Natural Reproduction by Muskellunge in Middle Tennessee Rivers

Lila H. Warren[1,2,*] and Phillip W. Bettoli[3]

[1] Tennessee Cooperative Fishery Research Unit, Tennessee Technological University, Cookeville, TN 38505. [2]Present address: West Virginia Division of Natural Resources, South Charleston, WV25303. [3]U.S. Geological Survey, Tennessee Cooperative Fishery Research Unit, Tennessee Technological University, Cookeville, TN 38505.
* Corresponding author – lilawarren@gmail.com

Abstract- Native *Esox masquinongy* (Muskellunge) in the Cumberland River drainage, Tennessee, were nearly extirpated in the 1970s due to decades of over-fishing and habitat degradation from coal mining, logging, and other land-use practices. In an effort to preserve the species in that drainage, a stocking program began in 1976 in the upper Caney Fork River system in middle Tennessee. A trophy Muskellunge fishery eventually developed; however, it was unknown whether muskellunge were naturally reproducing in the upper Caney Fork River system or whether the fishery was wholly dependent on the stocking program. We used seines, backpack electrofishing, and boat electrofishing gear in 2012 to sample age-0 Muskellunge throughout the upper Caney Fork River system. Natural reproduction was documented in the mainstem Caney Fork River above Great Falls Dam and three of its four major tributaries. Age-0 Muskellunge grew rapidly and reached total lengths of 399 mm by 9 October 2012. A cessation of stocking for several years coupled with routine monitoring should reveal whether natural recruitment is sufficient to sustain the populations in those rivers.

Introduction

Esox masquinongy Mitchill (Muskellunge) is the largest member of the Family Esocidae and is a popular and economically valuable sportfish in North America. At one time there were thought to be three Muskellunge subspecies based on regional differences in coloration: the Great Lakes subspecies *E. m. masquinongy*, the western or northern subspecies *E. m. immaculatus,* and the Ohio subspecies *E. m. ohioensis* (Crossman 1986, Crossman et al. 1986, Scott and Crossman 1973). Presently, the scientific name for Muskellunge is *Esox masquinongy* without a division into subspecies (Nelson et al. 2004). Muskellunge populations have not been well studied in the southern U.S. (Brenden et al. 2006); the most recent published study on riverine Muskellunge in Tennessee is more than 50 years old (Parsons 1959). In Tennessee, the native range of Muskellunge includes tributaries to the upper reaches of the Tennessee and Cumberland Rivers (Etnier and Starnes 1993, Parsons 1959).

In Tennessee during the early 20th century, Muskellunge were so prevalent in their native streams on the Cumberland Plateau that local anglers used nets, traps, gigs, trot lines, and even shotguns to harvest fish (Parsons 1958). Angling effort and Muskellunge fishing success declined during the early 1950s and illegal harvesting was identified as one of several problems the species faced (Parsons 1958). Muskellunge populations were described as "rapidly dwindling" in the 1950s and habitat in more than 168 km of native Muskellunge streams in Tennessee had been destroyed by acid mine drainage.

Great Falls, a large waterfall on the Caney Fork River near Rock Island, Tennessee, had historically prevented Muskellunge and other large piscivores such as *Sander vitreus* Mitchill (Walleye) and *Sander canadensis* Griffith and Smith (Sauger) from migrating upstream of the falls into the upper Caney Fork River and its tributaries (Little et al. 1983). In 1955, 20 native

Muskellunge fingerlings were transplanted from Rock Creek, Tennessee, a Cumberland Plateau stream, to the upper Caney Fork River in a pilot study to test stocking efficacy. In 1957, five of the fish from the original stocking were observed (Parsons 1958).

Muskellunge populations were severely depleted throughout their native range in Cumberland Plateau streams by the early 1970s (Riddle 1975) and were declared endangered in the state of Tennessee in 1975 by the Tennessee Wildlife Resources Commission. Habitat destruction from coal mining was identified as the primary cause of Muskellunge population decline; overfishing, poor logging practices, and pollution by industrial and domestic sources also negatively impacted native Muskellunge (Garavelli 1977, Little et al. 1983, Parsons 1952, Parsons 1958, Riddle 1975, TWRA 2011). To prevent the disappearance of Muskellunge from the Cumberland Plateau, the Tennessee Wildlife Resources Agency (TWRA) began stocking Muskellunge into the upper Caney Fork River system above Great Falls Dam in 1976. Although the upper Caney Fork River system is not part of the native range of Muskellunge in Tennessee, TWRA chose it as a focal area for establishing a Muskellunge population because it is in the Cumberland River drainage, it is similar in habitat to the species' native streams in Tennessee, and there was no threat of future habitat degradation by coal mining (Little et al. 1983). Additionally, the pilot study in 1955-1957 confirmed that Muskellunge stocked into the upper Caney Fork River could survive.

Muskellunge have been stocked sporadically in the upper Caney Fork River and its tributaries above Great Falls Dam since 1976 (Table 1). Tennessee Muskellunge populations recovered sufficiently from their imperiled status and the fishery was reopened in 1988 with a 915-mm TL minimum total length (TL) limit and a creel limit of one fish per day (TWRA 2011). The Muskellunge fishery in the upper Caney Fork River system is gaining popularity as a trophy

fishery and anglers have reported catching fish longer than 1.3 m TL in recent years. During annual spring electrofishing surveys, adult Muskellunge are routinely captured that display signs of spawning activity (i.e., flowing eggs or milt; lesions; torn fins). Some natural reproduction was thought to occur in the upper Caney Fork watershed above Great Falls Dam (J. Swearingen, TWRA, Crossville, TN, pers. comm.); however, it was not known with certainty whether natural reproduction was occurring or whether recruitment was sufficient to maintain the fishery. Soon after the Muskellunge stocking program began in 1976, Little et al. (1983) recognized the need to determine whether natural reproduction was occurring. Despite this recommendation, there has been no formal investigation of natural reproduction in the system until now. Therefore, the first objective of this study was to determine if natural reproduction of Muskellunge occurs in the upper Caney Fork River system. When sufficient numbers of wild fish were captured, we sought to describe their growth and the habitats in which they were captured.

Study Area

This study was conducted on the upper Caney Fork River and its four major tributaries (Calfkiller River, Rocky River, Collins River, and Cane Creek) above Great Falls Dam. The Caney Fork River is a tributary to the Cumberland River. The Tennessee Electric Power Company constructed Great Falls Dam upstream of Great Falls in 1916 for the purpose of power generation; it was sold to the Tennessee Valley Authority (TVA) in 1939 (TVA 2011). Great Falls Lake is 35.4 km long and has a surface area of approximately 740 ha at full pool. Seventy-six km of the Collins River, 20 km of the Calfkiller River, 16 km of the Rocky River, and 11 km

of Cane Creek were sampled in this study. An additional 7-km reach of the mainstem Caney Fork River near its confluence with Cane Creek was sampled.

Methods

We used seining, backpack electrofishing, and boat electrofishing in 2012 to determine the extent of natural reproduction of Muskellunge in the main stem of the upper Caney Fork River and its four major tributaries above Great Falls Dam (Fig. 1). We chose sampling sites for seining and backpack electrofishing based on wadeability, accessibility by small motorboat or canoe, and suitability of habitat for age-0 Muskellunge based on the literature. We used a bag seine (6 m x 1.8 m with a 1.8 m x 1.8 m bag) to sample wild age-0 Muskellunge between 23 June and 22 August 2012. The wings of the seine had 6.3-mm mesh and the bag had 4.7-mm mesh. The seine was constructed of nylon delta knotless material and had a double lead-line and large floats. We followed a modified version of the seining protocols of Farrell and Werner (1999), Murry and Farrell (2007), and Kapuscinski et al. (2010, 2012), whereby the seine was pulled parallel to shore for 20 m and then swung into shore. Sampling sites ranged from about 20 to 100 m of shoreline and no more than three seine hauls were made at each site. Each site sampled with the seine was revisited 24-48 hours later and sampled using backpack DC-electrofishing gear (Smith-Root model LR-24). A single zigzag pass was made through each site by a two-person crew and the time was recorded. We also sampled for age-0 Muskellunge beginning 23 August 2012 using a Smith-Root 2.5 GPP electrofishing unit mounted in a 4.3-m johnboat powered by a jet-drive outboard motor. Surveys targeted likely Muskellunge nursery habitat in reaches of all four tributaries accessible by motorboat, as well as reaches of the upper Caney Fork River mainstem that could not be seined or electrofished using backpack electrofishing gear. Boat

electrofishing transects were not of a predetermined length of shoreline or time, but total pedal-time at each site electrofished was recorded.

Each age-0 Muskellunge captured was weighed (g) and measured (TL, mm). The only age-0 Muskellunge stocked into the upper Caney Fork River system in 2012 (n = 25) were radio-tagged and they were not stocked until November 2012; therefore, all age-0 Muskellunge we observed in 2012 were wild fish. Before they were released all fish were tagged with a PIT tag to identify possible recaptures.

At sampling locations where age-0 Muskellunge were collected (or observed but not netted) we measured depth and visually classified dominant and sub-dominant substrates as predominantly silt/clay, sand, gravel, pebble, cobble, or boulder based on the particle size ranges outlined by Bain (1999). Macrohabitat was classified as pool, backwater, riffle, run, or littoral (Younk et al. 1996). Using a 1-m^2 floating grid we visually estimated the percentage of woody debris, vegetation, and detritus to quantify cover, and identified aquatic vegetation to the genus level (Craig and Black 1986, Farrell and Werner 1999, Murry and Farrell 2007, Zorn et al. 1998). When age-0 Muskellunge were captured in seine hauls, habitat parameters were measured at the beginning and end of each 20-m haul and averaged; for fish collected or observed with electrofishing gear, habitat parameters were measured at the spot where fish were first observed. Waypoints identifying fish capture locations were mapped using ArcGIS 10.0 (ESRI, Redlands, CA).

Results

Eighteen wild age-0 Muskellunge were observed in the Calfkiller River, Cane Creek, the Collins River, and the upper Caney Fork River (Fig. 2); one of those 18 fish could not be netted

but its location and habitat data were recorded. No age-0 Muskellunge were collected in the Rocky River. The first wild fish was collected in a seine haul on 25 June 2012; the last was captured in a boat electrofishing sample on 26 October 2012. No wild fish had a PIT-tag (i.e., none were recaptures from earlier in the season). Of the three gears, boat electrofishing was the most efficient means of collecting age-0 Muskellunge. Eleven fish were collected (a twelfth was observed) using boat electrofishing gear (6.2 hours of pedal time) in 9 field days by a two-person crew. Six fish were collected in 80 seine hauls in 11 field days by a two-person crew (mean catch = 0.075 $\pm$ 0.030 *SE*). No wild Muskellunge were collected by backpack electrofishing (5.9 hours of sampling time) in 9 field days by a two-person crew.

Age-0 Muskellunge grew quickly and ranged from 148 mm TL (13 g) in June to 399 mm TL (320 g) by 9 October 2012 and growth was linear over that interval (F = 216.11; df = 1, 13; P < 0.0001; R^2 = 0.9433; Fig. 3). The only two fish collected from the upper Collins River were collected late in the season and were much shorter than their counterparts; for modeling purposes they were considered outliers and excluded from the regression model. When those two fish were included in the linear model, the estimated daily growth rate dropped from 2.34 mm/day to 1.80 mm/day (F = 38.12; df = 1, 15; P < 0.0001; R^2 = 0.7176).

Nursery habitats were shallow (mean depth = 71 cm ± 8.7 *SE*) backwater or run macrohabitats and substrates were predominantly silt and sand. Vegetative cover averaged 33% (± 9.4) and the most common aquatic vegetation species in those nursery habitats (in decreasing order of prevalence) were *Justicia* spp. (Waterwillow), *Myriophyllum* spp. (Milfoil), and *Polygonum* spp. (Knotweed). Cover by woody debris and detritus averaged 11% (± 4.8) and 7% ($\pm$ 2.6), respectively, where wild age-0 Muskellunge were captured or observed.

Discussion

We documented natural reproduction in four of the five rivers we sampled in the upper Caney Fork River system. Whether 2012 was a good (or poor) year for natural reproduction and recruitment in the upper Caney Fork River system is unknown, but the data presented herein can serve as a baseline for future studies of Muskellunge recruitment in the Caney Fork River system.

Age-0 Muskellunge in the Caney Fork River system grew to nearly 400 mm TL by early October. The large sizes achieved by the end of the growing season might be attributed to a warm spring and spawning that began about six weeks earlier in 2012 than is usual in Tennessee (Parsons 1959). Average total lengths for age-1 Muskellunge ranged from 216 mm to 338 mm TL in prior studies in Tennessee and five other states (Axon 1978; Belusz 1978; Brewer 1980; Larscheid et al. 1999; Miles 1978; Parsons 1959; Schloemer 1936). Wild Muskellunge in Wisconsin Lakes reached approximately 250 mm TL by the end of their first growing season and approximately 375 mm TL by the end of their second growing season (Jonas et al. 1996). No age-0 Muskellunge were collected early in the season from the upper Collins River to compare to the two age-0 fish that we collected from that reach late in the season (which were excluded from the growth model). Additional field observations will be required to confirm that age-0 Muskellunge in the upper Collins River grow slower than in other parts of the upper Caney Fork River system.

Similarly, Muskellunge nursery habitats in other locales were shallow (25-50 cm deep, Zorn et al. 1998; <150 cm deep, Farrell and Werner 1999) with modest amounts of emergent and submerged macrophytes (Kapuscinski et al. 2012; Murry and Farrell 2007; Zorn et al. 1998). One of the most common aquatic plants that occurred in nursery areas in the present study (e.g.,

Myriophyllum spp.) was also common in Muskellunge nursery bays of the upper St. Lawrence River (Farrell and Werner 1999).

The availability of suitable prey species is an important characteristic of Muskellunge nursery habitat. There was a direct relationship between age-0 Muskellunge occurrence and prey availability, specifically Cyprinids *Notropis* spp., *Fundulus diaphanous diaphanous* L. (Banded Killifish) and *Etheostoma olmstedi* Storer (Tessellated Darters), in St. Lawrence River nursery bays (Murry and Farrell 2007). Banded Killifish, cyprinids, and darters were the most important prey items for age-0 Muskellunge in the Niagara and St. Lawrence Rivers (Kapuscinski et al. 2012). When age-0 Muskellunge were collected in a seine haul in the present study, other species collected were ecologically similar to species identified as important prey of age-0 Muskellunge in northern U.S. rivers (Murry and Farrell 2007). Seine hauls in which age-0 Muskellunge were collected in the present study commonly included several cyprinid species (e.g., *Notropis telescopus* Cope [Telescope Shiner], *Luxilus chrysocephalus* Rafinesque [Striped Shiner], *Lythrurus fasciolaris* Gilbert [Scarlet Shiner], and *Campostoma anomalum* Rafinesque [Central Stoneroller]), as well as *Etheostoma etnieri* Bouchard (Cherry Darter) and Northern Studfish *Fundulus catenatus* Storer (Northern Studfish). Muskellunge recruitment in Kentucky streams was related to the relative abundance of small forage fishes, including cyprinids (Brewer 1980). Kapuscinski et al. (2012) concluded that the availability of fusiform prey species should enhance survival of age-0 Muskellunge. Although we did not estimate prey abundance or biomass, prey species composition in the upper Caney Fork River system appears adequate for age-0 Muskellunge.

Because stocking has been irregular since 1976 and annual boat electrofishing surveys by the TWRA did not begin until 2007, it is difficult at the present time to determine whether the

Muskellunge populations in the upper Caney Fork River system are self-sustaining. If stocking is discontinued, managers should be able to discern within a few years through annual boat-electrofishing surveys of age-0 and adult Muskellunge whether those populations are, in fact, self-sustaining or whether supplemental stockings are needed to maintain viable, fishable stocks.

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Table 1. Records of Muskellunge stocked into the upper Caney Fork River system, TN.

Year	River Stocked	Source	Number
1976	Caney Fork	Minor Clark, KY	62
	Bee Creek	Minor Clark, KY	40
1979	Caney Fork	Eagle Bend, TN	404
	Calfkiller	Eagle Bend, TN	120
1980	Calfkiller	Eagle Bend, TN	356
1982	Collins	Eagle Bend, TN	664
1983	Collins	Minor Clark, KY	66
1984	Caney Fork	Minor Clark, KY	2,500
1991	Caney Fork	Minor Clark, KY	302
1994	Calfkiller	Minor Clark, KY	50
	Collins	Minor Clark, KY	70
	Rocky	Minor Clark, KY	45
1997	Calfkiller	Minor Clark, KY	84
	Collins	Minor Clark, KY	118
2000	Caney Fork	Minor Clark, KY	40
	Collins	Minor Clark, KY	100
2002	Caney Fork	Minor Clark, KY	60
	Collins	Minor Clark, KY	288

Table 1 (continued).

Year	River Stocked	Source	Number
2005	Caney Fork	Minor Clark, KY	60
	Collins	Minor Clark, KY	100
	Collins	Eagle Bend, TN	56
2006	Caney Fork	Minor Clark, KY	200
	Caney Fork	MO Department of Conservation	547
	Collins	Minor Clark, KY	210
	Collins	MO Department of Conservation	1,000
2007	Caney Fork	Minor Clark, KY	250
	Collins	Minor Clark, KY	250
2008	Calfkiller	Eagle Bend, TN	45
2010	Calfkiller	Minor Clark, KY	388
	Cane Creek	Minor Clark, KY	100
	Caney Fork	Minor Clark, KY	100
	Collins	Minor Clark, KY	521
	Collins	Eagle Bend, TN	122
2011	Collins	Minor Clark, KY	600
2012	Collins	Table Rock, NC	25

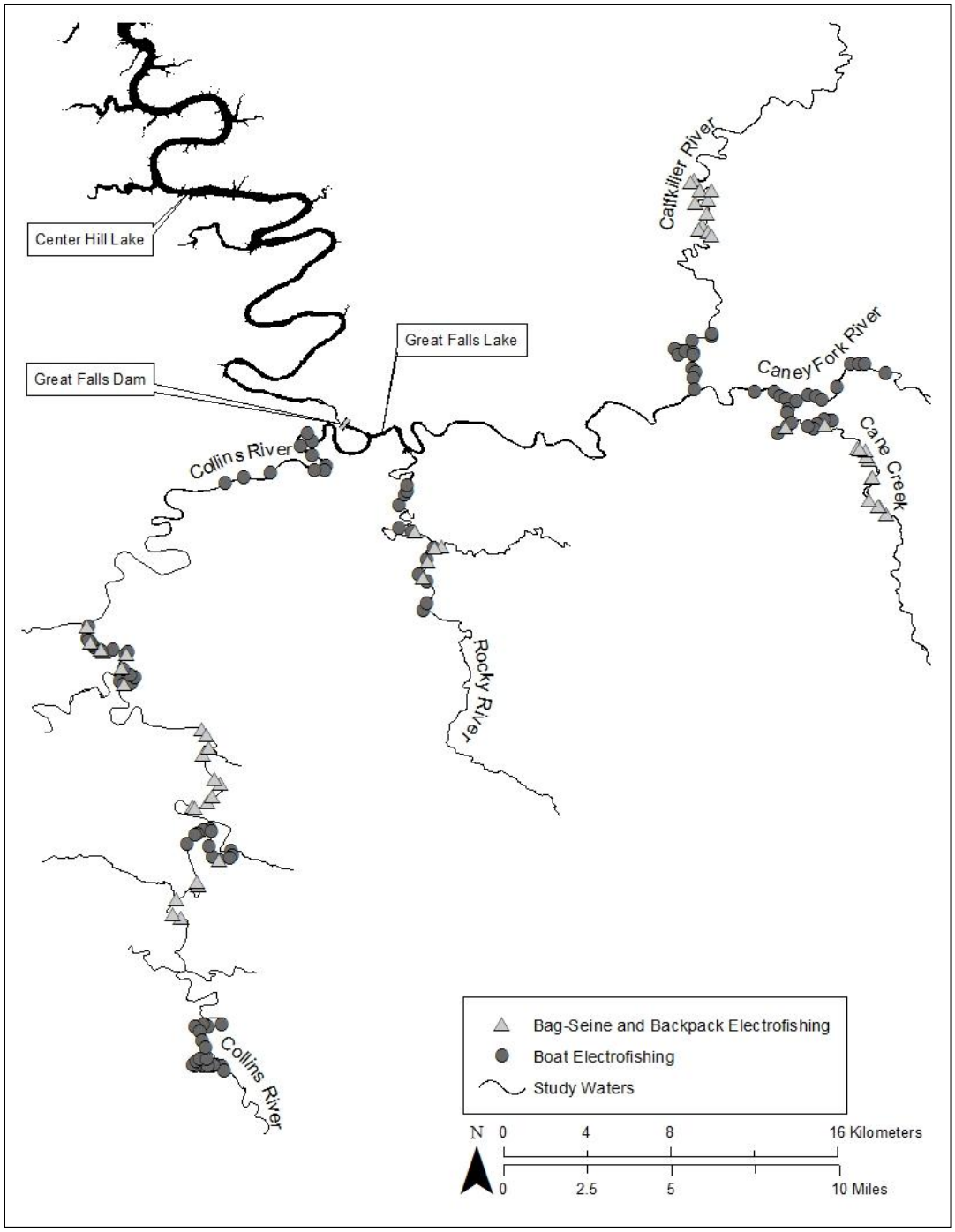

Figure 1. Map of sampling locations for age-0 Muskellunge in the upper Caney Fork River system, Tennessee, using three different sampling gears: bag-seine, backpack electrofisher, and boat electrofisher.

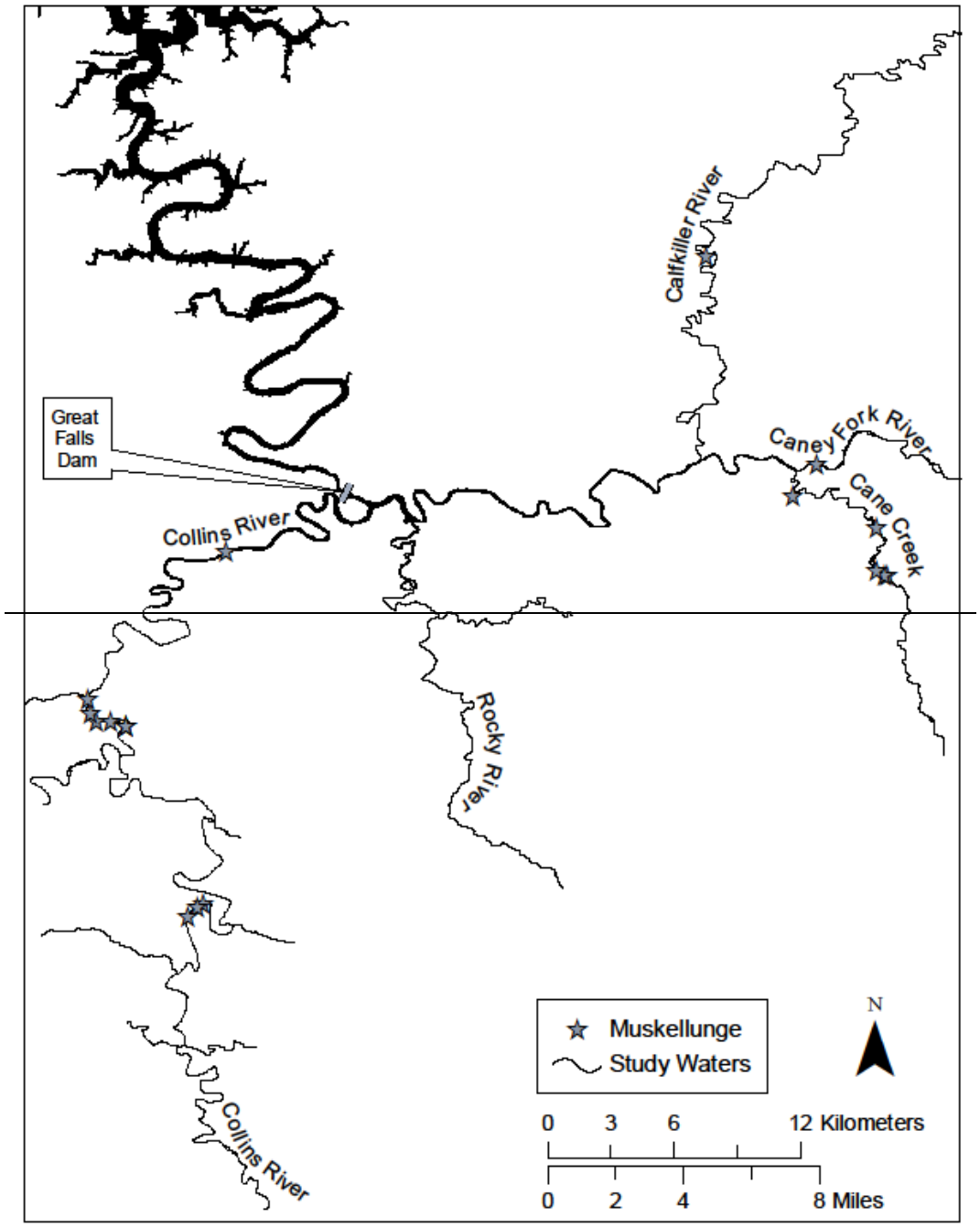

Figure 2. Map of locations where wild age-0 Muskellunge were collected and nursery habitat was quantified in the upper Caney Fork River system, Tennessee.

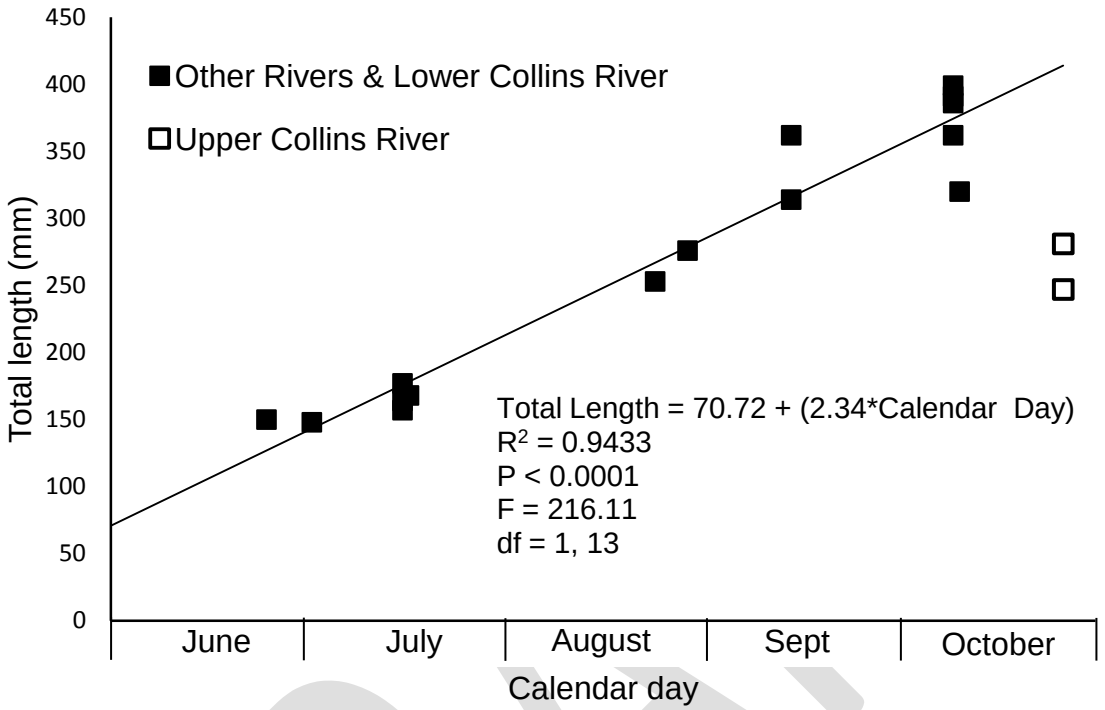

Figure 3. Growth of age-0 Muskellunge collected in the upper Caney Fork River system, Tennessee, in 2012. Two fish collected in the upper Collins River were excluded from the model. The first calendar day was June 1, 2012.