Seasonal Movement and Distribution of Smallmouth Bass in a Virginia Impoundment

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Abstract: We described seasonal movements of smallmouth bass (Micropterus dolomieu) in Lake Moomaw, a 1,024-ha western Virginia impoundment, using ultrasonic telemetry in combination with a mark-recapture tagging study. Documentation of lake sections occupied over the course of a 2-year period was used to assess the extent and magnitude of spring migrations of bass to the headwaters of the reservoir. Fish using the headwaters during the spring were drawn mainly from adjacent areas within 9 km of the headwaters, although fish from as far away as the dam were recovered in the headwater area. Use of the headwaters by smallmouth bass from the lake was estimated at less than 20% of the adult population during the spawning season. Redistribution information was also collected and showed that smallmouth bass returned to areas previously occupied prior to spawning. Spawning site fidelity was determined from 6 smallmouth bass tracked over 2 consecutive years; 3 of these fish utilized the same sites during both spawning seasons.

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Many southeastern reservoirs support quality, self-sustaining populations of smallmouth bass. These populations were often derived from riverine stocks present at impoundment. Some lentic smallmouth bass have been reported to exhibit potamodromy, spawning in tributary rivers (Robbins and MacCrimmon 1977, Gerber and Haynes 1988). This characteristic might be even more prevalent for reservoir populations because reservoirs have more flow-through than natural lakes and their smallmouth bass are typically of river origin. However, the degree to which reservoir smallmouth bass populations utilize tributary rivers for reproduction has not been reported. Lake Moomaw, Virginia, has a spawning run of smallmouth bass to its headwaters, which receives intense fishing pressure from harvest-oriented bank anglers. This visible fishery prompted concerns regarding its impact on the reservoir's smallmouth bass population. We used a combination of mark/recapture tagging and

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telemetry observations to describe movement patterns of smallmouth bass within the Lake Moomaw system before, during, and after the spawning season. Our objectives were to: 1) determine general spawning locations and seasonal movements; 2) document general spawning site fidelity; and 3) estimate the percentage of the smallmouth bass population spawning in the headwaters.

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Methods

Lake Moomaw is a 1,024-ha flood control reservoir located in the headwaters of the James River Drainage of Bath and Allegheny counties, Virginia. Gathright Dam impounded the Jackson River, forming Lake Moomaw, in 1981. Total length of the reservoir is 19 km, with 70 km of shoreline. The lake was divided into 4 sections for this study (Fig. 1). The main body of the lake was divided into 3 sections (upper—280 ha; middle—400 ha; and lower—280 ha) that utilized natural land features to delineate between sections. Habitat within these main-lake sections consists of a deep, wide and rocky lower section; a shallow, riverine upper section with rocky outcrops, stumps and downed trees for cover; and a middle transitional zone between these habitat types. The fourth section used in this study was the headwaters of the lake, at the confluence of the Jackson River and its major tributary, Back Creek, the site of the spring bank fishery (2 ha, 1 km long).

Tagging

Adult smallmouth bass (fish >300 mm) were captured throughout the 3 main-lake sections from November 1994 through May 1995 and January through April 1996 using sinking monofilament gill nets (50 mm bar mesh, 30.5 m length, 1.8 m depth) stretched perpendicular to the shoreline and along the bottom of the lake. Adult smallmouth bass were also collected from the headwaters of the lake using a pulsed DC electrofishing boat at night during February through May 1995 and again in April 1996. Efforts were made to collect fish from all 3 sections of the lake and the headwaters to obtain a representative sample of the lake population. Fish were measured for total length (to 1.0 mm) and weight (to 1.0 g) and tagged with a highly visible individually numbered dart tag. Tags were attached through the pterygiophores, below the soft rays of the dorsal fin. Each tag was individually numbered, and it included a phone number to contact as well as a reward notice for returning the information contained on the tag. Posters advertising the tagging study were displayed at all boat ramps, bank fishing areas, and local tackle and bait stores in the vicinity of the lake. A total of 278 smallmouth bass were tagged from 15 March to 17 May 1995, while an additional 149 were tagged from 30 September to 25 April 1996.

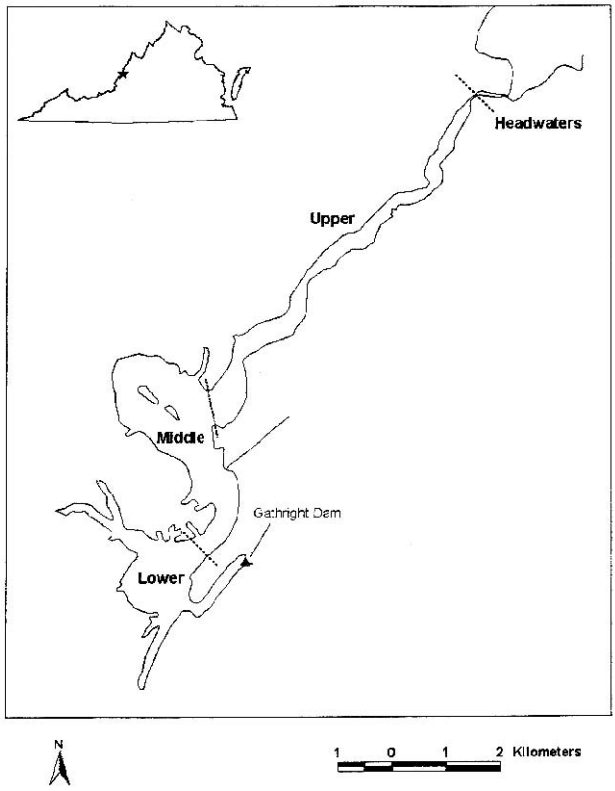

Figure 1. Map of Lake Moomaw, Virginia, denoting the 4 lake sections.

Tag return information was used to describe movements between the original tagging location and the area of recapture. Smallmouth bass were classified as having moved when they were recaptured (by anglers or by biologists during surveys) in a different lake section than where they were tagged. Fish recaptured in the same section in which they were tagged were considered sedentary. Fish tagged in the main lake and recovered in the headwaters yielded information on the lake section of origin for fish that presumably spawned in the headwaters. The proportion of tagged fish that was recovered in the headwaters provided an estimate of the percentage of smallmouth bass that spawned in the headwater area. Smallmouth bass tagged in the headwaters during the spawning season and later recovered in the main body of the lake described post-spawning redistribution of this segment of the population.

Telemetry

Temperature-sensing ultrasonic transmitters (16 x 60 mm; 22 g in air, 24-month life; Sonotronics model CTT-83) were surgically implanted into 8 smallmouth bass

prior to the 1995 spawning season (mid-April), and an additional 12 fish prior to the 1996 spawning season. Total length of smallmouth bass implanted with transmitters ranged from 325 mm to 510 mm. Bass were collected from all 3 sections of the reservoir in an attempt to obtain a representative sample of the lake population. Each transmitter was inserted into the abdominal cavity through a 2-cm incision located adjacent to the abdominal midline above the anal vent following procedures similar to those of Hampton (1993) and Ridgeway and Schuter (1996). Incisions were closed using surgical staples, and the smallmouth bass were immediately released to the area of capture.

Between January 1995 and April 1996, ultrasonic transmitters were implanted in 7 smallmouth bass in the lower section of the reservoir, 6 in the middle section, and 7 in the upper section of the reservoir. Tracking of individual fish ranged from zero to 18 months (mean of 8 months); 3 fish were tracked for $\leq$1 month and discounted from further analysis. Six smallmouth bass were tracked through 2 spawning seasons (1995 and 1996), and 10 through the 1996 spawning season.

Telemetry observations included assessing locations using a uni-directional hydrophone (Sonotronics model DH-2). Tracking occurred weekly during the spawning season and monthly during winter. Locations were obtained twice per month during other seasons. Smallmouth bass were tracked from February 1995 to September 1996, and locations derived using methods similar to Cole and Morning (1997). Locations were determined by using a U.S. Geological Survey topographic map in combination with easily identifiable landmarks along the shoreline. Locations were determined by triangulating the position of fish from multiple compass bearings, using shoreline features, and driving the boat into close proximity to the fish. The entire lake was searched by boat during each tracking survey.

Spawning sites were inferred from the location of fish with transmitters during periods when water temperatures were conducive to spawning (16–22 C; Carlander 1977, Jenkins and Burkhead 1993, Lukas and Orth 1995), and smallmouth bass showed sedentary behavior in areas with suitable spawning habitat. Smallmouth bass would commonly reside in an area with desirable spawning habitat for several weeks before returning to the areas previously occupied. Six smallmouth bass that were tracked for both the 1995 and 1996 spawning seasons provided information on spawning site fidelity.

Results and Discussion

Tag Returns

Of the 427 smallmouth bass tagged (Table 1), 33% were recaptured by anglers or biologists. Of these recoveries, 79% were recaptured in the spring (Table 2). Lentic smallmouth bass have been reported to range widely, especially during the spring (Robbins and MacCrimmon 1977, Gerber and Haynes 1988, Reeser 1995). The results of our tag returns show that the majority of smallmouth bass movement in Lake Moomaw is associated with the spring spawning season, and fish that do move

Table 1. Distribution at time of dart-tagging of smallmouth bass in Lake Moomaw, Virginia. Percent of line total is in parentheses.

Year	Lower	Middle	Upper	Headwaters	Total
1995	63 (23%)	44 (16%)	110 (40%)	61 (22%)	278
1996	19 (13%)	88 (59%)	18 (12%)	24 (16%)	149
Total	82 (19%)	132 (31%)	128 (30%)	85 (20%)	427

Table 2. Origin and recapture location of dart-tagged smallmouth bass in Lake Moomaw, 1995 and 1996.

	Year	Lower	Middle	Upper	Headwaters	Total
Lower origin	1995	3	1	0	1	5
	1996	9	5	2	0	16
Middle origin	1995	1	2	0	0	3
	1996	9	14	5	5	33
Upper origin	1995	1	0	5	6	12
	1996	2	1	4	5	12
Headwaters origin	1995	1	0	0	16	17
	1996	2	1	1	10	14
Total		28	24	17	43	112

during this time likely redistribute to areas previously occupied as the spawning season ends. The catch of tagged fish in areas other than those in which they were originally captured was greatest during the spring and almost non-existent during other seasons. During the spring of 1995, 30% of recaptured smallmouth bass were recovered in areas outside of their original tagging section in the reservoir (Table 2), while in the spring of 1996, 49% had moved between lake sections. However, 87% of fish that were recaptured after the peak period of movement (spring spawning and redistribution period, April through mid-June) were recovered in the lake section in which they were tagged, indicating a tendency to return to the same general area occupied prior to the spawning season.

Tag returns during the spring give insight into the lake sections used for spawning. Bass tagged in the lower section were recovered primarily in the lower and middle sections (86%, Table 2). Fish tagged in the middle section were recovered in the middle and lower sections, predominantly (72%). Fish tagged in the upper section were more likely to be recovered in the upper section and headwaters area (83%). Headwaters tagged fish were predominantly recovered in the headwaters during the spawning season (84%). This information indicates that smallmouth bass that travel to the headwaters during the spring are primarily drawn from the upper section of the

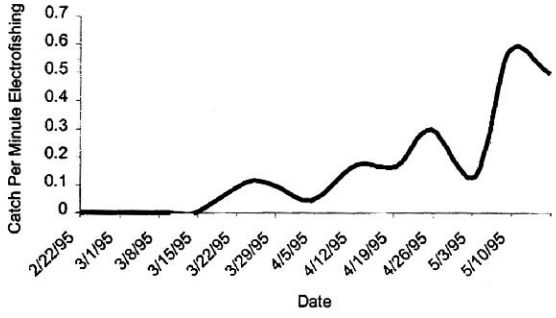

Figure 2. Electrofishing catch per minute for adult smallmouth bass captured in the Headwaters of Lake Moomaw, 1995.

reservoir, although some fish from all lake sections are found here. Further, fish from the lower 2 sections of the reservoir are more likely to use the lower sections during the spring spawning season than up-lake areas. The lower main-lake section appears to be at least as important as the headwaters area during the spring spawning season.

Although smallmouth bass spawning migrations to the headwaters of a reservoir have been documented before (Robbins and MacCrimmon 1977, Gerber and Haynes 1988), no estimates of the magnitude of these runs have been presented to date. Repeated electrofishing in the headwaters of the reservoir show this area is primarily used during the spring spawning season (Fig. 2). Information obtained from our 2-year tagging project indicated that only a small portion of the reservoir's smallmouth bass population used the headwaters to spawn each year. Excluding fish tagged in the headwaters, 81 tagged fish were reported, 17 (21%) of which were recaptured in the headwaters. This suggests that a large portion of the adult smallmouth bass population remain in the main body of the reservoir. This is confirmed by the fact that even during the spring, when movements of fish outside of their home areas were highest, most recaptured smallmouth bass were recovered in the original location of tagging, showing no spawning migrations. Therefore, the majority of smallmouth bass are not exposed to the headwater fishery. Information obtained from our tag returns indicates that exploitation rates (adjusted for tag loss, mortality and nonreporting) are approximately 16%–20% for the smallmouth bass using the headwaters during the spring. The headwaters fishery results in an annual exploitation rate of 4%–6% on the total lakewide population (Garren 1998).

Telemetry

Distribution of smallmouth bass during the spawning period can be classified by 3 patterns of movement: sedentary (stayed within home lake section), down-lake movements, and up-lake movements. In both years, 50% of the fish did not leave the lake section in which they were tagged, showing no spawning migration tendency.

Table 3. Number and location of telemetered smallmouth bass during the spawning seasons (1995 and 1996) relative to location at transmitter implantation in Lake Moomaw, Virginia.

		Spawning Location			
Origin	Year	Lower	Middle	Upper	Headwaters
Lower	1995	2			
(*N*=6)	1996	3	1		
Middle	1995	2			
(*N*=7)	1996	2	2		1
Upper	1995			1	1
(*N*=9)	1996	2		3	2

Down-lake movements were documented for 27% of smallmouth bass with transmitters during the spring spawning season over both years. Conversely, 23% of study fish showed an up-lake migration pattern over the course of the study. As found with tagging, only a small percentage of smallmouth bass migrated up-lake during the spring. Down-lake migrations accounted for slightly more movements than up-lake, and indicate that habitat features found down-lake are at least as important as those found elsewhere. All smallmouth bass that did migrate during the spring spawning period and were not harvested returned to the lake section in which they were captured after the spawning season ended.

Smallmouth bass implanted with transmitters typically restricted their spring movements to areas nearby their lake section of origin. Fish in the lower section of the reservoir were more likely to stay in this area than travel to other areas of the lake. Five of 6 fish from this section did not leave the lower lake while the sixth bass traveled up-lake to the middle section during the spawning season (Table 3). Of the 7 bass implanted with transmitters in the middle section of the lake during the study, 6 either migrated down-lake to the lower section or remained sedentary during the spawning season, while 1 traveled up-lake to the headwaters. Eight bass fitted with transmitters in the upper section of the lake were tracked during the spawning seasons. Seven of these fish either remained sedentary or moved up-lake to the headwaters, while 1 fish traveled down-lake to the lower section of the reservoir.

Up-lake migrations to the headwaters were documented for a small percentage of the fish with transmitters (17% in 1995 and 19% in 1996). The spawning season movement pattern of reservoir fish observed in the telemetry data substantiates that from tag returns (21% of spring tag returns for reservoir fish were recovered in the headwaters). The fish used for both the telemetry project and the tagging project were captured throughout the lake in order to obtain a representative sample of the smallmouth bass population. However, electrofishing data collected in each of the 3 lake sections indicate relative densities of bass vary among lake sections, with greatest densities found in the lower section, and lowest densities found in the middle sec-

tion (P. Bugas, pers. commun.). To the extent that these combined samples of fish are representatives of the overall population, approximately 20% of the lake population use the headwaters to spawn each year.

Our telemetry results corroborate the findings of others, showing that after the spawning season ends (mid-Jun) smallmouth bass redistribute to areas occupied previously (Forney 1961, Peterson and Myhr 1977, Langhurst and Schoenike 1990). Four fish moved up-lake during the spring, while 5 moved down-lake. Two fish that migrated to the lower section and 2 fish that showed up-lake migrations were harvested prior to the end of the spawning season and did not provide any redistribution information. The remaining 5 fish all redistributed to the same lake section occupied prior to the spawning season, and show that smallmouth bass do home in on areas used previously. Similar results were obtained from the tagging portion of the current study, which showed the majority of bass captured after the spawning season were obtained in the lake section they occupied when tagged.

Over the course of the 2-year telemetry project, 6 fish were tracked for 2 consecutive spawning seasons. Information on exact nest location was unavailable for smallmouth bass that moved to the headwaters during the spawning season. One smallmouth bass made a spawning trip to the headwaters during both 1995 and 1996, while 1 other bass traveled to the headwaters during 1996 only. The remaining smallmouth bass stayed in the reservoir. General nest locations were obtained over both spawning seasons. Of these fish, 3 of 4 were located within 200 m of areas used the previous year during the spawning period. In Lake Opeongo, Ontario, Ridgeway et al. (1991) found 81% of smallmouth bass spawned within 200 m of their previous nest site. Robbins and MacCrimmon (1977) also noted this tendency of smallmouth bass to use areas previously used for spawning and showed that 34% of surviving river spawning smallmouth bass in Lake Simcoe, Ontario, return to the upriver spawning site in subsequent years. Although the sample size of repeat spawners with transmitters in this study is low, it appears that there is the tendency for spawning site fidelity.

Movements of smallmouth bass have been well documented by researchers utilizing telemetry and tagging/recapture methods. These studies have shown smallmouth bass typically restrict travel to distances $<$10 km from their original tagging location or "home area," although greater distances have been recorded (Forney 1961, Robbins and MacCrimmon 1977, Pflug and Pauley 1983, Todd and Rabeni 1989, Kraai et al. 1991, Reeser 1995). Results from this study show similar trends. Reservoir headwaters use by smallmouth bass outfitted with transmitters only occurred during the spring spawning period and was dominated by fish originating from nearby areas (the upper lake section, and to a lesser extent, the middle lake section), which agrees with the movement patterns found by other researchers. A few dart-tagged smallmouth bass did travel to the headwaters from the lower section (as much as 19 km), but this was exceptional. Smallmouth bass rarely traveled over 9 km to reach the headwaters.

Redistribution information of smallmouth bass that used the headwaters is limited. Only 1 of 6 bass with transmitters moved to the headwaters in 1995, and 3 of 16 bass moved to this area during 1996. Two of these fish were harvested in the headwa-

ters fishery, while the other 2 moved downstream to the original capture area. Redistribution of dart-tagged fish from the headwaters is limited to 8 bass tagged in the headwaters and captured elsewhere. These fish were recaptured throughout the reservoir and show that smallmouth bass using the headwaters to spawn during the spring redistribute throughout the lake. This redistribution is also documented by repeated electrofishing in the headwaters during the spring, which showed these fish did not stay in the headwaters year around, but used this area seasonally (Garren 1998). Past research has documented the redistribution of smallmouth bass from spawning areas back to home areas (Robbins and MacCrimmon 1977) as well as the ability of smallmouth bass to home to areas previously occupied in both lakes and streams (Fajen 1962, Hubert and Lackey 1980, Todd and Rabeni 1989, Langhurst and Schoenike 1990, Kraai et al. 1991). Based on this documented homing tendency by other researchers, it is assumed that smallmouth bass moving out of the reservoir to the headwaters during the spring redistributed to the same areas of the reservoir occupied prior to their spawning migrations. This is supported by our observations of the movements of the smallmouth bass with transmitters we tracked within the lake: all of the fish (excluding those harvested or otherwise removed from the sample) returned to the lake section where they were originally captured after making seasonal spawning migrations.

Tag returns and telemetry results indicate that headwaters-spawning smallmouth bass are drawn primarily from the upper third of Lake Moomaw. Suitable smallmouth bass spawning habitat in the upper section of the reservoir is relatively scarce, which apparently prompts some resident bass to seek it elsewhere, both down-lake and in the headwaters. It is also possible that headwaters spawners represent a distinct genetic stock. Robbins and MacCrimmon (1977) found evidence of a genetically distinct, potamodromous stock in Lake Simcoe, Ontario. However, our limited data on spawning site fidelity demonstrates that Lake Moomaw smallmouth bass may not consistently choose to spawn in the headwaters in successive years, which is contrary to expectations for a potamodromous genetic stock.

The Lake Moomaw headwaters shoreline fishery is very harvest-oriented. However, only about 20% of Lake Moomaw smallmouth bass spawn in the headwaters, and the boat-based lake fishery is primarily catch-and-release (Garren 1998). Tag returns indicate that 16%–20% of headwaters spawners are harvested during the spring fishery, resulting in an annual exploitation rate of approximately 4% on the total Lake Moomaw smallmouth bass population. The headwaters smallmouth bass fishery is concentrated, highly visible, and consumptive, but its impact on the Lake Moomaw smallmouth bass population is negligible.

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