ESTIMATING RATE OF EXPLOITATION FROM TAG RETURNS AND FISHING EFFORT

R. B. REED, Department of Fisheries and Allied Aquacultures, Agricultural Experiment Station, Auburn University, Auburn, AL 36849
W. D. DAVIES, Department of Fisheries and Allied Aquacultures, Agricultural Experiment Station, Auburn University, Auburn, AL 36849

Abstract: A method was developed for estimating rate of exploitation from the rate of decline in catch per unit effort of tagged fish. The method was used to estimate exploitation of largemouth bass *(Micropterus salmoides)* at a 75-ha Chambers County Public Fishing Lake, Alabama. Fishing effort directed towards largemouth bass was estimated from an access creel survey employing nonuniform probability sampling. The estimated 58 percent rate of exploitation agreed well with an independent estimate made using catch records and an estimate of the number of harvestable-sized (> 249 mm total length) bass in the population.

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A number of states have built public or community lakes to augment fishing from reservoirs and natural waters. Typically, these lakes are small (< 100 ha) and have been stocked with combinations of largemouth bass *(Micropterus salmoides)* and bluegill *(Lepomis machrochirus)* (Hackney 1975). Channel catfish *(Ictalurus punctatus)* have been routinely stocked along with bass and bluegill in Missouri public lakes (Graham 1974). In Alabama public lakes, bass-bluegill stockings have been supplemented with stockings of channel and white catfish *(Ictalurus catus)* redear sunfish *(Lepomis microlophus)* and in some cases, threadfin shad *(Dorosoma petenense)* (Byrd and Crance 1965, Powell 1975).

Public and community lakes are often subject to intense fishing pressure. Rassmussen and Michaelson (1974) reported fishing pressures of 121-202 hrs/ha/yr on some Missouri public lakes. In Alabama, 20 public fishing lakes received an average fishing pressure of 55 angler trips/ha/yr or 192 hrs/ha/yr during the period 1950-1964, while individual lakes averaged up to 94 angler trips/ha/yr or 329 hrs/ha/yr (Byrd and Crance 1965). More recently, Powell (1975) reported fishing pressure had increased to over 121 angler trips/ha/yr on at least 1 of these lakes. As the number of licensed anglers and the cost of gasoline to travel to the more remote reservoirs increase, fishing pressure on public and community lakes will likely increase.

Changes in community structure and reductions in fishing quality have long been associated with excessive bass harvest in small impoundments. Frequently, excessive bass harvest has been reported in lakes recently opened for fishing. While excessive bass harvest has been reported less frequently in established systems, the high fishing pressure on some public lakes suggests that bass may be over harvested. Further increases in fishing pressure will make over harvest more probable.

According to Anderson (1974), largemouth bass populations with good growth may be classified as management problems when there is: 1) adequate recruitment and high mortality, or 2) low recruitment and low mortality, or 3) low recruitment and high mortality. Given that recruitment is generally adequate in managed public lakes whether through spawning or stocking, mortality then becomes the primary concern for management. Since the fishing mortality component of total mortality is generally considered to be the most amenable to management (Anderson 1974), the exploitation rate of largemouth bass assumes primary importance in the formulation of a management strategy.

Quantification of the exploitation rate is often a problem for fishery managers in that estimates of an initial population and subsequent catch from that population are either unavailable or imprecise. In this paper, we present a method for determining the rate of exploitation from tag returns and creel survey data. The method is general in that tagging can be conducted over an extended period of time. When coupled with an independent estimate of survival, a complete breakdown of all sources of mortality can be obtained.

METHODS

Chambers County Public Fishing Lake is a 75-ha impoundment near Lafayette, Alabama, built and managed by the Alabama Department of Conservation and Natural Resources. Opened for fishing in June 1963, the lake has received an average annual fishing pressure of 31 angler trips/ha. During the period 1975-1979, average annual fishing pressure was 33 angler trips/ha and average annual bass harvest was 2.9 fish/ha weighing 0.9 kg each.

Management procedures for Alabama public fishing lakes were discussed by Byrd and Crance (1965) and Powell (1975). These include fertilization, liming, and periodic balance checks using seining techniques described by Swingle (1956). Fishing permits (currently $1.50/day) are required for those 12 and older. Daily creel limits are 6 largemouth bass, 20 bream (bluegill and redear combined), 6 catfish, 50 crappie, and 2 hybrid striped bass. There are no length restrictions. Fishermen are required to have their catch recorded by the resident lake manager before leaving the lake.

Largemouth bass were sampled on 5 occasions during the period March 30, 1979, to May 5, 1979. Sampling was conducted during daylight hours using half-wave, pulsed direct current. Harvestable-sized bass, those longer than 249 mm total length (TL), were tagged with individually numbered spaghetti tags (FloyFT-4, lock on). Tags were inserted below the soft dorsal between the interneural bones. The resident lake manager retained tags from harvested bass and these were picked up weekly.

An access creel survey was conducted at Chambers County lake during April-September 1979. The objective of the creel survey was to estimate, on a monthly basis, effort directed toward largemouth bass as a function of the number of fishing permits issued. Malvestuto et al. (1978) suggested nonuniform probability sampling as a means of improving survey precision and this technique was employed. Monthly sampling probabilities were assigned based on the standard deviation of the number of fishing permits issued for the respective month during the years 1964-1978. Sampling units were days the lake would be open for fishing. Sampling units were stratified into weekdays (Monday through Friday) and weekends (Saturday, Sunday, and holidays) and a total of 11 days were randomly chosen for sampling from each stratum. Within each stratum, the probability of a given day being chosen for sampling was the monthly probability divided by the number of sampling units in the stratum for the month.

On sampling dates the creel clerk would arrive at the lake before fishermen began leaving and remain until closing. As fishermen left the lake they were questioned as to time spent fishing for each of 3 species categories: 1) largemouth bass, 2) bream and crappie, and 3) catfish. Except where indicated otherwise by the anglers, total effort was divided equally among the target species. For each sampling date, total effort for all species categories was divided into total bass effort. This result was multiplied by the mean trip length to give an estimate of bass effort per permit issued (BEPP) for the date. Monthly estimates of BEPP were computed as the weighted mean of BEPP for all sampling dates in the month. The number of fishermen interviewed on a sampling date was used as the weighting factor.

Weekly catch per unit effort (CPE) values for tagged bass were computed for the 24-week period March 30, 1979, through September 19, 1979:

CPEw = CTw / (BEPPj X Pw)

where CPEw = catch per unit effort of tagged bass during week w,

CTw = catch of tagged bass during week w,

Pw = number of permits issued during week w, and

BEPPj = bass effort per permit issued for the month in which week w begins.

When the natural log of CPEw (lnCPEw) is regressed against time, the slope of the regression line, with sign changed, is an estimate of the weekly instantaneous rate of disappearance (Z'w). Because tagging of bass continued through week 6, CPEW for weeks 1 through 5 was adjusted for the lesser number of tagged fish available for harvest during these weeks:

CPEwadj = CPEw X N'6 / N'w

where CPEwadj = catch per unit effort of tagged bass during week w adjusted for the number of tagged bass available for harvest and

$N'w = \frac{1}{2} \sum Ti\{\exp[-Z'w(i-i) + Z'w(l-2)]\}$

where Z'w = -slope of the regression of CPEw vs time,

i = weeks

T1 = 122 = number of tagged bass released at the start of week 1,

T2 = 167 = number of tagged bass released at the start of week 2,

T3 = 0 = number of tagged bass released at the start of week 3,

T4 = 59 = number of tagged bass released at the start of week 4,

T5 = 61 = number of tagged bass released at the start of week 5, and

T6 = 59 = number of tagged bass released at the start of week 6

for all $i-x > 0$

where x = 1,2,3,. . . . .,24.

If $i-x < 0$, $\exp(-Z'w(i-x)) = 0$.

LnCPEw (weeks 1-5 adjusted, weeks 6-24 unadjusted) was then regressed against time to give a second approximation of Z'w. This approximation was used to adjust CPEw's for weeks 1 through 5 as above. The procedure was repeated until successive approximations of Z'w were the same.

Weekly instantaneous rates of fishing mortality (Fw) were calculated as proposed by Van Den Avyle (1979):

$$Fw = CTw / N'w.$$

The weekly rates were summed to give an estimate of F for the 24-week period.

Using an estimate of the annual instantaneous rate of mortality (Z) for harvestable-sized bass (Reed 1980), the weekly instantaneous rate of mortality (Zw) was estimated:

$$Zw = Z / 52.$$

The exploitation rate for the 24-week period was then estimated:

$$\mu 24 = [(F_{24}) (Aw)^{24}] / 24\ Zw$$

where Aw = 1-exp (-Zw).

RESULTS AND DISCUSSION.

Effort directed toward largemouth bass per angler was greatest in April and September and least in June and July (Table 1). Although an attempt was made to interview each fishermen using the lake on a sampling date, boat fishermen were interviewed more successfully than bank fishermen. The former group fished for bass more than the latter so the survey results should be regarded as maximum estimates of bass effort.

Table 1. Effort directed toward largemouth bass at Chambers County Lake, per permit issued April through September 1979, as determined by creel survey.

Month	Effort (hrs) directed toward largemouth bass per permit issued
April	0.509 a
May	0.354 ab
June	0.269 b
July	0.256 b
August	0.372 ab
September	0.393 ab

a,b Values followed by the same letter are not significantly different (Duncan's multiple range test P = 0.05).

Table 2. Weekly catch (CTw) and number of permits issued (Pw), catch per unit effort (CPE), average number present (N'w) and instantaneous rate of fishing mortality (Fw) for tagged bass at Chambers County Lake for the period March 30, 1979, through September 13, 1979.

Week	CTw	Pw	CPEw[1]	N'w	Fw
1	6	590	0.07	119.1	0.05
2	22	675	0.09	277.0	0.08
3	5	759	0.02	264.3	0.02
4	15	619	0.06	309.9	0.04
5	24	678	0.08	355.4	0.07
6	10	597	0.05	396.9	0.02
7	7	587	0.03	378.7	0.02
8	14	537	0.07	361.4	0.04
9	17	523	0.09	344.9	0.05
10	6	535	0.02	329.1	0.02
11	3	453	0.03	314.1	0.01
12	4	441	0.03	299.8	0.01
13	5	361	0.05	286.1	0.02
14	4	490	0.03	273.0	0.01
15	2	431	0.02	260.5	0.01
16	4	315	0.05	248.6	0.02
17	5	253	0.08	237.3	0.02
18	2	190	0.04	226.4	0.01
19	1	236	0.01	216.4	0.00
20	8	225	0.10	206.2	0.04
21	2	187	0.03	196.8	0.01
22	2	175	0.03	187.8	0.01
23	1	331	0.01	179.3	0.00
24	1	149	0.02	171.1	0.00

[1]weeks 1-5 adjusted for the lesser number of tagged fish available for harvest (tagging of bass not completed until week 6).

Fig. 1 is a plot of LnCPEw vs time for tagged bass. The ascending portion of the curve, through week 6, reflects the addition of tagged bass to the population during this period. That portion of the plot corresponding to weeks 6-24 has a slope of -0.0567. This initial estimate of Z'w stabilized at 0.0467 after four iterations. Fig. 2 is a plot of lnCPEw vs time with the CPEw's for weeks 1 through 5 adjusted. The slope of the regression line differs from zero at the 5 percent level of significance.

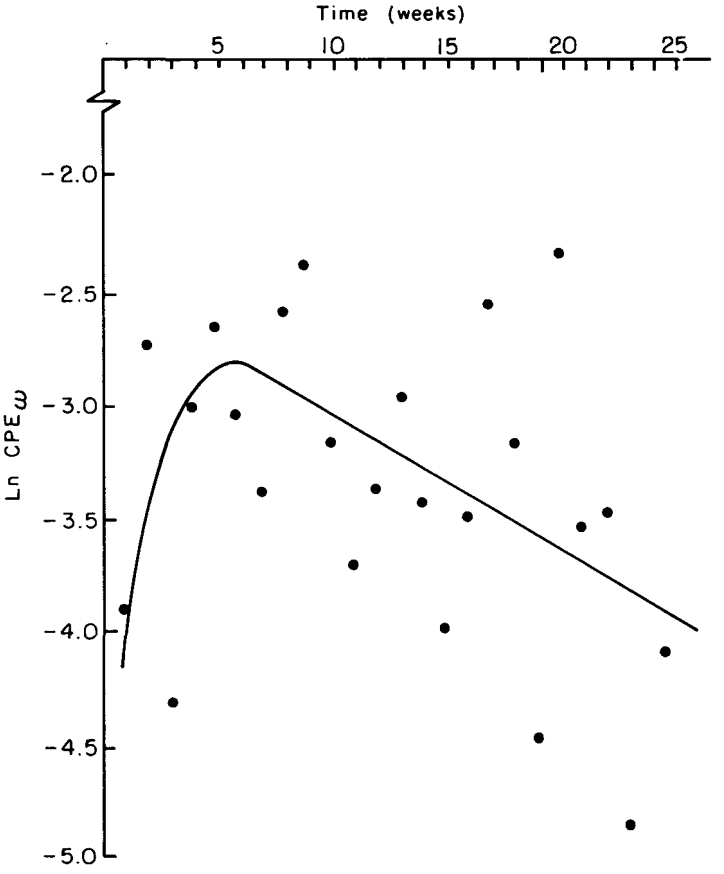

Fig. 1. Natural log of weekly catch per unit effort VS time for tagged bass at Chambers County Lake for the period March 31, 1979 through September 13, 1979.

Table 2 shows the estimates of Fw determined from the catch of tagged bass and the estimated number of tagged fish in the population. The exploitation rate of tagged bass for the 24-week period was 0.43. The apparent exploitation rate for the same period obtained by dividing the number of tagged fish caught by the number of fish tagged was 0.36.

Expansion of the results for the 24-week period to an annual basis can be done by dividing the estimated exploitation rate by 0.75, the proportion of total bass harvest for 1979 that occurred during April-September. The annual exploitation rate thusly calculated is 0.58. An independent estimate of the exploitation rate can be made by dividing the estimated number of harvestable-sized bass, 2368, (Reed 1980) into the catch for the 12-month period following the population estimate, 1370 bass. The estimated rate of

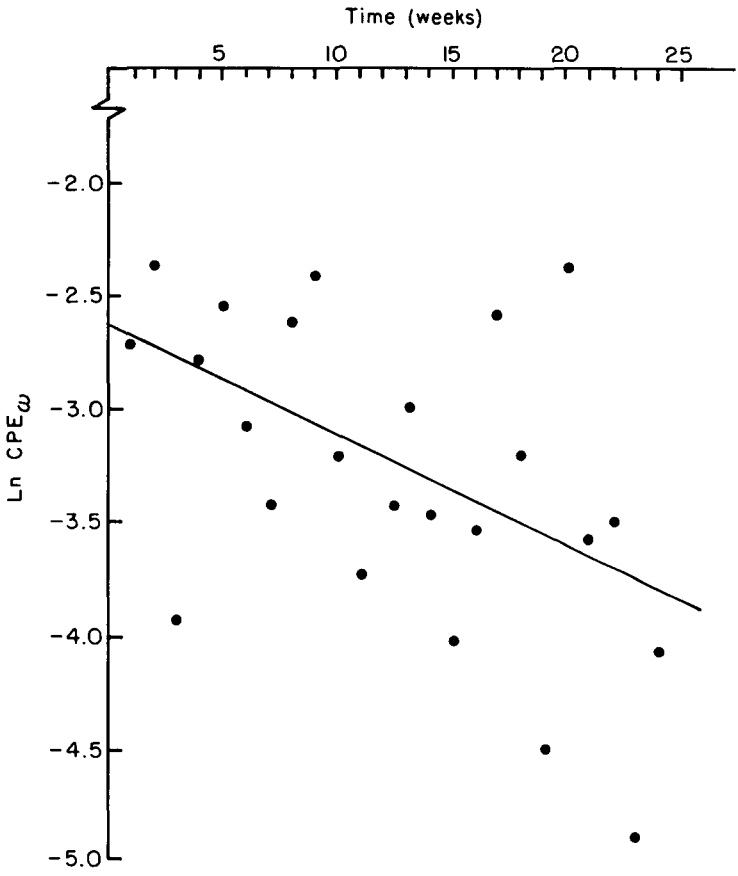

Fig. 2. Natural log of weekly catch per unit effort VS time for tagged bass at Chambers County Lake for the period March 31, 1979 through September 13, 1979 with LnCPEw for weeks 1 through 5 adjusted.

exploitation by this method is also 0.58. The annual expectation of natural death (v) is the difference between the exploitation rate and 0.79, the annual mortality rate, or 0.21. The difference between Zw and Z'w, 0.016, is an estimate of the weekly instantaneous rate of tag loss.

In addition to the advantage of being able to tag fish over an extended period of time, estimation of the exploitation rate from tag returns and fishing effort offers another, more significant advantage over estimating exploitation rate from a population estimate and catch statistics. Whereas the information gained from the latter method is limited to an estimate of the exploitation rate, the former method results in a complete breakdown of all sources of mortality and gives information as to the seasonal distribution of fishing mortality.

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