BARKLEY LAKE SYMPOSIUM

COMPARISON OF VARIOUS MARK-RECAPTURE TECHNIQUES FOR ESTIMATING ABUNDANCE OF LARGEMOUTH BASS IN BARKLEY LAKE, KENTUCKY

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Abstract: Estimates of the number of largemouth bass (*Micropterus salmoides*) 153 mm and longer in Crooked Creek Bay made by mark-recapture techniques were compared with rotenone estimates. Electrofishing was used to collect bass for marking, while electrofishing and angling provided recaptures. Estimates obtained by Petersen and Schnabel methods generally were lower than rotenone estimates. Both methods estimated the number of intermediate-size bass more accurately than adult bass. Size distributions of bass captured by angling, electrofishing, and rotenone recovery showed no differences in the location of their central tendencies. All 3 sampling methods were selective for bass in the 293 to 368-mm size group. Electrofishing and rotenone also showed selectivity for 445 to 521-mm bass.

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The Barkely Reservoir study provided a unique opportunity to compare mark-recapture estimates of largemouth bass (*Micropterus salmoides*) numbers with rotenone recoveries on a relatively large expanse of water. Recent literature indicates an increased interest in obtaining population estimates for black basses (*Micropterus* spp.) in reservoirs by mark-recapture techniques. Shoreline electrofishing is commonly used to collect bass for marking. Recaptures are obtained by electrofishing (Houser and Rainwater 1975; Zweiacker and Brown 1971), angling (Aggus and Rainwater 1975, Hammond and Ager 1975), or a combination of the 2 techniques (Ginstead and Wright 1973, Hickman and Hevel 1975, Seawell and Hevel 1978).

Few studies have compared mark-recapture estimates with estimates obtained by other methods. Grinstead and Wright (1973) compared mark-recapture estimates of bass numbers with cove rotenone samples and found that the estimates varied widely. Bryant and Houser (1971) compared late summer cove rotenone samples with mark-recapture estimates in the following spring and found general agreement between the two. However, cove areas in both studies averaged less than 2 ha and it is questionable how well they represented bass population densities in open water areas.

This study was undertaken to determine whether mark-recapture estimates based upon shoreline electrofishing and angling adequately represent reservoir bass populations, when compared to reotenone recoveries.

MATERIALS AND METHODS

On 20 September 1978, block nets were placed across the mouth of Crooked Creek Bay and Shaw Bay to enclose an 85-ha area. The shoreline, including the block nets, was divided into 8 identifiable segments. During the nights of 20-22 September, 2 boats utilizing alternating current were used to capture black basses by shoreline electrofishing. Each crew sampled 4 segments per night, resulting in the entire shoreline being sampled on each date. All bass were identified, mesured (total length), and those 153 mm and larger were marked with a numbered dart tag (Dell 1968) inserted just below the soft-rayed portion of the dorsal fin. All fish were released within the shoreline segment of capture. Tag numbers of recaptured fish were recorded during the 21 and 22 September samples.

Local Bass Angler Sportsman Society members participated in a fishing tournament in Crooked Creek Bay on 23 and 24 September. Fishing hours were from 0700-1200 hours each day. All bass caught were measured, weighed, examined for tags, and released outside of Crooked Creek Bay.

On 26 September 1978 rotenone was applied to kill all fishes in Crooked Creek Bay (Summers and Axon 1979). Mark-recapture estimates of largemouth bass numbers were compared with the number of bass recovered in the rotenone sample and with an adjusted rotenone estimate expanded for nonrecovery of marked bass. Bass caught during the angling tournament and release outside of the bay were added to rotenone recoveries for all comparisons.

Population estimates for largemouth bass in Crooked Creek Bay were made utilizing Chapman's modifications of the Petersen and Schnabel formulas (Ricker 1975). A Petersen estimate based upon electrofishing only was obtained by considering 20 and 21 September as marking samples and 22 September as the recapture sample. A second Petersen estimate was made using the angling tournament as the recapture sample and all 3 electrofishing nights as the marking sample. All samples were utilized for making the Schnabel estimate. Separate population estimates were made for all bass 153 mm and greater in total length; intermediate size bass ranging from 153 to 241 mm; and adult bass which were 242 mm and longer. Variances for the Petersen and Schnabel estimates were calculated from equations supplied by Ricker (1975) and Serber (1973), respectively. Confidence intervals were obtained by taking square roots of the variances and using t-values for the normal curve. Confidence intervals for pooled estimates were obtained in the same manner after summing the individual variances.

RESULTS AND DISCUSSION

Tagging

During the 3 nights of electrofishing, 367 (4.32 fish/ha) largemouth bass 153 mm and longer were tagged (Table 1). Of these, 271 were tagged during the first 2 nights. In addition, 7 spotted bass (*Micropterus punctulatus*) were captured, but were not included in any of the data analyses. No evidence of tag loss or injury due to tagging was detected.

TABLE 1. Numbers of largemouth bass marked, captured, and recaptued in Crooked Creek Bay, 20-24 September 1978.

Date	Method	Item	Size group: All bass >152 mm	Intermediates 153-241 mm	Adults >241 mm
9/20	Electrofishing	Captured	134	63	71
		Marked	134	63	71
		Recaptured	0	0	0
9/21	Electrofishing	Captured	150	102	48
		Marked	137	100	37
		Recaptured	13	2	11
9/22	Electrofishing	Captured	116	66	50
		Marked	96	57	39
		Recaptured	20	9	11
9/23-24	Angling	Captured	90	43	47
		Marked	0	0	0
		Recaptued	27	7	20

Tournament Catch

During the angling tournament, 34 anglers fished a total of 170 hours (2.0 hours/ha) and caught 90 largemouth bass (1.1 fish/ha) 153 mm or longer (Table 1). One spotted bass also was caught, providing an overall catch rate of 0.54 bass/hour. Twenty-two (65%) of the anglers caught at least 1 fish. Twenty-seven (30%) of the largemouth bass caught during the tournament were recaptures. These recaptues represented 7.4% of the number marked.

Population Estimates

All 3 mark-recapture estimates for largemouth bass 153 mm and longer were lower than the number recovered in the rotenone sample (Table 2). The Peterse estimate using angler caught fish for recaptures provided the most conservative estimate. This estimate (1196 fish) was 36% below the rotenone estimate, adjusted for nonrecovery of marked fish. The 95% confidence interval around this estimate did not include the number of bass recovered in the rotenone sample or the adjusted rotenone estimate. The highest mark-recapture estimate was 1515 bass obtained by the Petersen method utilizing electrofishing as the recapture technique. This estimate was 20% below the adjusted rotenone estimate The Schnabel estimate (1386 bass) was 27% below the adjusted rotenone estimate. The confidence interval around the Schnabel estimate included the number of bass actually recovered from the rotenone sample, but did not include the adjusted rotenone estimate.

TABLE 2. Comparisons of largemouth bass population estimates in Crooked Creek Bay by Petersen and Schnabel mark-recapture methods and rotenone recovery.

Method	Estimates by size groups			
	All bass >152 mm	Intermediates (I) 153-241 mm	Adults (A) >241 mm	$\sum$ I + A
Petersen				
N (recaptures by electrofishing)	1515	1099	463	1562
95% CI	942-2088	500-1698	243-683	924-2200
N (recaptures by angling)	1196	1216	338	1554
95% CI	834-1558	497-1935	232-444	828-2280
Schnabel				
N	1386	1402	366	1768
95% CI	1032-1740	734-2070	254-478	1091-2445
Rotenone recovery				
N	1642	1075	567	1642
N[a]	1882	1233	643	1876

N[a] Adjusted for unrecovered bass.

Dividing the bass population into 2 size groups and estimating their numbers separately resulted in close agreement between mark-recapture and rotenone estimates for intermediate size fish. All 3 mark-recapture estimates were within 14% of the adjusted rotenone estimate (1233 fish). Closest agreement with the rotenone estimate was achieved using the Petersen method with recaptures by angling (1216 fish).

All mark-recapture estimates for adult fish were less than the adjusted rotenone estimate (643 fish). The Petersen estimate (338 fish) using angling recaptures and the Schnabel estimate (366 fish) were 47% and 43%, respectively, less than the adjusted rotenone estimate. Confidence intervals around these values did not include the number of fish actually recovered from the rotenone sample or the adjusted rotenone estimate. The Petersen method with recaptures by electrofishing provided an estimate of 463 adult bass, which was 28% below the adjusted rotenone estimate.

Summing mark-recapture estimates for the 2 size ranges to obtain a population estimate of 153 mm and larger bass improved their agreement with rotenone estimates. Both Petersen estimates were similar and were approximately 18% below the adjusted rotenone estimate. The Schnabel estimate (1768 bass) was only 6% below the adjusted rotenone estimate. However, the overall accuracy of the Schnabel estimate was achieved at the expense of severely underestimating the number of adult bass.

The number of bass actually recovered in the rotenone sample established the minimum number of bass inhabiting Crooked Creek Bay at the time of the study. Since almost 88% of the marked bass at large in the bay were recovered in the rotenone sample (Axon et al. 1979), apparently most of the bass population was recovered. This agrees with the findings of Henley (1966) who reported that over 84% of the black basses were recovered in a rotenone sample. Therefore, since the expansion for unrecovered bass is relatively small, we believe the adjusted rotenone estimate accurately appraises the size of the Crooked Creek Bay largemouth bass population.

All of the conditions necessary for an unbiased mark-recapture estimate (Ricker 1975) appear to have been met, with one possible exception. Since the time between the marking and recapture samples was brief, it is questionable whether the marked fish became randomly mixed with the unmarked. Releasing marked fish in the area of capture should have promoted mixing along the shoreline. Some movement along the shoreline occurred during the 3 nights of electrofishing, as 43% of the recaptures were made outside of the segment where they were tagged and released. However, we do not know to what degree the marked fish mixed with bass not on the shoreline. Van Den Avyle (1976) presented evidence of age II and older largemouth bass segregating into offshore and shoreline groups during the summer. Electrofishing and angling (to some extent) are shoreline activities. If the bass were segregated and mixing was limited, the mark-recapture estimates should have been conservative, which they generally were. Conducting mark-recapture studies in the spring, when more bass are near the shoreline, should reduce this bias.

Sample sizes attained in this study approximated the effort recommended for preliminary studies or management surveys by Robson and Regier (1964). Efforts at this level should provide estimates having an accuracy of 0.5 with a precision of 0.95. All Petersen estimates for the Crooked Creek Bay largemouth bass population were within 50% of the adjusted rotenone estimate.

Size Distributions

Length frequency distributions of the Crooked Creek largemouth bass population derived from the electrofishing, angling, and rotenone samples were compared (Fig. 1). A Kolmogorov-Smirnov nonparametric 2 sample test (Siegel 1956) indicated no significant differences in the length distributions obtained from electrofishing and angling samples ($P>0.05$). However, the distribution obtained from the rotenone recovery was significantly different from the distributions obtained by electrofishing and angling ($P\leq0.05$). The length distributions also were compared using a Mann-Whitney U Test (Siegel 1956), which is sensitive to differences due to location of the central tendency. This test yielded no evidence ($P>0.05$) of differences in the central tendencies between any of the 3 length distributions.

These tests indicate that length distributions obtained with rotenone may differ from distributions obtained by electrofishing and angling. However, it is unlikely that this difference is caused by one distribution being skewed toward larger or smaller fish than

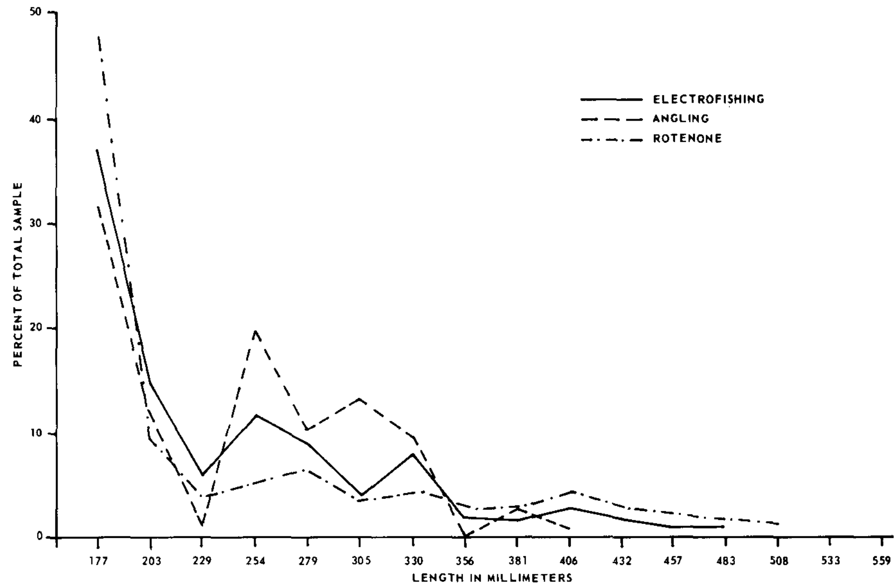

Fig. 1. Length frequency distributions of largemouth bass in Crooked Creek Bay derived from electrofishing, angling, and rotenone samples.

the other distributions. Aggus and Rainwater (1975) and Seawell and Hevel (1978) report that electrofishing and tournament angling yielded similar length distributions for bass populations. Electrofishing has been shown to be selective for larger fish and may overestimate their relative abundance (Simpson 1978).

The size selectivities of the electrofishing, angling, and rotenone samples from Crooked Creek bay were evaluated by determining the ratios of recaptured (r) to marked (m) bass in various size groups. When these ratios are plotted against size classes, a gear selectivity curve is generated (Robson and Regier 1968). Inspection of the curves reveals general agreement among the 3 techniques (Fig. 2). The curves for electrofishing and angling rise from the 153 to 216-mm group to a peak at the 293 to 368-mm group. Both curves then decline at the 369 to 444-mm groups and the electrofishing curve climbs to another peak at 445 to 521 mm. With the exception of a decrease at the 217 to 292-mm group, the rotenone curve parallels the electrofishing curve. It is not clear whether the apparent decrease in selectivity of all three techniques for the 369 to 444-mm group is real. The number of marked fish was low in this size class and one additional recapture would have radically changed the shape of the curve for any technique.

The electrofishing selectivity curve generally agrees with Simpson's (1978) findings that electrofishing is selective for 203 mm and larger bass. However, in compiling a length distribution this selectivity may be counteracted by a relative scarcity of larger bass along the shoreline during most seasons. Cooper and Schafer (1954) found that age-frequency distributions of largemouth bass may be influenced by the depth at which sampling occurred. They observed that older bass tended to reside in deeper water. Assuming bass size is a function of age over most age groups, their study would indicate that larger bass are less accessible to shoreline electrofishing than smaller bass.

The selectivity curve for angling suggests that the greatest selectivity occurs in the 293 to 368-m size range. Holbrook (1975) showed that the majority of the bass caught in several tournaments fell within this size range. However, the enforcement of minimum

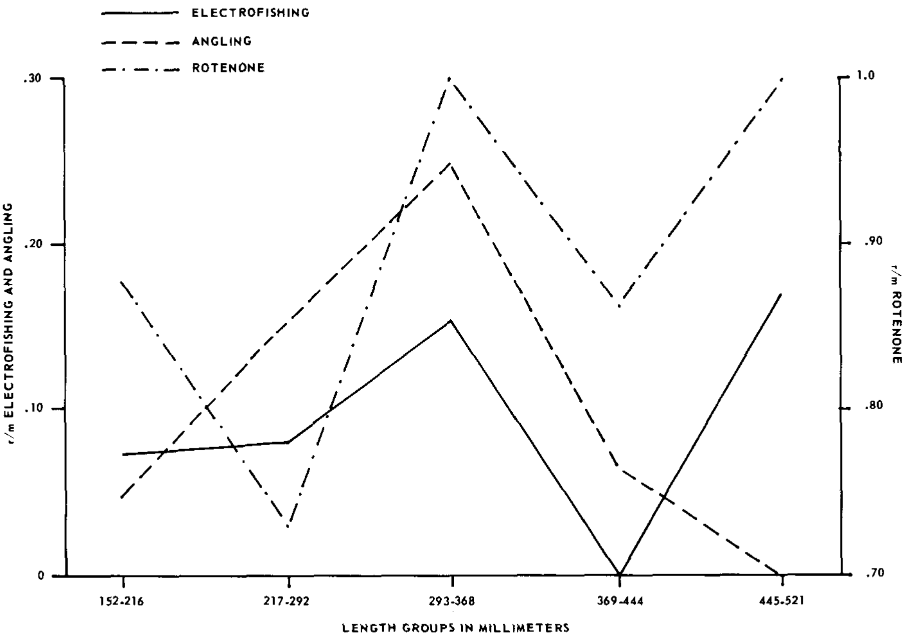

Fig. 2. Size selectivity of electrofishing, angling, and rotenone for largemouth bass as measured by the ratio of number recaptured (r) to number marked (m).

size limits on tournament catches undoubtedly influenced the length distributions. Since no bass greater than 444 mm were caught in the Crooked Creek Bay tournament, little can be inferred about the selectivity of angling for bass above this length. The failure to catch larger fish indicates a decrease in selectivity. Analyses of r/m ratios in tournaments having larger catches should provide more information regarding the selectivity of angling for larger fish.

LITERATURE CITED

Aggus, L.R., and W.C. Rainwater. 1975. Estimating largemouth bass populations in reservoirs from catches in angling tournaments. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 29:106-114.

Axon, J.R., L.G. Hart and V.S. Nash. 1979. Recovery of tagged fish during the Crooked Creek Bay rotenone study at Barkley Lake, Kentucky. Proc. Annu. Conf. Southeast. Assoc. Fish Wild. Agencies. 33:680-687.

Bryant, H.E., and A. Houser. 1971. Population estimates and growth of largemouth bass in Beaver and Bull Shoals reservoirs. Amer. Fisheries Soc. Spec. Publ. 8:349-357.

Cooper, G.P., and R.N. Schafer. 1954. Studies on the population of legal-size fish in Whitmore Lake, Washtenaw and Livingston counties, Michigan. Trans. North Amer. Wildl. Conf. 19:239-257.

Dell, M.B. 1968. A new fish tag and rapid cartidge fed applicator. Trans. Amer. Fisheries Soc. 97:57-59.

Grinstead, B.G., and G.L. Wright. 1973. Estimation of black bass, *Micropterus* spp., population in Eufaula Reservoir, Oklahoma with discussion of techniques. Proc. Ok. Acad. Sci. 53:48-52.

Hammond, D.E., and L.A. Ager. 1975. A mark-recapture study on largemouth bass used in conjunction with a creel survey. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 29:106-114.

Henley, J.P. 1966. Evaluation of rotenone sampling with scuba gear. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 20:439-446.

Hickman, G.D., and K.W. Hevel. 1975. Comparison of population estimates of largemouth bass in Forest Lake, Missouri utilizing a bass tournament and an electroshocker for collection of recaptures. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 29:102-105.

Holbrook, J.A. 1975. Bass fishing tournaments. Pages 408-415 *in* R.H. Stroud and H. Clepper, eds. Black bass biology and management. Sport Fishing Institute, Washington, District of Columbia, USA.

Houser, A., and W.C. Rainwater. 1975. Production of largemouth bass in Beaver and Bull Shoals lakes. Pages 310-316 *in* R.H. Stroud and H. Clepper, eds. Black bass biology and management. Sport Fishing Institute, Washington, District of Columbia, USA.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bull. 191.

Robson, D.S., and H.A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Trans. Amer. Fisheries Soc. 93:215-226.

Robson, D.S., and H.A. Regier. 1968. Estimation of population number and mortality rates. Pages 124-158 *in* W.E. Ricker, ed. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford, England.

Seawell, W.M., and K.W. Hevel. 1978. Comparison of two methods of recapturing marked fish for estimating black bass populations in a reservoir. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 32:437-445.

Serber, G.A.F. 1973. The estimation of animal abundance and related parameters. Charles Griffin and Company, London, England.

Siegel, S. 1956. Nonparametric statistics for the behavioral science. McGraw-Hill, New York, New York, USA.

Simpson, D.E. 1978. Evaluation of electrofishing efficiency for largemouth bass and bluegill populations. Master's thesis. University of Missouri, Columbia, Missouri, USA.

Summers, G.L., and J.R. Axon. 1979. History and organization of the Barkley Lake rotenone study by the Reservoir Committee, Southern Division, American Fisheries Society. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies. 33:673-679.

Van Den Avyle, M.J. 1976. Analysis of seasonal distribution patterns of young largemouth bass (*Micropterus salmoides*) by use of frequency-of-capture data. J. Fisheries Board Canada 33:2427-2432.

Zweiacker, P.L., and B.E. Brown. 1971. Production of a minimal largemouth bass population in a 3000-acre turbid Oklahoma reservoir. Amer. Fisheries Soc. Spe. Publ. 8:481-493.