RATES OF ANGLER EXPLOITATION OF LARGEMOUTH, SMALLMOUTH, AND SPOTTED BASS IN CENTER HILL RESERVOIR, TENNESSEE

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Abstract: A tag-and-reward procedure was used to estimate exploitation rates of black bass (*Micropterus* sp.) during 1975 and 1976 in Center Hill Reservoir, Tennessee. Returns of reward tags by anglers indicated annual exploitation rates of 13.3 (22.2%) for largemouth (*M. salmoides*), 12.9 (15.6%) for smallmouth (*M. dolomieui*) and 14.8 (18.5%) for spotted bass (*M. punctulatus*). Within each year, exploitation rates were not significantly different between species or size groups. Rates were lower in 1976 than in 1975 for all species, but the difference was significant only for largemouth bass. In 1975, when tag reward values were publicly announced, most data suggested that tags with no reward value were returned at rates lower than those observed for reward tags. In 1976, when a random-reward procedure was used, differential rates of return were not detected. Monthly graphs of recaptures (R) expressed as a percentage of the total catch (C) from creel survey data indicated that tag loss and (or) differential mortality caused exploitation estimates based on 12 months of returns to be too low. If R/C ratios had remained at levels similar to those observed during the first 2 or 3 months following tagging, rates of about 30% would have been observed for all species in both years. Comparisons of observed and adjusted exploitation rates with estimated rates of natural mortality indicated that overharvest of black bass is probably not occurring in Center Hill Reservoir.

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Sport fishing pressure is increasing steadily nationwide, and it has been predicted that black bass populations will be subjected to continually higher rates of fishing intensity (Martin 1974). Estimates of angler exploitation and total annual mortality are needed to determine if changes in regulations could improve fishing quality and prevent overharvest. Few estimates have been reported in the United States, and most have been only for largemouth bass. Annual exploitation rates ranged from 20 to 65% in California and from 5 to 50% in other states (Table 1).

The objective of this study was to estimate rates of angler exploitation for largemouth bass, smallmouth bass and spotted bass in Center Hill Reservoir, TN.

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METHODS AND MATERIALS

Center Hill Reservoir was impounded by the U.S. Army Corps of Engineers in 1948 for flood control and power generation. Center Hill Dam is located on the Caney Fork River, 52.8 km above its confluence with the Cumberland River at Carthage, Tennessee. Eight commercial boat docks and 10 recreational areas provide boating access to the reservoir.

The reservoir has a drainage area of 5,631 km^2, a total storage capacity of 2.58 x $10^9 m^3$, and an average depth of 28 m. At full pool elevation (209 msl), Center Hill covers an area of 9,332 ha with a shoreline of 668 km (Moss 1967). Water levels generally increase during January and February to an average of 196 m (msl) in March through May, and then decline from June through November to about 193 m (msl) in December.

Table 1. Published annual exploitation rates (%) throughout the United States for largemouth (LMB), smallmouth (SMB), and spotted bass (SPB).

	LAKE		SPECIES			
State	*Name*	*Surface Area* (ha)	*LMB*	*SMB*	*SPB*	*Source*
Ala.	·Guntersville		16			Miller (1950)
Ala.	Wheller		6-15			Hulse and Miller (1959)
Ark. and Mo.	Beaver	11,420	9-16			Bryant and Houser (1971)
Ark. and Mo.	Bull Shoals	18,400	7-14			Bryant and Houser (1971)
Calif.	Millerton	2,023	20			Fisher (1953)
Calif.	Clear	16,188	20			Kimsey (1957)
Calif.	Sutherland	117	36			La Faunce et al. (1964)
Calif.	Folsom	4,047	40			Rawstron (1967)
Calif.	Merle Collins	403	45-65			Rawstron and Hashagen (1972)
Calif.	Folsom	4,047	47			Rawstron (1974)
Calif.	Berryessa	8,094	58			Rawstron (1974)
Ga.	Allatoona	4,047			31	Kirkland (1963)
Ill.	Ridge	7	25-30			Kirkland (1963)
Ind.	Shoe	17	20			Ricker (1942)
Iowa	Big Creek		11-19			Paragamian (1976)
Mich.	Sugar Loak	73	37-50			Cooper and Latta (1954)
Minn.	Gladstone	195	15-16			Maloney et al. (1962)
Tenn.	Norris	1,005	19	19	19	Eschmeyer (1942)
Tenn.	Norris	1,005	5-21	15-24	30-40	Manges (1950)
Tenn.	Watauga	2,602	42	40		Chance (1955)
Tenn.	South Holston	3,069	41	42		Chance (1955)
Wisc.	Brown's	160	12			Mraz and Threinen (1955)

The lake is classified as eutrophic based upon phosphorus, nitrogen, and dissolved oxygen concentrations and hydraulic characteristics (U. S. Army 1975). Total phosphorus and nitrogen range from 0.0 to 0.32 mg/1 and from 0.2 to 1.2 mg/1, respectively. The reservoir becomes thermally and chemically stratified from March through November.

Bass over 203 mm total length were collected for tagging at night with a 230 Volt DC boom-type electrofishing unit. Floy FD-67 anchor tags were inserted on the right dorsal side of the fish near the middle of the dorsal fin (Dell 1968). Tags were brightly colored, numbered, and had the address where rewards could be obtained. Length, weight, date, and location of capture were recorded, and each fish was released near its capture site. Tags were applied from May 4 to 6, 1975, and from April 26 to 29, 1976.

Signs requesting fishermen to return tags were posted at access points on the lake, and announcements were made in news releases through local newspapers and radio stations. Questionnaires were sent to all fishermen that returned tags to obtain information about time and place of recapture.

In 1975, 5 tag colors were used and fishermen were informed of monetary values corresponding to each. White and yellow tags had no monetary value, but blue, green, and orange tags were worth $5, $10, and $15 rewards, respectively. In 1976, all tags were colored orange with randomly assigned reward values of $1 to $100. In this year, fishermen had no knowledge of tag values until they were returned.

Unpublished creel census data provided by Tennessee Wildlife Resources Agency were used to estimate the monthly catch of each species in 1975 and 1976. These estimates were used with the tag return data to evaluate tag retention, tagging mortality, and other factors affecting reliability of the exploitation estimates.

Chi-square tests were used to test for significant differences between frequency distributions of fish versus length or tag values. A row (R) by column (C) framework was utilized to test equality of frequency distributions between rows in the analysis. An overall chi-square statistic was first computed by using marginal totals of the RxC tables to calculate expected frequencies (Conover 1971), and when the overall chi-square indicated inequality of distributions, sources of inequality were analyzed by examining specific columns of the RxC table.

RESULTS

1975

Between 4 and 6 May 1975, 657 largemouth, 146 smallmouth, and 182 spotted bass were tagged. Total lengths for all species ranged from 203 to 545 mm, but the average length for spotted bass was significantly shorter than those for largemouth and smallmouth bass (Table 2).

The numbers of tags returned within 1 year indicated annual exploitation rates of 18.0, 13.0, and 14.8% for largemouth, smallmouth, and spotted bass, respectively (Table 2). Approximately 82 - 89% of the returns for each species were made during the first 3 months following tagging. Average lengths and length-frequency distributions (at tagging) for returned fish were not significantly different from those observed during the marking period, indicating no size-selective harvest by anglers.

Since the reward values of tags of different colors were publicly announced in 1975, the possibility of differential rates of return between tag values was evaluated by comparing value-frequency distributions at marking and return. For largemouth bass, there was a significant difference between value-frequencies because the rate of return of nonreward tags (12.2%) was significantly lower (Table 3) than rates for the reward tags (15.0 - 26.6%) Rates for the reward tags were not significantly different between tag values. A more appropriate estimate of annual exploitation for largemouth bass, based only on reward tags, would be 22.2%. For smallmouth and spotted bass, returns of nonreward tags tended to be lower than those for the other tags, but the differences were not significant (Table 3). The ability of the chi-square tests to detect differences between return rates of reward and nonreward tags for these species may have been hampered by the small number of returned tags.

Annual exploitation estimates based on returns of reward tags for largemouth bass (22.2%) and all returns for smallmouth (14.8%) and spotted bass (13.0%) were not significantly different at $p < 0.05$. The chi-square test, however, would have been significant at $p < 0.10$. The shorter average length of spotted bass probably was not an important source of variation between species because intra-species analyses consistently showed no size selectivity by anglers. Another chi-square test, based only on returns of reward tags, again showed no significant species differences, but the calculated chi-square was considerably lower than that from the initial test. This indicated that variability between return rates of nonreward tags was responsible for most of the variability between exploitation rates of the three species. The most appropriate estimates of annual exploitation, based only on tags with reward value, were 22.2, 15.6 and 18.5% for largemouth, smallmouth, and spotted bass, respectively. These rates will be used in all subsequent analyses and discussion.

1976

Between 26 and 29 April 1976, 1,165 largemouth, 325 smallmouth, and 486 spotted bass were tagged. Total lengths ranged from 203 mm to 586 mm, but as in 1975, the average length of spotted bass was significantly lower than those for the other species (Table 2).

Tag returns within 1 year indicated annual exploitation rates of 13.3, 12.9, and 12.3% for largemouth, smallmouth, and spotted bass, respectively. There were no significant

Table 2. Numbers, average total lengths (mm) and 95% confidence intervals (CI) of tagged and returned largemouth, smallmouth, and spotted bass in Center Hill Reservoir, 1975 and 1976.

Year Species	TAGGED FISH Number	TAGGED FISH Ave. Length (C.I.)	RETURNED FISH[a] Number	RETURNED FISH[a] Ave. Length (C.I.)	Estimated Annual Exploitation
1975					
Largemouth	657	325.6 (321.5-329.7)	118	328.9 (319.8-338.0)	0.180
Smallmouth	146	314.1 (302.7-325.5)	19	296.9 (267.4-326.4)	0.130
Spotted	182	266.3 (258.9-273.1)	27	272.8 (254.0-291.6)	0.148
1976					
Largemouth	1165	329.6 (326.3-332.9)	155	329.1 (321.2-337.0)	0.133
Smallmouth	325	278.1 (271.7-284.5)	42	283.2 (256.4-310.0)	0.129
Spotted	486	269.3 (265.4-273.2)	60	272.6 (262.5-282.7)	0.123

[a]The average lengths and confidence intervals for returned fish refer to their sizes at tagging.

Table 3. Number tagged, numbers returned, and percentages returned for largemouth, smallmouth, and spotted bass tagged during May 1975.

Species	TAG VALUE $0	$5	$10	$15	Reward Tag Total	Total
Largemouth						
Number Tagged	279	109	128	141	378	657
Number Returned	34	29	19	36	84	118
% Returned	12.2	26.6	15.0	25.5	22.2	18.0
Smallmouth						
Number Tagged	56	35	32	23	90	146
Number Returned	5	7	5	2	14	19
% Returned	8.9	20.0	15.6	8.7	15.6	13.0
Spotted						
Number Tagged	63	54	33	32	119	182
Number Returned	5	10	3	9	22	27
% Returned	7.9	19.1	9.1	28.1	18.5	14.8

differences in exploitation between species. Approximately 86 - 95% of all tag returns were made within three months following tagging, and comparisons of average lengths and length-frequency distributions for tagged and returned fish again indicated no size-selective harvest by anglers.

The revised reward procedure in 1976 eliminated the effect of the anglers' bias against returning tags of no value. Chi-square tests showed no significant differences between value-frequencies at marking and return.

Inter-Year Comparisons

For all species, exploitation rates estimated from the 1975 tagging period were higher than those of 1976, but the only significant difference ($p < 0.05$) was between the rates of 22.2% for largemouth bass in 1975 versus 13.3% in 1976 (Table 4). Lower rates in 1976 may have been partly due to reduced fishing pressure at 253,790 man-hours between May 1975 and April 1976 compared with 216,335 between May 1976 and April 1977. The 1976-77 effort was about 85% of the 1975-76 value, and the 1976 exploitation estimates were 60, 83, and 66% of the 1975 values for largemouth, smallmouth, and spotted bass, respectively.

Table 4. Comparisons of estimated exploitation rates for largemouth, smallmouth, and spotted bass between 1975 and 1976 tagging studies. Values for 1975 are from reward tags only.

	YEAR		
Species	*1975*	*1976*	*Calculated Chi-Square* (1 d.f.)
Largemouth			
Number Tagged	378	1165	
Number Returned	84	155	5.39*
% Returned	22.2	13.3	
Smallmouth			
Number Tagged	90	325	
Number Returned	14	42	0.47
% Returned	15.6	12.9	
Spotted			
Number Tagged	119	486	
Number Returned	22	60	2.10
% Returned	18.5	12.3	

*Indicates that the percentages returned were significantly different between years ($p < 0.05$).

Average lengths at tagging for largemouth and spotted bass were not different between 1975 and 1976, but the average length of tagged smallmouth bass was signficantly higher in 1975 (314 mm) than in 1976 (278 mm). For all species in both years, length-frequencies of returned fish were not significantly different from frequencies at tagging, which indicated that differences in exploitation rates between years were probably not related to the sizes of fish tagged. Rawstron (1967) also found no significant differences between length frequencies of tagged and returned largemouth bass.

DISCUSSION

Violations of assumptions of no tag loss, differential mortality, or increased angling vulnerability after tagging could have affected exploitation estimates in this study. Declines in tag returns beyond 2 or 3 months after tagging suggested that one or more of the above factors was important. Graphs of the number of recaptures (R) divided by estimated catch rates (C) from creel survey data for each species showed maxima during the first or second month after tagging in both years (Fig. 1). The R/C ratios should have remained nearly constant throughout each annual period if all assumptions were satisfied.

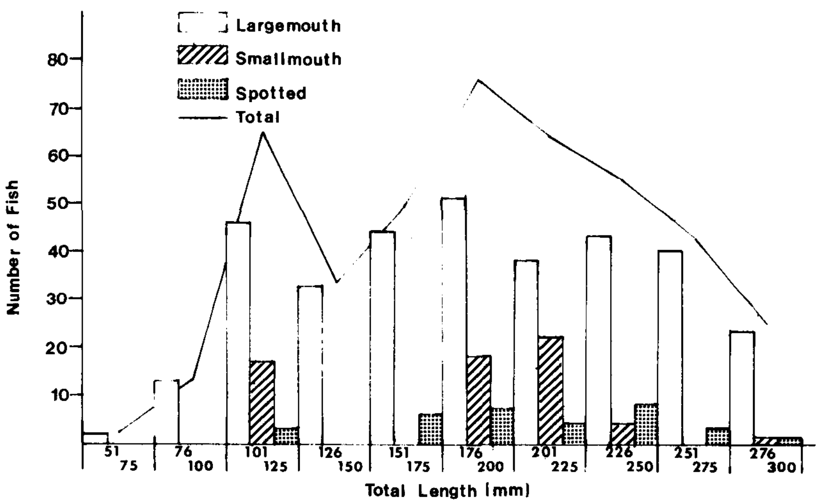

Fig. 1. The number of tagged recaptures (R) expressed as a proportion of the estimated angler catch (C) for 12-month periods following tagging in 1975 and 1976.

From available data, it was not possible to simultaneously evaluate or separate the effects of tag loss, increased vulnerability, or increased mortality. If significant tag loss and (or) differential mortality occurred, estimated exploitation rates would be lower than the true rates. If vulnerability to angling was increased by tagging, the estimated rates would be higher than actual rates.

Published evaluations of the FD-67 tag indicate that poor retention is the most serious problem associated with this marking technique. Pritchard et al. (1974) reported that only 33.3 - 43.3% of FD-67 tags used on largemouth bass were retained after three months and that retention was only 10.0 - 24.0% after nine months. Wilbur and Duchrow (1972) found that 74% of largemouth bass marked with the FD-67 tag retained the mark after three months. Pritchard et al. (1974) also indicated that largemouth bass mortality may have been increased by tagging. They reported mortalities, after 12 months, of 63% for tagged and 45% for untagged bass.

The sensitivity of annual exploitation estimates to violations of the above assumptions was evaluated by assuming that either increased angling vulnerability or tag loss and differential mortality were responsible for the maximum R/C values observed shortly after tagging. If vulnerability was increased, the R/C ratios soon after tagging were too high, and ratios should have remained at levels approximately equal to the July-August R/C values in both years (Fig. 1). If these ratios had been observed throughout each 12-month period after tagging, exploitation rates for each species wold have been about 12% in 1975 and 10% in 1976. If, however, the maximum R/C ratios during May or June were due to subsequent tag loss and (or) differential mortality, the R/C ratios should have remained at values consistent with those observed soon after tagging. If these levels had been observed throughout each 12-month period after tagging, estimated annual rates in both years would have been about 37% for largemouth bass, 31% for smallmouth bass, and 29% for spotted bass.

Since tag loss, differential mortality, and increased vulnerability could have occurred simultaneously, it is likely that actual exploitation rates were intermediate within the ranges indicated by the above estimates. Most published evidence suggests that tag loss and differential mortality are most important, thus, estimates based on 12 months of tag returns were probably too low in both years. Rates of approximately 30% for each species are probably more accurate estimates of true exploitation in Center Hill Reservoir.

Published exploitation rates for largemouth bass (excluding those from California) are comparable to the ones calculated in this study (Table 1). California rates tended to be higher than in other areas, which may be due to greater fishing effort. The calculated annual rates of 22.2% in 1975, 13.3% in 1976, and the revised estimate of 37% for largemouth bass in the present study are comparable to rates reported by Eschmeyer (1942) and Manges (1950) for Norris Reservoir, Tennessee (Table 1). Chance (1955), however, reported somewhat higher rates (41% and 42%) for largemouth bass in South Holston and Watauga Reservoirs, Tennessee. Rates for smallmouth and spotted bass in Center Hill Reservoir are slightly lower than values reported by other investigators.

The potential impact of fishing on bass populations was evaluated by comparing estimated rates of exploitation with total mortality rates calculated from samples collected during two previous studies on Center Hill Reservoir (Coomer 1976, Hargis 1965). Coomer reported total annual mortality rates of 62%, 53%, and 85%, for largemouth, smallmouth, and spotted bass over 203 mm total length, respectively, and Hargis reported rates of 56% for largemouth, 71% for spotted, and 76% for smallmouth bass. The approximate total annual mortality rate for each species was obtained by averaging estimates from these studies, which gave rates of 58, 75, and 78% for largemouth, smallmouth, and spotted bass, respectively.

Annual exploitation rates (u) estimated in this study and total annual mortality rates (A) obtained from Hargis (1965) and Coomer (1976) were used to calculate natural mortality rates (v) from:

$$v = A - u.$$

This formula is applicable when fishing and natural mortality operate concurrently (Ricker 1975).

Estimated exploitation rates from 1975 and 1976 were averaged, and the natural mortality rate was calculated for each species (Table 5). Exploitation ranged from 24 to 41% of natural mortality, indicating that the fishery was not a predominate cause of black bass mortality. When based on the assumption that R/C declined due to tag loss or differential mortality, exploitation estimated for smallmouth and spotted bass was less than natural mortality, but exploitation of largemouth bass was 180% of natural mortality. (Table 5).

Previously published studies indicate that overharvest of black bass is indicated only when fishing mortality is considerably higher than natural mortality. Kimsey (1957) reported that overharvest of largemouth bass was not a problem in Clear Lake, California, which had an estimated annual exploitation rate of 20% and a natural mortality rate of 36% (Table 6). He also stated that an exploitation rate of 40% would not have been excessive. La Faunce et al. (1964) concluded that a 40% rate of exploitation was

Table 5. Total annual mortality, exploitation rates, and natural mortality rates for largemouth, smallmouth, and spotted bass in Center Hill Reservoir, Tennessee.

Species	*Total Annual Mortality* (A)	*Exploitation Rate* (u)	*Natural Mortality* (v)	*u/v*
Original Estimates[a]				
Largemouth	0.58	0.17	0.41	0.41
Smallmouth	0.65	0.14	0.51	0.27
Spotted	0.78	0.15	0.63	0.24
Estimates Assuming Tag Loss and (or) Differential Mortality				
Largemouth	0.58	0.37	0.21	1.76
Smallmouth	0.65	0.31	0.34	0.91
Spotted	0.78	0.29	0.49	0.59

[a]Exploitation rates (u) used here are averages of 1975 and 1976 estimates, using reward tags only.

not harmful to a bass population having a total annual mortality of 70%. Rawstron and Hashagen (1972), however, reported possible overharvest in Merle Collins Reservoir, California, when exploitation rates ranged from 36% to 65% and natural mortality ranged from 11% to 56% over a five year period (Table 6). It appears, therefore, that annual exploitation rates as high as about 30% would not indicate overharvest of black bass in Center Hill Reservoir.

This study indicates that evaluations of tag loss, differential mortality, and effects of tagging on angling vulnerability should parallel studies using the tag-and-reward method. This supplementary information would provide more accurate evaluations of exploitation and angler impact on fish populations. The 1975 study also indicated that public knowledge of tag values biased exploitation estimates, suggesting that a random reward system like that used in 1976 should be routinely employed.

Table 6. Published relationships between fishing and natural mortality for largemouth bass.

Location	*Fishing Mortality*	*Natural Mortality*	*Source*
Clear Lake, Calif.	0.20	0.36	Kimsey (1957)
Sutherland Res., Calif.	0.36	0.34	La Faunce et al. (1964)
Merle Collins Res., Calif.			
1965	0.36	0.56	Rawstron and Hashagen (1972)
1966	0.45	0.26	
1967	0.62	0.24	
1968	0.65	0.11	
1969	0.65	0.21	

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