Impact of Localized Harvest on the Population of Smallmouth Bass

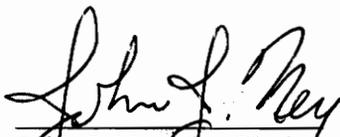## (*Micropterus dolomieu*) of Lake Moomaw, Virginia.

By

Daniel A. Garren

Thesis submitted to the Graduate Faculty of the Virginia Polytechnic Institute and State

University in partial fulfillment of the requirements for the degree of
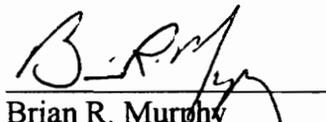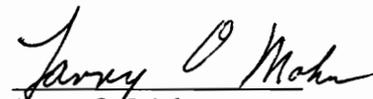
Master of Science

in

Fisheries and Wildlife Sciences

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February 1998

Blacksburg, Virginia

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Abstract

Lake Moomaw, a 1,024-ha flood control reservoir in Bath and Allegheny counties, Virginia contains a migratory population of smallmouth bass that congregate in the headwaters of the reservoir during the spring spawning period, where they are vulnerable to a shore-based, harvest-oriented fishery. The extent of this fishery and resulting effects on the smallmouth bass population were analyzed by means of a creel survey in the headwaters area during the spring spawning seasons of 1995 and 1996. Effort, catch, and harvest, as well as user characteristics and motivations data were obtained from direct interviews with anglers using this area. Estimates for 1995 indicated extensive fishing pressure per ha, with 1,167 angler hours per ha spent fishing for smallmouth bass in the headwaters, while in 1996 almost 1,400 angler hours per ha were spent in this area. Catch and harvest rates were relatively low and sustainable during both years, with 124 smallmouth bass caught and 82 harvested in 1995, while 318 smallmouth bass were caught and 222 harvested in 1996. An extensive capture-recapture

study yielded estimates of exploitation rates for smallmouth bass in the reservoir of 12-15% annually. Exploitation of the whole-lake population occuring in the spring headwaters fishery was estimated at 4-6%, while the exploitation rate on the subset of the population using the headwaters during the spring was 11-14%. Analysis of movements of smallmouth bass in the reservoir using ultrasonic telemetry and dart tag recaptures indicated that the subset of the population using the headwaters was mainly drawn from the upper and middle portions of the reservoir, and that significant amounts of spawning occurred in the lower section of the reservoir as well. Areas used by smallmouth bass for reproduction were documented with summer and fall electrofishing to determine relative abundance of young-of-the-year smallmouth bass in the reservoir, and showed spawning to take place throughout the reservoir. Densities of young-of-the-year shifted as fall progressed, with highest densities in the middle portion of the reservoir in early fall, indicating that reproductive inputs from the headwaters were realized in the lake as fall progressed. The headwaters fishery is a high-profile activity which, during 1995-96, had a low and sustainable impact on the Lake Moomaw smallmouth bass population.

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INTRODUCTION

The smallmouth bass, *Micropterus dolomieu* has been described as being "inch for inch and pound for pound, the gamest fish that swims" (Henshall 1889). Historic territory encompassed the Great Lakes-St. Lawrence and upper Mississippi basins, southward in the Ohio basin to Georgia and Alabama, and westward to the Red drainage of eastern Oklahoma (Jenkins and Burkhead 1993). Due to the popularity of these superior sportfish, introductions around the natural geographic barriers have occurred. Viable populations have been established across the United States and in Canada, Hawaii, Asia, and Africa (Coble 1975). Smallmouth bass adapt well to reservoirs that impound streams containing suitable habitat, and they are prolific in many natural northern lakes (Jenkins and Burkhead 1993).

Construction of dams force stream-dwelling smallmouth bass to adapt to a lentic environment. Habitat alterations and introductions of nonnative species may alter smallmouth bass behavior. This may include spawning migrations which occur infrequently in natural lentic populations of smallmouth bass. When suitable spawning habitat is not available or not utilized by lentic populations of smallmouth bass, they may migrate to tributary streams seeking preferred spawning environments.

Smallmouth bass in Lake Moomaw, a western Virginia flood control reservoir, appear to migrate in this manner. Numerous reports from anglers familiar with Lake Moomaw report migrations of smallmouth bass out of the reservoir and into the headwaters (the confluence of the Jackson River and Back Creek and beyond) during the

spring spawning period. Concern arises from the fact that there is substantial angling

pressure in the headwaters area during the spring, and potentially significant harvest of

smallmouth bass. Problems may arise if a large percentage of the population of

smallmouth bass in Lake Moomaw uses the headwaters for spawning in the spring and

angling pressure results in substantial harvest. Potential effects include reduced spawning

success and recruitment, as well as overfishing the adult population. This study addresses

the behavior and status of smallmouth bass in Lake Moomaw by focusing on seasonal

movements of smallmouth bass, angler harvest in the headwaters during the spring

spawning period, and the effects of this harvest on the overall population of smallmouth

bass in this lake.

In Virginia, smallmouth bass mature at three to four years of age (Jenkins and

Burkhead 1993). This developmental state varies for individual fish in each year class,

with larger fish in a year class typically developing into adults faster than smaller fish of

the same year class (Raffetto et al. 1990). Spawning occurs in the spring as temperatures

increase to 16-22°C. At this time, adult fish move into littoral zones and prepare to

spawn. Males are responsible for building nests that frequently occur in 0.5 to 1.2 m of

water, but can occasionally occur as deep as 6 m (Coble 1975). A male will guard the nest

for one to two weeks before the fry swim up out of the substrate, and an additional two to

three weeks until the fry disperse (Ridgeway 1989). Vogele (1981) notes that the length

of the spawning season depends on the rate of water temperature rise during the nesting

period. Not all fish of breeding age will reproduce each year. The smallmouth bass's

vulnerability to angling during the spawning period can result in nest failure and increased

angler harvest. Raffetto (1990) found very few males to breed more than once in their lifetimes both in the laboratory and in a temperate seepage lake in Wisconsin. Robbins and MacCrimmon (1977) found that legal and illegal harvest resulted in a loss of 47% of the spawning population in Lake Simcoe, Ontario.

Numerous studies have been conducted involving smallmouth bass movement in lakes and reservoirs, including work by Webster (1953), Forney (1961), Peterson and Myhr (1976), Robbins and MacCrimmon (1977), Hubert and Lackey (1980), Pflug and Pauley (1983), and Gerber and Haynes (1988). All of these studies involved either radio telemetry, ultrasonic telemetry, or tagging with later recapture. Smallmouth bass usually are sedentary, with well defined home ranges. Previous work has exhibited diel (Demers et al. 1996, Cole and Morning 1997) and seasonal patterns of movement (Peterson and Myhr 1977). Todd and Rabeni (1989) found definite patterns of diel activity and habitat use in stream-dwelling smallmouth bass, and this activity to be modified by seasonal changes in water temperature. Gerber and Haynes (1988) found that little movement occurred during nights.

Seasonal migrations occur as spring water temperatures increase to 12° C and higher, when smallmouth bass move out of residence areas and into spawning areas. In reservoirs, this can be in the tributaries, as documented by Robbins and MacCrimmon (1977). Fish may remain in tributaries from a few weeks to the entire summer, perhaps even becoming permanent stream residents (Gerber and Haynes 1988). As temperatures continue to increase, smallmouth bass move out of spawning areas and back to their residence areas. During winter, smallmouth bass are usually found in deep water around rocky cover (Munther 1970).

Smallmouth bass are able to "home" in on specific locations. Mark-recapture and biotelemetry studies have revealed that smallmouth bass often restrict their movements to a small home area that can vary from 0.3 to 2.21 hectares (Walters 1986). Discrete stocks of smallmouth bass are found within large lakes and reservoirs due to the establishment of these home ranges (Webster 1953; Gerber and Haynes 1988). In 2,000-ha Lake Sammamish in Washington, Pflug and Pauley (1983) found 81% of nondisplaced smallmouth bass were recaptured in the area where they were originally captured and marked, showing a definite affinity for a home area. Homing has been observed in studies involving displacement of smallmouth bass to areas outside their home ranges. In both breeding and nonbreeding seasons, smallmouth bass will usually return to the point of capture, and displaced bass will usually move more than nondisplaced bass (Hubert and Lackey 1980; Pflug and Pauley 1983; Gerber and Haynes 1988). A mark-recapture study in 12,000-ha Oneida Lake in New York found about 80% of recaptured smallmouth bass occurred within 2.4 km of their tagging sites (Forney 1961). Pflug and Pauley (1983) found 41% of fish released outside the original capture site returned to the initial capture site in Lake Sammamish. Displaced smallmouth bass returned to the initial capture areas from as far as 9.7 km. Many fish returned to the exact location, such as a dock, or other notable landmark, from where they originated.

Problem Summary and Purpose of This Study

Fisheries managers and some anglers were concerned about potentially substantial harvest of smallmouth bass in a localized area of Lake Moomaw during the spring. Spawning smallmouth bass congregate in the headwaters of the reservoir, at the confluence of Back Creek and the Jackson River, where fishing effort and harvest appear to be intensive. This study assesses the headwaters fishery and its impacts on smallmouth bass in Lake Moomaw. I quantified angler harvest in the headwaters area and related this to the main lake fishery. I also described seasonal movements to determine the magnitude and duration of bass migration to the headwaters region. Distribution and relative abundance of young-of-the-year smallmouth bass throughout Lake Moomaw were documented to evaluate headwater harvest impact on recruitment.

Little research has been done on limnodromous stocks of smallmouth bass. Robbins and MacCrimmon (1977) and Gerber and Haynes (1988), described the movements of stream-spawning lacustrine smallmouth bass stocks. Neither of these studies estimated the percentage of the lacustrine population that utilized lotic environments for spawning or the magnitude of angler harvest that resulted from these large groups of congregated fish. If a large percentage of a population of smallmouth bass use a small, easily accessible area such as the headwaters of Lake Moomaw for spawning and angler harvest is significant, the size structure of the population and relative densities

of smallmouth bass in the reservoir may be affected. Sustained recruitment and reproduction of the lentic-based population could also be affected.

This study addresses the issue of springtime movements and harvest and the resulting effects on the population of smallmouth bass in Lake Moomaw, Virginia. It is likely that similar movements occur in other reservoirs. If this is the case, problems may arise in these other systems regarding recruitment and spawning success. Managers in these other systems may not be aware of this aspect of smallmouth bass behavior in reservoirs but it may be important in conserving their fisheries if localized harvest results in overfishing or poor recruitment. Information obtained from this study should prove valuable to management of limnodromous stocks of smallmouth bass in lakes and reservoirs throughout the present range of the species.

Goal and Objectives:

The goal of this research was to determine the impact of localized harvest on the smallmouth bass population of Lake Moomaw. Specific objectives of the study are:

1. Describe seasonal movement patterns and distribution of smallmouth bass in Lake Moomaw;

2. Quantify the spring headwaters harvest and assess its effect on the adult smallmouth bass population of the lake; and

3. Evaluate the resulting effects on reproductive success and recruitment in Lake Moomaw.

STUDY AREA

Lake Moomaw is a 1,024-ha reservoir located in the headwaters of the James River drainage of Bath and Allegheny counties, Virginia (Figure 1). Gathright Dam impounded the Jackson River, forming Lake Moomaw, in 1981. The U.S. Army Corps of Engineers operates the dam to provide flood control and to augment low flows to improve water quality along the Jackson and James Rivers downstream. Fluctuations in the normal full pool level (482.5 m elevation above sea level) may range from 1 to 7 m, but are typically 3 to 5 m annually. Maximum depth of the reservoir is 45 m and mean depth is 15 m. The reservoir consists of a deep, wide and rocky lower section, a shallow, riverine upper section with rocky outcrops, stumps, and some downed trees for cover, and a middle transitional zone between these habitat types. Total length of the reservoir is 19 km, with 70 km of shoreline.

The confluence of Back Creek and the Jackson River is considered the headwaters of Lake Moomaw (Figure 2). Private land begins about 300 m upstream from the confluence on each tributary, and marks the upper limits of the bank-based headwater fishery. The lower bounds of the headwaters is located 400 m below the confluence of the tributaries at Mclintic bridge. Access to fish the lake from the bank is limited below this bridge by a cliff on the east side of the reservoir, and several shallow mud flats on the west side. Total surface area of the headwaters area is 2.1 ha. Anglers can readily access about 90% of the bank in this area due to a series of trails that wind along the shore, providing ample room to fish.

LAKE MOOMAW
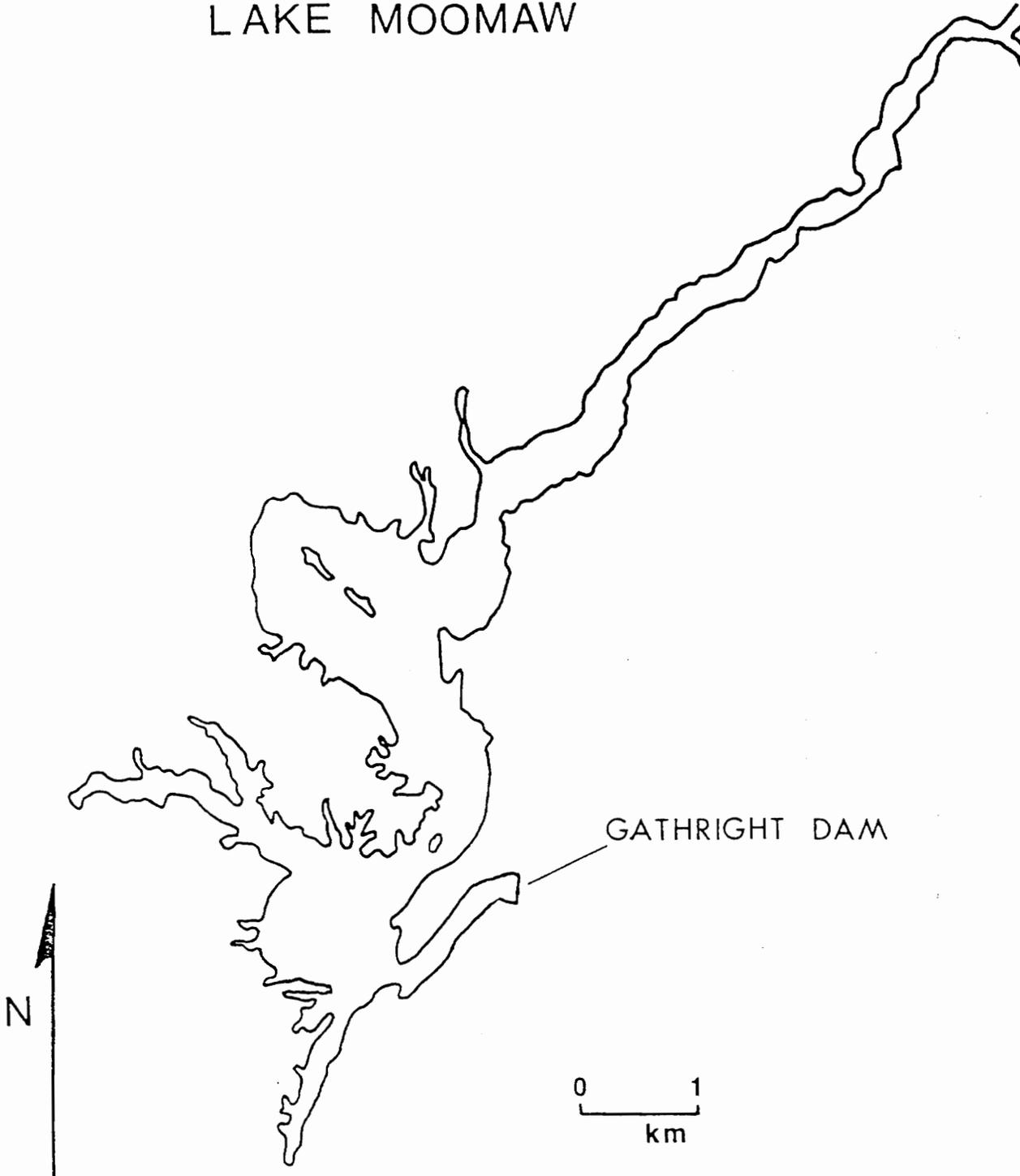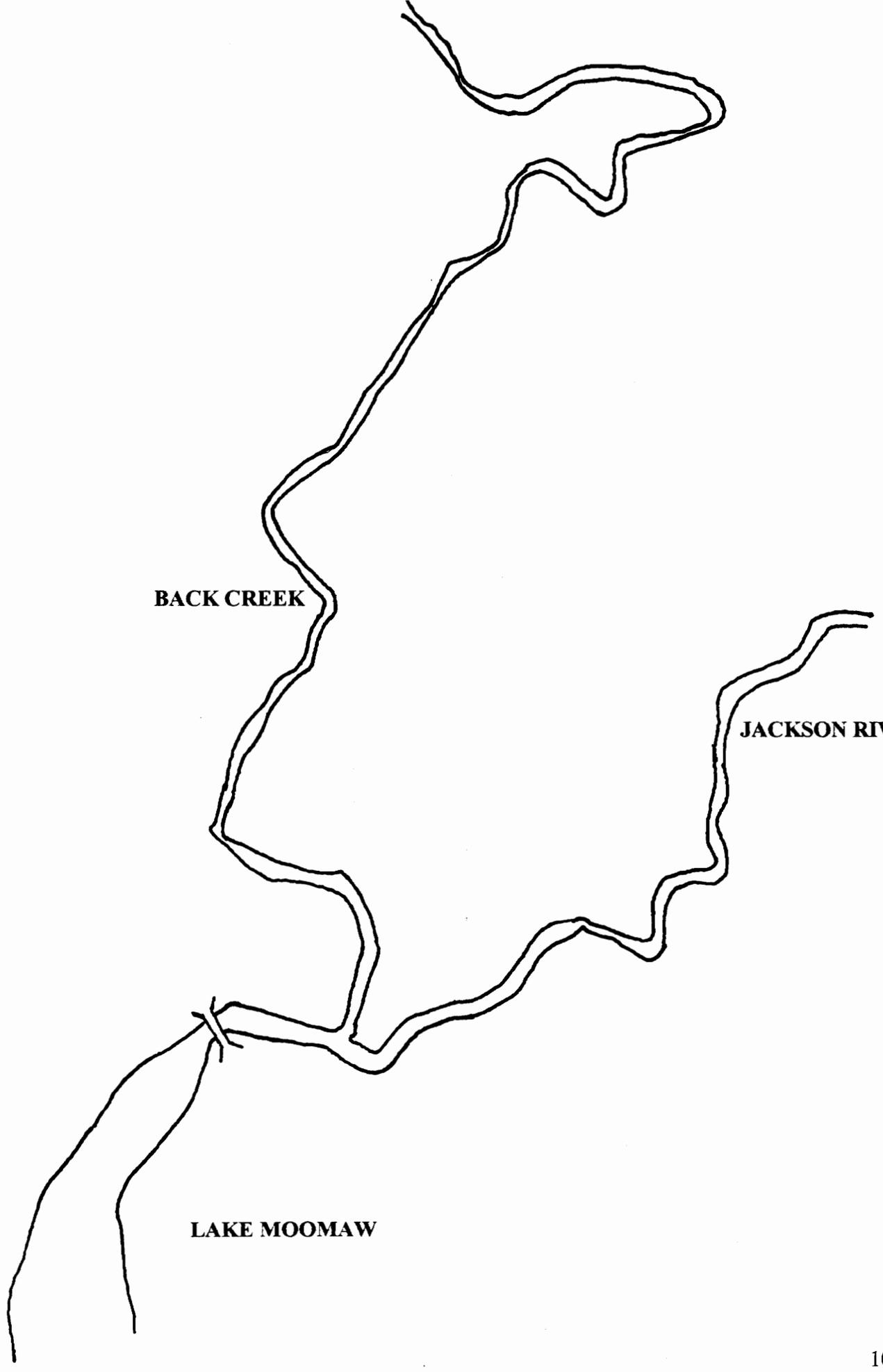
GATHRIGHT DAM

N

0   1
km

BACK CREEK

JACKSON RIVER

LAKE MOOMAW

Lake Moomaw supports a two-story fishery for both warmwater and coldwater species. Coldwater species including brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* are stocked in Lake Moomaw, while warmwater species such as largemouth bass *Micropterus salmoides* and smallmouth bass *Micropterus dolomieu*, channel catfish *Ictalurus punctatus*, black crappie *Pomoxis nigromaculatus* and yellow perch *Perca flavescens*, as well as bluegill *Lepomis macrochirus*, redbreast sunfish *Lepomis auritus*, and redear sunfish *Lepomis microlophus* are found in the reservoir. Species such as gizzard shad *Dorsoma cepedianum*, alewife *Alosa pseudoharengus* and spottail shiners *Notropis hudsonius* provide forage for predatory fish. The black bass fishery in the lake is currently managed with a minimum length limit of 305 mm, and five fish per person per day bag limit.

Federal and state-owned lands surround Lake Moomaw. There are no private residences on the banks of the lake, although there are a few private residences within 2 km of the headwaters on the Jackson River upstream of the lake. Access to the lake is provided through three boat landings, although shoreline fishing is possible at some sites. Most anglers target trout, black bass or a combination of these species. A previous creel survey by the Virginia Department of Game and Inland Fisheries (Bugas 1992) indicated that fishing pressure was relatively light, probably because of the lake's location well away from urban areas.

METHODS

It was necessary to estimate the number of smallmouth bass harvested in the headwaters fishery to determine if exploitation in this area during the spring was excessive, and potentially detrimental to the population in the reservoir. To do this, I implemented a creel survey during 1995 and 1996 to monitor harvest in this area during the spring. It was also necessary to determine the extent of smallmouth bass use of the headwaters during the spring spawning period. I used a movement study with ultrasonic telemetry to obtain specific movements of adult smallmouth bass, and a tagging-recapture project that monitored general movements of a large number of smallmouth bass. Additionally, I attempted to quantify areas in the reservoir and headwaters that were responsible for spawning and recruitment of smallmouth bass and whether spawning habitat was limited to the headwaters and tributaries of the lake. Further, I attempted to monitor dispersal of age-0 smallmouth bass from lake sections with good spawning habitat to other areas of the reservoir.

Creel survey

I conducted a creel survey at the confluence of the Jackson River and Back Creek from March through May in 1995 and 1996 to determine angler use, catch, and harvest of the headwaters fishery. I used the access point survey method described by Pollock et al. (1994) because access was limited to two parking lots or a small stretch of road nearby for anglers to park. I sampled one randomly chosen weekday per week in 1995, and all

weekend days and holidays. As angling pressure increased during March of 1995, I added

one additional weekday per week to the sampling schedule. In 1996, two randomly

chosen weekdays per week were sampled, as well as all weekend days and holidays

throughout the survey period. I further stratified sample days into morning and evening

periods of equal length. Because angler pressure variation throughout an entire day was

unknown in 1995, I assigned equal probabilities to morning and evening periods. In

addition to the half-day periods sampled, I randomly chose two weekdays and two

weekend days each month to sample the entire day from sunup to sundown. Full day

sampling allowed documentation of daily variation in angling pressure, which I used to

adjust 1996 sampling. For 1996, I assigned probabilities of 0.4 for morning periods and

0.6 for evening periods based on angler pressure information gathered during the full-day

samples in 1995. In 1996, I again sampled four full days per month to estimate

distribution of effort during the day. In all, over 28% of the total potential fishing time

was sampled during the creel survey.

I estimated angler effort in the headwaters by making a series of instantaneous

counts of anglers on an hourly basis. Instantaneous counts are made quickly such that

there is little or no change in the position and numbers of anglers during the count

(Pollock et al. 1994). The first count occurred during the first hour of the sample period

at a randomly determined time, and successive counts followed at hourly intervals. Total

time to conduct each count was less than 5 minutes.

Attempts were made to interview all parties fishing in the headwaters at the

completion of their fishing trips during sampling periods, although a small percentage of

interviews were missed due to several parties leaving concurrently, or parties not wanting

to be interviewed. Information gathered from interviews included time spent fishing in the area, species preference, catch and harvest information, number in the party, angler origin, and whether anglers fished from the bank or a boat. Additional information collected in 1996 included angler demographics; size class of fish released and reason for release; seasonal use of the headwaters; age of anglers; environmental organization affiliation; and awareness of a bass-tagging project. Anglers were interviewed in 1996 concerning their motivations and values regarding the headwater fishery. Interviewees were given a list of factors that may have influenced their decision to fish in this area on that particular day. Anglers then chose the most important three factors influencing their decision to fish the headwaters.

I estimated effort, catch, and harvest using methods described by Pollock et al. (1994). Fishing effort, catch and harvest were first calculated by stratum (weekday, weekend for each month), then combined to get total estimates for each month and each year's effort, catch, and harvest. I estimated daily fishing effort ($\hat{e}_i$) with the formula:

$$\hat{e}_i = I_i * T,$$

where I_i is the average of the instantaneous hourly counts for that day, and T is the length of the fishing day in hours. Total effort ($\hat{E}$) for a stratum was obtained by expansion:

$$\hat{E} = K * N;$$

where K is the mean daily fishing effort for that stratum, and N is the total number of days in the stratum. I repeated these calculations on all strata for the survey period; overall monthly and annual effort were obtained by summing the stratum totals.

I calculated variance for effort calculations with the equation:

$$V = \Sigma(e_i - K)^2 / n - 1$$

where e is the daily fishing effort, and n is the number of days sampled in that stratum. Variance of daily samples (Var E) was estimated as:

$$\text{Var K} = V/N, \text{ and}$$

$$\text{Var E} = N^2(\text{Var K})$$

with standard error (SE) as the square root of Var E.

I estimated catch and harvest by first expanding half-day samples to a full day of fishing. To accomplish this, I divided estimated half-day values of catch and harvest of smallmouth bass by the probability of sampling on that day, resulting in daily catch and harvest values. I multiplied this value by the total days in that stratum to obtain expanded catch and harvest information for each stratum. I summed stratum totals to obtain total catch and harvest. Calculations for variance and standard deviation for catch and harvest information were obtained using the same formulas used to calculate effort parameters.

Population Dynamics

Fish Collection

I assessed fish movements, developed estimates of adult smallmouth bass abundance, and determined rate of exploitation by marking adult (>305 mm TL) smallmouth bass with dart tags. Bass were captured in sinking monofilament gill nets (50.8 mm bar mesh, 30.5 m length, 1.8 m depth) stretched perpendicular to the shoreline, and obliquely along the bottom in all areas of the reservoir to obtain a representative sample of the smallmouth bass population. Nets were fished in all three sections of the reservoir during the fall of 1994, fall, winter and spring 1995, and the spring of 1996. I minimized stress and injury to smallmouth bass by only fishing nets for two hours before removing entangled fish. Total lengths (mm) and weights (gm) were recorded for each fish. I tagged smallmouth bass captured prior to March 1995 with a visual implant (VI) tag containing an alpha-numeric code for identification. These tags were placed in the branchiostegal membrane below the opercular plate. However, angler recognition of these low visibility tags was nonexistent, and movement information obtained from these tags was limited to recaptures by biologists. Therefore, after March 1995 I tagged all captured fish using a highly visible individually numbered dart tag attached below the side of the soft rays of the dorsal fin, through the pyterigiophores. Each tag contained an identifying number as well as a phone number and the name of the regional fisheries biologist to contact when a tagged fish was encountered. Tagged fish were immediately released to the area of capture. I tagged a total of 125 smallmouth bass in the main body of the lake

using VI tags in 1994 and 1995, 217 fish using dart tags in 1995, and 124 smallmouth bass using dart tags in 1996.

I also collected adult bass from the headwaters area of the lake using nighttime electrofishing during February through May in 1995, and April 1996. I repeatedly sampled the headwaters to determine use of this area by smallmouth bass and to tag the fish using the area. The headwaters area was sampled 14 times between 2 February 1995 and 17 May 1995, and four times in April 1996 using a boom electrofisher with pulsed DC current. I sampled the entire shoreline above Mclintic Bridge (Figure 2) and into both tributaries as far as possible before riffles impeded further upstream movement. Measurements and dart tag application were the same as for gill nets. A total of 65 smallmouth bass were tagged in the headwaters using this method in 1995 (five of which were tagged with a VI tag), while 26 smallmouth bass were dart-tagged in 1996.

Exploitation

I calculated exploitation rates for smallmouth bass in the reservoir. For this study, annual exploitation was defined as the percentage of the adult smallmouth bass harvested by anglers in a year's time. Accurate estimates of exploitation are needed to relate the amount of harvest occurring in the reservoir to the total lake population. There are three exploitation rates of concern in Lake Moomaw: the total lake exploitation rate; the amount of exploitation occurring in the headwaters spring fishery on fish from the entire lake population; and the exploitation rate on the portion of the smallmouth bass population that uses the headwaters to spawn.

I estimated exploitation by using total number of tagged fish anglers reported harvesting divided by the total number tagged for both the main lake and the headwaters. Exploitation rates calculated in this manner were unadjusted for tag loss, mortality of tagged fish and angler non-reporting of tags, underestimating total exploitation.

Posters were displayed at all access points around the lake and at local tackle shops and convenience stores around the area. These posters helped to raise angler awareness of the tagging project, and to encourage returns of the tags by anglers. Additionally, in 1996, I instituted a reward program, offering anglers who captured a tagged fish a variable reward ranging from US $5 to $25 for the information contained on the tag, as well as capture location and a reasonably accurate length and weight of the fish. I used information on length and weight as a means of determining whether an angler was creating data to collect a reward. I posted fliers to announce the tag reward program in 1996.

Assumptions for the exploitation method used in this study included: random mixing of tagged and untagged individuals, equal vulnerability of tagged and untagged individuals, no tag loss, complete recognition of tagged fish, and complete reporting of tagged fish caught. I believe the first two assumptions were met because tagged fish were captured and released throughout the reservoir, which would promote random mixing, and the method of capture and tag application should not have affected catchability. In a tagging study on Oneida Lake, NY, Forney (1972) found that tagged smallmouth bass were no more vulnerable to angling than untagged fish. Because the tags were dart tags in bright yellow, green, or red, it is also safe to assume that the anglers were able to recognize all tagged fish encountered. Although it is not possible to know if these

assumptions were met, I assumed errors associated with these assumptions to be minimal, and that they would not affect the outcome of this study. However, significant tag loss and/or nonreporting by anglers would cause an underestimation of exploitation, and could potentially alter the outcome of exploitation estimations.

Improved estimates of exploitation result by adjusting estimated error rates, and then recalculating exploitation. Estimating mortality, tag loss, tagging and handling mortality, and angler nonreporting result in more accurate exploitation estimates. Because total time to apply tags and measure fish was less than 90 seconds, I assumed tagging and handling mortality to be minimal and not to affect the overall outcome of this study. Further, no observed mortality resulted from tagging and handling during this study. Duration of the tagging project was 17 months. Therefore, it was necessary to adjust the total number of living fish tagged to reflect mortality and tag loss over this time period as well as adjusting tag reports from anglers to compensate for nonreporting.

Mortality and Tag Loss Adjustments

I used springtime electrofishing catch-per-unit-effort data from the VDGIF for 1988-1992 to calculate annual survival. Previous years' samples of smallmouth bass collected by VDGIF during spring sampling were aged by analysis of scales. Five bass from each centimeter class were aged over consecutive years. Length-at-age information was calculated for each years' data collected by VDGIF, and was used to assign all fish from each years' sample to a corresponding age-class. Data from 1988-1992 were used because age and growth information was taken during each year during this period,

allowing a cohort of bass to be followed over successive years. I then calculated survival of one age class over one year as:

$$CPU \text{ (year X) / } CPU \text{ (year X-1)}$$

I calculated survival for all year classes from ages 2 to 3, 3 to 4, and 4 to 5. Capture of smallmouth bass beyond age 5 was rare, and conclusions drawn from this small sample were considered unreliable. Subsequent analysis ignored these older age classes. I pooled results of survival calculations to determine mean annual survival for ages 2-5. To obtain an overall rate to adjust tagged fish with, I assumed this survival rate was constant for all ages greater than age 2.

I also adjusted the number of tagged smallmouth bass in the reservoir to reflect tag loss over time. I double-tagged 123 smallmouth bass with both a VI tag and a dart tag in order to estimate tag loss from recapture of these fish. Examination of remaining tags would indicate the percentage of each type of tag lost, which I could then expand to the total population. Mourning et al. (1994) found the differential tag loss between anchor tags and VI tags to be insignificant after 60 days in a study on hatchery rainbow trout. In the current study, actual recaptures of double-tagged fish by individuals skilled in recognizing the VI tags were too low to allow for accurate estimations of tag loss. Therefore, I ignored VI-tagged fish in the exploitation portion of the study, and focused on dart-tagged fish. I obtained a value from the literature of 15% annual tag loss (85% retention) for smallmouth bass tagged with a Floy spaghetti tag (White and Beamish 1972) and converted this to an instantaneous monthly tag loss rate by using the formula:

$$S = e^{-Zt}$$

and replacing S with the 85% annual tag retention rate, and solving for Z. This calculated

instantaneous rate was then applied to all fish tagged each month (t) to reflect the loss of

tagged fish from the sample population. Estimations were conducted similar to mortality

estimates, and reflect tags lost prior to the beginning of the 1996 spawning season in

March.

I also adjusted estimates of tag returns for angler nonreporting using several

methods. First, I obtained estimates of nonreporting rates from other studies. Second, I

expanded the number of tags witnessed by the creel clerk in the creel survey to estimate

the total number of tags returned from this area. A nonreporting rate was derived by

comparing the actual number of tags returned from the headwaters to the estimated

number of tags that should have been returned. To estimate a daily tag return rate, I used

the formula:

$$T(C)/P(S)$$

where T(C) is the total number of tagged fish caught and turned in to the creel clerk

during a survey period and P(S) is the estimated weighted percentage of fishing pressure

occurring during that half of the day as determined by full-day sampling. I then calculated

the mean daily tag return rate, and multiplied the number of days in each creel stratum by

this rate to obtain the expected number of tag returns. I then compared this expected

number of tag returns from the creel survey to the total number returned from this area to

estimate a nonreporting rate. A third method I used in 1996 was to question anglers about

returned tags during the creel interviews. Creel clerks asked interviewees a series of

questions to determine the percent of anglers catching tagged fish who reported the tags.

Anglers were asked three questions regarding tag reporting during interviews: 1) Are you aware of the tag reporting project? 2) Have you caught a tagged fish? 3) Did you report the tag? When anglers responded that they had not heard of the tagging project or reward program, the creel clerk informed them of the project and how they could help. The nonreporting rate is the ratio of anglers who stated they had not reported a tagged fish compared to those who had caught a tagged fish. I used two estimates of angler nonreporting for this study, which resulted in a range of values on population estimates and exploitation calculations.

I then used the annual mortality rate and annual tag loss rate to adjust the total number of fish tagged over the course of the study to living tagged fish with dart tags present in the reservoir at the beginning of March 1996. I converted the annual survival rate and tag loss rate to instantaneous rates, and applied those to fish tagged each month prior to March 1996 to obtain the estimated number of tagged fish present in the reservoir that still retained their dart tags. This estimate of tagged fish present in the reservoir was then used in further exploitation calculations.

I calculated catch rates and exploitation rates using capture-recapture methods for 1996 only, because more reliable tag returns resulted from the reward offered during this time. I calculated the main lake catch rate (percentage of smallmouth bass caught by anglers) using:

$$C/T*100$$

where C is the total number of tagged smallmouth bass caught by anglers (after adjustments for nonreporting), and T is the total number of smallmouth bass tagged

lakewide after adjustments for mortality and tag loss. Similarly, I calculated the main lake

exploitation rate (percentage of smallmouth bass harvested by anglers) using:

$$H/T*100$$

where H is the total number of tagged smallmouth bass harvested by anglers in the

reservoir. I used similar calculations to determine the headwaters reporting rate and

exploitation rate of the whole lake population:

$$Ch/T*100$$

and

$$Hh/T*100$$

where Ch is the number of tagged fish caught in the headwaters and Hh is the number of

tagged fish harvested in the headwaters. I calculated the headwaters reporting rate and

exploitation rate of the headwaters stock using:

$$Ch/Th*100$$

and

$$Hh/Th*100$$

where Th is the total number of smallmouth bass tagged in the headwaters.

Population Estimates

I also attempted to estimate the adult smallmouth bass population in the lake using capture-recapture methods. I conducted shoreline electrofishing in June 1996 to recapture smallmouth bass tagged over the course of the study. Transects sampled consisted of stratified random samples throughout the reservoir. I selected five transects in each section of the reservoir, and sampled each of them one time for 600 seconds before termination of electrofishing. Sampling consisted of driving the electrofishing boat 1 to 3 m from the shore, and collecting all fish that could be collected. I obtained a population estimate for the lake using the Peterson index and used Chapman's modification because less than seven fish were recaptured (Van Den Avyle 1993). However, some assumptions of this method were not met, and attempts to validate violated assumptions were made. To aid with error associated with tag loss and mortality between the marking period and recovery period, I adjusted the number of fish tagged prior to June 1996 for these factors as described earlier. Other assumptions including complete recognition of tagged fish, equal vulnerability of tagged and untagged fish, equal mortality between tagged and untagged fish, random mixing of tagged and untagged fish, and no additions to the population during the study period could potentially affect the outcome of this estimate. I believe recaptured tagged fish were easily recognized by anglers due to the high visibility of the dart tags. Both tagged and untagged fish should remain equally vulnerable to recapture and be evenly distributed throughout the population since tagging occurred throughout the reservoir. Therefore, errors associated with these assumptions are believed to be minimal, and not to affect the overall outcome of this estimate.

Additionally, I attempted to estimate the smallmouth bass population in the reservoir by dividing the total number of adult smallmouth bass harvested in the reservoir by the exploitation rate obtained from the tagging study. I estimated total annual harvest for the lake as a whole by combining fish harvested from the VDGIF access point creel survey in 1992 which estimated total harvest for the lake, and the 1995-1996 headwaters creel survey. I combined the two surveys because I believe the 1992 creel survey did not accurately account for harvest in the headwaters fishery, and underrepresented total lakewide harvest. This calculation resulted in a first-order estimate of population size.

Length-Frequency Comparisons

I calculated a length-frequency distribution of the fish harvested during the creel survey, and compared this to a length-frequency distribution of tagged fish. I tested these data for normality using a Wilk-Shapiro rankit sum test, and found the data to be normally distributed. I used a two-sample t-test ($\alpha=0.05$) to detect differences between the mean size of fish caught in the two fisheries. Tagged fish were caught by electrofishing, which selects for larger individuals in a population (Reynolds 1983), and large-mesh gillnets, which also are more effective at catching large individuals (Hubert 1983). Assuming that the combination of these gears selects for fish of harvestable size (greater than 305 mm), I was then able to determine if anglers in the headwaters were harvesting fish of greater length than the mean lake population, although size selectivity of these different gears may affect this comparison. Beamsderfer and Reiman (1988) showed different sampling gear including gill nets and angling selected for different sizes of smallmouth bass, resulting in underestimates of PSD by 20%, and overestimates of mortality by 22% when all gears (gill

nets, trap nets, electrofishers and rod and reel) were combined. However, results from their study indicated both angling and gill nets appeared to sample similar segments of the population. Further, in the present study, anglers did not harvest any fish less than 305 mm, while the minimum size selected with gill nets was rarely smaller than 280 mm. Therefore, I believe that direct comparison of fish length obtained from these two methods to be accurate.

Relative Weight Calculations

I calculated relative weights for fish used in the tagging project as a means of assessing overall condition and use of available forage. Fish used for this portion of the project were captured in the spring, winter and fall throughout the reservoir. Relative weight was calculated using the formula:

$$W_r = (W/W_s) * 100$$

where W is the weight of an individual and W_s is a length-specific standard weight predicted by the equation:

$$\log_{10}(W_s) = -5.329 + 3.200 * \log_{10}(length)$$

Where -5.329 is the revised intercept and 3.200 is the revised slope derived using the regression-line-percentile (RLP) technique suggested by Anderson and Neumann (1996).

I then calculated the mean relative weight for the length-groups defined by the five-cell model proposed by Gabelhouse (1984).

Distribution and Movement

I described distribution and movements of smallmouth bass in the reservoir using ultrasonic telemetry to determine exact movements of 20 adult smallmouth bass throughout the study period, and complementary dart tagging to determine general movements of large numbers of adult smallmouth bass.

Dart Tagging

I obtained information on movement of tagged fish by recaptures from biologists working on the lake, or from anglers catching and reporting tagged fish caught. I instituted a reward program in 1996 that offered anglers who caught a tagged fish a reward for turning in information on capture location of the fish. I randomly chose the value of each reward, which ranged from US $5 to $25. Maximum reward value of $25 was used with the intent of having a maximum reward that encouraged reporting of captured tagged fish, but was not great enough to increase angling pressure in the reservoir. I then used tag return information to determine movements between the original tagging location, and the area of recapture by the anglers. I defined a smallmouth bass to have moved when it was recaptured in a different lake section than where it was tagged. I classified fish recaptured in the same section where they were tagged as

sedentary, even though they could have traveled throughout the reservoir between tagging and recapture.

I compared movements among lake sections to determine if there was a difference in the degree of movements of fish tagged in one section of the lake as opposed to another section of the lake. 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. Bass tagged in the headwaters and later recovered in the main body of the lake indicated the areas of the reservoir where these headwaters-spawning fish redistributed.

I also compared the number of recoveries from each of the lake sections to the number of smallmouth bass tagged in each section using a Chi-square test. I used this information to determine if smallmouth bass were drawn from the whole lake population or a subset of the lake. Additionally, I attempted to use a Chi-square test to determine redistribution proportions of fish tagged in the headwaters and later recovered in the main portion of the reservoir, but recaptures of these fish were limited (n=2 or 3 in all cells) and did not add additional credible information.

Ultrasonic Telemetry

I surgically implanted temperature-sensing ultrasonic transmitters (16 X 60 mm; 22 g in air) in eight smallmouth bass >325 mm TL prior to the 1995 spawning season, and an additional 12 fish prior to the 1996 spawning season. All of these fish were captured using horizontally set gill nets as previously described. I implanted transmitters in

smallmouth bass from all three sections of the reservoir to obtain representative samples of the lake population.

Surgical implantation of transmitters began with removal of the scales in a 2-cm by 3-cm area in the hypaxial tissue near the anal vent. I then made a 2-cm incision in this area, and inserted the transmitter. The incision was closed using a surgical skin stapler (Hampton 1993). I used no anesthesia on these fish, and immediately released them to the area of capture.

Transmitters (Sonotronics model CTT-83) were distinguishable by a unique pulse code of beeps and pauses that correlated to an identifying number. The period between pulses was affected by ambient temperature of the transmitter and enabled ambient temperatures of fish to be determined. I calibrated the temperature sensing transmitters in the laboratory using known temperatures and a BASIC program (TAGCAL1.BAS) that converted the pulse code revealed by the transmitters to the actual temperature fish were occupying.

Telemetry observations included assessment of horizontal position using a uni-directional hydrophone (Sonotronics model DH-2) and documentation of the temperatures chosen by fish. Tracking occurred an average of two times per month in ice-free months from 23 February 1995 to 18 September 1996.

I recorded horizontal positions of smallmouth bass using a USGS topographic map, and easily identifiable landmarks along the shoreline. I determined location by triangulating the position of fish from multiple bearings. The boat was then driven over the bass when structure and overhead cover allowed, and referencing landmarks relating to the location of the fish were obtained. When the receiver was positioned above the

transmitter, the location of the signal appeared to be coming from all directions, as opposed to one specific direction. Each location was immediately recorded on a map of the lake. Temperatures chosen by these fish were determined by comparing milliseconds between pulses as recorded by a digital ultrasonic receiver (Sonotronics model USR5B) with the calibrations determined in the lab.

I estimated both mean distances traveled between successive fixes and maximum distance traveled overall for each smallmouth bass carrying a transmitter. Maximum distance traveled for each transmitter-equipped fish was estimated by measuring the greatest in-lake distance among all location fixes using a map wheel and scale on the topographic map. These distances are considered minimal estimates of distance traveled because it is unlikely that these bass moved in a straight line. I determined mean distance traveled between fixes by pooling all distance measurements of an individual smallmouth bass over a specific time period divided by the total number of fixes.

I tested the data collected on smallmouth bass telemetry movements for normality using a Shapiro-Wilks test. Results of this test showed the data to not be distributed normally, so nonparametric statistics were used in further analyses. I compared both seasonal movements (mean and maximum distances traveled versus season) and movements between lake sections (mean and maximum distances traveled versus lake section) using Kruskal-Wallace nonparametric one-way ANOVA. I defined seasons as spring (March, April, May), summer (June, July, August), fall (September, October, November) and winter (December, January, February). Mean and maximum distances traveled versus total length of bass were analyzed for association using a linear regression and untransformed data.

Spawning locations were inferred from the horizontal position of fish with transmitters during periods when water temperatures were suitable to spawning, and bass showed sedentary behavior in areas with habitat suitable to spawning. During April and May, lake temperatures were between 16°C and 22°C, a range found conducive to smallmouth bass spawning (Carlander 1977, Jenkins and Burkhead 1993, Lukas and Orth 1995). As temperatures climbed to this range, smallmouth bass movements increased as fish moved to areas with suitable spawning habitat. Fish moving from the lake section in which they had been tagged were assumed to be on migrations associated with spawning during April and May. Smallmouth bass would commonly reside in an area with habitat suitable for spawning for several weeks during the spawning period before returning to the lake section where they had been tagged. Locations of telemetered fish during these periods were assumed to be those used for spawning. Some smallmouth bass traveled to the headwaters and out of the reservoir during the spawning period. Tracking using an ultrasonic receiver in turbulent water is not possible, and these fish could not be located during periods when they were not in the reservoir. I assumed that these fish were in the headwaters area or tributaries to the lake for spawning purposes if they were relocated within the reservoir at the conclusion of the spawning period.

Reproduction and Recruitment

In this study, I evaluated the importance of the headwaters spawning area to the remainder of the reservoir. If spawning areas are limited in abundance, management goals

should focus on protection of these areas to allow successful spawning. I determined

areas used for spawning of smallmouth bass in Lake Moomaw using several methods,

particularly line transect snorkel surveys to count spawning smallmouth bass on nests, and

to count smallmouth bass fry. I then determined which lake sections were used most for

spawning. Additionally, I used repeated fall electrofishing to document changes in relative

densities of age-0 smallmouth bass in each lake section. This allowed information to be

gathered on migrations of these fish or increased survival through the fall.

1995 Sampling

I used several methods in 1995 to calculate relative abundance of nesting and age-

0 smallmouth bass. I conducted line transect snorkel counts for smallmouth bass nests and

attending males in late March by swimming pre-determined transects along the shoreline

of the reservoir, and attempting to count nesting smallmouth bass. Transects were

determined by dividing the shoreline into 1.6 km sampling units. Starting points within

each sampling unit were randomly chosen, and sampled for 300 m. I intended to calculate

relative densities of nesting fish by determining the mean fish per 100 m in each transect

for the lower, middle, and upper sections of the reservoir. However, this method of

sampling reproductive distribution was unsuccessful because windy conditions increased

turbidity along the shoreline of the lake during the spring spawning period, making

accurate counts of nesting fish impossible. I made several attempts to count nesting

smallmouth bass before abandoning this method.

Alternatively, I used densities of young-of-the-year smallmouth bass as an

indication of areas important to spawning in the reservoir. In a study in Wisconsin,

Langhurst and Schoenike (1990) found no evidence of young-of-the-year or yearling smallmouth bass migrating out of the Embarrass River to the Wolf River to overwinter even though older smallmouth bass did. Copeland and Noble (1994) found little movement of age-0 largemouth bass from the cove where nesting occurred on B. Everett Jordan Lake in North Carolina. They found only 4 of 46 recaptured fish to have moved outside of the cove where tagging occurred. Assuming smallmouth bass behave similarly to largemouth bass and do not disperse far from their nests during the first several months after hatching, general areas used for spawning can be determined by densities of these fish in an area. I conducted line transect snorkel surveys in June and July 1995 to determine relative densities of age-0 smallmouth bass in the three lake sections as an indication of the important spawning areas in the reservoir. Sampling protocol and design were similar to those used for the spring nest count transects. Two to four divers each swam a transect of 100 m in 36 of 44 sections in the reservoir . The remaining eight sections were not sampled due to time constraints. All divers swam 100 m in each transect, for a total of 200 to 400 m in each transect, depending on the number of divers available on each sampling day. Divers swam in 1 to 3 meters of water, and close to the bottom to count smallmouth bass that retained their juvenile markings. Widths of transects depended on water clarity, but averaged around 3 meters. I pooled individual divers' counts on each transect to obtain the mean count per 100 m, then pooled all transects in each lake section (lower, middle and upper) to obtain a mean density for each section of the reservoir for comparison among lake sections. Snorkel counts also were conducted in the headwaters of the reservoir. I sampled a total of 6 km immediately above the reservoir in Back Creek, and three stations in the Jackson River within 3 km of

the reservoir for a total of 1 km in this tributary. This information resulted in estimates of relative densities of age-0 fish per 100 m in each section of the reservoir and the headwaters, an indication of the reproductive use of each lake section.

Age-0 smallmouth bass also were sampled in the fall of 1995 using a boat electrofisher with pulsed DC current at 3-6 amps. All sampling trips for age-0 smallmouth bass incorporated one netter who collected all smallmouth bass encountered. Length-at-age back calculations for Lake Moomaw show age-0 smallmouth bass to be between 90 and 96 mm the following May (Bugas 1995). Therefore, all smallmouth bass less than 100 mm were classified as age-0 fish. Each of the three sections of the reservoir (lower, middle, and upper) had three stations sampled, for a total of nine stations lakewide. Each station was sampled for 600 seconds (distance varied between runs, but averaged around 400 m). Fish were collected and measured to the nearest mm. Data were tested for normality using Wilks-Shapiro Rankit Sum test, and were not found to be distributed normally. I used the Kruskal-Wallace test to detect differences in catch rates of young-of-the-year smallmouth bass among lake sections.

1996 Sampling

During early June 1996, I used scuba gear to document the presence of age-0 smallmouth bass before dispersal from the nest at three stations in the lower section of the lake and four stations in the middle section. The upper section and headwaters were not sampled due to equipment malfunctions and time constraints. The lower section and middle section of the reservoir were sampled first because spawning is known to occur in the upper and headwaters sections of the reservoir. High densities of age-0 smallmouth

bass at this early life stage made accurate counting of these fish impossible, so presence and absence of these fish were recorded for each 100 m station sampled. Sampling areas using SCUBA pre-dispersal observations eliminates the possibility of mis-classifying an area as having spawning activity based on fall electrofishing, which may document age-0 fish that have migrated from other sections of the reservoir. Presence of these juvenile smallmouth bass indicate areas used by bass for spawning.

In 1996, I conducted repeated electrofishing trips during August and September in all sections of the reservoir to document temporal and spatial changes in relative densities of age-0 smallmouth bass. Sampling occurred in alternate weeks from 1 August to 18 September 1996. I chose three stations in each section of the reservoir, but no stations in the upper section of the reservoir above station 9 (approximately 2 km downlake from the headwaters) because normal fall drawdowns of the reservoir typically preclude sampling in the headwaters area with an electrofishing boat.

The nine stations used in 1996 electrofishing sampling were chosen based on the likelihood of age-0 smallmouth bass being present as indicated from 1995 snorkel surveys. I did not choose stations randomly because I could better address changes in densities and migrations of age-0 smallmouth bass by sampling areas that would likely have these fish present. Sampling occurred in alternate weeks (a total of four sampling periods) to detect differences in the densities of fish caught in each section over time, a possible indication of migrations among lake sections. I electrofished the shoreline in these areas, collecting all smallmouth bass. Each individual transect began at the same starting point on each sampling date, and was sampled for 600 s, as in 1995. Catch rates (#/min) were not found

to be normally distributed, so I compared catch rates among lake sections using Kruskal-

Wallace test.

RESULTS

Creel Survey Information

A total of 778 anglers in 336 parties were interviewed throughout the two years of spring creel survey. During the three-month survey period, the number of angler interviews was greatest in April and lowest in May for both years (Figure 3). The majority of anglers interviewed stated they were fishing for smallmouth bass, largemouth bass, or unspecified black bass during both years (Figure 4). Some angling parties stated they were not targeting a specific species, and were assumed to be after smallmouth bass, the species most often caught in spring. Table 1 summarizes information regarding characteristics of angling parties gathered during 1996.

Anglers targeting smallmouth bass in the headwaters of Lake Moomaw expended a total of 2,452 hours (SE 219) during the spring of 1995, for a total of 1,168 hours per ha. In 1996, anglers spent 2,938 hours (SE 387) fishing in the headwaters during spring, for a total of 1,399 hours per ha. March 1995 had 26% more effort than March 1996. Effort for April 1996 was roughly 50% greater than that in 1995. In May 1996, effort was 30% greater than May 1995 (Table 2).

This effort resulted in a total estimated catch for the headwaters of 124 smallmouth bass in 1995 (SE 32), and 309 smallmouth bass (SE 61) in 1996. Anglers
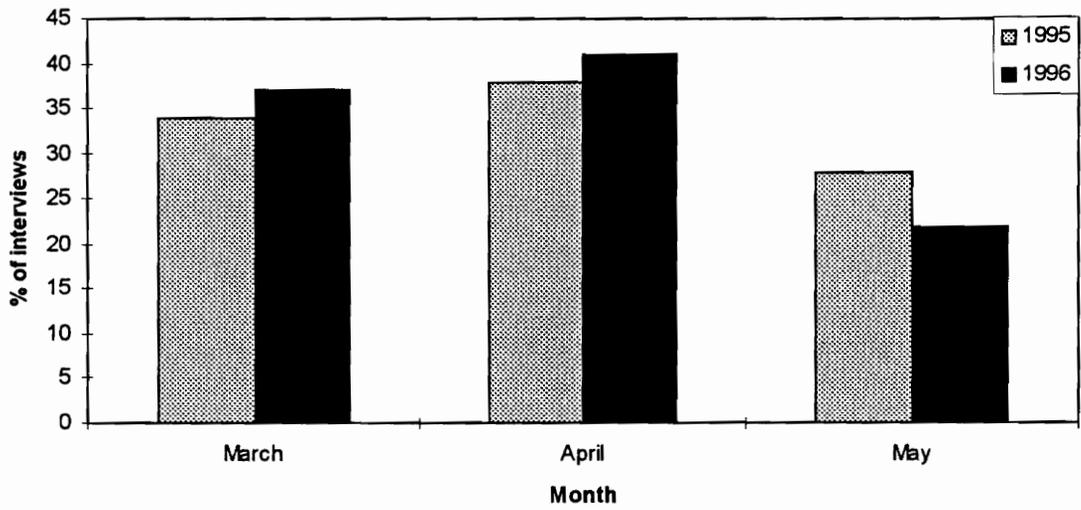
Figure 3. Percent of angler interviews by month for the headwaters during the 1996 creel survey in Lake Moomaw.
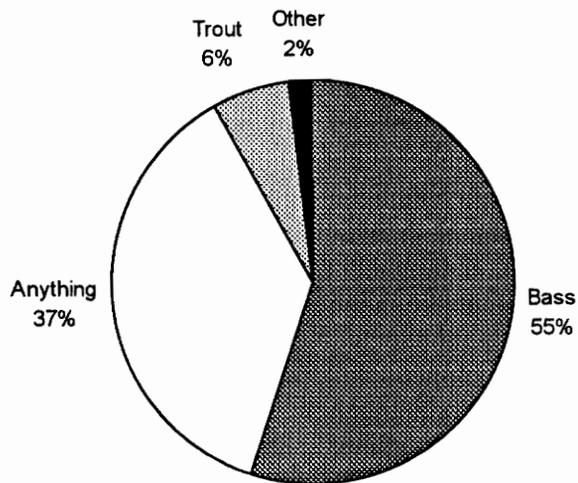
Figure 4. Target species of anglers fishing in the headwaters of Lake Moomaw in 1996.

Table 1. Angling party statistics gathered in the 1996 spring headwaters creel survey, Lake Moomaw.

Parameter Description			
Party size	Mean 2	Max 13	Min 1
Rods per person	Mean 2	Max 6	Min 1
Bait type	Bait (57%)	Lures (18%)	Both (25%)
Access	Bank (92%)	Boat (8%)	Both (0%)

Table 2. Angler effort, catch and harvest with associated standard error in parenthesis for the headwaters fishery in Lake Moomaw, 1995 and 1996.

	Effort in hrs (SE)	Catch (SE)	Harvest (SE)	Catch/Hour
March 1995	857 (81)	56 (25)	48 (19)	0.07
April 1995	924 (147)	29 (9)	19 (7)	0.03
May 1995	671 (142)	39 (18)	15 (7)	0.06
1995 Total	**2,452 (219)**	**124 (32)**	**82 (22)**	**0.05**
March 1996	676 (190)	34 (20)	33 (20)	0.05
April 1996	1,391 (236)	129 (39)	84 (21)	0.09
May 1996	871 (239)	146 (42)	99 (30)	0.17
1996 Total	**2,938 (387)**	**309 (61)**	**216 (48)**	**0.11**

harvested an estimated 82 of 124 smallmouth bass caught in 1995 (66%), and 216 of 318 caught (68%) in 1996 (Table 2).

Creel clerks gathered information on the size of smallmouth bass released and reasons for release during the 1996 survey. I then separated released smallmouth bass into legally harvestable fish (>305 mm), and sub-legal fish to determine the harvest rate on legally harvestable fish (Table 3). Anglers harvested 85% of fish greater than 305 mm. Smallmouth bass of legal size that were released (13) were between 305 and 449 mm; none of the 17 smallmouth bass greater than 450 mm were released. Forty-five percent of the anglers who released smallmouth bass cited the minimum size limit as the reason for release, while another 45% stated they practice catch and release and 10% gave other reasons. No anglers reported releasing fish in the headwaters because a limit had been caught.

Sixty-eight percent of anglers fishing in the headwaters area during the spring indicated they used this area at other times of the year. Forty-one percent of these anglers fished the headwaters in the summer, 37% used the area year around, 13% used the area in the spring and fall and 8% used the headwaters area during all seasons except winter.

Information gathered from the questions pertaining to angler motivations for fishing the headwaters indicated fishing success and consumptive use of this resource were more important to anglers than social or aesthetic reasons for fishing. Responses related to catching or harvesting fish comprised four of the five most frequent responses given by anglers regarding reasons for fishing in the headwaters. Social reasons for coming to this area ranked second to these utilitarian views. Emphasis on fishing skills and aesthetic

Table 3. Smallmouth bass caught by anglers in the spring headwaters fishery of Lake Moomaw, 1996 and the size class of released fish.

Size Class	<305 mm	305 - 449 mm	>449 mm	Total
Number Caught	26	69	17	112
Number Released	26	13	0	39

reasons for fishing in the headwaters were given less frequently (Table 4). Age of anglers using the headwaters fishery was fairly evenly distributed (Figure 5).

Few anglers fishing in the headwaters stated that they belonged to fishing or conservation organizations (13%). Organizations to which anglers belonged included North American Fishing Club, Fly Fishing Federation, The Nature Conservancy, American Fisheries Society, Sierra Club, Audubon Society, National Wild Turkey Federation, Isaac Walton League, International Fishing Club and Trout Unlimited.

The headwaters fishery in Lake Moomaw is primarily a local fishery, with 53% of anglers traveling less than 41 km to fish the area. Most anglers resided in either Bath or Alleghany counties. Nine percent of the anglers traveled from out of state, primarily from towns 33-75 km away in West Virginia (Figure 6).

Eighty-six percent of the anglers fishing the headwaters area had heard of the tagging project, and were aware of this study. Only 8% of anglers interviewed had caught a tagged fish in the lake. Of these, 89% said they had reported the tag.

Population Dynamics

Tagging of smallmouth bass was completed by 12 April 96. A total of 465 fish were captured and tagged using gill nets before this date, 431 of which were tagged with a dart tag or combination dart tag and Visual Implant tag. These fish came from all areas of the reservoir. Additionally, 92 adult smallmouth bass were captured and tagged in the headwaters using electrofishing before the completion of the tagging portion of the study (Figure 7).

Table 4. Factors influencing anglers decision to fish in the headwaters area of Lake Moomaw during 1996. Each respondend indicated three reasons for fishing the headwaters.

Reasons to fish the headwaters area:	# of anglers indicating this response
Had success here before	64
To catch fish to eat	53
Opportunity to catch lots of fish	49
Close to home	48
Opportunity to catch trophy fish	42
To be with friends and family	34
To view the scenery	29
Less crowded than other places I fish	22
For the solitude	20
To test my fishing skills	14
Opportunity to catch _____ Species	11
Easy access	10
Friends went here	8
Other	8
Ease at which fish are caught	0
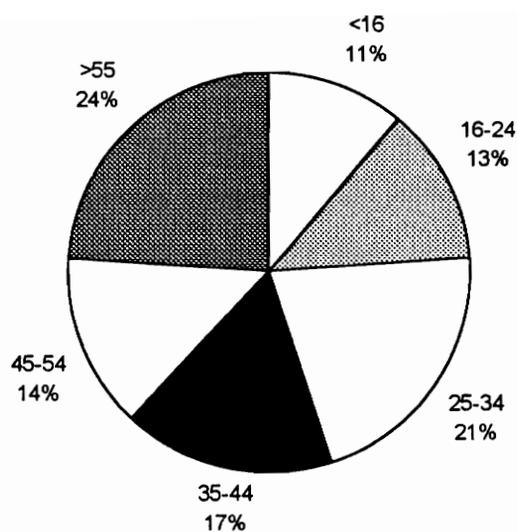
Figure 5. Age distribution of anglers interviewed in the headwaters fishery of Lake
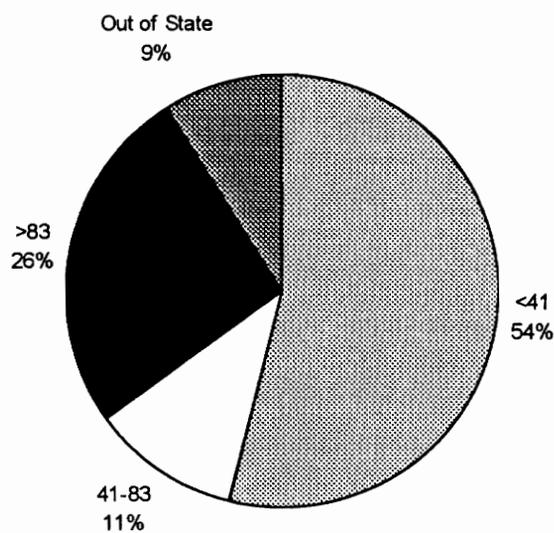
Moomaw, 1996.

Figure 6. Distance traveled (in km) by anglers to fish in the headwaters of Lake

Moomaw, 1996.
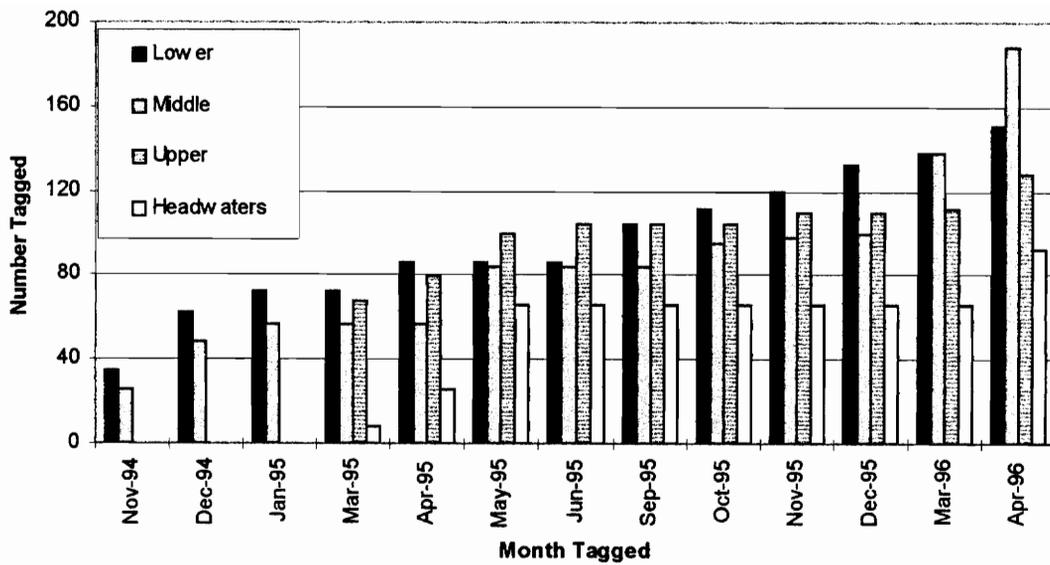
Figure 7. Cumulative tagging progress by lake section and date for Lake Moomaw from November 94 through April 96.

Adjustments to Tagged Fish Numbers

Estimated annual mortality for smallmouth bass in Lake Moomaw ranged from 93% from age 4 to 5 in 1990 to 3% mortality from age 2 to 3 during the same year (Table 5). Mean annual mortality for smallmouth bass in the lake was 61% as determined by analysis of electrofishing data from past years. Previous research on streams and rivers estimated total annual mortality ranging from 36% in the Jacks Fork River, Missouri (Covington et al. 1983), to 71% in five Iowa streams (Paragamian 1980). Sanderson (1958) estimated mean annual mortality for a lotic population of smallmouth bass in the Potomac River Basin at 57%, while Fajen (1975) compiled estimates of lotic smallmouth bass populations ranging from 34-49%; Paragamian and Coble (1975) found mortality in the Red Cedar and Plover Rivers, Wisconsin to be 55% and 65% respectively; Kauffman (1983) estimated mortality on the Shenandoah River to be 65%; Weathers and Bain (1992) estimated Tennessee River mortality at 50-57%. Mortality estimates on populations of smallmouth bass in lakes and reservoirs are less common than estimates for rivers. Other estimates of annual mortality include 58% in Lake Michigan (Latta 1963), while Forney (1972) found the mean annual mortality over a 14-year period in Oneida Lake, NY to average 43% annually, and Van Woert (1981) estimated mortality at 92% for smallmouth bass between 203 and 356 mm in Lake Shasta, CA. Beamsderfer and North (1995) reviewed 409 papers on smallmouth bass in North America and calculated a mean annual rate of natural mortality of 35%, and found a lower degree of natural mortality in Northern populations. The mortality estimate derived from Lake Moomaw is slightly higher than the national average, but within the extremes of variation reported elsewhere.

Table 5. Mortality estimates from Lake Moomaw from 1988 to 1991 based on

springtime electrofishing catch per unit effort.

Mortality from ages:	2-3	3-4	4-5
Year of sample			
1988	11%	82%	83%
1989	56%	64%	93%
1990	3%	63%	93%
1991	37%	84%	

I was not able to estimate tag loss from fish that I had double-tagged, due to low recapture of these fish, and unreliable retention of the VI tags. However, White and Beamish (1972) estimated annual tag loss of smallmouth bass with anchor tags to be 15%. This is similar to other research which showed anchor tags to have a low rate of loss. Muoneke (1992) found white bass lost 24.8% of their tags after one year, and Timmons and Howell (1995) found buffalo fishes lost 3% of anchor tags after one year. I used the 15% annual tag loss estimated by White and Beamish (1972) as the best estimate of annual tag loss in this study.

Estimates of angler nonreporting of tagged fish caught vary considerably in the literature. Other tagging studies that utilized highly visible tags and a reward system to encourage anglers to report tags estimated angler nonreporting as low as 40% for black crappie in several Georgia reservoirs (Larson et al., 1991) and as high as 64 to 85% depending on fish species in a Texas recreational marine fishery (Green et al. 1983). Haas (1990) found reward incentives to increase tag returns compared to when no reward was offered. Even with a reward incentive, Matlock (1981) found 72% of highly visible tags surreptitiously implanted during creel interviews in Texas were not returned. Eder (1990) found angler nonreporting of tags to be 7% from creel interviews on Jamesport Community Lake, Missouri.

I also estimated nonreporting by using tags returned to the creel clerk during creel interviews. I obtained estimates of reporting rates by expanding the number returned to obtain the expected total number of tags to be returned, then comparing that to the actual total number returned from the same area. Using this expansion for 1995, an estimated 13 tags should have been returned. The actual return was 14. An estimated 19 tags should

have been returned in 1996, while the actual return was 21. Thus, in both years, actual returns exceeded expected returns, indicating a high rate of angler reporting of captured tagged fish.

The third method I used was direct interviews asking anglers their reporting frequencies during creel interviews. From the series of questions asked during the creel survey regarding angler return of tags, it is apparent that a minimum of 11% of anglers catching tagged fish were not reporting these tags. This estimate is considered a minimum, because the creel clerk interviewed anglers in person. Anglers who said they had caught a tagged fish might have said they reported the tag to avoid personal embarrassment. Based on the results of other researchers, it is possible that this estimate of 11% nonreporting rate is low. However, since expansions of creel returns of tags indicate a high rate of return, this estimate may not be as inaccurate as other researchers have found. Because of the large amount of variability in angler nonreporting rates, I decided to use two rates to adjust the number of tags reported. I used the value of 11% obtained from the creel survey interviews, and a low value from the literature of 40% (Larson 1991). Using two values to adjust tag returns for nonreporting resulted in two estimates for each exploitation calculation, as well as for the population estimate.

Exploitation

There were few tag returns during the 1995 spring fishing season. Because the numbers of tags present in the population during this time was low (210 tags) and the amount of returns was also low (18 tags returned), I did not estimate exploitation using 1995 data. After rewards were established in 1996, tag returns increased dramatically.

Also, more tags were present in the population at this time, allowing more accurate exploitation estimates by using 1996 data only.

Anglers reported catching 98 of the 432 fish tagged with dart tags over the two-year study period, of which, 80 were caught in 1996. The overall catch rate during 1996 was estimated to range from 33 to 41% after adjusting for mortality and tag loss through spring 1996, and for nonreporting (Table 6). Estimates of angler harvest on these tagged fish ranged from 33 to 42 fish, resulting in an annual exploitation rate for the total smallmouth bass fishery in the lake including the headwaters ranging from 12 to 15% lakewide.

Smallmouth bass tagged throughout the lake and caught by anglers in the headwaters were estimated at 20 to 25 after adjustments for nonreporting (Table 7). These returns include both fish tagged in the main portion of the reservoir and those tagged in the headwaters over the two-year period. The overall catch rate for the headwaters fishery on the whole lake population is 7 to 9%, with an annual exploitation rate of 4 to 6% of the total lake population being harvested in the headwaters area during the spring.

After adjustments for mortality and tag loss, 49 smallmouth bass tagged in the headwaters in 1995 and 1996 were estimated to be present in the headwaters during the spring of 1996 (Table 8). After adjustments for angler nonreporting, an estimated 11 to 14 of these fish were caught in the headwaters fishery resulting in a catch rate of 23 to 29%. Anglers harvested an estimated eight or ten of these fish, resulting in an annual exploitation rate of 16% to 20% for the headwaters stock.

Table 6. Figures used to estimate main lake exploitation based on estimated tagged fish present and estimated angler tag returns from Lake Moomaw 1996. Tags adjusted to reflect annual mortality rate of 64%, annual tag loss of 15%, and nonreporting rates of 11% and 40%.

	Total Fish (1996)	After Mortality	After Tag Loss	With 11% nonreporting	With 40% nonreporting
SMB Dart Tagged	432	288	272	--	--
SMB Caught	80	--	--	89	112
SMB Harvested	30	--	--	33	42

Table 7. Figures used to estimate headwaters exploitation on the total population based on estimated tagged fish present and estimated angler tag returns from Lake Moomaw 1996. Tags adjusted to reflect annual mortality rate of 64%, annual tag loss of 15%, and nonreporting rates of 11% and 40%.

	Total Fish (1996)	After Mortality	After Tag Loss	With 11% nonreporting	With 40% nonreporting
SMB Dart Tagged	432	288	272	--	--
SMB Caught	18	--	--	20	25
SMB Harvested	11	--	--	12	15

Table 8. Figures used to estimate headwaters exploitation on the stock of smallmouth bass using the headwaters during the spring based on estimated tagged fish present and estimated angler tag returns from Lake Moomaw 1996. Tags adjusted to reflect annual mortality rate of 64%, annual tag loss of 15%, and nonreporting rates of 11% and 40%.

	Total Fish (1996)	After Mortality	After Tag Loss	With 11% nonreporting	With 40% nonreporting
SMB Dart Tagged	89	53	**49**	--	--
Caught in Headwater	10	--	--	11	14
Harvested in Headwaters	5	--	--	8	10

Population Estimates

Results from the capture-recapture calculations estimated the population of adult smallmouth bass in the reservoir at 4,069 fish greater than 305 mm. However, the standard deviation for this estimate is 1,753 with the coefficient of variation (CV) of 0.43. Van Den Avyle (1993) states that population estimates with CV values greater than 0.20 are usually not adequate, so this estimate must be considered unreliable.

Based on the 1992 VDGIF creel survey and the 1995-1996 headwaters creel survey, I estimated the total annual harvest of smallmouth bass in the reservoir to be approximately 900 fish. Mean annual harvest from the headwaters creel survey averaged 149 adult smallmouth bass annually (1995 and 1996). Harvest figures from the 1992 creel survey indicate 732 smallmouth bass (exclusive of the headwaters) were harvested that year. The exploitation rate for the lake as calculated by the tag return information gathered in 1996 is 12 to 14% annually. Therefore, I estimated the adult smallmouth bass population ranged from 6,430 to 7,500 fish present in the reservoir.

Length Frequency Comparison

I compared the length frequencies of tagged fish versus fish measured in the creel survey. Results show the mean length of fish harvested in the creel survey (408 mm) was slightly larger than the length of those tagged (377 mm). There was no significant difference (P=0.37) in the mean length of smallmouth bass captured by gillnet for the tagging effort (377 mm TL) versus smallmouth bass caught and harvested by anglers in the headwaters fishery (408 mm TL). Further, information gathered during the spring 1996 creel survey indicated that most fish released in the headwaters fishery were below

the legal size limit (305 mm). Therefore, if these fish are added to the catch of anglers fishing in the headwaters, there would likely be very little difference in the comparison of means between gill nets and angling.

Relative Weight Calculations

A total of 431 fish were used in relative weight calculations. These bass were caught throughout Lake Moomaw (Table 9). Relative weight decreased as size increased, although all relative weight calculations show the bass in the lake to be well-conditioned.

Distribution and Movement

Information obtained from ultrasonic telemetry and the tagging-recapture project show similar and complementary patterns. Both aspects of the movement study documented spawning-related use of the various lake sections, and the degree of use of each section, as well as origin and redistribution of fish spawning in each of the lake sections.

Dart Tags

A total of 557 smallmouth bass were tagged in Lake Moomaw over the course of this study. I tagged 253 smallmouth bass with Visual Implant tags and 427 smallmouth bass with dart tags of which 123 were tagged with both a VI and a dart tag. Smallmouth

Table 9. Relative weight calculations for smallmouth bass in Lake Moomaw, Virginia based on the size classification proposed by Gablehouse (1984).

Size Class	<280	281-350	351-430	431-510	>510
Relative Weight	97	99	95	93	83

bass were tagged in all areas of the lake to obtain a representative sample of the adult population in the reservoir (Table 10). A total of 41 recaptures were obtained from biologists and anglers fishing in the reservoir during 1995 (12% of all fish tagged in 1995). All of the returns were reported by 30 May 1995. In 1996, a total of 101 recaptures were reported (18% of all fish tagged in the study). Ninety percent of these returns were reported by 30 June 96, and 100% of the returns by 20 November 96. Tag returns from both years consisted of smallmouth bass tagged in all sections of the reservoir and headwaters (Table 11 and 12). One tagged smallmouth bass was recaptured three times over the period of the study (once by biologists, twice by anglers), while 13 tagged fish were recovered twice (eight by anglers on both recaptures, three by a biologist and later an angler, and two by biologists both times). Seventy-nine percent of all recoveries occurred during the spring, while 18% occurred during the summer and the remaining recoveries occurred during the fall and winter.

Information obtained from the tagging portion of this study substantiates results found using telemetry. In both 1995 and 1996, tagged smallmouth bass were recovered in all areas of the reservoir (Table 11 and 12). Recaptures were low (n < 2 in some cells) in some lake sections during one or both years, so I pooled both years together for statistical analysis (Table 13). The number of tagged fish recovered was not proportional to the number of fish tagged in each lake section (P<0.05), indicating either vulnerability to angling of fish from each section was not equal, or there was unequal angling pressure among lake sections, or the distribution of tagged fish had changed since tagging. The largest percentage of fish caught were recaptured in the area of tagging, but a larger percentage of tag returns came from the headwaters (38 recoveries, 89 fish tagged)

Table 10. Distribution at tagging of smallmouth bass in Lake Moomaw. Percent of annual total in each location is in parenthesis.

Year	Lower	Middle	Upper	Headwaters	Total
1995	86 (25%)	83 (25%)	100 (30%)	66 (20%)	335
1996	65 (29%)	103 (46%)	28 (13%)	26 (12%)	222
Total	151 (27%)	186 (33%)	128 (23%)	92 (17%)	557

Table 11. 1995 smallmouth bass recapture location and origin of tagging. Percent of annual total in each location is in parenthesis.

	Lower	Middle	Upper	Headwaters	Total
Lower origin	5 (12%)	2 (5%)	0 (0%)	1 (2%)	8 (20%)
Middle origin	1 (2%)	3 (7%)	0 (0%)	0 (0%)	4 (8%)
Upper origin	1 (2%)	0 (0%)	4 (10%)	7 (17%)	12 (30%)
Headwaters origin	1 (2%)	0 (0%)	0 (0%)	16 (39%)	17 (42%)

Table 12. 1996 smallmouth bass recapture location and origin of tagging. Percent of annual total is in parenthesis.

	Lower	Middle	Upper	Headwaters	Total
Lower origin	14 (14%)	6 (6%)	3 (3%)	0 (0%)	23 (23%)
Middle origin	10 (10%)	20 (20%)	6 (6%)	7 (7%)	43 (43%)
Upper origin	2 (2%)	3 (3%)	4 (4%)	5 (5%)	14 (14%)
Headwaters origin	3 (3%)	2 (2%)	2 (2%)	14 (14%)	21 (20%)

Table 13. Smallmouth bass recapture location and origin of tagging for both 1995 and 1996 combined. Percent of overall total is in parenthesis.

	Lower	Middle	Upper	Headwaters	Total
Lower origin	19 (13%)	8 (6%)	3 (2%)	1 (1%)	31 (22%)
Middle origin	11 (8%)	23 (16%)	6 (4%)	7 (5%)	47 (33%)
Upper origin	3 (2%)	3 (2%)	8 (6%)	12 (8%)	26 (18%)
Headwaters origin	4 (3%)	2 (1%)	2 (1%)	30 (21%)	38 (27%)

than all other areas. The lower section had 31 tag returns and 151 fish tagged, the middle section had 47 tag returns and 186 fish tagged, and the upper section had 26 tag returns and 128 fish tagged.

Forty-one smallmouth bass with tags were captured and reported in 1995 (Table 11). Eight smallmouth bass originally tagged in the lower section were recovered. These fish showed little tendency to travel far from the lower section, as only one fish was captured from the upper section and headwaters, while the majority of these fish were recaptured in the lower section. Recovered fish tagged in the middle section also displayed a tendency to stay in or near the lower and middle sections of the lake, with all recoveries from this section occurring in these areas. Smallmouth bass tagged in the upper section of the reservoir were recaptured more frequently in other areas of the lake, specifically in the headwaters. Upper section tagged fish were not recovered in the lower or middle section as readily as in the upper and headwaters, with only one fish recaptured from the lower section. Bass tagged in the headwaters were recovered almost exclusively in the headwaters, with the exception of one fish recaptured in the lower section. However, 1995 tag recovery information may be biased because there were no reward incentives offered to anglers for return of recaptured fish. Although posters were displayed at all access points on the reservoir, anglers may not have been aware of the tagging study, or may not have been inclined to return tags as readily as in 1996 when the reward was offered. Additionally, the presence of a creel clerk in the headwaters may have encouraged anglers fishing in this area to report tagged fish captured, increasing the number of tags obtained from this area.

Information obtained from 1996 tag returns showed similar patterns in location of recapture (Table 12). Most of the bass tagged in the lower section were recaptured in the lower section, while a small number (six fish) were recaptured in the middle section.   Only three of these 23 recaptures were obtained from the upper section, while none came from the headwaters, showing little tendency for these fish to travel up the lake. Recoveries of tagged bass from the middle section were mainly from the middle section, with the remainder of these tag recoveries split fairly evenly among the lower section and the upper and headwaters sections, indicating that fish moving from this section may travel either uplake or downlake, with no strong preference for either direction. Recoveries of fish tagged in the upper section of the lake and later recaptured in 1996 came fairly evenly from the upper section and headwaters, and downlake in the lower and middle sections, showing that these fish tend to travel both uplake and downlake. Fish tagged in the headwaters were later recovered mainly in the headwaters. However, the fish tagged in this area and later recovered outside of the headwaters were evenly spaced throughout the reservoir. The reward increased public awareness of this project during 1996, most likely aiding in more complete returns of recaptured fish, and consequently yielding more accurate information of smallmouth bass movements in the reservoir.

Additionally, fish tagged in the headwaters during the spring give insight into redistribution of these spawning bass. The seasonal use of the headwaters area was demonstrated by late winter and spring electrofishing. Repeated sampling in the headwaters during 1995 using a boat electrofisher found no smallmouth bass in late winter. Catch began to increase as spring progressed (Figure 8).
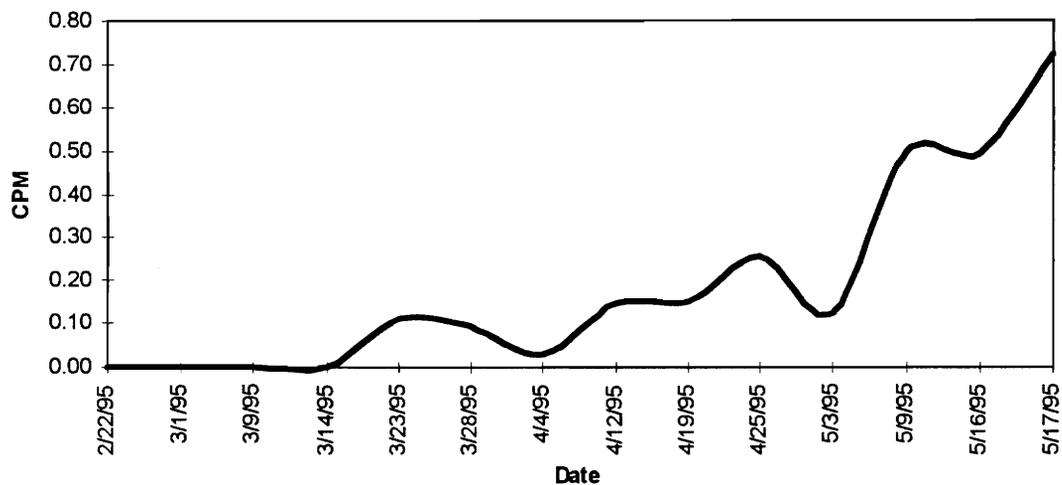
Figure 8. Catch per minute electrofishing for smallmouth bass in the headwaters of Lake

Moomaw, 1995.

During the spring of 1995, only 35% of all tagged smallmouth bass recaptures came from the three sections within the lake (Lower, Middle, Upper). In 1996, 75% of all tagged smallmouth bass recoveries came from the main lake while the remaining 25% came from the headwaters. Of the 41 recaptures in 1995, 13 (32%) came from outside of their original tagging section in the reservoir (moving), while in 1996, 49 of 101 smallmouth bass (49%) recaptured had moved (Figure 9). These recaptures occurred immediately before, during, and immediately after the spawning period (March through June), with the number of tag reports decreasing dramatically after this period. Of the tagged fish recaptured after the spawning and redistribution period (after 30 June) in 1996, 87% were caught in the same area of tagging, showing they had redistributed to locations previously occupied, or had not moved from these areas.

During both 1995 and 1996, the majority of fish captured in the headwaters (67% of 1995 recaptures, 54% of 1996 recaptures) were tagged in the headwaters (Figure 10). This is probably due to the fact that these bass were tagged only during the spawning season when recapture was most likely. Excluding these fish, the composition of the returns from the headwaters (pooled over both years) was 5% from the lower section (one fish), 35% from the middle section (seven fish), and 60% from the upper section (12 fish). This composition indicates that the headwaters spawning stock is not drawn from the whole-lake population equally. Further, only seven recaptures of headwater-tagged bass were recovered outside of the spawning season: one each in the lower, middle, and upper sections of the lake, and four from the headwaters. No smallmouth bass were recovered in the headwaters after June in either year.
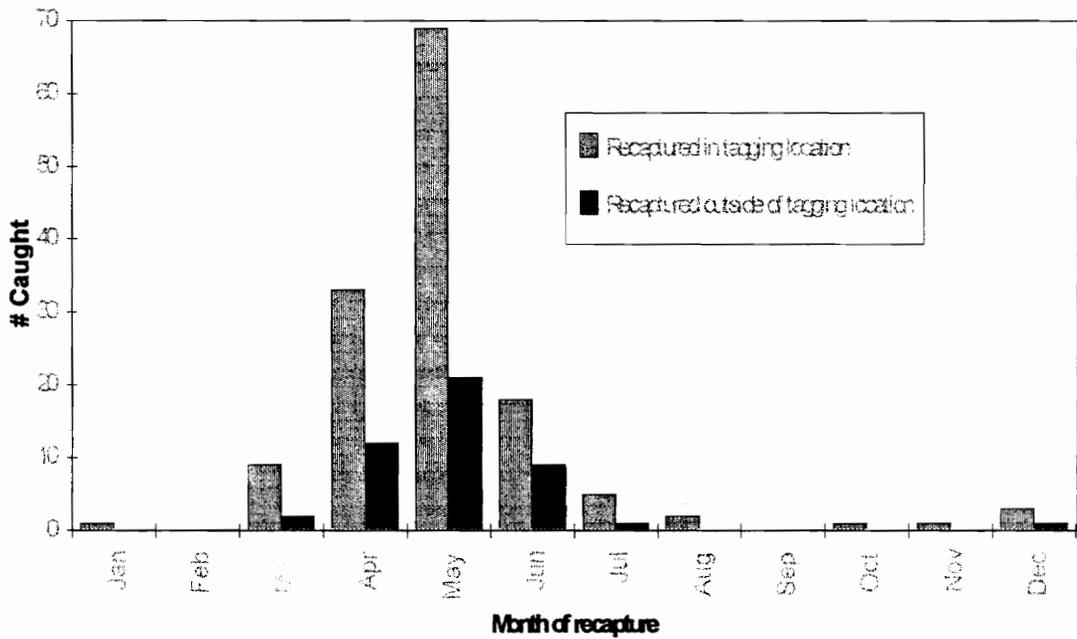
Figure 9. Seasonal recapture of smallmouth bass tagged in Lake Moomaw, 1995 and 1996 pooled data.
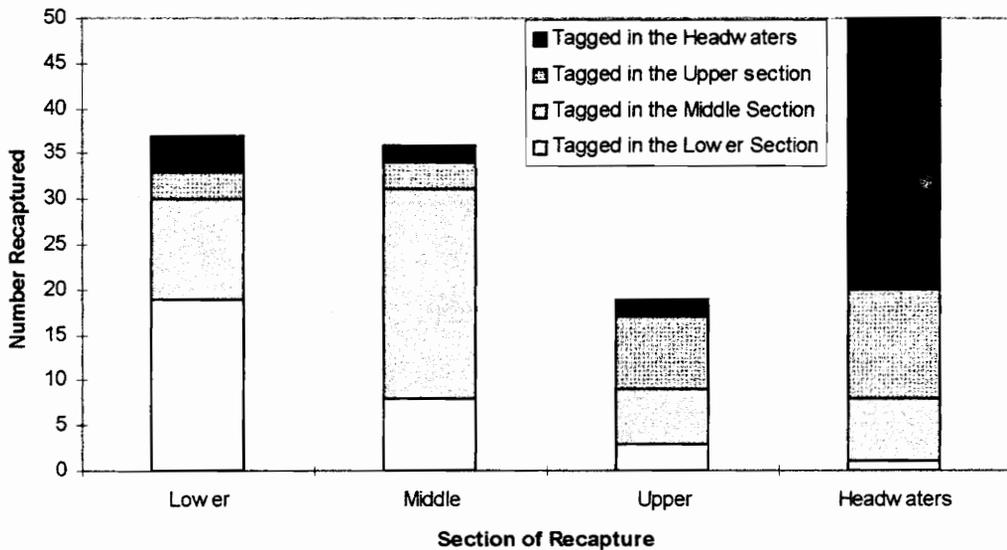
Figure 10. Distribution at recovery of smallmouth bass tagged in each of the lake sections, 1995 and 1996 pooled data.

Between January 1995 and April 1996, I implanted ultrasonic transmitters in seven smallmouth bass in the lower section of the reservoir, six in the middle section, and seven in the upper section of the reservoir (Table 14). I implanted eight of these fish prior to the 1995 spawning season, and the remaining 12 before the 1996 spawning season. Tracking duration ranged from 0 to 18 months (mean of 8 months). I tracked six smallmouth bass through the 1995 spawning season, 17 into the 1996 spawning season, and six for both spawning seasons.

Two of the eight smallmouth bass (fish numbers 5 and 6) implanted with transmitters in 1995 showed no movement after surgery, indicating possible mortality. Temperatures recorded for these two fish were well below the mean temperature for the other six fish, indicating these transmitters were lying on the bottom of the reservoir in the hypolimnion. Therefore, I assumed these fish had died shortly after surgery. I never located one of the smallmouth bass (fish number 9) implanted with a transmitter in 1996. This fish may have been harvested and not reported shortly after implantation, or the transmitter failed. Additionally, fish number 20 was tracked for only one month before transmitter failure or harvest, and was excluded from analysis.

During this study, I located telemetered smallmouth bass in the lower section most frequently during the spawning period, with four of six fish found in this area in 1995, and eight of 17 fish in 1996 (Figures 11 and 12). No smallmouth bass with transmitters were found in the middle section in 1995 during the spawning season, and only three

Table 14. Summary of ultrasonic transmitter implantation and tracking information for smallmouth bass in Lake Moomaw.

ID #	Date Tagged	Length (mm)	Tagging Location	Fixes	Months Tracked
1	1-9-95	355	Lower	34	16
2	1-9-95	325	Middle	34	17
3	1-17-95	510	Lower	34	18
4	1-17-95	445	Middle	29	13
5	1-17-95	446	Lower	0	0
6	1-17-95	443	Lower	0	0
7	3-14-95	482	Upper	28	14
8	3-14-95	425	Upper	19	13
9	11-21-95	426	Lower	0	0
10	11-21-95	423	Lower	8	7
11	11-21-95	397	Middle	9	6.5
12	11-21-95	372	Middle	17	10
13	11-21-95	387	Middle	17	10
14	11-21-95	346	Upper	16	9
15	11-21-95	352	Upper	11	6
16	11-21-95	408	Upper	10	5.5
17	3-14-96	434	Lower	13	6
18	4-4-96	380	Upper	13	5.5
19	4-4-96	430	Middle	11	5
20	4-4-96	440	Upper	4	1
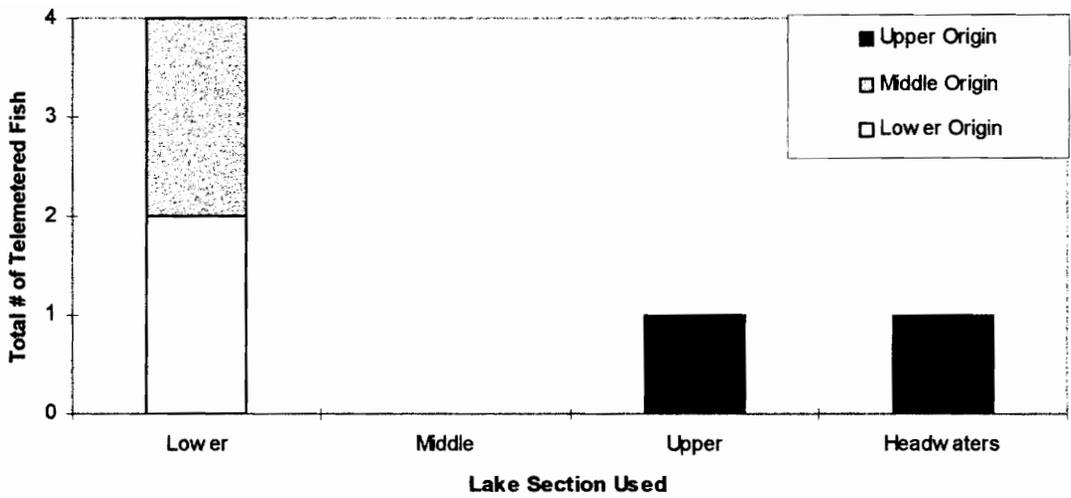
Figure 11. Location of telemetered smallmouth bass during the 1995 spawning season relative to location at transmitter implantation.
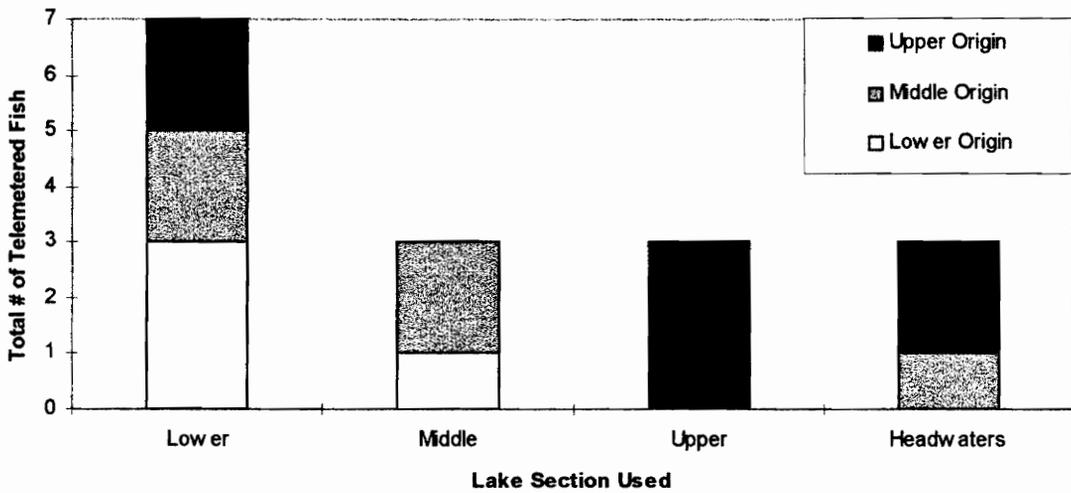
Figure 12. Location of telemetered smallmouth bass during the 1996 spawning season relative to location at transmitter implantation.

transmitter-equipped fish were found in this area during the 1996 spawning season. One transmitter-equipped smallmouth bass used the upper section during the spawning season in 1995, and three in 1996. One smallmouth bass with a transmitter traveled to the headwaters during the 1995 spawning season, while three were found in the headwaters in 1996.

Movements of smallmouth bass with transmitters from the lower section were concentrated in the lower section during the spring spawning period. During the 1995 spawning season, both telemetered smallmouth bass present in this section (numbers 1 and 3) stayed in the lower section throughout tracking. In March 1996, five smallmouth bass with transmitters (numbers 1, 3, 10, 11, 17) were present in the lower section. Four of these fish remained in the lower section throughout the spawning season. The fifth fish (number 17) began moving upstream at the beginning of April. This fish may have been moving towards the headwaters to spawn, but was harvested in the middle section on 11 May 96.

Smallmouth bass implanted with transmitters in the middle section showed variable movements during the spring spawning season. Two telemetered smallmouth bass (numbers 2 and 4) present in this area during the 1995 spring spawning period traveled into the lower section. After the spawning period ended, these fish moved back to the middle section of the reservoir. Five smallmouth bass with transmitters (numbers 2, 4, 12, 13, 19) were present in the middle section prior to the 1996 spring spawning period. Of these fish, numbers 2, 12 and 13 were found in the middle section during the spawning season. One of the remaining fish (number 4) traveled to the lower section during the spawning period. Location of this fish was unobtainable after 11 May 96, indicating this

fish was either harvested and not reported while in the lower section or the transmitter failed. The fifth fish (number 19) traveled upstream towards the headwaters during the spawning season. A location was not obtainable for this fish on 21 May 96, presumably because this fish was in the headwaters. Locations on this fish were obtained over the next several tracking periods as this fish returned to the middle section after the spawning season.

Adult smallmouth bass from the upper section of the reservoir also showed variable movements. Two fish (numbers 7 and 8) with transmitters were present in the upper section of the reservoir prior to the 1995 spawning season. Fish number 7 spent the spawning season in the upper portion of the reservoir. Fish number 8 moved to the headwaters during this period and returned to the upper section as the spawning season ended. Six transmitter fish (numbers 7, 8, 14, 15, 16, 18) were present in this section prior to the 1996 spawning season. Of these, numbers 14, 16 and 18 stayed in the upper portion of the reservoir during the spawning period. Two of the remaining three fish (numbers 7 and 8) traveled to the headwaters and were harvested by anglers. The remaining fish (number 15) moved to the lower section during the spawning period and was harvested by an angler.

Six fish with transmitters were present in the reservoir during the 1995 spawning season (fish numbers 1, 2, 3, 4, 7, 8). Of these six smallmouth bass, one (number 8) traveled to the headwaters during this time period. During the 1996 spawning season, 16 smallmouth bass with transmitters were present in the reservoir, of which numbers 7, 8, and 19 traveled to the headwaters during the spawning season (Figure 11 and 12). Telemetered smallmouth bass that presumably spawned in the headwaters were originally

captured in the upper section (one in 1995 and two in 1996) and the middle section (one

fish in 1996). No smallmouth bass from the lower section with transmitters traveled to the

headwaters to spawn during either year.

Six smallmouth bass with transmitters were tracked for both spawning seasons:

two smallmouth bass from the lower section (numbers 1 and 3), two from the middle

section (numbers 2 and 4), and two from the upper section (numbers 7 and 8). In 1996,

fish numbers 1 and 3 from the lower section of the reservoir were located within 200 m of

1995 locations during the spawning season. Smallmouth bass number 4 from the middle

section traveled back to the lower section in 1996, and was located within 100 m of the

previous year's location during the spawning season. Fish number 2 remained in the

middle section during the 1996 spawning season, although this fish had traveled to the

lower section during the spawning season in 1995. Fish number 7 (upper section origin)

was located in the upper section of the reservoir during the 1995 spawning season, while

fish number 8 (upper section origin) migrated to the headwaters. Both of these fish

traveled to the headwaters during the spawning season in 1996. I presume that these fish

spawned in the areas where they resided during the spawning seasons, although exact

spawning location for these fish was unobtainable due to turbulent waters in this area

rendering ultrasonic tracking equipment useless.

I compared both maximum distances traveled and mean distance traveled between

fixes for fish in each of the three lake sections to determine if movements in one section

were greater than other sections. Mean distances moved between fixes were 0.68 km,

0.80 km, and 0.69 km for bass of the lower, middle, and upper lake origin, respectively,

and were not significantly different (P=0.9423, Kruskal-Wallis test). Maximum distances

moved ranged from 1.41 km to 9.94 km for bass with transmitters. Mean maximum distances moved were 2.62 km, 3.57 km, and 5.63 km for bass of the lower, middle, and upper lake origin, respectively. However, statistical analysis found these differences to be insignificant (P=.5308, Kruskal-Wallis test) due to high variance within the data (10.76), and a small sample size (16 bass with transmitters located more than 7 times).

Length of smallmouth bass was not related to either mean or maximum distance traveled (P=0.36 and 0.34 respectively). However, degree of movement differed among the four seasons (P<0.01), with mean distances moved between fixes significantly lower in winter (0.21 km) than in spring (0.77 km) summer (0.64 km) or fall (0.74 km).

Seasonal use of the different lake sections varied between 1995 and 1996. During 1995, fish with transmitters used the lower and middle sections of the reservoir year around, with the upper section used only during the spring and winter months by a small percentage of bass with transmitters, and the headwaters used only during the spring and early summer. In 1996, some telemetered fish were found in both the lower and middle sections as well as the upper section during all seasons, while the headwaters were again only used in the spring and early summer. The larger sample size in 1996 probably resulted in a more accurate description of seasonal use of lake sections (Figure 13).
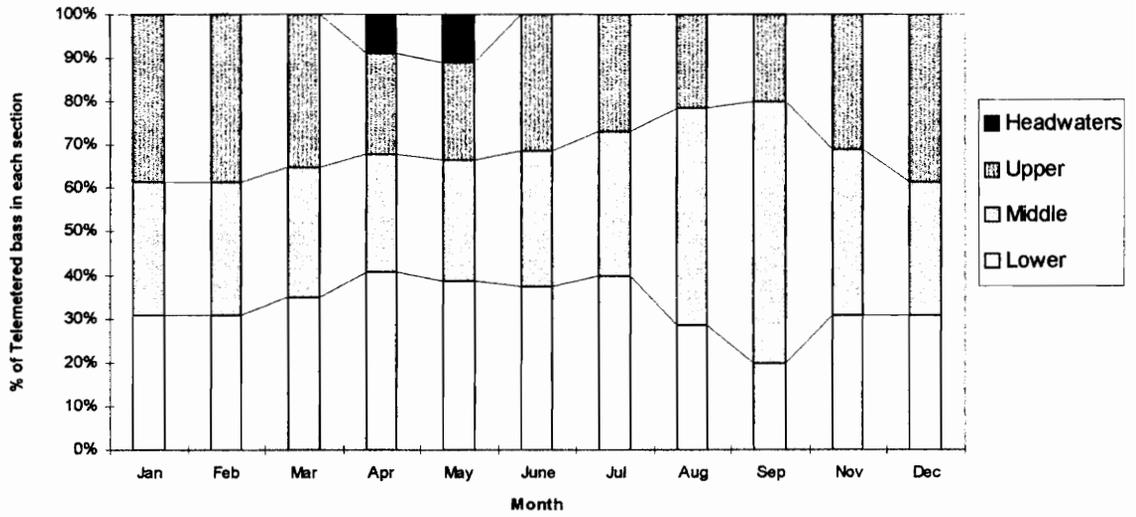
Figure 13. Seasonal use of the lake sections by smallmouth bass with ultrasonic transmitters - Pooled data from 1995 and 1996.

Reproduction and Recruitment

1995 Sampling

Line transect snorkel surveys during 1995 resulted in variable information. The same group of divers was used throughout the survey on all sections of the reservoir, although not all divers were available for use on all transects sampled. Additionally, divers' capabilities varied in the amount of time they could stay submerged and their efficiency at locating age-0 smallmouth bass. Therefore, the pooled results of relative densities varied between samples, rendering exact quantification of densities per shoreline distance inaccurate. However, the estimates derived from this method are still valuable for comparisons among lake sections. Although exact quantification of age-0 smallmouth bass per shoreline distance was not possible, the relative densities observed yielded information on the reproductive contribution of each of the lake sections.

During June and July 1995, line transect snorkel surveys showed age-0 smallmouth bass to be present in all sections of the reservoir, and in both of the major tributaries. I estimated mean densities per 100 m for all sections of the reservoir to be greatest in the tributaries to the reservoir (Jackson River and Back Creek), and to progressively diminish downlake, with the lowest densities in the lower section (Figure 14). However, a Kruskal-Wallis test (α=0.05) showed this difference to be insignificant (P=0.66). Assuming that age-0 smallmouth bass at this early stage in their life (20 to 50 mm TL and 1 to 3 months old) do not migrate far from the area of their nest, it again becomes apparent that smallmouth bass are spawning in all areas of the reservoir.
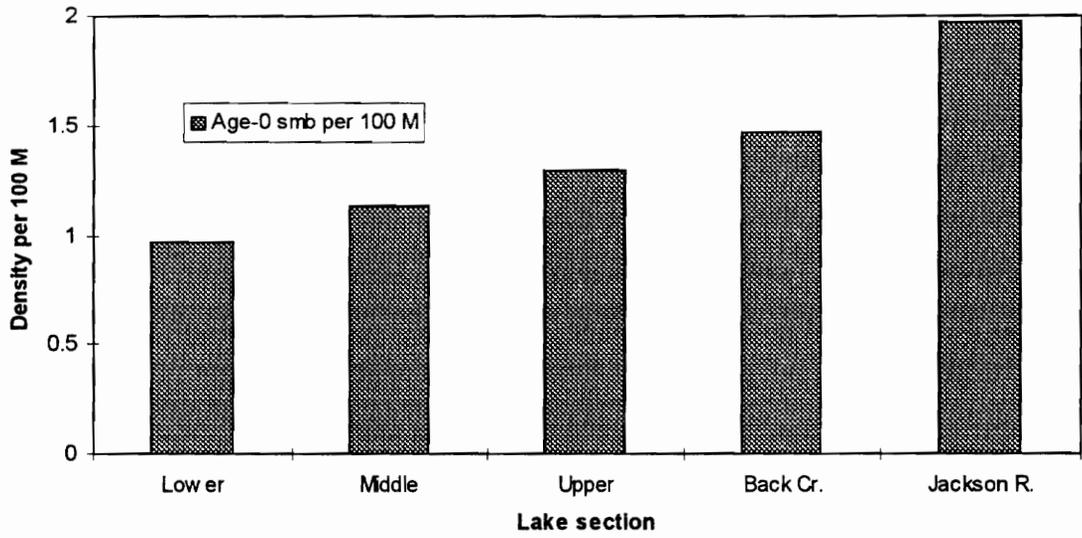
Figure 14. Age-0 smallmouth bass densities per 100 m as determined by snorkel surveys in Lake Moomaw during June and July 1995.

Line transect snorkel surveys of the magnitude used for this study are very labor intensive. Differing habitat types, water clarity, and water depths between the two tributaries and the various lake sections made consistent spotting of age-0 smallmouth bass difficult. Due to water clarity fluctuations, time constraints, and the variable results obtained from different divers, I did not repeat this method in 1996. However, substrate information such as slope, composition, and available cover was noted during these surveys, and was used in determining 1996 electrofishing sample stations for young-of-the-year bass. Results from the 1995 snorkel transects showed that habitat in the lower and upper sections of the reservoir was more favorable for spawning of smallmouth bass than that of the middle section. The lower section contained numerous areas with gravel substrate, submerged stumps and rocks and a slope less than 45°. The substrate in the middle section consisted mainly of silty areas interspersed with gravel, and areas with minimal cover. The upper section contained a mixture of silt and gravel substrate, with areas of cobble and boulder mixed in. In all, the upper section offered more spawning habitat than the middle section, but not as much as the lower section. Habitat in the areas of the two tributaries sampled consisted of areas of low flow with pebble, rock, and boulder substrate, and ample cover for smallmouth bass spawning.

Results of a one-time night electrofishing sample for age-0 smallmouth bass in September 1995 differed from results found with snorkel surveys earlier in the summer. Catch rates (catch per minute) were greatest in the lower and middle sections of the reservoir with 48% and 44% of all age-0 fish caught being from these sections respectively, and only 7% of the total catch coming from the upper section (Figure 15).
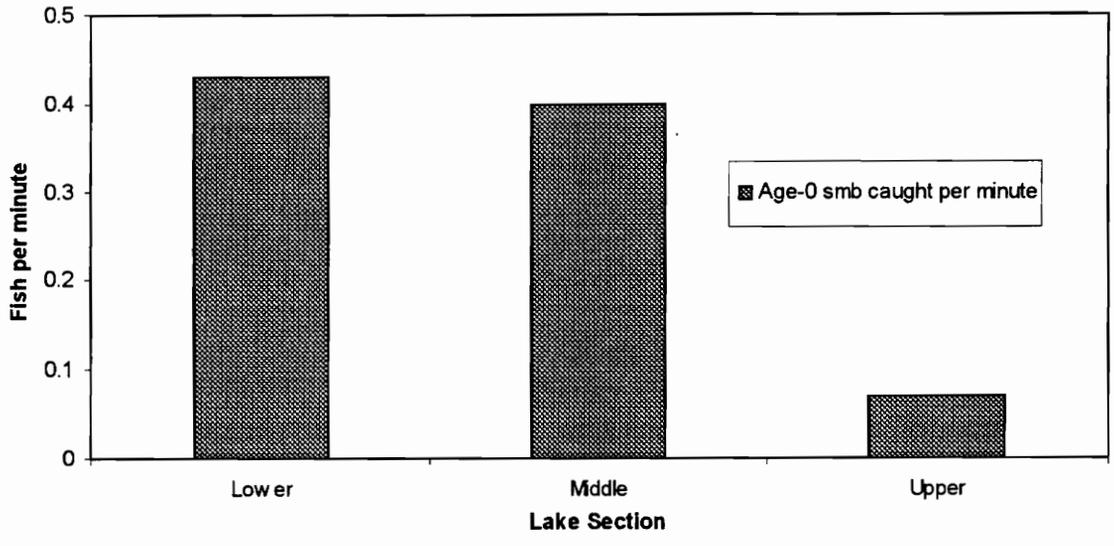
Figure 15. Lake Moomaw young-of-the-year mean catch per minute for electrofishing for the three sections of the reservoir, Fall 1995.

Although a difference among lake sections is apparent, statistical analysis showed this difference to be insignificant (P=0.32, Kruskal-Wallis test) due to the small sample size and high variability of catch within lake sections. No sampling was conducted in the headwaters in 1995 due to fall drawdowns of the reservoir, although I was able to thoroughly sample the upper section.

1996

Dive transects in June, 1996 documented the presence of age-0 smallmouth bass in both the lower and middle sections of the reservoir (transects were not performed in the upper lake). I observed schools of age-0 smallmouth bass at two of three stations sampled in the lower section of the reservoir, while one of four transects in the middle section had smallmouth bass fry present.

Repeated nighttime electrofishing for age-0 smallmouth bass in 1996 revealed different results from both the limited 1995 electrofishing data and the 1995 snorkel survey. I compared catch per minute of age-0 smallmouth bass over sampling dates, and found a difference in catch-per-unit-effort among sampling dates (p=0.001, Kruskal-Wallis test). I also tested for differences among lake sections on each of the four sampling dates using a Kruskal-Wallis test. I found no differences on any of the sampling dates (p=0.67 on 1 Aug 96; p=0.36 on 13 Aug 96; p=0.41 on 27 Aug 96; p=0.14 on 18 Sep 96), primarily because of high variance between repetitions on each sampling date.

Nighttime electrofishing on 1 August yielded the highest catch per minute of age-0 smallmouth bass in the lower section, with second-highest catch per minute in the middle section and the lowest catch per minute in the upper section (Figure 16). Samples taken
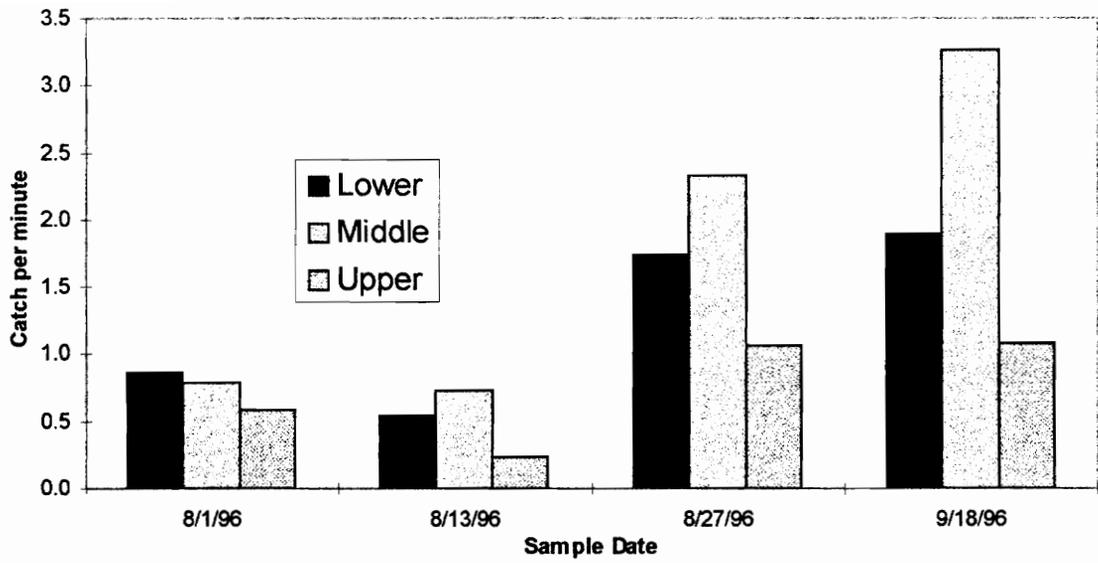
Figure 16. Catch per minute of electrofishing effort of age-0 smallmouth bass from Lake Moomaw fall electrofishing 1996.

on 13 and 27 August and 18 September resulted in highest catch per minute in the middle section and lowest in the upper section. Percentage of age-0 fish caught reflected the same trend, with percentages of the total catch decreasing over the two-month sample period in the lower and upper sections, and increasing in the middle section (Table 15).

An attempt to sample the headwaters area by electrofishing during September resulted in no catch of age-0 smallmouth bass because turbulence reduced visibility and catch. Line-transect snorkel surveys from 1995 were considered to be the most effective indicator of abundance in the headwaters due to the shallow depth, and ease of sampling using snorkel surveys. Snorkel transects in July 1995 indicated that these tributaries had high densities of age-0 smallmouth bass per kilometer in early sampling, and probably contributed significantly to the age-1 smallmouth bass population in the reservoir. Densities of age-0 smallmouth bass in these tributaries may have changed over time due to survival or migrations of these fish.

Table 15. Percentage of nightly total catch from Lake Moomaw fall electrofishing 1996

in each of the lake sections (1,800 seconds sampling time per lake section per date).

	Lower Section	Middle Section	Upper Section
1 August 96	38	35	27
13 August 96	36	49	15
27 August 96	34	45	21
18 September 96	30	53	17

DISCUSSION

Creel Survey

Anglers fishing the headwaters of Lake Moomaw expended significant effort in pursuit of smallmouth bass during the spring. Estimated angler hours fished per hectare for smallmouth bass in Virginia reservoirs were 30.6 h/ha on Philpott Reservoir in 1980 (Whitehurst 1981), 36.8 h/ha in Claytor Lake in 1988 (LaRoche 1988), 38.5 h/ha in Smith Mountain Lake in 1992 (Duval 1992), and 48.2 h/ha in Claytor Lake in 1992 (Southwick 1992). Lake Moomaw supported the least amount of pressure on smallmouth bass overall, with 28.4 h/ha annually, while the headwaters sustained pressure of 1,283 h/ha in pursuit of these fish during the spring alone. Per hectare, this area was the most extensively used portion of the reservoir. Recreational anglers used this area heavily during the spring, and indicated they used this area throughout the year.

Although anglers expended significant effort in pursuit of smallmouth bass in this area, catch and harvest were relatively low during both years of the study. Average yearly catch for 1995 and 1996 was 217 smallmouth bass, and average harvest was 149 smallmouth bass. Catch rate of smallmouth bass in the headwaters of Lake Moomaw was 0.05 fish per hour in 1995 and 0.11 fish/hr in 1996, which, on average is greater than that reported for Smith Mountain Lake, VA in 1992 (<0.001 fish/hr) and Philpott Reservoir, Va. in 1980 (0.04 fish/hr, Whitehurst 1981), but substantially lower than that reported from Wautauga Reservoir, TN. (0.36 fish/hr, Cheek and Pollock 1991). Factors other

than catch rates must draw anglers to the headwaters for effort to be as high as it is while catch rates are so low. Most likely, it is the easy access in this area coupled with the potential to catch fish that draws anglers to the headwaters during the spring.

Estimated overall harvest of smallmouth bass from the 1992 creel survey in Lake Moomaw was 732 bass (0.71 bass per ha). The 1992 survey did not adequately sample the headwaters of the reservoir, and underrepresents actual lakewide harvest. Assuming that catch and harvest in the main lake fishery have remained stable since the 1992 survey, a total annual harvest including the headwaters of 900 smallmouth bass (0.87 bass per ha) lakewide seems likely. Additional studies in Virginia have shown harvest of smallmouth bass to range from 0.012 fish/ha in Smith Mountain Lake in 1992 (Duval 1992) to 1.7 fish/ha in Philpott Reservoir in 1980 (Whitehurst 1981). Cheek and Pollock (1991) found harvest to range from 0.17 smallmouth bass harvested per ha in Norris Reservoir, TN to 2.96 fish/ha in Wautauga Reservoir, TN. Jenkins (1975) found harvest to range from 0 to 56 kg/ha throughout North America. Therefore, the overall harvest at Lake Moomaw falls within normal ranges of harvest in Virginia and the Southeast. With lakewide harvest at 900 smallmouth bass annually, the headwaters fishery would therefore be responsible for less than 20% of the total annual harvest in the lake. This harvest comes from a highly conspicuous area over a relatively short period of time. Therefore this catch is highly visible and may lead observers of the fishery to draw incorrect conclusions regarding the amount of harvest that is occurring in this area.

I expected the overall percentages of tagged fish returned to increase from 1995 to 1996 due to the implementation of the reward program. Eight percent of all fish tagged were reported caught in 1995 versus 18% in 1996. After the reward program began in

1996, effort in the headwaters fishery increased 43% from the previous year. This agrees with results of other researchers (Eder 1990, Haas 1990) that showed reward incentives increased tag returns. Eder (1990) also reported that a monetary reward increased fishing pressure in a local fishery in Missouri. By implementing a reward program for return of tagged fish, it is possible that I influenced fishing pressure in this area. However, the maximum reward for a tag was $25.00, and was probably not substantial enough to increase angler effort in the headwaters. The increase in effort was more likely related to more favorable fishing conditions or increased catch rates than an influence in behavior due to monetary rewards offered for tagged fish. This discrepancy in returns between years indicates that either catch of tagged fish increased in 1996, or that there was a larger amount of nonreporting in 1995. Based on the literature, I believe that rewards increased the reporting rate in 1996 over 1995 which allowed for more accurate estimates of exploitation.

The 1992 creel survey (Bugas 1993) showed that the overall harvest rate (amount of captured fish being harvested) for black bass was 12%, indicating the lake fishery is oriented towards releasing captured fish more than consumptive use of bass captured. Information obtained from the tagging project in this study found that 44% of tagged fish captured were harvested overall, reflecting a higher rate of harvest lakewide than was previously documented. In the headwaters creel survey, the overall harvest rate for smallmouth bass was even higher (68%) especially for trophy-sized fish (100%). I do not believe the harvest rate was influenced by the tagging/reward program because anglers qualified for rewards regardless of whether the fish was harvested or not. Overall, a large percentage of the smallmouth bass captured were harvested throughout the reservoir.

Consequently, the spring headwaters fishery may not differ from that of the main lake fishery to the degree previously believed, as anglers target fish to harvest for food or trophies lakewide.

The consumptive nature of the headwaters fishery is supported by the response of anglers to the question which addressed the motivations of anglers in the headwaters. The most frequent responses to this question were harvest oriented, indicating that catching fish for food or trophies is the main reason that anglers came to this area. Social and aesthetic reasons for fishing in this area ranked below these utilitarian views. A New York statewide angling survey (1988) showed factors affecting fishing satisfaction (such as being with friends and family and viewing pleasant scenery) were more important than factors dealing with catching and eating fish (Connelly et al. 1990). Similarly, a survey in Illinois showed that enjoyment of the outdoors was the main reason residents fished, while catching fish for food was fourth on a list of seven factors (Illinois Sport Fishing Survey 1994). In Virginia, only 12% of respondents to a trout angler survey in both 1986 and 1993 indicated catching fish for food was the primary reason for fishing, while fun and relaxation was the primary reason for 56% and 50% of respondents respectively (Mohn 1993). Mullett (1980) found harvest motives to be less important (only 12% of respondents) than the enjoyment of the out-of-doors as the primary reason for fishing in Idaho. Galloway et al. (1986) found only one characteristic as being unimportant in a Colorado survey - large creel limits. These studies have indicated that utilitarian views relating to catch and harvest of fish in some waters are not valued as highly as they are in the headwaters fishery of Lake Moomaw. This is representative of the unique smallmouth bass fishery that has developed in the headwaters. Therefore, if management

of this resource is going to satisfy angler wants in this area, fish of quality size must be present for anglers to harvest.

This headwaters fishery appears to be a seasonally productive fishery. While anglers may use this area during the entire year, the heaviest pressure occurs during the spring. Angler catch rates should be highest at this time due to the presence of spawning smallmouth bass. Electrofishing repeatedly in this area from February to August indicated limited presence of smallmouth bass at times other than the spring. No smallmouth bass were caught in the winter months in this area. Densities of these fish increased as March progressed, reaching a peak in mid-April. Towards the end of May, smallmouth bass densities began to decrease again, as these fish moved back into the main body of the reservoir. The headwaters area of the reservoir offers a diminishing opportunity as smallmouth bass move back to the reservoir in late spring. Some anglers continue to fish in this area throughout the year, probably due more to ease of access than to high success rates. This indicates the bank-based fishery in this area is important year-round, even if catch rates diminish significantly during times other than the spring.

The fishery in the headwaters of Lake Moomaw is intense during the spring. Angler effort per hectare in this fishery is more than seven times greater than on the main lake. The creel survey in 1992 showed the whole reservoir sustained 83.5 hours of fishing pressure per ha of which 28.5 h/ha was spent on smallmouth bass. I estimated mean effort over the two-year study in the headwaters at almost 1,300 hours per ha for the March-May period alone, of which over 90% was targeted towards smallmouth bass. This is indicative of the overall importance of this area as part of the fishery of Lake Moomaw,

contributing almost 4% of the total annual fishing effort in an area of less than 0.2% of the total lake surface.

Most headwaters anglers are local residents, coming from Bath, Alleghany, or Augusta counties, or one of the towns located nearby in West Virginia. These anglers are familiar with the spring run of smallmouth bass, and are aware of the opportunity to catch these fish during this time. The majority of anglers fishing the headwaters live within 25 miles of the headwaters fishery and are able to respond quickly when runs of smallmouth bass are good. If local anglers are having success in this area, they may tell other anglers or bring friends along on their next outing. This has the potential to increase effort in the headwaters when catch rates are good, resulting in greater catch and harvest of fish in this area.

Lake Moomaw is a steep-sided reservoir with limited access to fishing areas from the bank. The VDGIF creel survey conducted in 1992 (Bugas 1993) was an access point survey based at the three boat ramps on the lake. This survey showed 75% of anglers using the reservoir were fishing from boats. Due to limited bank access throughout the reservoir, the main portion of the lake is most easily fished from boats. Contrary to the 1992 VDGIF creel survey, the headwaters creel survey showed 92% of the fishing pressure in this area to be coming from bank anglers. The headwaters area presents one of the few opportunities for anglers to catch quality fish from the bank, and should be considered in any management decisions.

Population Dynamics

I calculated exploitation of the overall lake population from the 1996 tag returns when angler nonreporting was believed to have been lower due to the reward offered to anglers for reporting tagged fish caught. Reported exploitation rates on lentic populations of smallmouth bass are relatively scarce, but ranged from 68% in Shasta Lake, Ca (Van Woert 1981) to 4-21% in Oneida Lake (Forney 1972). Robbins and MacCrimmon (1977) estimated exploitation to be 36% in a potamodromous stock of smallmouth bass, and attributed an unspecified majority of this harvest to the river. Exploitation derived from this tagging project at 12-14% annually indicated that fishing mortality of smallmouth bass was at an acceptable level. The exploitation rate of 16-20% of the smallmouth bass population using the headwaters during the spring was also within current management goals. However, these exploitation figures were calculated after adjusting tagged fish present in the lake to reflect an annual mortality rate of 61%. This mortality estimate may be an overestimate of actual mortality in the reservoir, which would make the exploitation estimates higher than actual exploitation. Regardless, managers should be aware of the potential for increased catch and resulting harvest with a significant increase in effort.

The population estimate derived from the capture-recapture Peterson estimator and the estimate derived using lakewide exploitation and total lakewide harvest both show the population to be less than 7,500 adult smallmouth bass in the reservoir. Additional captures of tagged fish as well as additional recaptures of marked fish would result in more reliable estimates for population size using Peterson's method. The estimate derived from exploitation figures is also crude as these figures are based on estimated angler

returns of tagged fish. A high degree of nonreporting or failing to compensate for this

nonreporting would lead to underestimation of overall exploitation rates and

overestimation of the population. Further, by not compensating for tag loss and mortality,

exploitation rates would again be underestimated, causing overestimation of population

size. I believe the methods used to compensate for these potential errors to be adequate,

the figures used in these calculations to be reasonable, and the population estimates to be

acceptable. In Lake Moomaw, densities of adult smallmouth bass range from 6.0 to 7.3

fish/ha. Other research has shown populations of these fish at 1.8 fish/ha in John Day

Reservoir, OR (Beamsderfer and Reiman 1988) and 2.0 fish/ha in Lake Texoma (Gilland

et al. 1991), although comparisons of densities between lentic systems have limited value

due to the variation in the physical characteristics of different systems. Much higher

densities have been recorded for streams and rivers than in lakes and reservoirs. Both

population estimates obtained in this study show that the population is large enough to

sustain the mean annual harvest in the headwaters fishery at the current levels of catch and

harvest.

Distribution and Movement

Information obtained from the two-year tagging project indicated that only a small

portion of the smallmouth bass population used the headwaters to spawn each year.

Excluding fish tagged in the headwaters, only 19% of all fish recovered were captured in

the headwaters, suggesting that a large percentage of the adult smallmouth bass

population remained in the main body of the reservoir. However, this figure cannot be

directly equated to the percentage of the population using the headwaters, because it is influenced by variable fishing pressure in each of the lake sections, as well as vulnerability to both angling and electrofishing in the headwaters. Areas of the reservoir other than the headwaters are not as heavily fished by anglers due to remoteness and limited access from the bank, and may not have produced tag returns in proportion to the abundance of tagged bass in those areas. Therefore, the percentage of adult smallmouth bass that travel to the headwaters during the spring is probably less than the 19% tag return rate would suggest. However, this estimate shows that use of this area is limited to a small percentage of the smallmouth bass in the reservoir, regardless of the actual value expressed.

Telemetry data confirmed the tagging study results. In both 1995 and 1996, less than 20% of the fish with transmitters traveled to the headwaters during the spring. The fish used for the telemetry project were captured throughout the lake in order to obtain a representative sample of the smallmouth bass population. If these fish represent the overall population, it is likely that less than 20% of the lake population use the headwaters to spawn each year. This figure is useful as validation of the estimate of the percentage of the adult smallmouth bass population traveling to the headwaters found in the tagging portion of the study, and indicate that a small percentage of the population used the headwaters during the spring. Therefore, the majority of spawning smallmouth bass remain in the main body of the lake, and are not exposed to the headwaters fishery.

Only 43% of all tagged smallmouth bass recaptured over the two-year study were taken outside of their tagging location. The most sedentary fish in the reservoir were tagged in the lower section, with over 60% of recovered fish from this area recaptured in the area of tagging. The lower section offers adequate habitat smallmouth bass require

throughout a year. Sedentary behavior decreases uplake, reaching a minimum of 30% of fish tagged in the upper section of the reservoir recaptured in the same lake section. Although sufficient habitat exists in this area to meet smallmouth bass requirements during most of the year, spawning habitat is less prevalent than in the remainder of the reservoir, which may force smallmouth bass to move to other areas during the spring in search of suitable spawning areas. Additionally, bass moving to the upper portion of the lake from other sections in the reservoir which also lack spawning habitat may increase competition for the limited suitable spawning habitat in this section, forcing excess fish to seek out spawning areas elsewhere.

Information gained from both the tagging-recapture study and the telemetry portion of the study show that smallmouth bass using the headwaters primarily originate from the upper and middle sections of the reservoir. Tagged fish from all sections of the reservoir were recaptured in the headwaters during one or both years of the study. However, recoveries of tagged fish in the headwaters during the spawning period were not proportional to the number of fish tagged in each section. Headwaters recoveries were dominated by bass tagged in the upper and middle sections of Lake Moomaw. Use of the headwaters by fish with transmitters was limited to fish from the upper and middle sections exclusively. Other researchers found that smallmouth bass movements usually were limited to less than 10 km. Forney (1961) found that 63% of recovered tagged bass in Oneida Lake, NY were caught within 4.2 km of the initial tagging site. Robbins and MacCrimmon (1977) showed that smallmouth bass using the Pefferlaw River (tributary to Lake Simcoe, Ontario) to spawn generally did not distribute more than 4 km from the mouth of the tributary, but occasionally distributed as much as 20 km. Pflug and Pauley

(1983) found smallmouth bass to move no more than 4.3 km from the area of capture in Lake Sammamish, WA, while most moved less than 1.9 km. In the Jacks Fork River in Missouri, Todd and Rabeni (1989) found upstream movements of smallmouth bass to be most common in the spring although some downstream movements were noted. The median distance moved upstream was 1.3 km (max 7.5 km), while the median downstream distance was 0.2 km (max 5.7 km). Kraai et al. (1991) documented extensive movements up to 6.5 km outside of home ranges during the spring in Meredith Reservoir, TX. My research supports the findings of these past studies with regard to distances moved during the spring. Based on this information, it is likely that the headwaters spawning stock is drawn more from areas close to the headwaters (upper and middle sections) than the whole lake, although it is likely that some fish from all areas of the lake may use the headwaters.

General use of the headwaters by smallmouth bass was more accurately described with the tagging-recapture study as opposed to the telemetry study primarily because of sample size. The telemetry project was limited to 20 implanted fish, of which 16 survived long enough to give useful information. The tagging-recapture project consisted of a large number of tagged fish (557), and a large number of recaptures (142).

In 1995, 59% of all tags returned by anglers came from the headwaters area, while in 1996 26% of returns came from this area. Returns of tagged fish caught in the main lake increased from 31% of all tags returned in 1995 to 74% in 1996. The discrepancy in the percentage of tag returns coming from the headwaters over both years can be attributed to several factors. During the spring of 1995, a creel clerk was present in the headwaters, making reporting of captured tagged fish in this area easy. The presence of

the creel clerk also raised awareness of the smallmouth bass study on the reservoir with anglers using this localized area, and may have made anglers more enthusiastic about returning captured tags. The increase in returns from the main lake in 1996 can be attributed to the offering of a reward during the 1996 fishing season. This reward, along with posters advertising the project, likely increased angler awareness of the ongoing smallmouth bass study and encouraged return of these tags from the main lake. The larger number of returns of tagged fish in 1996 gave thorough information on fish movements and allowed for better estimates of exploitation.

Redistribution information of smallmouth bass using the headwaters at the close of the spawning season is limited. Only one of six bass with transmitters moved to the headwaters during 1995, and three of 16 bass moved to this area during 1996. Two of these fish were harvested in the headwaters fishery, while the other two moved downstream to the original capture area, one each in the upper and middle sections. Redistribution of dart-tagged fish from the headwaters is limited to eight bass tagged in the headwaters and recaptured 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. Redistribution of the headwaters spawning bass is also shown by repeated electrofishing in the spring, which showed these fish did not stay in the headwaters year around, but used this area seasonally. When this electrofishing information is combined with the limited tag return information, it is apparent that the fish using the headwaters during the spring redistributed throuthout the reservoir as summer progressed. Past research documented the ability of smallmouth bass to home to areas previously occupied in both streams and lakes. Fajen (1962) documented homing between

pools on small Ozark streams in Missouri. Hubert and Lackey (1980) stated that smallmouth bass had the ability to home in Center Hill Reservoir, TN. Todd and Rabeni (1989) showed bass to disperse in the spring and return to the areas previously occupied on the Jacks Fork River in Missouri. Langhurst and Schoenike (1990) found smallmouth bass to return to residence areas from as far away as 69-87 km in the Wolf and Embarrass Rivers, Wisconsin. Kraai et al. (1991) also stated that smallmouth bass showed extensive movements outside of home ranges during the spring, and these fish to later return to their home areas in Meredith Reservoir, TN. Based on the homing abilities of smallmouth bass demonstrated in previous research, 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 the spawning migrations.

Combined results from the tagging study and the telemetry study also show that the lower section of the reservoir is vital to smallmouth bass reproduction. Extensive movements of smallmouth bass with transmitters to the lower portion of the reservoir in the spring were documented during both years tracking occurred, including bass from the middle and upper lake sections. Additionally, during the spring of 1996, 60% of tagged smallmouth bass recaptured in the lower section were originally tagged in another section of the reservoir, while only 33% of tagged fish recaptured in the middle and upper sections during this time originated in another section of the lake. This again demonstrates the attraction of the lower section to smallmouth bass during the spring period, presumably because of the presence of good spawning habitat in this area as observed by snorkel surveys.

Although the upper section is not used by smallmouth bass as heavily as the lower section during the spring, telemetry observations show the upper portion of the reservoir is used more than the middle section. One smallmouth bass was found in the upper section during the 1995 spawning season, while three smallmouth bass were found in the upper section during the 1996 spawning season, one of which traveled from the middle section. Dart tag returns in this area show bass to have moved from the lower and middle sections as well as the headwaters during the spring, although the majority of tagged fish recaptured in the upper area were tagged there. Based on the low number of telemetered smallmouth bass using the upper section of the reservoir during the spring spawning period, it would appear that the upper portion of the reservoir does not support as much reproductive activity as the lower portion of the reservoir. Habitat observations during the summer confirm the lack of spawning habitat in this area, and lend credence to findings from the movement study. However, tag returns from this section during the spring indicate that fish are traveling to this area from all other sections in the lake, although these movements could be associated with headwaters spawning.

Over the course of the two-year telemetry project, six fish were tracked for two consecutive spawning seasons. Information on exact nest location was unavailable for smallmouth bass that moved to the headwaters during the spawning season. However, fish that stayed in the reservoir were tracked, and nest locations were obtained over both spawning seasons. Of these fish, four of six were located in the same areas used the previous year during the spawning period. Repeated trips to the headwaters during the spawning period were observed in one of the fish tracked. This tendency by smallmouth bass to use areas previously used for spawning has been observed by other researchers.

Ridgeway et al. (1991) found that approximately 81% of male smallmouth bass returning to spawn in Lake Opeongo, Ontario spawned within 200 m of their previous nest site, while the remainder nested between 200 and 1,200 m from their previous nest sites. Robbins and MacCrimmon (1977) found that about 34% of surviving river spawning smallmouth bass in Lake Simcoe, Ontario return to the upriver spawning sites in subsequent years. Although the sample size of repeat spawners with transmitters in Lake Moomaw is low, it is apparent that there is the tendency for these fish to spawn in areas used in previous years. If repeated spawning migrations to the headwaters occurr, these river spawning fish would be repeatedly exposed to the headwaters fishery, increasing their likelihood of being caught and harvested in this fishery. However, the limited spawning habitat in the middle and upper sections may continue to drive surplus production of bass to the headwaters, and ensure continued runs of these fish during the spring. Alternatively, the tributaries to the reservoir (Back Creek and the Jackson River) may reach temperatures conducive to spawning before the lake does. This may draw smallmouth bass from the reservoir to the tributaries for spawning purposes, providing the opportunity for these fish to spawn earlier than bass remaining in the reservoir. A third motive governing smallmouth bass movements to the headwaters is the possibility of a distinct stock of bass in the reservoir. All smallmouth bass in the reservoir are desendent from the riverine stock present in the Jackson River prior to impoundment. It is possible that a subset of this population retains the urge to spawn in a lotic environment, and will migrate to the headwaters to spawn. These fish would remain reproductively isolated from the population that spawn in the lake, although intermixing at times other than the spawning season does occur.

At the onset of this project, one of the major concerns of anglers and managers was that the majority of trophy smallmouth bass in the reservoir moved to the headwaters during the spawning season where they were subjected to intense harvest. If larger fish were more prone to movements necessary to reach the headwaters, there likely would be a relationship between body size and degree of movement. However, size of fish used for the telemetry project was not correlated with either average distance moved between fixes or maximum distances moved. Larger fish were not more likely to travel long distances than smaller adult bass. Therefore, typical spring migrations to the headwaters should contain a mix of both large and small bass, and not consist primarily of trophy fish. The creel survey showed smallmouth bass less than 430 mm, the size anglers consider memorable (Gablehouse 1984) to constitute over 60% of the total headwaters harvest, indicating that smaller adult fish were creeled more often than larger bass in this fishery. Spring electrofishing in the headwaters during 1995 showed that over 75% of smallmouth bass over 305 mm were less than memorable size, which would make harvest of these smaller fish more likely.

Even in the spring, distances traveled for fish in each of the lake sections were not significantly different when compared among lake sections, providing support for the conclusion that spawning runs to the headwaters were most likely comprised of bass from the upper end of the reservoir. Maximum distances traveled likely would be greater for bass with transmitters from the lower section of the reservoir and decrease upstream if a substantial number of smallmouth bass traveled from the lower lake to the headwaters during the spring. Although the total telemetry sample size is low (16 bass), this pattern was not evident. Tagging data showed fish traveling to the headwaters during the

spawning season originated from close by this area, as opposed to coming equally from all areas of the reservoir. Telemetry observations substantiate this, with all telemetered fish that used the headwaters originating from the middle and upper lake sections.

Movements of smallmouth bass with transmitters increased as temperatures increased in the spring. These movements were greatest during the spring, summer, and fall as smallmouth bass moved to and from suitable spawning habitat and decreased towards the end of fall as fish moved to their overwintering habitats. Peterson and Myhr (1977) found smallmouth bass to be more active in spring and fall than in summer and winter, as did Hubert and Lackey (1980). However, Gerber and Haynes (1988) found activity in summer to be greater than in spring. This study shows similar patterns of movement, although differences between spring, summer and fall movements were not significantly different. The pattern of movement demonstrated by smallmouth bass in Lake Moomaw coincides with the seasonal use of the headwaters area, with these fish redistributing throughout the reservoir as spawning ends and summer progresses. Robbins and MacCrimmon (1977) and Gerber and Haynes (1988) both found smallmouth bass that spawned in tributaries redistributed back into the lake as summer progressed. Likewise, I observed redistribution of smallmouth bass with transmitters that used the headwaters, indicating that the headwaters fishery for smallmouth bass is likely to yield quantities of bass only during the spring spawning period.

The telemetry portion of the study shows that smallmouth bass were present in all areas of the reservoir during the spawning season. The small portion of the fish with transmitters that traveled to the headwaters during the spawning season indicated that area was not the favored spawning area in the reservoir, but was used by a small percentage of

the population. The small proportion of tag returns coming from fish tagged in the lake and recaptured in the headwaters confirm the limited use of this area during the spring. These fish may be traveling to the headwaters as a result of limited spawning habitat in the lake, or competition for quality spawning habitat. Robbins and MacCrimmon (1977) suggested that fluctuations in the size of spawning runs may be attributed principally to a combination of year-class strength and angling mortality. Because fishing mortality is low in Lake Moomaw, year-class strength coupled with limited spawning habitat may be the primary factor governing strength of spawning runs to the headwaters. Additionally, homing and nest site fidelity may be responsible for adding some degree of strength to these spawning runs. The smallmouth bass that used this area for spawning returned to the main portion of the lake after spawning ended.

Reproduction and Recruitment

Attempts to obtain relative densities of smallmouth bass nests and attending males in March 1995 were unsuccessful due to high winds resulting in turbidity in littoral areas around the reservoir. After several sample days yielded minimal results, I discontinued shoreline sampling. However, a small number of smallmouth bass nests were observed in all areas of the lake, demonstrating that smallmouth bass spawned throughout the reservoir. Spawning areas appeared to be patchy in distribution, and limited by several factors including substrate type with cobble being the best, bank slope of less than 45°,

and presence of available cover such as boulders and submerged stumps. Carlander (1977), Vogele (1981), Jenkins and Burkhead (1993) and others have described spawning habitat of smallmouth bass to consist of gently sloping bottoms with substrate of broken rocks, bedrock or large gravel, and prominent objects such as rocks, logs, rootwads, and stumps in close proximity to the nest. Areas with silt or clay bottom are rarely used. The lower section and to a lesser extent the upper section both have numerous areas with substrate that meets these requirements, while the middle section has a more silty substrate and very little cover other than aquatic macrophytes. Todd and Rabeni (1989) found smallmouth bass to rarely select habitat consisting of vegetation beds in any season or time period.

Fall electrofishing in 1995 showed relative densities of age-0 smallmouth bass to be highest in the lower section of the reservoir, and to progressively diminish uplake. These results conflicted with those obtained earlier in the year from snorkel surveys. Differential sampling methods may affect total numbers of fish counted in each section, but relative densities should show trends of abundance throughout the lake. Although snorkel surveys were too variable to quantify densities, these surveys indicated higher relative densities of age-0 smallmouth bass in the headwaters and upper lake, and lower densities downlake. This discrepancy in results between snorkel counts and electrofishing could indicate a migration of age-0 smallmouth bass from the upper section of the reservoir and headwaters into the lower and middle section. Alternatively, increased survival in the lower and middle sections of the reservoir could also cause changes in the relative densities of smallmouth bass fry in these areas over time. Information regarding movements of age-0 smallmouth bass is very scarce. Pardew (1992) showed that age-0

smallmouth bass stocked in Beaver Shoals Reservoir in Arkansas dispersed as far as 9 km in a downstream direction within 24 days after being stocked. In a study on Cayuga Lake, Webster (1953) found stream-hatched fingerling smallmouth bass to remain in Taughannock Creek until their first summer, when they would gradually drift downstream to the lake and disappear from the creek by September. Langhurst and Schoenike (1990) found no evidence that young-of-the-year or yearling smallmouth bass migrated in the Embarrass River, Wisconsin.

The conflicting results obtained in 1995 between snorkel surveys and fall electrofishing suggested the possibility of smallmouth bass spawning in one area of the reservoir, and their progeny migrating to habitat more suitable to juvenile survival elsewhere in the reservoir as winter approached. Therefore, fall sampling in 1995 potentially could have yielded inaccurate conclusions regarding important spawning areas in the lake. As found in 1995 snorkel surveys, scuba transects in 1996 showed the presence of smallmouth bass fry in the lower and middle sections of the reservoir although abundance was limited. The scarcity of spawning smallmouth bass in the middle portion of the reservoir agrees with general habitat observations from the 1995 snorkel surveys. Although no scuba transects were conducted in the upper section of the reservoir, spawning smallmouth bass were observed in this section during the 1995 snorkel surveys. Both 1995 and 1996 transect surveys supported the observation of better spawning habitat in the lower and upper sections compared to the middle section, and confirm that spawning is not limited to the headwaters of the reservoir.

Repeated electrofishing trips to the fixed stations during 1996 showed overall numbers of young-of-the-year and catch per minute increased as sampling progressed into

August. These increases could result from increased recruitment to the electrofishing gear as the young smallmouth bass grew, or by increased vulnerability as these fish moved to easily sampled habitat. Okeyo and Hassler (1985) found age-0 smallmouth bass to move from more protected areas around tributaries into littoral habitats exposed to wave action and turbidity as they grew, and as weather conditions moderated in the fall. Sabo and Orth (1994) found juvenile smallmouth bass to use shallower stream habitats four to six weeks after dispersal from the nest than immediately after dispersal. Walters and Wilson (1996) also found age-0 smallmouth bass to orient towards shallow water. A combination of increased vulnerability to sampling gear due to larger size of young smallmouth bass and habitat shifts to shallower water was probably responsible for the increase in catch rates and increased numbers captured on progressive samples.

A surprisingly large percentage (35% initially) of the young-of-the-year fish were caught in the middle section of the reservoir. This section has the least desirable habitat for smallmouth bass spawning, and was expected to have the lowest densities of young-of-the-year smallmouth bass. However, as sampling progressed into September, this area increased in the percentage of smallmouth bass captured, reaching a maximum on the last sampling date of 53% of the total catch, while catch per minute increased four-fold over this 6-week period. The percentage of the total catch coming from the lower section decreased by 10% by the end of sampling, while the upper section decreased by 9%. Even though the overall percentage of fish captured decreased in both the lower and upper sections, catch per minute (CPM) doubled in both of these sections between 1 August and 18 September, indicating a consistent increase in catch as vulnerability increased. Assuming consistent survival throughout the reservoir, no spatial differences in

catchability and no immigration or emigration between lake sections, any increases in catch or catch per unit effort should result from increased recruitment to the sampling gear and should be constant between all lake sections. However, both catch and CPM increased disproportionally in the middle section, indicating either increased vulnerability to sampling in the middle section, or increased numbers of young smallmouth bass in this section resulting from migrations of these fish from other lake sections.

No attempts were made to measure differences in age-0 survival between lake sections. I assumed that survival was consistent throughout the lake for these fish. Additionally, catchability did not appear to change between lake sections. Water clarity appeared to be the same in each section on each sampling date, and all samples contained similar shallow, rocky substrate. Therefore, I believe that the increasing densities of age-0 smallmouth bass in the middle section are a direct result of migrations of these fish from the other lake sections. If a migration such as this was responsible for the increase in catch per minute from the middle section, CPM in the upper section of the reservoir would be expected to increase more than in the lower section as this influx of fish moved through this area. However, catch in the lower and upper sections increased similarly. This may indicate that age-0 smallmouth bass are also migrating to the middle section from the lower section as well as the upper and headwaters area. The substantial increase in the catch-per-unit-effort of the middle section over time indicates the importance to young-of-the-year survival in this area, possibly resulting from better juvenile habitat. Walters and Wilson (1996) described juvenile smallmouth bass as being habitat generalists, although the presence of cobble, shallow water and aquatic vegetation increased the likelihood of seeing these fish. Sechnick et al. (1986) found that microhabitat use by young fish may

shift with changes in the available habitat or prey. It appears the middle section may have special value as a juvenile rearing ground, and could contribute a significant amount to the overall age-1 smallmouth bass population in the reservoir.

From the information gathered in this portion of the study, it is apparent that recruitment of juvenile smallmouth bass to the lake population is not contingent on the fish spawning in the headwaters, as spawning is occurring in all areas of the reservoir. While the headwaters area has the highest densities of young-of-the-year and must contribute to the lake population, these fish also are recruiting to the population from spawnings occurring in the lake itself. However, the spawning occurring in the headwaters may serve as a buffer for the reservoir during times of year-class failure in the lake if conditions are more favorable in these tributaries. Further, the middle portion of the reservoir may be critical to juvenile survival and eventual recruitment to the age-1 population as indicated by the high densities of these fish in the middle section during the fall.

SUMMARY AND CONCLUSIONS

1. I assessed fish movements, developed estimates of adult smallmouth bass abundance, and determined rates of exploitation by marking adult (>305 mm TL) smallmouth bass with dart tags. Bass were captured in sinking monofilament gill nets and shoreline electrofishing throughout the lake in 1994-1996.

2. I also determined movements of bass by implanting ultrasonic transmitters in 20 smallmouth bass over the course of this study. Four of the implanted fish died or were harvested shortly after implantation. The remaining fish were tracked for up to 18 months (mean of 8 months), six of which were tracked over two spawning seasons.

3. Spawning locations of telemetered smallmouth bass were identified when behavior of these fish and physical conditions indicated spawning was likely to be occurring. Only one of six smallmouth bass during the 1995 spawning season and three of 16 bass in 1996 traveled to the headwaters. The lower section was used most (12 fish over the 2-year period), followed by the upper section (4 fish), and the middle section (3 fish). The fish that used the headwaters to spawn were originally tagged in the upper lake section (3 fish) and the middle section (1 fish). All fish returned to the original lake section where tagging occurred after spawning ended. Additionally, headwaters recoveries of dart tagged fish were dominated by bass tagged in the upper and middle sections, but not the lower section of the lake.

4. Of fish tagged with dart tags in the main portion of the reservoir and later recaptured, only 19% were recovered in the headwaters during the spring of 1995 and 1996. Additionally, less than 20% of smallmouth bass with transmitters traveled to the headwaters. This suggests that a large percentage of the adult population remained in the main body of the reservoir, and were not exposed to the headwaters fishery.

5. Six smallmouth bass were tracked over both the 1995 and 1996 spawning seasons. Four of these six fish used the same general areas used the previous year during the spring spawning period, showing a tendency of bass to use the same spawning areas repeatedly.

6. There was no difference in maximum distance traveled (P=0.51) and mean distance traveled between fixes (P=0.89) for fish in each of the three lake sections. Size of smallmouth bass was not related to either mean or maximum distance traveled (P=0.56). Degree of movement differed among seasons (P<0.01), with mean distances moved significantly lower in winter than spring, summer, or fall.

7. Effort expended by headwaters anglers during the spring of 1995 was estimated at 2,452 hours, while in 1996, 2,938 hours were spent in this area. The headwaters received the greatest amount of angling pressure on a per hectare basis, and appeared to be an important part of the bank fishery in the lake.

8. Catch estimates for anglers fishing the headwaters were relatively low, with an estimated 124 smallmouth bass caught in 1995, and an estimated 318 fish caught in 1996. Catch rates in the headwaters were low during both years, with 0.06 fish per hour in 1995 and 0.09 fish/h in 1996. Harvest estimates for 1995 were 82 smallmouth bass, while in 1996 an estimated 222 fish were harvested. Percentage of the fish harvested was high, and consistent between years (66% in 1995 and 69% in 1996), indicating that harvest is a motivating factor for anglers fishing in this area.

9. A total of 776 anglers in 336 parties were interviewed throughout the two years of spring creel census. During the 1996 creel survey, 92% of anglers interviewed indicated they were targeting smallmouth bass or anything that would bite. Since smallmouth bass are the primary catch in this area during the spring, anglers not specifying a certain species were assumed to be fishing for smallmouth bass. Bank fishermen comprised 92% of all anglers in this area, while 82% of anglers used bait or a combination of bait and lures. Age distribution of anglers fishing the headwaters was even. Anglers rarely traveled more than 83 km to fish the headwaters, while the majority of anglers traveled less than 41 km. Very few anglers interviewed belonged to a fishing club or conservation organization (13%).

10. Anglers indicated harvest-oriented reasons were most important in their decision to fish the headwaters most often during the 1996 creel survey. Four of the five most frequently given responses had to do with catching or harvesting smallmouth bass. Social reasons for fishing in this area were given less frequently, while emphasis on

fishing skills and aesthetic reasons for fishing the headwaters was rarely given. Based on this question, it appears that users of this resource are interested in harvesting fish over other factors.

11. Three rates of exploitation were calculated during the course of the study: 1) the lakewide exploitation rate; 2) exploitation occurring in the headwaters on the lakewide population; and 3) exploitation of the subset of the population that used the headwaters to spawn. Adjustments were made to the number of tagged fish expected to be in the lake population based on an annual mortality rate of 61% (determined by analyzing previous years electrofishing data), and an annual tag loss rate of 15%. Tag returns from anglers were adjusted to reflect a range of nonreporting rates from 11% to 40%. After adjustments, overall exploitation of the lake population was estimated at 12-15%, while exploitation of the total lake population occurring in the headwaters was 4-6%, and exploitation of the subset of the lake population using the headwaters to spawn was estimated at 16-20%. All three of these exploitation rates were low, and should not be detrimental to the lake population.

12. The population of adult (>305 mm) smallmouth bass in Lake Moomaw was estimated at 4,069 (4.1/ha) using a mark-recapture procedure. A second estimate, made by dividing annual harvest by annual exploitation rate , ranged from 6,430 to 7,500 adult smallmouth bass (6.4-7.4/ha). Both of these population estimates show that the population can withstand the current levels of exploitation.

13. There was no significant difference (P=0.37) in the mean length of smallmouth bass captured by gillnet for the tagging project (mean of 377 mm TL) versus smallmouth bass harvested by anglers in the headwaters fishery (mean of 408 mm TL).

14. The headwaters fishery appears to be productive primarily during the spring. Repeated electrofishing beginning in February 1995 showed smallmouth bass to be absent in the headwaters. Densities began to increase in late March, reached a peak in mid-April, and decreased as May progressed. During the creel survey, anglers indicated they used this area throughout the year, although catch rates were probably greatest during the spring. This indicated the bank-based fishery in this area was important year-around, even if catch rates diminished significantly during times other than the spring.

15. Presence of age-0 smallmouth bass during summer and early fall was used as an indication of smallmouth bass spawning areas. Snorkel surveys were conducted in all areas of the reservoir and headwaters during the summer of 1995. Additional scuba transects were conducted in late spring, 1996. Densities of these fish during the summer were highest in the headwaters and decreased downstream, although this difference was not significant (P=0.66). These transects showed the presence of age-0 smallmouth bass in all areas of the lake, and indicated that spawning occurred throughout the reservoir.

16. Age-0 smallmouth bass densities were greatest in the headwaters and upper lake sections during the summer of 1995, but shifted towards the lower section as fall progressed. Densities found during 1996 sampling were greatest in the middle section. Although spawning occurred throughout the reservoir, substantial additions to the lake population of young-of-the-year bass may be coming from the spawning occurring in the headwaters as these fish migrate downlake.

17. Habitat suitable for smallmouth bass spawning was noted during 1995 snorkel surveys. Areas with bank slope less than 45°, cobble or boulder substrate, boulder, stump, or logs for cover, and low flows were deemed preferred spawning habitat. The headwaters of the reservoir had abundant habitat meeting these requirements. The lower and upper sections of the reservoir appeared to have more habitat meeting smallmouth bass spawning requirements than the middle section.

18. There are three possibilities governing smallmouth bass movements to the headwaters during the spawning season. The first is that the limited spawning habitat in the reservoir forces the surplus production of bass to the headwaters in search of preferred spawning sites. The second possibility is that water temperatures in the headwaters and tributaries may reach levels conducive to spawning before the lake temperatures reach this level, attracting bass with the opportunity to spawn earlier than if these fish remained in the reservoir. The third possibility is the presence of a distinct stock of smallmouth bass that prefer to spawn in this riverine habitat.

MANAGEMENT RECOMMENDATIONS

The results of this study indicate that significant numbers of anglers use the headwaters during the spring. Although considerable effort is expended towards smallmouth bass in this area, harvest is modest. Easy access to quality fishing from the bank in this area provides anglers with opportunities for fishing found in limited abundance throughout the reservoir. Further, exploitation from this harvest-oriented fishery is low, and will probably not impact the overall population even at much higher exploitation rates. Therefore, restrictions on use of the headwaters would not benefit the lake population, and would deprive large numbers of anglers from a unique opportunity to catch and harvest smallmouth bass.

It appears that several factors may be responsible for the spring run of smallmouth bass to the headwaters. The first possibility for these migrations is the result of limited spawning habitat in the reservoir which may force surplus production of bass to seek adequate spawning habitat in the headwaters area. Ultrasonic telemetry and movements of dart tagged fish both show that the majority of smallmouth bass remain in the reservoir to spawn, and prefer to direct spawning activity towards the lower section over all other sections. Snorkel survey observations showed less abundance of suitable spawning habitat in the middle and upper sections. The spring run of smallmouth bass in the reservoir consisted mainly of bass from the upper and middle lake sections. The low density of spawning habitat in these areas may be forcing bass that do not find a place to spawn in the lake to spawn in the headwaters. If this is the case, management of the smallmouth bass population could overlook the fish that use the headwaters to spawn, as these fish are

surplus production in the lake. Therefore, a majority of these fish could potentially be harvested, with little influence on the overall population in the reservoir.

A second possibility responsible for movements of smallmouth bass to the headwaters may be that water temperatures in the headwaters warm quicker than the main portion of the reservoir. This may be drawing fish from nearby areas to the headwaters for the earliest spawnings possible. Therefore, fish on these migrations would have increased value, as they may add to the lake population by the addition of young fish spawned in the headwaters. In this scenario, the abundance of headwaters-spawning bass will vary over years, depending on the rate of headwaters warming versus the main lake. If this is true, it is possible that headwaters harvest could be much higher than I observed in those years when more bass are attracted.

A third possibility is that the fish using the headwaters and tributaries to spawn are a separate and distinct stock of smallmouth bass. All smallmouth bass in Lake Moomaw are descendants from river-spawning bass that were present in the Jackson River and Back Creek at the time the dam was impounded in 1981. A portion of these fish living in the reservoir could retain the urge to spawn in a lotic environment, thus separating themselves behaviorally from lake-spawning smallmouth bass. These fish would be isolated from lake-spawning smallmouth bass during the spring spawning period, and may continue to breed exclusive from the lake fish. The spawnings occurring in the headwaters may complement lake spawning in years where lake spawning is unsuccessful, buffering fluctuations in year-class strength. If the headwaters spawners constitute a genetic stock, they might require protection if exploitation becomes excessive, in order to protect any genetic diversity and resulting increases in fitness of these fish.

Regardless of the reason that smallmouth bass are moving to the headwaters during the spring, overall exploitation on these fish is low. Exploitation rates were calculated using estimated mortality rates that are quite possibly higher than actual rates. If this were the case, estimates of exploitation found in this study would be higher than actual exploitation in the reservoir. Therefore, the smallmouth bass population in the reservoir, and the stock using the headwaters could withstand significantly greater harvest than is currently found in the reservoir.

Continued research at Lake Moomaw is warranted, both to sustain and to improve the smallmouth bass fishery in the lake. Periodic monitoring of the headwaters fishery should document changes in effort and harvest with fluctuating densities of spring run smallmouth bass. If harvest rate increases substantially (e.g., to 50%), a genetic analysis should be considered to determine if headwater spawners constitute a separate stock. Additionally, attempts to more accurately measure mortality should be made, so management decisions on the lake can be based on the best available data. Following densities of a cohort of bass over subsequent years should aid in estimating this valuable parameter.

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