Recovery of Riverine Muskellunge Populations in North Carolina

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Abtract: The muskellunge (*Esox masquinongy*) population of the French Broad River was sampled to determine relative abundance and growth characteristics and to document muskellunge reproduction. In addition, forage fish availability was also documented. Electrofishing catch per unit of effort rates were 4.7 fish/hour in the French Broad River. Over one-third of the muskellunge captured were non-stocked fish, indicating reproduction is occurring. Back-calculated total lengths for muskellunge in the French Broad River were 325, 476, 621, 727, 809, 881, 910, 961, and 1,026 mm total length at ages I-IX, respectively. Growth patterns of French Broad River muskellunge are similar to other riverine populations. That is, growth rates are faster at the younger ages (I-III) and slower at the older ages (VII-IX) than lacustrine populations.

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Muskellunge are native to the Tennessee and New River drainages of western North Carolina (Jordan 1889, Louder and Baker 1968). Point source chemical pollution within the French Broad River portion of the Tennessee drainage caused declines in muskellunge populations and resulted in their apparent extirpation (Cooper et al. 1977, Harned 1979). Pollution abatement practices, which commenced in the 1960s, restored water quality to the level where muskellunge survival was thought possible.

Muskellunge were stocked by the North Carolina Wildlife Resources Commission (NCWRC) in western North Carolina waters beginning in 1970 to reestablish a reproducing population and a muskellunge fishery. The stocking program has successfully reestablished the fishery. Informal interviews of local anglers indicated

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catch rates were 3 to 4 times better than the national average of 1 fish per 100 hours of fishing (T. W. Jones, NCWRC, pers. commun.).

Current stocking rates for the French Broad River are a continuation of those used to reintroduce muskellunge to western North Carolina waters. The stocking rates have not been adjusted to reflect possible natural reproduction, habitat quantity, current population densities, and forage availability. Consequently, the present stocking rates may be both biologically undesirable and cost ineffective to maintain.

In the summer of 1985, the amount of muskellunge habitat was determined for the French Broad River (Monaghan 1985). Once habitat quantities were identified it was still necessary to obtain biological data on the muskellunge before proper management plans for the species could be formulated.

The NCWRC, which had been reading scales for anglers, had not calculated age and growth statistics. In addition, there was evidence scales from muskellunge > 10 years of age are unreliable for use in determining ages (Harrison and Hadley 1979*b*). They recommended the use of cleithrum for ageing muskellunge for better accuracy.

In addition to the lack of age and growth information, data had not been collected to document the contribution of possible natural reproduction in the stream, relative abundance of muskellunge, or forage fish availability. The purpose of this study, therefore, was to verify scale and cleithra annuli readings, determine size at age, document the occurrence of natural reproduction, estimate density, and identify forage size and species available for muskellunge in the upper French Broad River.

The assistance of Dr. E. J. Crossman and his staff in ageing the cleithra as part of the Royal Ontario Museum's Cleithrum Ageing Project is appreciated. We are also grateful to Mr. Frank Wood and Carolina Power and Light Company for providing access to the river from their property and the Western North Carolina Muskie Club for its assistance. This project was cooperatively funded by the North Carolina Wildlife Resources Commission Federal Aid in Fish Restoration Project F-24 and Southern Illinois University Fisheries Research Laboratory.

Methods

Based on the results of Monaghan's (1985) habitat measurement study of the French Broad River, 5 study areas were selected. All sites were located upstream of Asheville. This section of river has a gradient of 0.5 m/km, the width ranges from 26 to 109 m, and mean pool depth is 1.5 m. Tree laps provide the predominant cover for muskellunge in this section averaging 12 laps/km. Aquatic macrophytes are almost completely absent in this section of the river.

The French Broad River received annual stockings of fingerling muskellunge from 1970 to 1981, except for 1974. Since 1981 the river has been stocked on an every other year basis. Fingerling stocking sizes have ranged from 51 to 279 mm, while total numbers stocked per year have ranged from 877 to 10,176.

During the fall of 1984 all study areas were electrofished on 3 separate occasions, except for sample site 3, which was sampled 4 times. A Smith-Root Type VI Electrofisher unit, set at 560 V DC and 60 pulses/sec, drew 6 to 7 amperes during sampling. Areas of still water, usually found behind tree laps, were approached from downstream and shocked only after the probes were situated over the structure.

All fish electroshocked were collected each trip. Species other than muskellunge were identified, measured, and placed in 2.5-cm groups. Those specimens that could not be identified in the field were later identified in the lab using keys by Scott and Crossman (1973), Clay (1975) and Pflieger (1975).

Muskellunge were measured to the nearest millimeter and weighed to the nearest 0.1 kg. Scale samples were taken from the left side of each fish, below the lateral line, one-half the distance between the pectoral fin and the insertion of the dorsal fin. Cleithra were removed from 1 fish in each 10-cm group. Those muskellunge from which cleithra were removed were later examined to determine sex and stomach contents. Scales and cleithra were also collected from muskellunge caught by anglers and from small, known-age (age 0) hatchery reared fish. These scales were used only to compute the body length-scale radius regression formula. Thus, scales collected over the 5-year period 1980–1984 were used in the back-calculations of length.

Scales were either mounted on slides using clear tape or an impression was made in acetate slides. The scales were read using a microfiche reader set at a magnification of 24X. Scale radii and distance to annuli were measured and recorded. The number of annuli on both cleithra and scales were checked for agreement when they were collected from the same fish. When a difference between scale and cleithra reading occurred the structures were re-read and, if the disagreement could not be resolved, they were deleted from back-calculations. Scales from 121 French Broad River muskellunge, ranging in size from 136 to 1,130 mm total length (TL) were read. Scale radii were regressed against total length at capture and lengths at the various ages were back-calculated according to the Lee Method (Lagler 1956).

The left pelvic fin was clipped on all fish stocked in 1983 and 1984. This provided the opportunity to collect known-age fish for validation of annuli. A cursory examination of food habits was made on fish sacrificed to obtain cleithra. All food items were identified to the lowest possible taxon.

When water temperature rose to 10° C in the French Broad River, 10 egg capture boxes were placed at sites identified as probable spawning habitat. In the spring of 1985 this temperature was reached during the month of April. Boxes were examined at least every other day for the presence of eggs. When water temperature reached 15° C, 20 days after deployment, the boxes were removed.

These boxes, similar to those described by Gammon (1965), consisted of 60-cm square wooden frame of 2.5-cm by 7.5-cm stock with a center rib. Fiberglass window screen, having a mesh size of 1.5 mm, was stapled to the frame. A 2.7-kg lead weight was attached to the center rib as ballast. The top of the box was covered by 6.3-mm hardware cloth to prevent predation on eggs by small fishes. Captured

eggs were preserved in 5% formalin and later examined to determine if they fit the descriptions of muskellunge eggs given by Galat (1973) and Scott and Crossman (1973).

In May 1985 the same areas were sampled for muskellunge larvae. Larvae sighted in still water areas along the banks were netted with a fine mesh dipnet. Larvae were also collected in 2 V-shaped light traps placed in still water areas. Light traps consisted of a wooden box with 2 glass panels forming an inward V on 1 side. Light traps were deployed in the evening and checked each morning for a total of 5 nights. All larvae collected by both methods were compared to muskellunge larvae collected from hatchery ponds and to descriptions provided by Galat (1973).

Results

Adult Sampling

Eighteen muskellunge were either captured or stunned during 3.8 hours of actual electrofishing. This represents capture rates of 4.7 fish/hour, 1.3 fish/km, or 0.4 fish/ha (Table 1). Four fish stunned by the electrofisher were not captured; however, these fish were included in the capture rate calculations. Out of the 14 muskie captured, 10 of them were collected in sample area 3. This area contains the greatest number of tree laps per kilometer and had the highest catch rate of all the sample areas at almost 12 fish/hour (Table 1.).

Most of the stomachs of muskellunge captured in this study were empty, however, 1 contained a river chub (*Nocomis micropogon*) and another contained a green sunfish (*Lepomis cyanellus*). Muskellunge for which stomach contents were examined ranged in weight from 0.9 to 7.5 kg.

Cleithra were collected from 10 muskellunge, ranging in size from 535 to 959 mm TL. Out of these 10 fish there was only 1 disagreement between readings from scales and cleithra.

The body-scale relationship was linear (Table 2). Muskellunge in the French Broad River grew rapidly to age III (621 mm). After age III, growth was much

Table 1. Catch per unit of electrofishing effort for muskellunge in the French Broad River during fall 1984.

	Catch per unit of effort			
Sample area	Fish/hour of electrofishing	Fish/ha	Fish/km shoreline	Number of fish captured or stunned
1	0.0	0.0	0.0	0
2	0.0	0.0	0.0	0
3	11.6	1.1	4.1	13
4	4.3	0.3	0.9	3
5	4.7	0.4	1.3	2
Mean ($\bar{x}$)	4.7	0.4	1.3	
TOTAL				18

Table 2. Growth of muskellunge collected from the French Broad River as calculated by the Lee method (TL = a + cS).[a]

N fish	Age group	Back-calculated lengths (mm) at annulus								
		1	2	3	4	5	6	7	8	9
5	I	327								
3	II	367	583							
11	III	345	534	661						
23	IV	309	492	642	759					
26	V	315	435	612	721	804				
29	VI	327	464	626	734	835	900			
12	VII	321	444	572	685	780	851	903		
8	VIII	338	454	576	684	774	854	904	946	
4	IX	305	537	653	736	814	886	946	991	1,026
Average total length (mm)		325	476	621	727	809	881	910	961	1,026
Average annual growth (mm)		325	151	145	106	82	72	29	51	65

[a]TL = 104.2 + 6.1S, $r^2 = 0.907$, $N = 121$.

slower with a total length of 1,026 mm reached at age IX (Table 2). Most fish caught by anglers were 4, 5, and 6 years old; these age groups represented 32%, 26%, and 24%, respectively, of the total number of fish creeled.

Two of the 14 muskellunge captured by electrofishing were from the 1983 year class and were not marked. One marked fish from the same year class was also captured. Three of the 14 fish captured were from the 1982 year class, a year in which no muskellunge were stocked in the French Broad River. Ages determined by cleithra agreed with those determined by scale readings for all of these 1982 and 1983 year class fish. In addition to the stream-hatched fish captured by electrofishing, several unclipped fish from the 1982 and 1983 year classes have been caught by anglers in both the upper and lower French Broad River.

Redbreast sunfish (*Lepomis auritus*), black redhorse (*Moxostoma duquesnei*), bluegill (*Lepomis machrochirus*), hybrid sunfish (*L. cyanellus* X ?), northern hog sucker (*Hypentilium nigricans*), green sunfish, white sucker (*Catostomus commersoni*), and river chub represented 83% of the fish captured. Several common carp (*Cyprinus carpio*) ranging in size from 50 to 100 cm, were also stunned during sampling.

Egg and Larvae Sampling

One opaque egg, 3.2 mm in diameter, was collected. From descriptions in the literature it could not be determined whether the egg was a muskellunge or a sucker egg. No muskellunge larvae were captured, either in the larvae traps or by dipnetting. Several catostomid larvae were captured by both methods.

Discussion

A catch rate of 4.7 fish/hour of electrofishing is the highest reported for muskellunge streams of the southeastern United States. Electrofishing in Kentucky streams produced catch rates of 0.5 to 1.3 muskellunge per hour in Kinniconick and Tygarts Creeks (Kornman 1983) and 0.1 to 1.5 fish/hour (mean = 0.4) in streams of the South Fork Kentucky River drainage (Jones and Stephens 1984). Catch rates in West Virginia streams averaged 0.9 fish/hour (Miles 1978). These differences may be related to gradient and the amount of instream cover. The gradients in Kentucky streams are 1.2 to 3.0 times as steep as the upper French Broad and the entire French Broad is lined with trees while most Kentucky streams are not (Jones and Stephens 1984). Lower gradient streams apparently are more conducive to providing the slow moving pool areas preferred by muskellunge which accounts for their greater abundance in these streams. As stated earlier trees provide excellent sources of cover after they fall into the river, and electrofishing capture rates were highest in the French Broad River where trees were most common. Thus, as in Kentucky streams (Kornman 1983), fallen trees are an important component of muskellunge habitat in the French Broad River.

Length at age data for muskellunge reported in this study are similar to those reported by Brewer (1980) for eastern Kentucky streams and Miles (1978) for West Virginia streams (Table 3). However, French Broad River muskellunge have much faster growth rates than those reported by Parsons (1959) for muskellunge in Tennessee streams (Table 3). This may be due to the difference between gradients of Tennessee streams, 2.5 m/km to 6.8 m/km (Parsons 1959), and the gradient of the upper French Broad River, 0.5 m/km.

When comparing muskellunge growth rates, the differences in growth pattern between riverine populations and lacustrine populations are evident. The concept,

Table 3. Back-calculated total lengths (mm) of muskellunge captured from various geographical locations.

Location	Age								
	I	II	III	IV	V	VI	VII	VIII	IX
Lacustrine									
Canada[a]		508	626	739	850	878	933	1,011	1,117
Wisconsin[b]	204	419	576	710	821	911	984	1,060	1,106
Pennsylvania[c]	198	437	622	754	861	958	1,036	1,105	1,163
Riverine									
Kentucky[d]	264	457	619	747	831	896	912		
Niagara River[e]	294	495	666	765	890	896	944	961	1,011
West Virginia[f]	292	483	607	701	765	808	879		
Tennessee[g]	170	348	488	640	754	826			
French Broad River[h]	325	476	621	727	809	881	910	961	1,026

[a]Hourston (1952).
[b]Schloemer (1936).
[c]Buss and Miller (1961).
[d]Brewer (1980).
[e]Harrison and Hadley (1979*a*).
[f]Miles (1978).
[g]Parsons (1959).
[h]Present Study.

proposed by Harrison and Hadley (1979*a*), that riverine populations are faster growing than lacustrine populations at the younger ages (I-III) and the reverse is true for older fish (VII-IX), is supported by the present study (Table 3). Harrison and Hadley (1979*a*) went on to suggest rapid growth during the first few years of life is due to the abundance of available prey in riverine systems. They attribute the slower growth, at older ages, to a decrease in the forage base of large prey species.

The upper French Broad River appears to provide an excellent forage base for muskellunge, comprised mainly of rough fish. Forage consists of prey items available for both adults and smaller-sized muskellunge. Green sunfish and river chubs are common in the 7.5- to 20-cm size range, while black redhorse, northern hog sucker, and white sucker are common in the 25- to 40-cm size range. Studies of other muskellunge populations show suckers, minnows, and sunfish are often found in muskellunge diets (Hourston 1952, Scott and Crossman 1973, Harrison and Hadley 1979*a*, Brewer 1980). Thus, it appears all ages of French Broad River Muskellunge have an adequate food supply available. The slower growth of French Broad River fish at older ages is probably due to factors other than a decrease in available forage.

Since better than one-third of the muskellunge captured by electrofishing were not stocked fish it is evident reproduction is occurring in the French Broad River. However, the question concerning the amount of natural reproduction occurring needs closer study and better documentation to help fishery managers make decisions concerning stocking rates.

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