collected the stunned black bass. Due to depth increases, we could only sample between hydropower pulses; however, there was considerable annual variation in base flows. In years with lower base flows, the shocker could move more freely in the channel and sample considerably more area than higher baseflow years. Therefore, we instructed each shocker to use their best judgement on techniques and strategy for targeting black bass and coordinate the dipnetters. This lack of strict method repeatability is common when electrofishing medium-sized streams and precludes meaningful estimates of effort and thus catch-per-effort; therefore, we did not record electrofishing times. Finally, because our electrofishing methods seemed to be selecting for small (≤100 mm TL) Smallmouth Bass, in 2016, we also used angling gear to collect larger individuals.

Otolith Methods for Age and Mark Determination.—We estimated the ages of all the black bass collected by counting otolith annuli with a compound microscope. The two authors evaluated each otolith independently and then assigned ages after disagreements were discussed and resolved. Otoliths ≤ age-1, were generally aged intact (without breaking); whereas, older otoliths were aged by breaking along the dorsal-ventral axis and polishing the break with 600-grit sandpaper. After aging, the otoliths were checked for OTC marks under a compound microscope with transmitted epiflourescent light. The otoliths were attached to microscope slides with cyanoacrylate glue and ground with 600-grit sandpaper, before exposing them to epiflourescent light. The authors independently verified the marks.

Due to the small size of many of the black bass collected, we often failed to recover both otoliths from each fish. In addition, the otoliths were sometimes destroyed by breaking for aging and were always destroyed when grinding to check for marks. Therefore, we were sometimes unable to both assign age and check for mark. In any analyses that considered either ages or marks, we only used the subset of fish for which we had observations of both age and mark presence or absence.

Data Analysis.—We calculated the relative weight (W_r) of Smallmouth Bass ≥150 mm TL (Kolander et al. 1993) and Largemouth Bass ≥150 mm TL (Wege and Anderson 1978). The percentage of stocked Smallmouth Bass in our samples was used as an estimate of the percentage of stocked Smallmouth Bass in the study reach and the Clopper and Pearson (1934) exact binomial method (R version 3.5.2) estimated 95% confidence intervals about the percentage. Finally, we used traditional Tukey-style boxplots to compare the TL-at-age of Smallmouth Bass collected by electrofishing and angling as well as to 20 other North Carolina populations surveyed by Goodfred et al. (2012).

Results and Discussion

Our objective was to stock 1,000 Smallmouth Bass annually. However, juvenile fish production via natural spawning in outdoor ponds is inherently difficult to predict and control. Although we requested 1,000 Smallmouth Bass annually, the pond production exceeded the request each year (Table 2). We marked all Smallmouth Bass produced each year and these fish were stocked throughout the study area; therefore, stocking numbers varied considerably each year.

We collected 232 Smallmouth Bass during our sampling. Of these, 164 could be both aged and checked for marks. None of the Smallmouth Bass collected were older than the stocked year classes. Overall, 96% of the Smallmouth Bass collected were marked and the individual age classes ranged between 93% and 100% marked (Table 3). Considering that no Smallmouth Bass were older than the stocked year classes and the marked percentage was very high, it's likely that 100% of the Smallmouth Bass were of hatchery origin but either we failed to detect the marks or the marks were not retained on a minority of the fish.

Smallmouth Bass were widespread throughout the seven sample reaches (Table 4). Although, the number caught each year was variable for each reach, we consistently collected more from reach 1 than any of the other six reaches (Table 4). The wide dispersion of Smallmouth Bass throughout the sample reaches indicates that the study area of the Green River contains abundant habitat for the species. In addition, anglers have reported encountering Smallmouth Bass up to 4 km upstream at Fishtop Access Area (Figure 1).

The two sampling gears, backpack electrofishing and angling, complemented each other to provide a broader assessment of the Green River Smallmouth Bass population. Backpack electrofishing selected for ≤age-1 Smallmouth Bass whereas angling collected mainly ≥age-1 fish. Where the gears overlapped at age-1, angling selected for larger fish; however, the age-2 fish collected by both gears were similar in size (Figure 3).

The stocked Smallmouth Bass year classes survived and grew in the Green River. The year classes averaged 38–66 mm TL (Table 1) at their spring stocking but grew to 72–99 mm TL (Table 4) when collected 4–5 months later in the fall. In addition, we observed individuals from each year-class recruiting to older age classes (Table 5). The growth of the stocked Smallmouth Bass was within the range of the North Carolina populations surveyed by Goodfred et al. (2012; Figure 4). Finally, the mean W_r values were relatively high and generally > 90 (Table 5).

In addition to Smallmouth Bass, we occasionally collected several other black bass species during this project. These included: 24 Largemouth Bass, 1 Spotted Bass *Micropterus punctulatus*, and 1 unknown black bass. Of these, 17 Largemouth Bass, the Spotted Bass, and the unknown back bass could be both aged and checked for OTC marks. These fish were generally collected as age-0 and all were unmarked. The unidentified bass was tentatively identified as a Redeye Bass in the field but was likely an intergrade between Alabama Bass and Bartram's Bass (see Introduction). Although we collected an unusually high number of age-0 Largemouth Bass electrofishing in 2015 (Table 6), these other black bass species were only encountered sporadically across years and rarely across reaches and did not form mature populations with multiple age classes characteristic of exploited sport fish populations. These species are often associated with reservoirs and had likely emigrated from either Lake Summit or Lake Adger (Figure 1).

We accomplished the objective of this research: the stocked fingerling Smallmouth Bass survived and recruited to older age classes and sizes that were vulnerable to angling gear. However, the hatchery-supported Smallmouth Bass fishery in the Green River, is still very young and has not yet produced the older and larger fish characteristic of the populations that anglers target. Future study should verify that the fish continue to survive and grow, and create a size and age structure comparable to other North Carolina Smallmouth Bass fisheries.

Finally, although we did not survey anglers, the local NCWRC Wildlife Enforcement Officers reported anglers utilizing the developing Smallmouth Bass fishery in the Green River. Previously, there was no angler activity in the study reach outside of trout stocking seasons, anglers are now fishing the Green River specifically targeting Smallmouth Bass in the summer and fall (Toby Jenkins, NCWRC, personal communication).

Management Recommendations

1. Continue annual fingerling Smallmouth Bass stocking in the Hatchery Supported Section of the Green River.
2. Re-sample Green River annually until 2023 with backpack electrofishing gear to verify that age-0 Smallmouth Bass are continuing to survive and to check for natural reproduction.
3. Re-sample Green River in 2023 with angling gear to verify that the stocking is still effective and to assess population characteristics as the Smallmouth Bass form a more mature population.
4. Begin using broodfish from the Broad River watershed in 2019.

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TABLE 1.—The length and GPS coordinates of the seven backpack electrofishing sample reaches on the Green River, September–October 2013–2016.

Sample Reach	Length (m)	Downstream Coordinate		Upstream Coordinate	
		Longitude	Latitude	Longitude	Latitude
1	150	35.28846	-82.29031	35.28777	-82.29179
2	208	35.29376	-82.28194	35.29229	-82.28263
3	86	35.30322	-82.27595	35.30265	-82.27661
4	215	35.30566	-82.27020	35.30649	-82.27236
5	191	35.29190	-82.28515	35.29084	-82.28679
6	211	35.29810	-82.28218	35.29634	-82.28150
7	267	35.31375	-82.25872	35.31218	-82.26092

TABLE 2.—The date, quantity, and mean TL of Smallmouth Bass stocked in the Green River, 2013–2016.

Stocking date	*N*	Mean TL (mm)
June 12, 2013	5,320	66
May 28, 2014	39,427	38
May 27, 2015	10,339	38
June 9, 2016	20,950	41

TABLE 3.—The quantity and percent of Smallmouth Bass collected from the Green River that were marked with OTC. This table only includes fish that were both aged and checked for OTC marks. The 2016 sample includes fish that were collected with backpack electrofishing and angling. Ninety-five percent confidence intervals about the marked percentage are reported parenthetically.

	Age							
	0		1		2		3	
Year	*N*	Mark (%)	*N*	Mark (%)	*N*	Mark (%)	*N*	Mark (%)
2013	8	100 (63–100)						
2014	22	95 (77–99)						
2015	22	95 (77–99)	23	96 (79–99)				
2016	46	98 (89–99)	13	100 (75–100)	25	93 (76–99)	1	100 (3–100)

TABLE 4.—Total number of Smallmouth Bass collected by backpack electrofishing at each of the seven sample reaches on the Green River, September–October 2013–2016. Sample reach 6 could not be sampled in 2015 because we encountered a hydropower flow pulse.

	Sample reach						
Year	1	2	3	4	5	6	7
2013	8	0	0	0	0	0	0
2014	19	2	8	3	1	5	1
2015	25	4	5	4	3	—	17
2016	29	9	14	11	5	16	4

TABLE 5.—Smallmouth Bass collected by backpack electrofishing and angling from the Green River, September–October 2013–2016. Mean values for TL, weight, and W_r are reported where calculable and standard deviations are reported parenthetically.

				Mean		
Year	Gear	Age	*N*	TL (mm)	weight (g)	W_r
2013	Electrofishing	0	8	91 (18)	12 (9)	—
2014	Electrofishing	0	22	72 (12)	4 (3)	—
2015	Electrofishing	0	22	99 (14)	21 (25)	—
		1	24	128 (26)	29 (24)	97 (4)
2016	Electrofishing	0	47	84 (15)	8 (6)	98
		1	4	127 (43)	30 (20)	92
		2	8	177 (21)	70 (23)	92 (9)
	Angling	1	9	149 (20)	40 (17)	89 (5)
		2	19	184 (23)	81 (32)	92 (5)
		3	1	289	375	107

TABLE 6.—Black bass species other than Smallmouth Bass collected by backpack electrofishing and angling from the Green River, September–October 2013–2016. Mean values for TL, weight, and W_r are reported where calculable and standard deviations are reported parenthetically. These fish were all unmarked.

Year	Gear	Species	Age	*N*	TL (mm)	Weight (g)	W_r	Mark (%)
2013	Electrofishing	Unknown	0	1	121	21	—	0
2014	Electrofishing	Largemouth Bass	0	1	58	2	—	0
2015	Electrofishing	Largemouth Bass	0	13	97 (15)	29 (32)	—	0
2016	Angling	Largemouth Bass	2	2	194 (2)	84 (7)	92 (3)	0
		Largemouth Bass	7	1	336	550	100	0
	Electrofishing	Spotted Bass	1	1	114	16	—	0

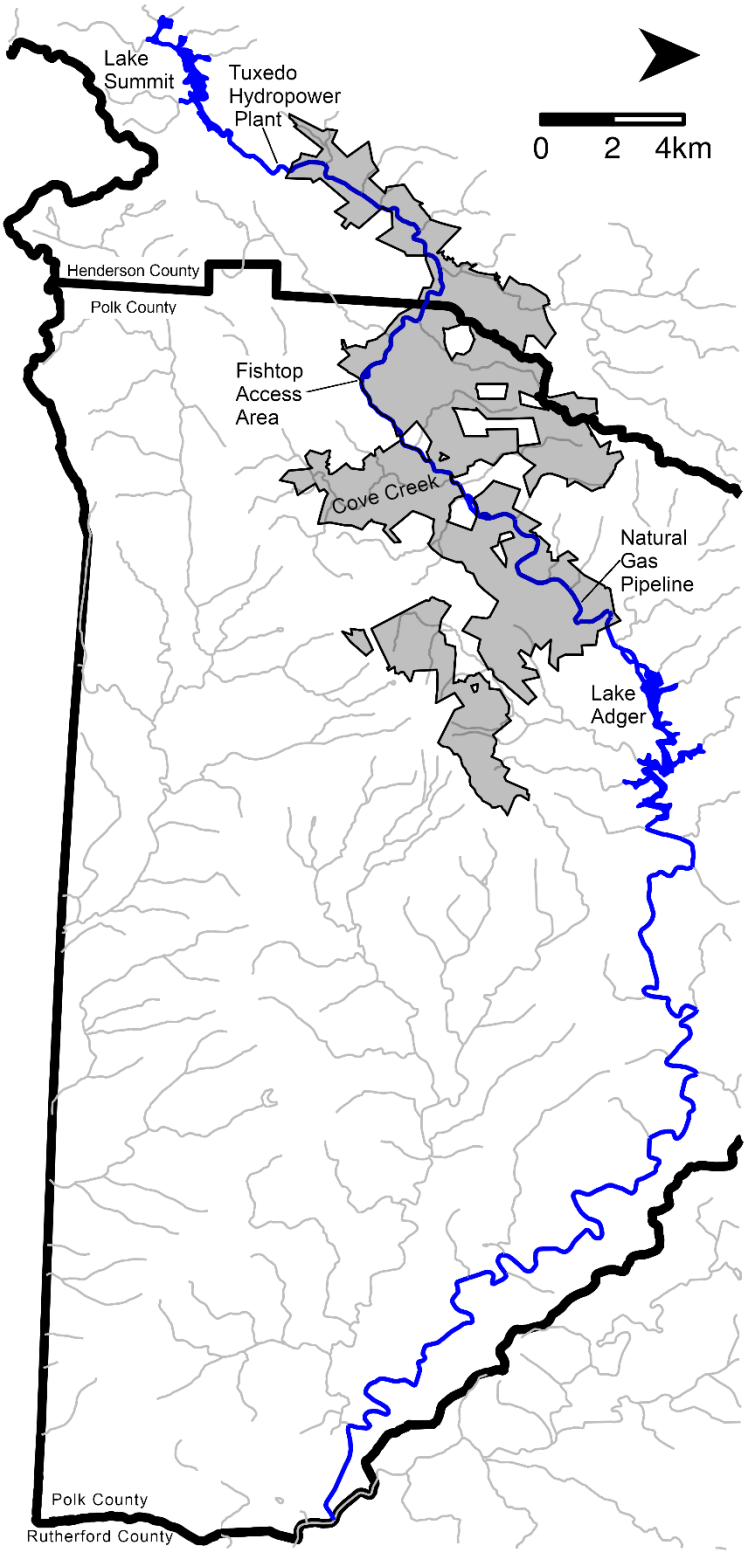

FIGURE 1.—Map of Green River (blue) from Lake Summit, Henderson County to Broad River, Polk/Rutherford County Line, North Carolina. Green River game lands are shown in grey.

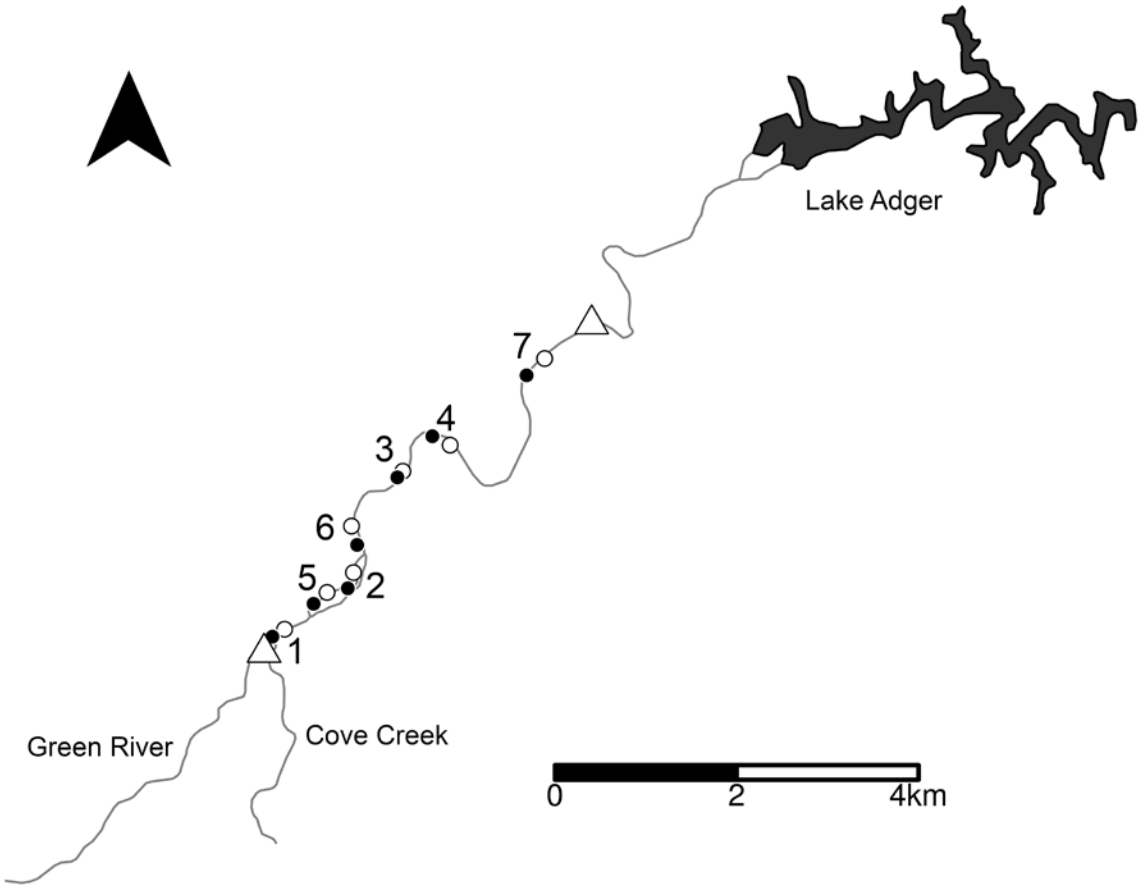

FIGURE 2.—Map of Green River, Polk County, North Carolina showing the 2013–2016 study reach (bounded by white triangles). The beginning (white circles) and ends (black circles) of the seven backpack electrofishing sample reaches are shown. The study reach was the Polk County Hatchery Supported section which stretches between the Cove Creek confluence and the subterranean natural gas pipeline crossing.

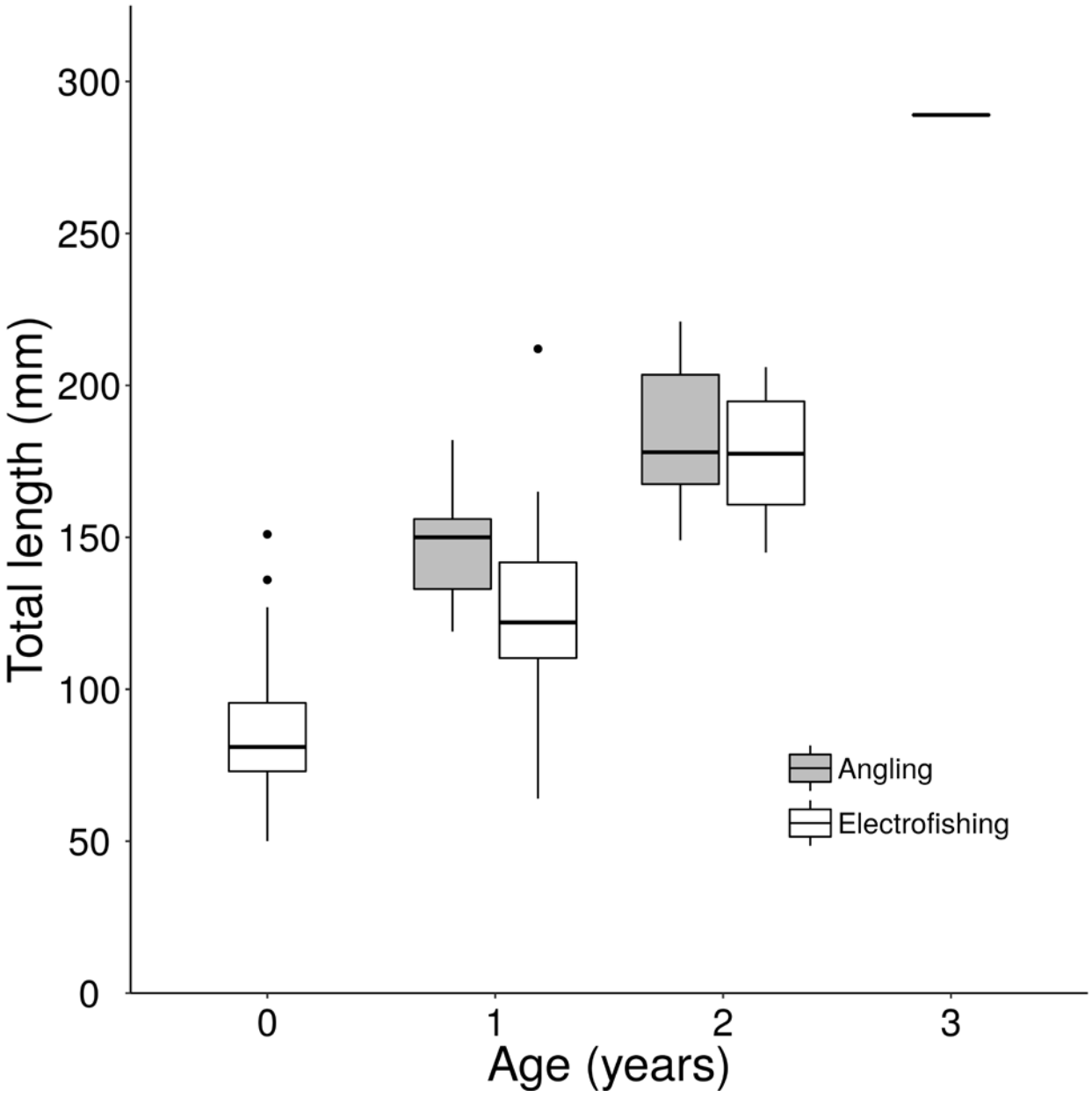

FIGURE 3.—Distribution of TL by age of Smallmouth Bass collected with backpack electrofishing and angling gear from the Green River, September–October 2013–2016. These are traditional Tukey boxplots: the dark line represents the median, the box represents the distance between the first and third quartiles, the whiskers show the range of observations within 1.5 quartiles of the box, and the dots are outlying values.

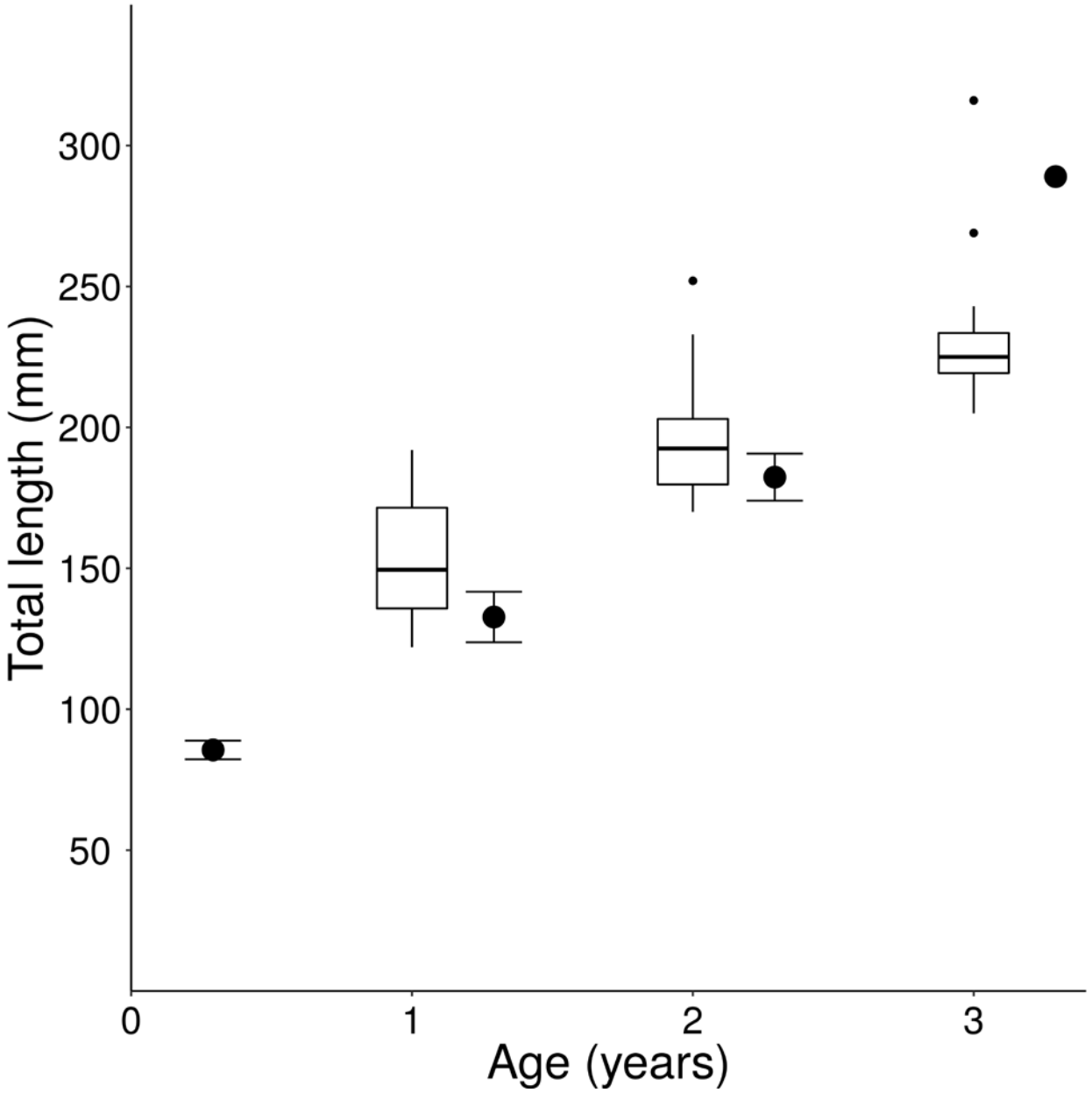

FIGURE 4.—Green River Smallmouth Bass mean TL at age (dots) compared to boxplots of the distribution of predicted TL at age from 20 North Carolina Smallmouth Bass populations surveyed by Goodfred et al. (2012). The Green River mean TL include all the fish that could be aged and checked for OTC marks from electrofishing and angling. The error bars are 95% confidence intervals about the mean. See Figure 3 for a description of the Tukey-style boxplots. The boxplots and points are offset from each other because Goodfred et al. (2012) estimated mean TL on June 1 (annulus formation); the Green River fish were collected about September 15.