BARKLEY LAKE SYMPOSIUM

EVALUATION OF STANDING CROPS OF FISHES IN CROOKED CREEK BAY, BARKLEY LAKE, KENTUCKY

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Abstract: The technique of sampling fish in coves by the application of rotenone ("cove-sampling") was evaluated in Barkley Lake, Kentucky, 26-28 September 1978. In 85 ha Crooked Creek Bay (which was subdivided into 24 coves and other subareas), 776 kg/ha of fish were recovered; the total adjusted for non-recovery of marked fish was 865 kg/ha. The numbers and biomass of fish in various coves within the Bay did not closely approximate the standing crop in the total area. Most major species of fish were either overrepresented or underrepresented in the cove samples. Larger coves (mean area, 4.9 ha) produced a more representative sample of the 85-ha Bay with respect to species composition, abundance, standing crop and length distribution. Results of the Barkley Lake study and those of a similar study in Douglas Lake, Tennessee, in 1965 indicated that many adjustment factors are required to equate small-cove standing crop estimates to those of a large bay or an entire reservoir.

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A biologist's inability to measure accurately the species, numbers, and biomass of fish in reservoirs has long been a major obstacle to understanding the dynamics of reservoir fish populations. Although attempts to minimize the problem have included many innovative approaches, "cove sampling"--the recovery of fish after the application of a piscicide (usually rotenone)--has been the most widely used sampling method in the southern United States. Much of the information about crops of fish is from coves and alongshore areas, because they can easily be sampled with rotenone. Improvements in rotenone sampling techniques have resulted in improvements in data collection (Lambou and Stern 1958, Surber 1960, Hall 1974). Analytical methods in which rotenone sampling data are applied to such considerations as the interactions of predators and prey have provided increased uses for the information collected (Swingle and Swingle 1968, Jenkins and Morais 1977). However, the study of the extrapolation of results from cove areas to larger portions of reservoirs has progressed little.

A study conducted on Douglas Lake, Tennessee, in September 1965 (Hayne et al. 1968), was the first major comparison of standing crops of fish in coves to standing crops in a larger area of a reservoir. The study yielded valuable insight into the relative population densities in coves and larger areas, and into the inherent variability of the cove sampling method. As pointed out by the investigators, however, a single assessment is insufficient to warrant generalizations about fish distributions.

The Reservoir Committee of the Southern Division of the American Fisheries Society selected Crooked Creek Bay, Barkley Lake, as a second site for comparing fish distribution in coves with that in a large arm of the reservoir. The study area differed physically from the Douglas Lake study in being on a mainstream impoundment (storage ratio = 0.04), and in being larger, comparatively shallow, and not thermally stratified. The objectives of this study were as follows: (1) to compare the species composition, abundance, standing crop, and size distribution of fish in different sizes of coves with those in the larger arm; (2) to determine variation between estimates of abundance and standing crop from replicated cove samples; (3) to compare the Barkley Lake results with those from the Douglas Lake study as a means of further evaluating relations of cove sampling estimates to fish populations in different types of reservoirs; and (4) to examine variation in standing crop, size distribution, and species composition of fish attributable to the location of a sample cove within the study area.

METHODS AND MATERIALS

Sampling areas

The history of the Barkley Lake study, description of the study site, field methods, and procedures used for preliminary data analysis were reviewed by Summers and Axon (1979). The aspect addressed herein is that of describing how adequately samples from different sizes of coves approximate a known assemblage of fish in a larger arm of a reservoir. The following population variables were considered: (1) the presence of species; (2) the species composition as percent of total numbers and weights; (3) the abundance and standing crop (numbers and weights) of all fish, and for major species separately; (4) the amount of variation inherent in a particular size of sample; and (5) the size distribution of species in coves as compared with that in the total Bay.

Using block nets, we divided the open-water area into 3 sections and recorded data separately for each. This procedure provided a measure of variation in the abundance, crop, and species distribution of fishes in relatively large areas of open water. Block nets isolated 0.4 ha samples in 2 of the 3 open-water areas to evaluate this sampling technique. In addition, a 0.4 ha brush shelter and a 0.4 ha tire shelter were constructed in 2 of the open-water areas. Evaluation of these treatments are presented by Pierce and Hooper (1979); their contribution to the standing crop is not treated separately in the present report. For this analysis, fish recovered from the brush-shelter, tire-shelter, and open-water block net samples were included in their respective open-water areas with appropriate corrections for area. The types of samples included in this analysis were 0.4, 0.8, and 1.4 ha coves, large coves, and open-water sections, each of which were compared with samples representing the total Bay.

Inasmuch as Crooked Creek Bay had few coves, we obtained replications by subdividing large coves to form coves of the size desired for sampling. The locations of these subdivisions are illustrated by Axon and Summers (1979). These subdivisions were combined to produce coves with the following areas (hectares):

0.4 ha coves
$C_4 = 0.44$
$D = 0.40$
$E = 0.42$
$F = 0.38$
$G_4 = 0.41$
$H_3 = 0.41$
$I = 0.39$

0.8 ha coves
$C_3 + C_4 = 0.85$
$G_3 + G_4 = 0.69$
$H_2 + H_3 = 0.81$

1.4 ha coves
$C_2 + C_3 + C_4 = 1.47$
$G_2 + G_3 + G_4 = 1.30$
$H_1 + H_2 + H_3 = 1.42$

Large coves
$C_1 + C_2 + C_3 + C_4 = 3.06$
$G_1 + G_2 + G_3 + G_4 = 6.69$

Species composition

We determined the number of species present in each sample area, and the total number of species collected in all samples of a similar size to determine how closely different sample sizes approximated the total number of species present in the Bay. Estimates within each sample were then compared statistically with a one-way analysis of variance for unequal subclass size. Comparisons among the means were made with a Student-Newman-Keuls test for unequal subclass size (Sokal and Rohlf 1969).

Species composition as percentage of both total numbers and weights of fish was calculated for each sample size, to provide a measure of how adequately the samples of different sizes approximated the relative composition of the fishes in the total Bay. To simplify calculations, we grouped a number of uncommon but closely related species into larger categories. For example, carpsuckers, gars, redhorses, and bullheads were considered as single entities although each contained 2 to 5 species. In all, 33 taxa of fish were used in this analysis.

Abundance and standing crop

Numbers and kg/ha of fish were calculated for: (a) all species of fish combined, and (b) separately for different species or species groups in each size of sample area. To provide an approximation of the total numbers and kg of fish recovered from sites with different areas, we computed the total number and weight of fish in a sample of a particular size and divided it by the total area represented by samples of that size. Adjustments for non-recovery of marked fish developed by Axon et al. (1979) were then applied to provide an estimate of total abundance and standing crop.

Coefficients of variation were calculated for untransformed numbers and weights of fish per ha to describe relative variation within samples from areas of similar size. Total numbers and kg of major species per ha in each section of the Bay, as separated by the block nets used to divide open-water areas, were calculated to obtain a mean and coefficient of variation for the population.

Length distribution

The length distributions of major species in coves of different sizes were compared with those of the total Bay to determine how adequately the length distributions of fish in a particular sample area approximated those of major species in the population. Even though a cove sample overrepresented or underrepresented the true abundance of a species in the Bay, it could provide a good relative measure of fish length distribution.

Hayne et al. (1968) used the ratio of the sample mean in coves to the mean for the total arm (termed bias) to explore this relation in the Douglas Lake study. We determined the same ratio to compare numbers and weights of fish per ha in each 2.54 cm class in coves with those for the total Bay.

Large variations in the abundance of fish of different length classes are common for most major species of fish in reservoirs. Differences in reproductive success and survival result in some length classes containing many individuals, whereas others contain few, often from only 1 or 2 locations. Weighting factors are therefore appropriate to adjust data for these differences. We used the jackknife procedure of Mosteller and Tukey (1977) to obtain weights for each length class of fish for each sample size. The procedure included the calculation of pseudo-variances, the reciprocals of which were used as weighting coefficients. First-through fifth-degree polynomial regressions were then computed to explore bias as number or weight for the different length classes. Selection of the best relation was based on highest values of the coefficient of determination (R^2) and the F ratio.

RESULTS

Species composition

A total of 56 species or closely related groups of fish were identified during the Barkley Lake sampling. This number is conservative, as an undetermined number of small species were grouped as "miscellaneous minnows" and treated as a single species in the field. Since the larger coves included the smaller areas at the heads of the coves, possible errors associated with not identifying the species of small fish, which were more abundant at the head ends of coves, would have occurred in data for coves of all sizes. Both the average number of species per sample and the total number of species found in all samples of a similar size increased progressively as sample size increased (Table 1). Significant ($P = 0.05$) increases in the average number of species per sample were found in large samples as compared with 0.4 ha coves; and in large coves and open-water areas as compared with 0.8 and 1.4 ha coves. The average number of species present in samples from areas of different sizes increased progressively from 23.7 in 0.4 ha coves to 43.0 in open-water areas. Total number of species collected in samples from areas of different sizes followed a similar trend.

TABLE 1. Average number of species of fish collected in samples from areas of various sizes, and total number of species collected from all sample areas of a similar size in Barkley Lake, 26-28 September 1978; average values not connected by the same subscript letter differ significantly at the $P = 0.05$ level.

Sample area	Average	Range	Total species collected
0.4 ha coves	23.7 a	21-27	33
0.8 ha coves	29.7 b	29-31	37
1.4 ha coves	34.0 b	32-37	43
Large coves	40.0 c	38-42	45
Open-water	43.0 c	40-47	51
Total arm	56		56

The species composition as percent of total number and weight of different fishes varied greatly among samples from areas of different sizes. All values based on individual coves were overestimates or underestimates of the percent composition as both number and weight, when compared with the total Bay. Small coves showed the largest differences (Tables 2 and 3). As in most reservoir fish assemblages, a few major species made up most of the total numbers and biomass. The 10 most abundant fishes in the Bay made up about 96% of total numbers, and 95% of total biomass. Among these major fishes, gizzard shad were dominant numerically, and gizzard shad, carp, and freshwater drum were dominant by weight in all samples from areas of all categories.

Abundance and standing crop

The weight of dead fish recovered in Crooked Creek Bay indicated a standing crop of 777 kg/ha. This total adjusted for non-recovery of marked fish was 865 kg (Table 4). Cove samples underrepresented the total biomass of fish for the Bay. Differences were largest in 0.4 and 0.8 ha coves where t - tests used to compare total crops in each cove size with that of the total Bay indicated significant ($P = 0.05$ differences). Total crop increased consistently and progressively as size of an area sample increased. Several major fishes, including bigmouth buffalo, smallmouth buffalo, channel catfish, white crappie, and threadfin shad were poorly represented in small coves, but formed a sizable portion of the total biomass in the Bay. Conversely, the standing crops of largemouth bass, most

TABLE 2. Species composition as percent of total number of fishes recovered in samples from areas of different sizes in Barkley Lake, 26-28 September, 1978 (numbers in parentheses indicate rank in order of abundance).

	Sampling Units					
Species	Total arm	0.4 ha coves	0.8 ha coves	1.4 ha coves	Large coves	Open water
Gizzard shad	61.0 (1)	78.1 (1)	76.9 (1)	77.7 (1)	65.1 (1)	60.5 (1)
Threadfin shad	25.6 (2)	0.7 (8)	0.4 (9)	0.9 (7)	15.7 (2)	27.1 (2)
Freshwater drum	6.2 (3)	2.6 (5)	2.5 (5)	5.1 (3)	5.5 (3)	6.3 (3)
White crappie	2.3 (4)	0.1 (13)	0.1 (14)	0.3 (11)	1.2 (6)	2.4 (4)
Bluegill	1.6 (5)	4.9 (3)	6.8 (2)	5.4 (2)	4.9 (4)	1.2 (5)
Longear sunfish	1.0 (6)	5.7 (2)	5.3 (3)	4.4 (4)	3.4 (5)	0.6 (7)
Channel catfish	0.6 (7)	0.1 (14)	0.1 (13)	0.3 (12)	0.5 (9)	0.6 (6)
Carp	0.3 (8)	0.1 (18)	0.3 (11)	0.3 (13)	0.4 (11)	0.3 (8)
White bass	0.3 (9)	0.3 (10)	0.3 (10)	0.5 (9)	0.3 (12)	0.3 (9)
Miscellaneous minnows	0.2 (10)	3.7 (4)	3.7 (4)	2.5 (5)	1.1 (7)	0.1 (17)
Largemouth bass	0.1 (11)	1.4 (6)	1.7 (6)	1.0 (6)	0.5 (8)	0.1 (16)
Warmouth	0.1 (12)	0.4 (9)	0.5 (8)	0.4 (10)	0.4 (10)	0.1 (10)
Madtoms	0.1 (13)	1.1 (7)	0.6 (7)	0.5 (8)	0.2 (14)	0.1 (14)
Yellow bass	0.1 (14)	0.1 (12)	0.1 (15)	0.2 (14)	0.3 (13)	0.1 (12)
Smallmouth buffalo	0.1 (15)	t (22)	t (21)	0.1 (18)	0.1 (16)	0.1 (11)
Blue catfish	0.1 (16)	0	t (24)	t (27)	t (26)	0.1 (13)
Bigmouth buffalo	0.1 (17)	t (25)	0	0	t (24)	0.1 (15)
Skipjack herring	0.1 (18)	t (21)	0.1 (19)	t (19)	t (22)	0.1 (18)
Bullheads	t (19)	0.1 (16)	0.1 (16)	0.1 (16)	t (18)	t (19)
Spotted sucker	t (20)	0.2 (11)	0.2 (12)	0.2 (15)	0.2 (15)	t (21)
Black crappie	t (21)	0.1 (19)	0.1 (17)	t (20)	t (20)	t (20)
Carpsucker	t (22)	t (24)	t (23)	t (22)	0.1 (17)	t (22)
Green sunfish	t (23)	0.1 (17)	0.1 (18)	0.1 (17)	t (21)	t (24)
Orangespotted sunfish	t (24)	t (20)	t (20)	t (21)	t (19)	t (26)
Black buffalo	t (25)	0	0	t (30)	t (30)	t (23)
Flathead catfish	t (26)	t (26)	t (25)	t (28)	t (29)	t (25)
Spotted bass	t (27)	0.1 (15)	0	t (24)	t (23)	t (29)
Paddlefish	t (28)	0	0	0	0	t (27)
Sauger	t (29)	t (23)	t (26)	t (25)	t (27)	t (30)
Goldeye-Mooneye	t (30)	0	0	t (29)	0	t (28)
Redhorses	t (31)	0	0	t (23)	t (25)	t (32)
Gars	t (32)	0	t (22)	t (26)	t (28)	t (31)
Others	t	0.1	t	t	t	t

t = less than 0.05%

TABLE 3. Species composition as percent of total weight of fishes recovered in samples from areas of different sizes in Barkley Lake, 26-28 September, 1978 (numbers in parentheses indicate the rank in order of abundance).

	Sampling Unit					
Species	Total arm	0.4 ha coves	0.8 ha coves	1.4 ha coves	Large coves	Open water
Gizzard shad	29.8 (1)	65.7 (1)	53.1 (1)	45.8 (1)	31.8 (1)	29.3 (1)
Freshwater drum	15.3 (2)	9.1 (2)	5.7 (3)	11.3 (3)	11.8 (3)	15.7 (2)
Carp	14.4 (3)	5.4 (3)	17.4 (2)	18.6 (2)	21.3 (2)	13.7 (3)
Threadfin shad	8.7 (4)	0.3 (13)	0.1 (20)	0.3 (14)	5.4 (5)	9.2 (4)
Bigmouth buffalo	7.6 (5)	0.2 (15)	0	0	0.9 (14)	8.4 (5)
Smallmouth buffalo	6.5 (6)	0.5 (12)	0.6 (12)	1.6 (9)	7.0 (4)	6.6 (6)
Channel catfish	4.8 (7)	1.3 (8)	1.6 (8)	3.6 (5)	4.7 (7)	4.8 (7)
White crappie	4.2 (8)	0.5 (11)	1.0 (10)	1.2 (11)	2.2 (8)	4.4 (8)
Bluegill	2.3 (9)	3.8 (5)	5.2 (5)	4.9 (4)	5.0 (6)	2.0 (9)
White bass	0.8 (10)	0.6 (10)	0.6 (11)	2.0 (8)	1.5 (12)	0.8 (12)
Carpsuckers	0.8 (11)	0.1 (19)	0.3 (14)	0.8 (12)	2.2 (9)	0.7 (14)
Paddlefish	0.8 (12)	0	0	0	0	0.9 (10)
Black buffalo	0.8 (13)	0	0	t (26)	t (30)	0.9 (11)
Blue catfish	0.7 (14)	0	t (26)	t (30)	0.1 (19)	0.7 (13)
Longear sunfish	0.6 (15)	5.0 (4)	3.9 (6)	2.9 (7)	2.1 (10)	0.4 (16)
Largemouth bass	0.6 (16)	3.4 (6)	5.6 (4)	3.4 (6)	1.6 (11)	0.5 (15)
Spotted sucker	0.2 (17)	1.6 (7)	1.9 (7)	1.3 (10)	1.1 (13)	0.1 (19)
Skipjack herring	0.2 (18)	0.1 (21)	0.2 (17)	0.1 (20)	t (25)	0.2 (17)
Flathead catfish	0.2 (19)	t (25)	0.1 (21)	t (23)	t (24)	0.2 (18)
Bullheads	0.1 (20)	0.3 (14)	0.4 (13)	0.3 (15)	0.2 (17)	0.1 (20)
Black crappie	0.1 (21)	0.1 (18)	0.2 (18)	0.1 (22)	0.1 (20)	0.1 (21)
Yellow bass	0.1 (22)	0.2 (17)	0.1 (19)	0.2 (16)	0.1 (18)	0.1 (22)
Warmouth	0.1 (23)	0.2 (16)	0.2 (16)	0.2 (17)	0.2 (16)	t (23)
Miscellaneous minnows	t (24)	1.1 (9)	1.4 (9)	0.7 (13)	0.3 (15)	t (27)
Sauger	t (25)	0.1 (20)	t (22)	0.1 (21)	t (23)	t (24)
Gars	t (26)	0	0.3 (15)	0.1 (19)	0.1 (22)	t (25)
Goldeye-Mooneye	t (27)	0	0	t (29)	0	t (26)
Redhorses	t (28)	0	0	0.1 (18)	0.1 (21)	t (32)
Spotted bass	t (29)	t (24)	0	t (28)	t (26)	t (29)
Madtoms	t (30)	0.1 (22)	t (24)	t (25)	t (28)	t (28)
Green sunfish	t (31)	t (23)	t (23)	t (24)	t (27)	t (30)
Orangespotted sunfish	t (32)	t (26)	t (25)	t (27)	t (29)	t (31)
Others	t	0.1	t	0.1	t	t

t = less than 0.05%

TABLE 4. Standing crop of fish as kilograms per hectare recovered (unadjusted), and estimated kilograms per hectare on non-recovery of marked fish (adjusted), from sampling areas of different sizes in Barkley Lake, 26-28 September, 1978.

	Sampling Unit											
	Total area		0.4 ha coves		0.8 ha coves		1.4 ha coves		Large coves		Open water	
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
Gizzard shad	231.9	255.1	237.4	261.1	244.0	268.3	271.9	299.1	195.0	214.4	239.1	263.0
Freshwater drum	119.3	143.3	33.0	39.6	26.3	31.5	66.7	80.1	72.5	87.0	128.1	153.7
Carp	112.3	121.3	19.7	21.2	79.8	86.2	110.3	119.2	130.3	140.8	112.3	121.2
Threadfin shad	67.8	74.6	1.2	1.3	0.6	0.7	2.0	2.1	33.0	36.3	75.6	83.0
Bigmouth buffalo	59.2	65.1	0.9	1.0	0	0	0	0	5.5	6.1	68.9	75.8
Smallmouth buffalo	50.6	55.7	1.8	2.0	2.8	3.1	9.4	10.4	42.7	47.0	53.6	59.0
Channel catfish	37.2	40.9	4.5	5.0	7.4	8.1	21.6	23.7	28.5	31.4	39.6	43.5
White crappie	32.5	35.8	1.9	2.0	4.5	4.9	7.4	8.1	13.4	14.7	36.3	39.9
Bluegill	18.1	20.0	13.6	15.1	23.6	26.0	29.0	31.8	30.9	34.0	16.7	18.3
White bass	6.7	7.1	2.3	2.4	3.0	3.2	12.0	12.8	9.4	10.0	6.6	7.0
Carpsuckers	6.3	7.0	0.4	0.4	1.3	1.5	4.7	5.3	13.3	14.6	5.5	6.1
Paddlefish	6.1	6.8	0	0	0	0	0	0	0	0	7.3	8.0
Black buffalo	6.1	6.8	0	0	0	0	0.1	0.1	t	0.1	7.2	8.0
Blue catfish	5.1	5.6	0	0	t	t	t	t	0.7	0.8	5.9	6.4
Longear sunfish	5.1	5.7	18.2	20.8	17.8	20.3	16.9	19.4	13.1	14.9	3.5	4.0
Largemouth bass	4.8	5.6	12.2	14.1	25.4	29.3	20.2	23.3	10.1	11.6	3.8	4.5
Spotted sucker	1.9	2.1	6.0	6.6	8.6	9.4	8.0	8.8	7.0	7.8	1.0	1.2
Skipjack herring	1.5	1.7	0.3	0.3	0.9	1.0	0.7	0.8	0.1	0.1	1.7	1.9
Flathead catfish	1.4	1.6	0.1	0.1	0.4	0.4	0.3	0.3	0.2	0.2	1.6	1.8
Bullhead catfish	0.8	0.9	1.1	1.2	1.8	2.0	1.9	2.1	1.0	1.1	0.8	0.9
Black crappie	0.6	0.7	0.4	0.4	0.8	0.8	0.5	0.5	0.4	0.5	0.7	0.8
Yellow bass	0.5	0.6	0.5	0.6	0.7	0.7	1.2	1.4	0.9	1.0	0.4	0.5
Warmouth	0.4	0.4	0.8	0.9	1.1	1.2	0.9	1.0	1.0	1.1	0.4	0.4
Miscellaneous minnows	0.4	0.4	3.9	4.3	6.6	7.3	4.3	4.7	1.9	2.1	0.1	0.1
Sauger	0.2	0.2	0.4	0.4	0.2	0.2	0.5	0.6	0.3	0.4	0.2	0.2
Gars	0.2	0.2	0	0	1.2	1.3	0.8	0.9	0.4	0.4	0.1	0.1
Goldeye-Mooneye	0.1	0.1	0	0	0	0	t	t	0	0	0.1	0.1
Redhorse	0.1	0.1	0	0	0	0	0.8	0.9	0.4	0.4	0	0
Spotted bass	0.1	0.1	0.1	0.1	0	0	t	t	0.1	0.1	t	0.1
Madtoms	t	0.1	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.1	t	t
Green sunfish	t	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	t	t
Orangespotted sunfish	t	t	t	t	t	t	t	t	0.1	0.1	t	t
Other	0.1	0.1	0.4	0.4	0.2	0.3	0.4	0.4	0.2	0.2	0.1	0.1
TOTAL	777.6	865.2	361.3	401.4	459.6	508.2	592.9	657.9	612.3	678.8	817.2	909.5

t = less than 0.05 kg/ha

sunfishes, and minnows and darters were largest in small coves. Among the major fishes, only gizzard shad and white bass showed no definite trends when standing crops in coves were compared with those in the total Bay. Total numbers of fish in coves did not reflect the same trends as standing crop. Large numbers of sunfish and small minnows in small-cove samples contributed to a numerical similarity among collections from areas of different sizes (Table 5).

Coefficients of variation for total numbers of fish per ha averaged about 45% of the respective means for most sample sizes. Relative variation in total weight of fish per ha was greatest in 0.4 ha coves and generally decreased as the size of an area sampled increased. Coefficients of variation for total weight of fish ranged from 25% in 0.4 ha coves to 12% in the total Bay (Table 6). Variation within species differed greatly. Total numbers and weight of gizzard shad, white bass, bluegills, bigmouth buffalos, and freshwater drum per ha were variable throughout the Bay; coefficients usually exceeded

TABLE 5. Numbers of fish recovered per hectare (unadjusted), and estimated number per hectare based on non-recovery of marked fish (adjusted), from sampling areas of different sizes in Barkley Lake, 26-28 September, 1978.

	Sampling Unit											
	Total area		0.4 ha coves		0.8 ha coves		1.4 ha coves		Large coves		Open water	
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
Gizzard shad	22084.0	24292.4	20735.4	22809.0	19283.0	21211.4	23620.9	25982.9	19226.7	21149.4	22869.7	25156.9
Threadfin shad	9245.7	10170.2	179.6	197.4	109.4	120.3	283.8	312.2	4635.9	5099.6	10235.9	11258.5
Freshwater drum	2243.0	2691.2	683.0	819.5	616.3	739.5	1548.2	1857.9	1623.8	1948.3	2366.5	2840.0
White crappie	815.8	897.6	35.6	39.3	31.6	34.6	103.2	113.6	355.2	390.8	910.2	1001.3
Bluegill	588.1	646.9	1299.7	1429.6	1705.5	1876.2	1656.6	1822.4	1437.5	1581.3	452.0	497.2
Longear	360.4	411.0	1512.4	1724.1	1335.0	1522.0	1323.9	1509.2	1007.3	1148.3	226.2	257.9
Channel catfish	217.6	239.3	35.1	38.5	31.9	35.1	91.4	100.5	153.9	169.2	232.4	255.6
Carp	107.4	116.1	16.5	17.8	66.9	72.1	85.5	92.4	111.4	120.3	109.7	118.3
White bass	103.7	109.9	75.8	80.3	68.2	72.1	138.3	146.7	101.5	107.7	105.7	111.9
Miscellaneous minnows	82.7	91.1	979.6	1077.7	916.4	1008.0	749.9	824.7	312.0	343.3	21.2	23.5
Largemouth bass	47.4	54.3	381.4	438.4	423.4	486.8	298.1	342.8	156.8	180.3	24.4	28.2
Warmouth	44.2	48.4	114.4	125.7	123.5	135.8	117.3	128.9	114.4	126.0	33.3	36.6
Madtoms	40.3	44.5	296.6	326.3	159.3	175.1	153.6	168.9	66.7	73.1	26.9	29.6
Yellow bass	38.0	41.7	38.5	42.2	29.9	32.8	65.2	71.6	81.8	89.9	30.6	33.8
Smallmouth buffalo	30.9	33.8	3.5	3.9	4.7	5.2	15.6	17.0	33.6	37.0	31.4	34.6
Blue catfish	23.7	25.9	0	0	0.7	1.0	0.5	0.5	2.2	2.5	27.4	30.1
Bigmouth buffalo	21.5	23.7	0.2	0.5	0	0	0	0	2.2	2.5	24.9	27.4
Skipjack herring	18.0	20.0	6.7	7.4	15.3	16.8	13.6	15.1	3.7	4.2	20.0	22.2
Bullhead	17.3	19.0	23.0	25.4	27.7	30.4	24.2	26.4	13.1	14.3	18.3	20.0
Spotted sucker	13.1	14.6	50.6	56.3	62.2	68.9	56.8	60.8	47.9	53.1	6.9	7.7
Black crappie	7.9	8.6	14.3	15.8	19.3	21.0	11.4	12.6	9.4	10.4	7.9	8.6
Carpsucker	7.4	8.1	0.2	0.5	1.2	1.5	5.7	6.4	16.5	18.3	6.4	6.9
Green sunfish	3.7	3.9	16.8	18.5	15.8	17.3	16.3	17.8	7.7	8.4	2.2	2.5
Orangespotted sunfish	2.7	3.0	8.6	9.6	5.2	5.7	7.2	7.9	9.9	10.9	1.5	1.7
Black buffalo	2.2	2.5	0	0	0	0	0.2	0.2	t	0.2	2.5	2.7
Flathead catfish	1.7	2.0	0.2	0.5	0.7	1.0	0.5	0.5	1.0	1.0	1.7	2.0
Spotted bass	1.7	1.7	24.9	27.4	0	0	4.2	4.7	3.0	3.2	0.5	0.7
Paddlefish	1.2	1.2	0	0	0	0	0	0	0	0	1.2	1.5
Sauger	0.7	1.0	1.7	2.0	0.7	1.0	2.7	3.0	1.7	2.0	0.5	0.7
Goldeye-Mooneye	0.7	0.7	0	0	0	0	0.2	0.2	0	0	0.7	1.0
Redhorse	0.2	0.2	0	0	0	0	4.9	5.4	2.2	2.5	t	t
Gars	0.2	0.2	0	0	1.2	1.5	1.2	1.2	1.0	1.2	0.2	0.2
Other	1.7	2.0	23.0	25.4	4.7	5.2	7.7	8.4	3.9	4.2	0.7	0.7
TOTAL	36173.1	40018.9	26557.4	29357.7	25059.9	27698.3	30408.7	33662.1	29543.9	32703.3	37800.1	41819.6

t = less than 0.05 fish per ha

40% of the means. Other species such as white crappies, largemouth bass, and channel catfish showed only about one-half the relative variation in both numbers and kilograms per ha.

Length distribution

Most length classes of the major fishes found in the Crooked Creek Bay were collected in cove samples. However, fish at certain lengths were nearly always present in greater or lesser quantities in coves than in the total Bay. Regressions of bias, as numbers and weights of major species against 2.54 cm length classes, frequently yielded significant ($P \leq 0.05$) correlations. These were usually adequately described by second or third degree polynomial regressions (Table 7). Bias with respect to length differed for most major species. However, patterns of bias within species were often similar, inasmuch as certain length classes of a particular species were consistently overrepresented or underrepresented in samples from areas of different sizes. For most major fishes, bias was

TABLE 6. Coefficients of variation for numbers and (in parenthesis) kilograms per ha of all fish and selected major species from areas of different sizes in Barkley Lak^, 26-28 September, 1978.

Species	Sampling Units					
	0.4 ha coves	0.8 ha coves	1.4 ha coves	Large coves	Open-water	Total arm
Gizzard shad	64 (46)	26 (13)	50 (34)	72 (56)	67 (52)	59 (44)
Threadfin shad	89 (89)	77 (66)	114 (130)	92 (92)	20 (18)	20 (19)
Smallmouth buffalo	89 (137)	35 (50)	46 (43)	34 (25)	45 (32)	33 (29)
Bigmouth buffalo	265 (265)	-- --	-- --	141 (141)	26 (30)	39 (43)
Channel catfish	132 (91)	97 74	12 (69)	40 (34)	14 (14)	15 (15)
White bass	61 (71)	25 (45)	84 (126)	99 (121)	70 (76)	55 (57)
Bluegill	55 (57)	4 (23)	28 (48)	38 (41)	25 (30)	40 (46)
Largemouth bass	57 (72)	14 (23)	7 (13)	20 (28)	28 (11)	25 (20)
White crappie	82 (73)	93 (113)	93 (16)	92 (29)	22 (14)	18 (10)
Freshwater drum	91 (98)	90 (97)	12 (12)	10 (1)	42 (37)	36 (43)
Carp	79 (86)	65 (65)	17 (21)	18 (0.1)	15 (20)	13 (17)
All fish	46 (25)	18 (17)	40 (23)	39 (16)	45 (15)	38 (12)

usually greater for small coves than for large ones. However, both the coefficients of determination (R^2) and level of statistical significances for correlation coefficients were usually highest for the large coves.

The regression coefficients presented provide coefficients for adjusting the numbers of fish of various kinds and lengths from different cove sizes to the total Bay. Because bias was calculated as a proportional measure for each length class, relationships for numbers and weights of fish were nearly identical. Coefficients describing bias with respect to length for the major species of fish in samples of different sizes are therefore illustrated only for numbers of major fishes (Table 7). Coefficients needed to adjust weights of fish in different cove sizes to those for the total Bay are available from the National Reservoir Research Program, Fayetteville, Arkansas, upon request.

DISCUSSION

Fish management agencies differ in the kinds of information they wish to derive from cove sampling. Therefore, this analysis does not address some questions regarding its use, or the interpretation of results. The present study concentrated on how closely samples from coves of various sizes approximated the species composition, variation, standing crop, and size distribution of fishes in samples from a larger area of a reservoir. Tabular data are presented in detail to provide basic information to workers with different interests. Original data have been stored on magnetic tape and are available at cost of reproduction from the Reservoir Committee.

Except for the Douglas Lake study (Hayne et al. 1968), we know of no quantitative estimate of standing crop comparable to that from Barkley Lake. Total standing crop as kg/ha in Barkley Lake was about 6 times that of Douglas Lake. However, standing crop estimates from coves in Barkley Lake compare reasonably well with similar cove samples from other mainstream reservoirs. Hall (1974) reported an average unadjusted standing crop of 279 kg of fish per ha in 12 TVA mainstream reservoirs. These estimates were based on cove samples of 0.4 to 1.6 ha. Adjusted standing crops of fish from coves in eight southern mainstream reservoirs sampled in 1972 and 1973 as part of the Reservoir Committee's Predator Stocking Evaluation averaged 562 and 481 kg/ha, respectively

TABLE 7. Regression coefficients describing bias in numbers of major fishes with respect to length (L) for different sample sizes, Barkley Lake, 26-28 September, 1978. The coefficient of determination (R^2) indicates the percent of variability in numbers of fish explained by the regression equation. The significance level (P) is the chance of obtaining an R^2 as large or larger when the hypothesis of no correlation is true. The centimeter class range indicates the range of sizes included in each regression equation.

	Sampling Units				
	Cove size	Regression coefficient	R^2	P	Cm-class range
Gizzard shad	0.4 ha	$0.422 + 0.04642L$	.18	0.137	5.1-27.9
	0.8 ha	$-0.706 + 0.1585L$	.45	0.011	5.1-33.0
	1.4 ha	$-0.417 + 0.1004L$	.69	< 0.001	5.1-33.0
	Large	$11.247 - 1.116L + 0.1855L^2$	.96	< 0.001	5.2-33.0
Threadfin shad	0.4 ha	$1.072 - 0.1982L + 0.00921L^2$	.86	0.082	2.5-15.2
	0.8 ha	$0.657 - 0.1147L + 0.03237L^2$	.97	0.016	2.5-12.7
	1.4 ha	0.020	--	--	2.5-12.7
	Large	$0.010 + 0.0310L$	.63	0.109	2.5-12.7
Smallmouth buffalo	0.4 ha	$1.433 - 0.0272L$	.60	0.070	17.8-50.8
	0.8 ha	$1.723 - 0.0760L$	.70	0.077	17.8-55.9
	1.4 ha	$24.516 - 0.957L + 0.00934L^2$	.49	0.009	17.8-55.9
	Large	$21.139 - 1.394L + 0.0322L^2 - 0.000248L^3$	.74	0.006	17.8-55.9
Channel catfish	0.4 ha	$3.557 - 1.331L + 0.0284L^2 - 6.53x10^{-4}L^3 + 5.41x10^{-6}L^4$	.40	0.010	7.6-50.8
	0.8 ha	$1.288 - 0.1903L + 0.01019L^2 - 0.000226L^3 + 1.82x10^{-6}L^4$	.50	0.029	7.6-73.7
	1.4 ha	$3.166 - 0.443L + 0.02315L^2 - 0.000485L^3 + 3.516x10^{-6}L^4$	.61	< 0.001	2.5-71.1
	Large	$3.532 - 0.296L + 0.00850L^2 - 7.103x10^{-5}L^3$	.90	< 0.001	2.5-73.7
White bass	0.4 ha	$2.708 - 0.207L + 0.00406L^2$	[illegible]	0.008	7.6-38.1
	0.8 ha	$2.794 - 0.212L + 0.00[illegible]4L^2$	.52	0.048	5.1-35.6
	1.4 ha	$4.127 - 0.385L + 0.010[illegible]L^2$	[illegible]	0.002	7.6-40.6
	Large	$3.230 - 0.2758L + 0.0067L^2$	.73	< 0.001	5.1-40.
Bluegill	0.4 ha	$8.101 - 0.916L + 0.02698L^2$	.69	0.047	2.5-2[illegible]
	0.8 ha	$11.569 - 1.435L + 0.0481L^2$	.78	0.005	2.5-[illegible]
	1.4 ha	$[illegible] + 0.585L - 0.1029L^2 + 0.00[illegible]04L^3$	[illegible]	0.069	2.5-22.8
	Large	$4.985 - 0.202L$	.97	< 0.001	2.5-22.8
Largemouth bass	0.4 ha	$14.27 - 0.577L + 0.00622L^2$	.78	0.013	2.5-50.8
	0.8 ha	$22.42 - 0.968L + 0.0128[illegible]L^2$	.52	0.025	5.1-53.3
	1.4 ha	$19.41 - 0.977L + 0.01451L^2$	.98	< 0.001	5.1-53.3
	Large	$4.51 - 0.0736L$	.98	< 0.001	5.1-53.3
White crappie	0.4 ha	$0.085 - 0.00981L + 0.000322L^2$	.21	0.196	5.1-30.4
	0.8 ha	$0.107 - 0.015L + 0.00022L^2$	.51	0.040	5.1-33.0
	1.4 ha	$1.[illegible] - 0.1791L + 0.00986L^2 - 0.000150L^3$	[illegible]	0.002	5.1-35.6
	Large	$0.166 + 0.0378L - 0.00104L^2$	.81	0.001	5.1-35.6
Freshwater drum	0.4 ha	$-1.000 + 0.2555L - 0.01568L^2$	.64	< 0.001	7.6-48.3
	0.8 ha	0.204	--	--	7.6-27.9
	1.4 ha	$1.036 - 0.0257L$	.32	0.023	2.5-40.6
	Large	$1.264 - 0.0352L$	.48	0.003	5.1-45.7
Carp	0.4 ha	$-0.351 + 0.0106L$	.40	0.035	40.6-66.0
	0.8 ha	$29.43 - 1.91L + 0.0406L^2 - 0.000278L^3$	.47	0.046	22.9-68.6
	1.4 ha	$1.700 - 0.1142L + 0.00203L^2$	.94	0.001	22.9-71.1
	Large	$13.27 - 0.594L \quad 0.00696L^2$	.63	< 0.001	22.9-68.6

(Aggus and Lewis 1978). Adjusted crops in 0.4, 0.8, and 1.4 ha coves in Lake Barkley were about 400,490, and 660 kg/ha -- reasonably close to the previously listed values. The relations between coves and larger areas observed in Barkley Lake suggested that the potential for sport and commercial fisheries in mainstream reservoirs is large. For certain major species, it is much greater than indicated from cove samples.

In both the Barkley and Douglas Lake studies, surface area was the basic physical measure used to compare the abundance and standing crops of fish in coves with the larger Bay. Results of the 2 studies suggested that cove samples approximated crops of fish in different ways when compared with the larger area. When compared with estimates for the entire Bay, 0.4 and 0.8 ha coves in Barkley Lake overrepresented or underrepresented numbers or weights of some major fishes by 5 to 50 times; and significantly underrepresented the total standing crop. In Douglas Lake, samples from coves rarely overrepresented or underrepresented the total numbers or weights of major species by more than 2.5 times; cove standing crop was also near that of the total Bay (Hayne et al. 1968).

There were large differences between the two sites in ratios of cove area to that of the total Bay. Coves made up about 34% of the total area sampled in the Douglas Lake study, but only about 14% of the area in Barkley Lake. Similar sizes of coves exhibited comparable relations. For example, 1.4 ha coves made up 9% of the total area in Douglas but only 3.5% of the total area in Barkley. This incorporation of a larger portion of the total area as various sizes of coves in Douglas Lake should logically have produced estimates more similar to those for the population in the total Bay.

Perhaps of greater importance, however, were differences in the morphometry of the Bays in Douglas and Barkley Lakes, which dictated the size and number of coves producing different representations of the fish population. In Douglas Lake, coves were evenly distributed from the head of the arm to the mouth (Hayne et al. 1968). The Bay studied had a much greater maximum depth (18.2 m compared with 5.5 m in Barkley) and was stratified thermally. Therefore, most fish should have been concentrated in the upper part of the water column. Coves included much of this depth range, and a sizable percentage of the available surface area and water volume.

In Barkley Lake, coves were located along the sides of the arm and were uniformly shallow (mean depths, 0.4 - 1.5 m). With the exception of one large outer cove section (G 1 of Axon and Summers, 1979), maximum depths were less than 2.6 m. Temperatures throughout the Bay varied by only 2C, and dissolved oxygen was mostly above 6 ppm. Under these environmental conditions, increases in sample area provided a good measure of increases in other physical characteristics. In sampling reservoirs with physical characteristics similar to those of the Barkley Lake site, the use of large coves should provide more representative measures of the population attributes analyzed herein.

We found no clear indication of what location within a reservoir is best for obtaining a representative cove sample. Further examination of this important sampling attribute is needed. At present, the somewhat subjective criterion of selecting coves on the basis of their representing major habitats, as recommended for the Predator Stocking Evaluation (Grinstead et al. 1977), remains the most workable compromise for general management evaluation. Recognizing that many physical and biological factors influence how a cove sample approximates the fish population in a large area of a lake, workers should standardize their samples with respect to cove size, location within a lake, and date of sampling.

The large variations in total numbers and weights of major fishes in coves, and bias with respect to size, ruled out the possibility of obtaining a single adjustment factor to equate standing crops of various fishes in coves with those in Crooked Creek Bay in Barkley Lake. These results support the findings by Hayne et al. (1968) that a single adjustment factor relating standing crop of fish in coves to a larger area of a reservoir is not attainable. In both studies, the relations between coves and the total Bays differed with respect to species, length classes within species, and the size of a cove from which a sample was taken.

Adjustment factors developed for Barkley differed from those defined by Hayne et al. (1968) for Douglas. Adjustments to relate crops of fish in coves to larger areas should therefore be limited to reservoirs with similar physical characteristics. The adjustments developed for Douglas Lake could perhaps be applied to deep, thermally stratified storage impoundments with high shoreline development factors; and those for Barkley Lake to large, shallow mainstream reservoirs in which thermal stratification is weak or non-existent. The adjustment factors defined for the Barkley study were used with good success by Jenkins et al. (1979) to examine proportional relations involving predator and prey fishes in Crooked Creek Bay. However, further testing is needed to determine whether these adjustments for various species adequately describe relations in other mainstream reservoirs.

Both the Barkley and Douglas studies produced unique data banks containing enormous amounts of information. Presentation of results from both studies has been limited by manpower and time constraints. Analyses have addressed practical applications of equating cove data to larger areas; many population features have not been analyzed. For example, the Barkley study yielded a unique measure of the spatial variation of fish in a large open water area. Though a measure of variation was developed for total fish and major species in these areas, much additional information remains to be gleaned from more detailed analyses of these spatial relations. The Barkley study revealed intriguing patterns of lag time in recovery of species over the 3-day recovery period. If these patterns could be verified by reexamination of the Douglas Lake data, they should provide biologists with better insights into how best to use their time in recovering fish after rotenone treatment.

Relations among length classes of fish as presented here provided a direct comparison of numbers and weights of fish in coves with those in a larger Bay. Further exploration of interrelations concerning size of fish and possible correlations between species with respect to their patterns of distribution in various areas of a reservoir, as suggested by Hayne et al. (1968) would be of great value to fishery biologists.

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