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Estimating Harvestable Largemouth Bass Abundance in a Reservoir with an Electrofishing Catch Depletion Technique

MICHAEL J. MACEINA

Department of Fisheries and Allied Aquacultures
Alabama Agricultural Experiment Station, Auburn University, Alabama 36849, USA

WILLIAM B. WRENN AND DONNY R. LOWERY

Tennessee Valley Authority, Office Service Annex 1B, Muscle Shoals, Alabama 35660, USA

Abstract.—We developed a Leslie catch depletion method that uses electrofishing gear to estimate the abundance of harvestable (≥251 mm total length) largemouth bass *Micropterus salmoides*. In March–April 1992 and 1993, 10 coves, ranging in surface area from 2.3 to 3.7 ha, in Lake Guntersville, Alabama, were enclosed with a block net, and largemouth bass were removed during four to seven 1-h collection periods. Catch per effort regressed against cumulative catch declined linearly over time in all coves. Density ranged from 6 to 143 fish/ha and biomass ranged from 3 to 112 kg/ha. In two coves, larger fish were caught during initial collection periods, which dictated regression of catch per effort for weight against cumulative weight caught. Catchability was constant over time and was not affected by day versus night electrofishing or by the time interval (≤16 h) between collection runs. Coefficients of determination for regressions between catch per effort of subharvestable (≤250 mm TL) largemouth bass and cumulative catch of these fish were highly variable and appeared to co-vary with the biomass of harvestable largemouth bass. This catch depletion method provides a less expensive and potentially more realistic assessment of largemouth bass populations in spring than cove rotenone sampling conducted during summer and allows live release of fish.

Obtaining reliable estimates of the population density and biomass of largemouth bass *Micropterus salmoides* in large (>1,000 ha) reservoirs is a difficult task. Data derived from cove rotenone sampling can provide this information, but these data are highly variable (Davies and Shelton 1983) and can cause public relations problems because large numbers of fish are killed. Most fishery biologists would probably agree that rotenone sampling provides reasonable estimates of largemouth bass that are age-1 and younger. For older fish, mark–recapture techniques have yielded largemouth bass population estimates in larger reservoirs (Aggus and Rainwater 1976; Hickman and Hevel 1976; Seawell and Hevel 1979; Harris et al. 1980). However, this method has several drawbacks: it is labor intensive because many fish must be marked, tag recovery may not be complete, and estimates are highly variable.

In Lake Guntersville, Alabama, ten 1.2-ha coves were sampled with rotenone in August 1990 and 1991 and 6.8 kg/ha of harvestable (≥251 mm total length, TL) largemouth bass were recovered (D. R. Lowery, unpublished data). An extensive creel survey conducted during the same years found that an average of 5.2 kg/ha of largemouth bass were harvested each year, which suggested that either fishing mortality was extremely high or biomass determinations of harvestable fish were low. Size-structure data collected by spring electrofishing (M. J. Maceina, unpublished data) and the high angler catch rate of 0.62 fish/h determined by the creel survey indicated that harvestable largemouth bass abundance was probably underestimated by rotenone sampling.

In addition to complete enumeration and mark–recapture, catch depletion or removal methods may be used to estimate population size (Ricker 1975). Catch depletion techniques are widely used in streams to estimate fish density (Johnson 1965; Mahon 1980), in part because of the potential problems with neutralizing rotenone in moving water. Estimation of adult fish abundance by depletion methods has been less common in freshwater lentic systems (Peterson et al. 1980). We used catch depletion methodology to formulate a new approach for estimating density and biomass of harvestable-size largemouth bass in reservoirs.

Methods

This work was conducted on Lake Guntersville, Alabama, a 28,000-ha impoundment of the Tennessee River. Between 22 and 26 March 1992, three coves, ranging in surface area from 2.3 to 3.7 ha, were blocked with 6-mm-bar mesh nets. Deployment of the nets was checked by scuba divers to ensure isolation of the cove. Water temperatures were 13–15°C. Between 29 March and 8 April 1993, another seven coves, ranging in size from 2.8 to 3.3 ha, were blocked; three of these coves were the same coves used in 1992. In spring 1993, water temperatures were 16–18°C. Total area sampled was 9.3 ha in 1992 and 21.5 ha in 1993. At three sites a net was set at the mouth of each cove, but at four sites nets were also set at the back of the cove to prevent fish from escaping to backwater less than 0.3 m deep.

Distances across coves ranged from 70 to 210 m, and shoreline length ranged from 420 to 730 m. Ratios of shoreline length to net length ranged from 1.1 to 5.2 because some coves were nearly as wide as they were long and others were long and narrow. Sample sites were devoid of submersed or emergent aquatic vegetation, but fallen trees and boat docks were found along the shoreline. Maximum depth was 1.8–4.0 m among coves, and Secchi transparency was 1.0–1.6 m.

Two identical 5.5-m electrofishing boats were used concurrently in each cove to collect largemouth bass. Electrofishing was initiated during daylight, but some fish were collected at night. Direct-current voltage of 6 A was applied, and fish were placed in live wells on the boat. Electrofishing boats sampled opposite sides of the cove, and each started near the outside (deeper) net and moved to the shallow end of the cove. Each boat fished for 15 min in water 0.5–1.0 m deep. Largemouth bass were brought to shore, measured for total length in millimeters, weighed to the nearest 5 g, fin-clipped, and released outside of the sampling cove. Then, electrofishing was continued immediately for another 15 min, but this time in deeper water (1.0–2.5 m), and fish were processed in the same manner. Thus, these four 15-min samples constituted 1 h of electrofishing, which was considered a complete unit of effort. Total electrofishing time to deplete the population ranged from 4 to 7 h per cove, and 1–16 h elapsed between units of effort for any single cove sample.

Population density was determined by least-squares linear regression of catch per hour (CPE; y-axis) against cumulative catch (x-axis), lagged for one unit of effort (Leslie and Davis 1939) because each electrofishing run or removal effort remained constant (Mahon 1980; Cowx 1983). The following assumptions for the proper use of the method were met: (1) natural or gear-related mortality did not occur over the short sampling interval, (2) immigration or emigration were prevented by the placement of nets, (3) recruitment was nonexistent during the short sampling time, and (4) the entire population inhabiting the coves was vulnerable to our collection gear. In addition, we examined the assumption that catchability remained constant. Population estimates were computed by dividing the regression intercept by the slope, and confidence intervals were calculated with the formula of Ricker (1975). Although a legal minimum length did not exist on Lake Guntersville, we considered largemouth bass 251 mm TL and larger as harvestable, based on observations from our creel survey.

Correlation coefficients and coefficients of determination were computed to describe relationships between variables, and a two-sample t-test was used to determine statistical differences between mean values. Coefficients of variation (CV = SD/mean) among samples taken within a year were computed to determine sampling precision. To assess if the efficiency with which fish were captured over time (catchability) was constant, Student residuals were computed by dividing residual values by standard error of the residuals from the regression of CPE on cumulative catch. These values were plotted against run number to assess if differences in catchability occurred over time or between daytime and nighttime electrofishing.

Results and Discussion

Derivation of Density and Biomass for Harvestable Largemouth Bass

For 8 of 10 population estimates, significant ($P < 0.10$) negative relationships were evident between CPE and cumulative catch (Table 1). For example, at Conner Cove in 1992, CPE declined threefold from 23 to 7 fish/h over six successive units of effort (Figure 1). For two coves sampled in 1993, slopes were marginally nonsignificant (P = 0.12–0.13) after 7 h of effort. Nevertheless, population estimates derived from these two coves were used in subsequent analysis.

Density estimates of harvestable largemouth bass were 25 fish/ha (CV = 67%) in 1992 and 42 fish/ha (CV = 109%) in 1993. The estimate at Short Cove was extremely high (Table 1), and without this observation, the CV associated with mean density was 50%. Coefficients of variation were similar to those typically observed for estimates derived using cove rotenone sampling (Davies and Shelton 1983).

Density estimates were similar between years for the three coves sampled in 1992 and 1993. At

TABLE 1.—Regression intercept coefficients (b_0), slope coefficients (b_1), coefficient of determination values (r^2), and associated probability levels (P) for Leslie-derived catch depletion population estimates (N_0) of largemouth bass. Biomass was determined, in most cases, by multiplying mean weight by density.

Year and cove	Cove surface area (ha)	Sampling units of effort	b_0	b_1	r^2	P	N_0	Density (fish/ha)	Biomass (kg/ha)
1992									
Conner	3.3	6	20.58	−0.1896	0.80	0.02	108	33	26.6[a]
Roseberry	2.3	5	8.82	−0.6828	0.94	<0.01	13	6	3.4
Mud (1)	3.7	7	15.42	−0.1128	0.58	0.05	137	37	18.9
1993									
Conner	3.2	4	36.74	−0.3483	0.96	0.02	105	33	36.1
Roseberry	3.1	5	6.47	−0.2474	0.83	0.03	26	8	5.8
Mud (1)	3.3	7	10.77	−0.1341	0.40	0.13	80	24	15.5
Barge	2.8	7	7.87	−0.1267	0.67	0.02	62	22	9.4
Honeycomb	3.1	7	12.82	−0.0899	0.41	0.12	143	46	38.9
Mud (2)	3.1	4	19.08	−0.3080	0.86	0.07	62	20	12.9
Short	3.0	6	76.65	−0.1783	0.86	<0.01	430	143	112.4[a]

[a] Biomass was determined by regressing catch per effort for weight (kg/h) against cumulative weight (kg).

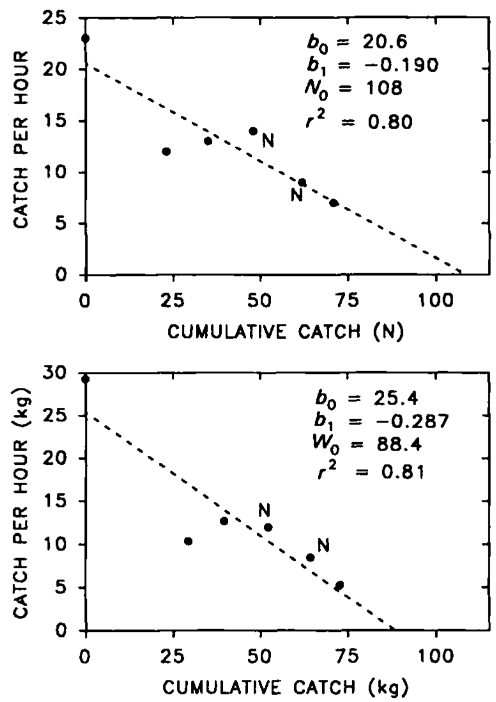

FIGURE 1.—Plots and regressions for numerical catch per hour versus cumulative catch (N; top) and catch per hour (kg) versus cumulative catch (W, kg; bottom) for Conner Cove, March 1992. Dashed lines indicate least-square regression lines. Regression intercepts (b_0), regression slopes (b_1), and coefficients of determination (r^2) are given; N_0 and W_0 represent estimated numbers and weight of harvestable largemouth bass inhabiting the cove. The N along the line designates data collected at night.

Conner, Roseberry, and Mud (1) coves, densities of 33, 6, and 37 fish/ha were estimated, respectively, in 1992 compared with 33, 8, and 24 fish/ha in 1993 (Table 1). For these three coves, density averaged 25 fish/ha in 1992 and was not significantly different (t = 0.55, P > 0.50) from the average of 22 fish/ha estimated in 1993.

We speculated that size-selective bias might occur with this method because electrofishing may be more likely to catch larger fish than smaller fish during the earlier collection periods (Reynolds

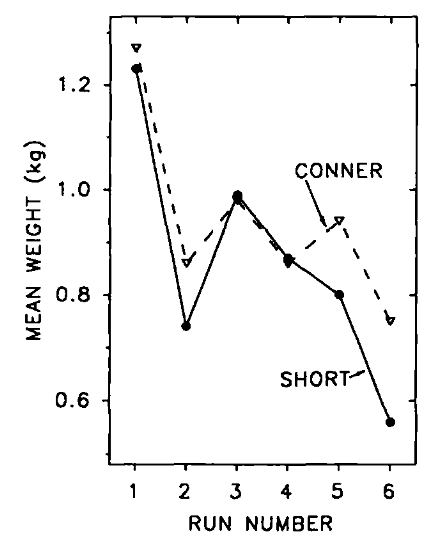

FIGURE 2.—Plot of mean weight versus collection run number from Conner and Short coves.

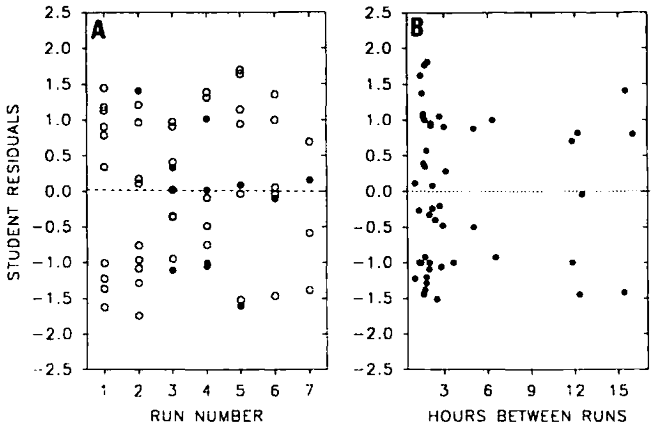

FIGURE 3.—(A) Student residuals plotted against collection run number for all ten regression equations that were computed between catch per effort and cumulative catch for largemouth bass more than 250 mm in total length. Open circles represent daylight collections and closed circles represent night collections. (B) The same Student residuals plotted against hours between collection runs.

1983), which would lead to potential bias in biomass computations (Cowx 1983). At Conner Cove in 1992 and Short Cove in 1993, mean weights were highest during the first sampling unit (Figure 2) and were inversely correlated with sampling order ($r = -0.74$ and -0.77, $P < 0.10$), which indicated that electrofishing captured larger fish in earlier runs. However, size-selective bias over sampling runs was not evident for the other eight samples.

If size-selective bias over time is evident, then biomass can be overestimated if the mean weight of fish is multiplied by density. Hence, if size selectivity is evident, total weight should be estimated by regressing weight-caught-per-hour against cumulative weight (Figure 1). Biomass (kg/ha) is then computed by dividing the estimated total weight by area. For example, at Conner Cove in 1992, biomass would have been estimated to be 33 kg/ha if mean weight of fish (1.00 kg) was multiplied by density (33 fish/ha). However, by regressing weight-caught-per-hour against cumulative weight we estimated biomass to be 26.6 kg/ha, a 24% difference. The upper bound 90% confidence interval for the latter estimate was 42.1 kg/ha, which suggested the two estimates were similar. However, we recommend that if positive size-selective bias is evident for weight, then regression based on weight-caught-per-hour will provide more conservative estimates and should be used to determine biomass; otherwise, regression based on number-caught-per-hour should be used.

Biomass averaged 16.3 kg/ha (CV = 72%) in 1992 and 33.0 kg/ha (CV = 113%) in 1993. As indicated earlier, the estimate from Short Cove was extremely high. Without this observation, biomass in 1993 averaged 19.8 kg/ha (CV = 72%) among the six remaining coves.

Catchability

Catchability appeared constant over successive collections, which satisfied an assumption of the depletion method. Student residuals plotted against run number were evenly distributed in a homoscedastic dispersal pattern over collection periods (Figure 3A), with no apparent curvilinear pattern, which indicated the relationship between CPE and cumulative catch was linear. Mahon (1980) and Bohlin and Crowe (1991) found that removal methods tended to underestimate the true population because fish tended to avoid sampling gear after successive sampling began. If this occurred, a higher proportion of negative residuals would be associated with the middle sampling intervals.

Catchabilities of harvestable largemouth bass were similar during day and night collections (Figure 3A). Twelve of the 58 sampling runs were conducted at night, and Student residuals for both day and night collections were evenly distributed around zero. In addition, the mean Student residual value for nighttime collections (-0.160) was not significantly different ($t = 1.59$, $P > 0.10$) than for the daytime collections (0.05). We expected catchability of harvestable largemouth bass to increase at night, but this did not occur.

The time duration between 1-h units of effort did not appear to affect catchability. We hypothesized that catchability might initially increase on the subsequent run after electrofishing was interrupted for several hours. A plot of Student residuals from the regression of CPE against cumulative catch was homoscedastic, with values evenly distributed around zero (Figure 3B). No relation (r = 0.02) was evident between Student residuals and time between runs.

Estimation of Subharvestable Largemouth Bass Abundance

For five of ten sample coves, estimates of the density of largemouth bass 250 mm or less TL produced nonsignificant ($P > 0.10$) relationships between CPE and cumulative catch. As determined by otolith examination, most of these fish were 1 year old (Maceina, unpublished data). Estimation of abundance of these fish would be of interest to determine potential recruitment to harvestable size; however, catchability was highly variable in some coves, as r values for the relationship between CPE and cumulative catch ranged from −0.97 to +0.44.

The appropriateness of the catch depletion method for estimating density is generally affected by the number of fish inhabiting an enclosed area. High abundance would tend to increase the probability of a pattern of initial high CPEs, followed by decreasing CPEs. The absolute number of smaller fish captured ranged from 25 to 103 and averaged 66 fish in coves where significant ($P < 0.10$) correlations were computed between CPE and cumulative catch (density ranged from 9 to 45 fish/ha). In coves where nonsignificant relationships were evident between CPE and cumulative catch, absolute number captured ranged from 24 to 84 and averaged 43 fish, slightly lower (t = 2.01, $P < 0.10$) than observed in coves where the depletion method worked. Thus, higher abundance of subharvestable largemouth bass may be related to improved application of this depletion technique.

The relationship between CPE and cumulative catch for determining density of largemouth bass 250 mm or less also appeared to be related to the biomass of fish greater than 250 mm inhabiting the cove (Figure 4). Significant ($P < 0.10$) negative relationships were computed between CPE and cumulative catch for subharvestable fish when harvestable biomass was less than 15 kg/ha. As harvestable biomass increased, these relationships progressively weakened and nonsignificant correlation coefficients were computed between subharvestable largemouth bass CPE and cumulative

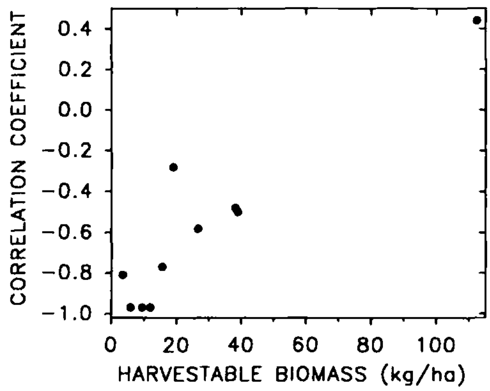

FIGURE 4. The correlation coefficient between catch per effort and cumulative catch of largemouth bass 250 mm in total length (TL) or less plotted against biomass of largemouth bass more than 250 mm TL (harvestable).

catch. We are uncertain why we observed this phenomenon, but antagonist behavior between prespawning adult harvestable fish and smaller juvenile fish, greater predation of small largemouth bass by larger fish inhabiting shallow water, or both may have occurred. Nevertheless, these findings suggested that this catch depletion method was not suitable for estimating abundance of subharvestable largemouth bass in our sample coves. However, in 0.11-ha enclosed areas that were entirely covered with submersed vegetation, Maceina et al. (1993) successfully depleted and estimated age-0 largemouth bass (47–141 mm TL) density. Differences between our findings and Maceina et al. (1993) were probably due to differences in size of areas sampled, habitat (vegetation versus no vegetation), electrofishing equipment, densities of young largemouth bass, and densities of adult largemouth bass.

Management Implications

Determination of harvestable largemouth bass density and biomass with this catch depletion technique could provide fishery biologists with another method for assessing standing stocks, monitoring changes, and evaluating management or experimental manipulation of largemouth bass populations in reservoirs. For 10 coves sampled with rotenone in 1990 and 1991, the CV of population density was 79%, similar to CVs of 72% and 113% computed for the catch depletion method in 1992 and 1993. We did not determine the accuracy of the catch depletion method because applying rotenone after catch depletion to verify estimates was impractical due to the large area sampled. However, mean catch depletion estimates of biomass made in spring 1992–1993 were about 3.6 times higher (24.7 kg/ha) than those made with rotenone in summer 1990–1991 (6.8 kg/ha). Considering mean annual harvest estimates (5.2 kg/ha), observations on the size-structure of the largemouth bass population, and annual survival estimates (60% for fish age 2–11; Maceina, unpublished data), the population density estimates made with the catch depletion method appeared to be more realistic than those made with rotenone sampling.

Other types of useful information besides population density and biomass can be collected with this catch depletion technique. These include size and age structure, and body condition estimates. However, we observed that after the first unit of effort, a high proportion of largemouth bass had freshly consumed prey fish protruding from their throats. Largemouth bass not initially collected during electrofishing were likely feeding upon stunned prey fish. Hence, body condition indices should only be calculated from fish collected during the first run.

To use this catch depletion method, we recommend that blocked coves that range in size from 2.0 to 3.5 ha be sampled in spring. Maximum water depth should not exceed 4.0 m. Most standard electrofishing boats usually cannot fish this deep, but over time, these fish may move to slightly shallower water and be vulnerable to collection. In support of this, we did not find any differences in catchability over time in our samples. Shallow, back portions of coves that are inaccessible to electrofishing should be blocked to prevent fish escape. Four to seven collection runs appeared to be adequate to cause a significant ($P < 0.10$) decline in CPE with cumulative catch. Catchability was constant over time and not affected by the time between collection runs, which varied between 1 and 16 h. In addition, catchability was similar between day and night collections. Thus, a rigid time schedule is not required.

Estimates of abundance that use catch depletion data can be made with techniques other than least-squares regression. However, Cowx (1983) found only an 18% difference between minimum and maximum density estimates among seven different formulas. Some of the computation methods examined by Cowx are tedious and require iteration. Using the least-squares regression method, we were able to estimate the necessary regression parameters on site with an inexpensive hand-held calculator (about $US30). Thus, immediately after the third collection interval (and succeeding intervals), a decision on whether to terminate sampling could be made, based on the statistical significance of the regression parameters.

This catch depletion method provides a less expensive alternative to rotenone sampling. Based on our previous experience, sampling of a single 2.0–3.5-ha cove would require 15 to 20 people and four working days in the spring when water temperatures are less than 20°C. In spring 1993, we completed sampling of the seven coves with the catch depletion technique in 8 d, for a total of 80 person-days. At least 420 person-days would be required to conduct rotenone sampling in these same areas. Undoubtedly, there would be negative public reaction to the application of rotenone to such large areas. Thus, another advantage of this electrofishing catch depletion method is that fish can be released alive.

Acknowledgments

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