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The Exploitation, Harvest, and Abundance of Largemouth Bass Populations in Three Southeastern Michigan Lakes

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THE EXPLOITATION, HARVEST, AND ABUNDANCE OF LARGEMOUTH BASS POPULATIONS IN THREE SOUTHEASTERN MICHIGAN LAKES*

By Greg W. Goudy

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ABSTRACT

Fishing pressure, exploitation, growth, mortality, harvest, population size-age structure, and abundance of largemouth bass (Micropterus salmoides) were measured in Pontiac, Whitmore, and Kent lakes in southeastern Michigan. The effects of a change in the minimum size limit from 254 mm to 304 mm in 1976, and a 200% increase in bass fishing pressure from the levels of 30 years ago, on bass populations were evaluated. Despite annual fishing pressure as high as 472 hours per hectare, producing exploitation rates ranging from 18% to 48% and total mortality rates from 31% to 53%, one bass population contained 22% more bass 254 mm and larger (20.2 bass per hectare) now than 30 years ago. There was a significant catch-and-release fishery of sublegal bass with from 200% to 600% more bass being caught and released than harvested. Though there was a greater percentage of large bass harvested than in the past, the number of bass harvested by anglers has fallen 25% and catch rates for harvested bass have dropped considerably to an average of 0.06 bass per hour.

Creel census clerks used a questionnaire to obtain angler opinions on bass fishing in Michigan. Seventy-seven percent of 1,113 fishermen interviewed responded that they fish for bass in Michigan at least once a year. Of the 862 bass anglers questioned, 27% reported that they usually release their catch. If there was catch-and-release fishing prior to the season opening, 58% of the bass anglers would approve delaying the opening of the bass season from late May until July 1 in order to increase

the size of bass available for harvest. Fifty-two percent of the bass anglers would rather catch one large bass than four small (but legal size) bass. Fishermen reported catching more bass but keeping fewer as a result of the size limit change. However, most anglers were happy with the new regulation citing that though they were keeping fewer bass, they were catching more large bass than before.

INTRODUCTION

No game fish is sought more often in Michigan's inland waters than the largemouth bass (*Micropterus salmoides*) and its popularity increases continually. The total estimated combined catch of largemouth bass and smallmouth bass (*Micropterus dolomieui*) from Michigan waters in 1978 was 4.4 million, of which most were largemouth (Michigan Sport Fishing Survey 1978). This study was conducted to obtain current information on the harvest and rate of exploitation of largemouth bass populations in Michigan lakes; the last Michigan studies of this type were done 20 to 30 years ago. Additionally, bass population dynamics were examined in terms of abundance, growth, mortality, and size-age structure.

Latta (1974) evaluated Michigan's fishing regulations for largemouth bass with Ricker's (1958) yield equation using state average rates of growth, mortality, recruitment, and exploitation. The results showed that for the average annual exploitation rate of 35%, the greatest harvest in weight occurred with a minimum size limit of 254 mm. However, with an increase in exploitation, the greatest harvest occurred at a 304-mm length limit. Therefore, because a continuous increase in fishing pressure was suspected, in 1976 the minimum size limit was raised from 254 mm to 304 mm in an attempt to maximize yield and protect spawning stocks.

The largemouth bass populations in three southeastern Michigan lakes were examined with a bass tagging program and a May-through-October creel census at each lake: (1) to evaluate how the size limit change has affected bass populations; (2) to assess the degree to which fishing pressure has increased in the last 20 to 30 years and whether exploitation rates have risen as a result; and (3) to determine angler opinions on bass fishing in Michigan.

METHODS AND MATERIALS

Study Sites

It was determined that an ideal lake for the purposes of this project would exhibit the following characteristics:

1. Contain an average or good population (in terms of abundance and growth) and fishery for largemouth bass;
2. Have a limited number of access points so it could be censused easily and thoroughly;
3. Would be 100 to 400 ha in size (a lake in this range could have a significant bass population and fishery but not be so large as to make it impractical to catch and tag enough bass for statistically valid data);
4. Have areas where bass concentrate so they could be readily caught and tagged;
5. Have cooperative anglers so tag returns would be maximal;
6. Have prior information on fishing pressure, harvest, etc. for comparison; and
7. Be suitable for bass fishing tournaments.

Pontiac, Whitmore, and Kent lakes were chosen for this study based on the above criteria. All three lakes are located on the outer fringes of the Detroit metropolitan area in southeastern Michigan and are considered to be representative of southern Michigan waters.

Pontiac Lake, in Oakland County, has an area of 237 ha but a maximum depth of only 11 m with 80% of the lake being 3 m or less in depth. The lake is a shallow-water impoundment with several islands and a dendritic shoreline characteristic of such bodies of water. Situated at the headwaters of the Huron River, the lake was enlarged to its present size in 1924 by a dam placed at the lake's outlet. Residential dwellings line most of the shoreline.

Whitmore Lake, in Washtenaw and Livingston counties, is a 274-ha natural lake with an oval outline. This lake is the deepest of the three with a maximum depth of 20.7 m and only half the lake being less than 3 m deep. Like Pontiac Lake, Whitmore Lake is bounded by residential homes and summer cottages.

Kent Lake, also located in Oakland County, is the largest of the three lakes with an area of 405 ha and a maximum depth of 11.4 m. It, too, is a shallow-water, dendritic impoundment on the Huron River with 70% of its area less than 3 m in depth. Located 28 km downstream from Pontiac Lake, the present Kent Lake was created when a dam was built in 1947 and the impounded Huron River inundated the original 24-ha lake. In contrast to the other lakes, Kent Lake is entirely surrounded by park land providing more opportunities for the public to fish from shore.

Bass Tagging

Largemouth bass were collected in each lake prior to the 1980 bass fishing season during a 4-week period extending from mid-April through mid-May. The first objective was to obtain a representative sample of largemouth bass for age and size frequency analyses. The second objective was to tag one legal size bass per hectare before the bass fishing season opened: (1) to make an initial population estimate through mark-and-recapture methods; and (2) to provide a means to determine exploitation rates by using tag returns obtained through the creel census.

Both electrofishing equipment and trap nets were used to collect the fish in order to minimize any gear selectivity. From 6 to 12 trap nets were set and run daily for a 5-day period in each lake. Electrofishing was originally tried during the day but this met with little success and a switch was made to night sampling with much better results. Most bass were caught at night by electrofishing shallow shoreline areas with a boom-type electroshocker powered by a 3-phase, 230-volt, alternating-current generator. The entire shoreline of each lake was electrofished once before any sections were sampled a second time, though in all instances it took more than one night to cover the lake. Very few areas were electrofished more than twice.

Captured bass were anesthetized with MS 222 anesthetic to facilitate handling during the tagging process. All largemouth and smallmouth bass, northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), and tiger muskellunge (*Esox lucius* X *Esox masquinongy*) collected were measured to the nearest millimeter total length and scale sampled for later age and growth determinations. Each fish in a representative sub-sample was weighed to the nearest 0.01 kg. Bass 250 mm and larger, northern pike and walleye 400 mm and larger, and tiger muskellunge 600 mm and larger, were tagged beneath the soft dorsal fin with a sequentially numbered Floy FD-68B anchor tag such that the T-bar anchor end of the tag was inserted between the interneural bones of the fin. The posterior portion of the soft dorsal fin was clipped as a secondary or back-up mark to provide a means of determining the rate of tag loss. The soft dorsal clip was used as it was felt this would be most noticeable to the creel census clerks checking for a tag in that area. All fish were released immediately after tagging, usually not more than 100 m from the point of capture. By the end of the 4-week sampling period a total of 1,064 largemouth bass, 92 smallmouth bass, 110 northern pike, 9 walleye, and 4 tiger muskellunge had been tagged in the three lakes.

A second series of electrofishing runs was made along the shoreline areas of each lake during a 1-week period in August to gain additional recapture information for population estimates. The same procedures were used as during the April-May sampling period in terms of fish collection, measurement, and taking of scales, but this time no fish were tagged.

Creel Census

A uniformed creel census clerk was stationed at each lake on a 5-day-per-week random schedule for 40 hours per week from May 15 through October 31, 1980, in order to interview anglers, examine their catch, and make periodic counts of the number of anglers fishing. For all practical purposes that time frame covered the entire bass fishing season on inland lakes in Michigan. All three clerks worked by the same census schedule so that the census would be uniform among lakes. The schedule was arranged so that in addition to the census days being randomly selected, all hours from 1/2 to 1 hour before sunrise to 1/2 to 1 hour after sunset on any particular census day were randomly sampled. Counts were made of the number of shore anglers and the number of fishing boats (boats with people actively fishing) at each lake twice a day; again the times were chosen randomly.

Angler hours and their variances were calculated for each time stratum (weekends and weekdays) in each month for each kind of fishing (boat and shore). Fishing hours per trip were obtained from each census interview and a monthly mean determined. The hours-per-trip mean was multiplied by the mean number of anglers for each stratum and the totals summed to obtain the total number of angler hours for each month.

The clerks were instructed to wait until anglers had finished fishing for the day before approaching them for an interview. The angler was asked a series of standard creel census questions involving residency, fishing method, bait used, species sought, and time fished. The total length of each fish kept was measured to the nearest millimeter. If there were a large number of any particular species, a random sample of 15 fish was selected for measurement. Bass, northern pike, tiger muskellunge, and walleye were examined for tags or fin clips. Additionally, each angler was asked if he ever fished for bass in Michigan. If so, he was asked a series of questions from a special bass fishing questionnaire which will be discussed later.

Catch estimates and their variances were calculated separately, by species, for each time stratum (weekends and weekdays) in each month for each kind of fishing (boat and shore). Catch-per-hour information was obtained from each census interview and a monthly mean determined for each species. The catch-per-hour mean was multiplied by the number of angler hours for that month to get a monthly harvest estimate.

The creel census clerks also recorded all bass caught in several bass fishing tournaments (five tournaments at both Kent and Whitmore, three at Pontiac). At the conclusion of each tournament all bass were measured to the nearest millimeter total length, weighed to the nearest 0.01 kg (sometimes to the nearest ounce), and checked for a tag or fin clip before being returned to the lake. No additional bass were tagged or fin clipped.

The clerks gave fishing diaries to those anglers who said they fished the study lakes once a week or more and were interested in recording their fishing activity and catch for the project. Each diary was provided with an attached pencil and instruction page. Anglers were instructed to do the following: (1) to record lake, date, hours fished, and number of anglers in the party; (2) to record all (small, large, tagged or not) largemouth bass, smallmouth bass, northern pike, walleye, and tiger muskellunge caught by their party; (3) to record species, lengths, tag numbers, and if fish were kept or released; (4) not to remove tags from fish which were to be released; and (5) to return the diary by November 1 to the address listed on the instruction page.

Age and Growth

Scales taken from bass collected during the spring tagging operation and the August sampling runs were put through a roller press and impressions made on cellulose acetate slides for age and growth determinations. Scales were read on a microprojector at a magnification of 44X. The distance from the focus to each annulus and to the scale margin was recorded in millimeters, key punched onto computer cards, and read into a computer file.

Separate scatter plots of the bass body length to scale radius relationship at each lake were produced by computer and from visual inspection all plots were determined to be linear. A regression line of length against radius for each scatter plot was fitted by computer using the method of least squares (Neter and Wasserman 1974). Since previous studies have shown the body-scale relationship to remain the same regardless of the time of year the scales are obtained (Carlander 1977), scale and length measurements from the spring and summer sampling periods were combined to increase the sample size at each lake.

A computer program using the Fraser modification of the direct proportion back-calculation procedure (Bagenal 1978) was used to back-calculate lengths at time of annulus formation. This formula can be expressed in the following form:

$$L_n = a + \frac{S_n}{S_c} (L_c - a)$$

where: L_n = length of fish when annulus n was formed

L_c = length of fish at capture

S_n = radius of annulus n

S_c = total scale radius

a = intercept from regression of length on radius

The Fraser modification takes into account the intercept value of a regression line when making length calculations, and as a result, is more accurate than the simple direct proportion method when the regression line does not pass through the origin (when the intercept is zero the formula reverts to the simple direct proportion form). In several largemouth bass studies the body-scale relationship has been shown to be a straight line through the zero intercept, but the Fraser type correction has also been used in many studies (Carlander 1977).

The value of "a" has often been interpreted as the length of the fish at the time of scale formation, when actually it is the intercept that will give the best straight line relationship (Carlander 1977). Intercept values for largemouth bass have been reported by Carlander (1977) to range from 0-64 mm. Scale formation generally occurs at 18-26 mm (Heidinger 1976).

Population Estimates

Population estimates for largemouth bass in Pontiac, Whitmore, and Kent lakes were made using both the Petersen and Schnabel mark-and-recapture methods. These methods assume that the proportion of marked fish in a random sample is the same as the proportion of a known number of marked fish in the population (Bagenal 1978).

Largemouth bass population estimates were calculated for each lake, from bass collected with electrofishing equipment and trap nets during the spring tagging operation, using a modified Schnabel mark-and-recapture method (Ricker 1975):

$$\hat{N} = \frac{\Sigma(C_t M_t)}{\Sigma R + 1}$$

where: $\hat{N}$ = estimated number of fish in the population

M_t = total marked fish at large at the start of day t

C_t = total sample taken on day t

R = total recaptures during the experiment

Approximate confidence limits were obtained by considering R as a Poisson variable. The Schnabel multiple census procedure, involving concurrent marking and recapture, requires that the population be constant, with no recruitment and no mortality during the experiment. However, it is often useful even if these conditions are only approximately satisfied (Ricker 1975).

For comparative purposes an additional largemouth bass population estimate was made for each size group ($\geq$254 mm and $\geq$304 mm) at each lake using the Chapman modification of the Petersen mark-and-recapture method (Ricker 1975):

$$\hat{N} = \frac{(M + 1)(C + 1)}{R + 1}$$

where: $\hat{N}$ = estimated number of fish in the population

M = number of marked fish in the population

C = number of fish in the sample

R = number of recaptures in the sample

The 95% confidence intervals were obtained from charts and tables appropriate to the binomial and Poisson distributions with R as the variable entered. The particular distribution used was determined by the R/C ratio according to the methods of Davis (1964). As all the catches involved less than 500 bass, when R/C was less than or equal to 0.1 the Poisson approximation was used and when R/C was greater than 0.1 the binomial distribution was used. The 95% confidence intervals for the binomial distributions were determined using the Clopper and Pearson (1934) chart of confidence belts.

Bass Fishing Questionnaire

When interviewed by a creel census clerk, each angler was asked if he ever fished for bass in Michigan. If so, he was asked a series of 12 questions from a special bass fishing questionnaire (Fig. 1). Questions from the bass questionnaire were asked each fisherman only once during the creel census period, even if he was interviewed on several occasions. The bass questionnaire was developed using standard questionnaire design principles so as to be as unbiased as possible. The questionnaire was structured to determine angler opinions on bass fishing in Michigan as it stands now, and bass fishing as anglers would like to have it in the future, with four basic objectives in mind: (1) to determine angler opinion on catch-and-release bass fishing--how common is it now, how many would do it in this lake, and how many would be willing to do it statewide; (2) to judge how fishermen would react to more restrictive legislation in terms of a longer closed season, or increased minimum size limit, to protect bass stocks; (3) to assess how anglers believe the change in the bass minimum size limit from 254 mm to 304 mm in 1976 has affected their catch; and (4) to evaluate whether fishermen prefer to catch several small bass or fewer large bass.

Bass Fishing Questionnaire

Have we interviewed you previously this year? (If yes, terminate interview.)

1. How often do you fish for bass in Michigan:
   1.Once or more a week 3.Three or four times a year 5.Never (terminate interview)
   2.Once or twice a month 4.Once a year

2. Do you usually: 1.Eat the bass you catch 2.Release them 3.Other

3. How often do you fish for bass in this lake:
   1.Once or more a week 3.Three or four times a year 5.Never (skip to question 6)
   2.Once or twice a month 4.Once a year

4. Suppose you were required to throw back all the bass you caught in this lake before June 30, so that you might catch and keep more large bass during the rest of the season. Would you:
   1.Strongly approve 3.Not care 5.Strongly disapprove (skip to question 7)
   2.Approve 4.Disapprove

5. Suppose you were required to throw back all the bass you caught in this lake during the entire fishing season, so that you might catch and release more large bass on each trip. Would you:
   1.Strongly approve 3.Not care 5.Strongly disapprove
   2.Approve 4.Disapprove

6. Suppose you were required to throw back all the bass you caught in any Michigan waters before June 30, so that you might catch and keep more large bass during the rest of the season. Would you:
   1.Strongly approve 3.Not care 5.Strongly disapprove
   2.Approve 4.Disapprove

7. How many years have you been fishing for bass in Michigan? _____ years
   (If ≤ 5, skip to question 11)

8. Are you aware that in 1976 the minimum size limit for bass was raised from 10 inches to 12 inches? 1. Yes 2. No (If no, skip to question 11)

9. Do you feel this change has allowed you to:
   1.Catch more bass 3.Catch fewer bass
   2.Catch the same number of bass 4.Do not know

10. Do you feel this change has allowed you to:
   1.Keep more bass 3.Keep fewer bass
   2.Keep the same number of bass 4.Do not know

11. In one fishing trip, would you prefer to catch and keep:
   1. 4 bass--12 inches long 3. 1 bass--16 inches long
   2. 3 bass--13 inches long 4. Does not matter

12. What would your choice be, if, in addition to keeping those bass, you caught and released the following number of bass (give angler the index card):
   1.With the 4 bass 12 inches long, you caught no additional bass
   2.With the 3 bass 13 inches long, you caught and released 2 bass 10-12 inches long
   3.With the 1 bass 16 inches long, you caught and released 5 bass 10-14 inches long
   4.Does not matter

Figure 1.--Bass fishing questionnaire asked anglers interviewed in the creel census at Pontiac, Whitmore, and Kent lakes in 1980.

Angler responses to the questions were summarized with a computer to determine the number and percentage of anglers responding in each question category. Additionally a two-way analysis was performed between many of the questions where a two-way contingency table was generated which compared how respondents in each individual category of one question answered a second question.

RESULTS AND DISCUSSION

Age and Growth

Linear regressions computed for the body-scale relationship of largemouth bass from Pontiac, Whitmore, and Kent lakes yielded intercept values of 42.9, 93.0, and 30.1 mm, respectively (Table 1). The intercepts of 42.9 mm and 30.1 mm obtained at Pontiac and Kent lakes fell within the range given in the literature and they were used in the back-calculations of length at age for the respective lakes. However, the 93.0-mm intercept for Whitmore Lake bass was considered to be unusually high as it lay beyond the previously reported intercept range. A second regression analysis of length on radius was conducted for Whitmore Lake bass using only scales taken from fish collected during the summer sampling period and an intercept of 53.6 mm was calculated with an r^2 of 0.92. This intercept was also somewhat suspect, however, in that the regression was computed from a sample of bass no older than age four. Using such a small age range yields questionable results because the accuracy with which the intercept can be calculated is affected by the range of sizes in the sample as well as the number of specimens (Carlander 1977). A 55.3-mm intercept, the mean value obtained when the three lake intercepts were averaged, was deemed the most appropriate value to use for back-calculating lengths at Whitmore Lake because it is close to the 53.6-mm intercept computed from summer scale samples and it falls within the upper range of intercepts used in other studies.

Table 1.--The y-intercept values and coefficients of determination (r^2) for linear regression lines of body length plotted against scale radius for largemouth bass from Pontiac, Whitmore, and Kent lakes.

Lake	Number of bass	Intercept (mm)	r^2
Pontiac	363	42.9	0.77
Whitmore	573	93.0	0.77
Kent	282	30.1	0.83

It is important to note how a change in intercept affects computed lengths, particularly in light of the adjusted intercept used for growth calculations at Whitmore Lake. Carlander (1977) reported that past growth histories estimated by the Fraser modification method differed only in the first 2 or 3 years of life with various intercept values. For Whitmore Lake bass, using intercepts varying as much as 63 mm, the difference in calculated length after 1 year of growth was 47 mm, but after 3 years the difference had dropped to only 7 mm (Tables 2 and 3). The estimated size of bass age four or older was not significantly affected by the intercept value. The use of the high intercept (93.0 mm) in the back-calculation equation resulted in the largest calculated sizes at age, yet after the initial year of growth, the succeeding growth increments were smaller than those computed from the lower intercepts. This gives an impression of the population with the largest bass at age actually growing the slowest.

In addition to differences in the amount of calculated growth arising as a result of the intercept value used, there are actual yearly fluctuations in growth due to differences in environmental conditions from year to year. Sometimes growth of a particular age group may be above the mean one year and below average the next (Tables 4-9). Lee's phenomena, that of back-calculated lengths and growth increments for a particular age group being smaller the older the fish from which they are calculated, was not apparent at any of the three lakes (Tables 4-9).

Growth of young bass was fastest at Kent and Pontiac lakes resulting in larger size at age for bass in these lakes compared to those in Whitmore Lake (Tables 10 and 11). Being shallow-water impoundments, both Kent and Pontiac lakes probably warm earlier in the spring and receive greater amounts of nutrient input than Whitmore Lake, possibly stimulating faster growth during the early years of life. Bass at Kent Lake were found to be larger than average for Michigan waters whereas growth at Pontiac Lake was

Table 2.--Back-calculated lengths (mm) at age for largemouth bass at Whitmore Lake computed with the Fraser modified direct proportion procedure using three different intercept values.

Intercept (mm)	Age									
	1	2	3	4	5	6	7	8	9	10
30.0	85	158	225	276	313	352	396	449	470	509
55.3	104	170	231	279	315	353	398	450	471	509
93.0	132	188	240	283	318	355	400	451	471	509

Table 3.--Back-calculated growth increments (mm) for largemouth bass at Whitmore Lake computed with the Fraser modified direct proportion procedure using three different intercept values.

Intercept (mm)	Age 1	2	3	4	5	6	7	8	9	10
30.0	85	75	66	56	52	46	39	35	44	34
55.3	104	67	59	51	48	43	37	33	41	32
93.0	132	55	50	44	41	38	33	30	38	29

Table 4.--Back-calculated lengths (mm) at age for largemouth bass from Pontiac Lake.

Year class	Number of bass	Age 1	2	3	4	5	6	7	8	9	10	11
1979	0											
1978	11	104	160									
1977	71	106	194	250								
1976	75	101	174	244	297							
1975	103	106	165	230	288	333						
1974	40	105	174	239	293	340	376					
1973	24	110	182	246	301	348	385	412				
1972	20	111	182	249	312	366	400	425	447			
1971	16	122	206	275	332	372	405	429	448	466		
1970	7	108	167	232	291	342	386	422	444	464	481	
1969	4	98	154	225	287	335	383	415	440	463	481	497
Weighted mean		106	177	242	296	342	388	421	447	465	481	497

Table 5.--Back-calculated growth increments (mm) for largemouth bass from Pontiac Lake.

Year class	Number of bass	Age 1	2	3	4	5	6	7	8	9	10	11
1979	0											
1978	11	104	56									
1977	71	106	88	56								
1976	75	101	73	71	52							
1975	103	106	59	65	58	45						
1974	40	105	69	64	55	46	36					
1973	24	110	73	63	56	47	36	27				
1972	20	111	71	67	63	54	35	24	22			
1971	16	122	84	70	57	40	32	24	19	18		
1970	7	108	59	65	59	52	44	35	23	19	17	
1969	4	98	56	72	62	48	48	32	25	22	19	16
Weighted mean		106	71	65	56	46	36	27	22	19	18	16

Table 6.--Back-calculated lengths (mm) at age for largemouth bass from Whitmore Lake.

Year class	Number of bass	Age 1	2	3	4	5	6	7	8	9	10
1979	31	116									
1978	69	97	160								
1977	109	106	181	243							
1976	205	106	179	237	287						
1975	91	103	159	220	270	319					
1974	46	95	149	206	262	306	349				
1973	9	91	150	201	255	301	336	369			
1972	9	101	163	222	276	330	380	423	459		
1971	3	100	157	226	285	328	365	400	426	469	
1970	1	106	156	231	309	365	397	416	442	477	509
Weighted mean		104	170	231	279	315	353	398	450	471	509

Table 7.--Back-calculated growth increments (mm) for largemouth bass from Whitmore Lake.

Year class	Number of bass	Age									
		1	2	3	4	5	6	7	8	9	10
1979	31	116									
1978	69	97	63								
1977	109	106	75	62							
1976	205	106	72	58	50						
1975	91	103	56	61	50	49					
1974	46	95	54	57	55	44	43				
1973	9	91	59	52	53	47	35	33			
1972	9	101	62	59	54	54	50	43	36		
1971	3	100	57	69	59	42	37	36	25	43	
1970	1	106	50	75	78	56	32	19	26	35	32
Weighted mean		104	67	59	51	48	43	37	33	41	32

Table 8.--Back-calculated lengths (mm) at age for largemouth bass from Kent Lake.

Year class	Number of bass	Age 1	2	3	4	5	6	7	8	9	10	11
1979	4	129										
1978	38	97	210									
1977	78	100	180	276								
1976	71	108	190	266	329							
1975	20	118	233	303	350	387						
1974	22	113	212	298	357	394	421					
1973	21	109	218	303	360	401	427	448				
1972	9	122	216	302	367	411	435	457	474			
1971	12	116	214	295	356	397	428	453	471	484		
1970	6	119	219	314	370	410	438	462	483	499	513	
1969	1	107	172	264	341	394	434	448	463	477	489	500
Weighted mean		107	199	283	345	397	428	453	474	488	510	500

Table 9.--Back-calculated growth increments (mm) for largemouth bass from Kent Lake.

Year class	Number of bass	Age 1	2	3	4	5	6	7	8	9	10	11
1979	4	129										
1978	38	97	113									
1977	78	100	80	96								
1976	71	108	82	76	63							
1975	20	118	115	70	47	37						
1974	22	113	99	87	59	37	27					
1973	21	109	109	85	57	40	27	21				
1972	9	122	94	86	65	44	24	22	17			
1971	12	116	97	81	62	41	31	25	18	14		
1970	6	119	100	95	56	41	27	24	21	16	15	
1969	1	107	65	92	77	52	40	14	15	14	12	11
Weighted mean		107	93	85	60	39	28	22	18	14	14	11

Table 10.--Back-calculated mean lengths (mm) at age for largemouth bass at Pontiac, Whitmore, and Kent lakes compared to the Michigan average.

Lake	Inter-cept (mm)	Age 1	2	3	4	5	6	7	8	9	10	11
Pontiac	42.9	106	177	242	296	342	388	421	447	465	481	497
Whitmore	55.3	104	170	231	279	315	353	398	450	471	509	
Kent	30.1	107	199	283	345	397	428	453	474	488	510	500
Michigan average[a]		107	180	239	295	335	373	414	441	466	491	

[a]May average for all Michigan waters (Laarman, Schneider, and Gowing 1981).

Table 11.--Back-calculated mean growth increments (mm) for largemouth bass at Pontiac, Whitmore, and Kent lakes compared to the Michigan average.

Lake	Intercept (mm)	Age 1	2	3	4	5	6	7	8	9	10	11
Pontiac	42.9	106	71	65	56	46	36	27	22	19	18	16
Whitmore	55.3	104	67	59	51	48	43	37	33	41	32	
Kent	30.1	107	93	85	60	39	28	22	18	14	14	11
Michigan average[a]		107	73	59	56	40	38	41	27	25	25	

[a] Derived from Laarman, Schneider, and Gowing (1981).

about average (Table 10). Cooper and Schafer (1954) reported the size of largemouth bass at Whitmore Lake in 1953 to be average, but in 1980, it appears that Whitmore Lake bass are somewhat smaller than average.

A question has sometimes arisen when anglers complain of a decrease in the number of large fish caught in a particular body of water as to whether this may be the result of changes in the gene pool caused by selective fishing, rather than exaggerated memories of times past, greater exploitation due to increased fishing pressure, or some environmental change. It is recognized that a minimum size limit regulation in sport or commercial fisheries can produce an unnatural selection process whereby the faster growing fish are preferentially caught at an earlier age (Gulland 1969; Favro et al. 1979). Even without a size limit, angling may preferentially select fish that grow faster because they require more food, are seeking prey more often, and therefore might be more susceptible to the angler's lure.

The question of whether faster growing largemouth bass were selectively captured by anglers in Pontiac, Whitmore, and Kent lakes was addressed by separately back-calculating lengths and growth increments at age for the group of tagged bass caught at each lake (Table 12). The results showed no significant difference in growth rates for the tagged bass caught by anglers (Table 12) compared to the population of tagged bass as a whole (Table 10) at any of the three study lakes.

Population Estimates

To increase the number of recaptures used in the Schnabel population estimates and thereby reduce the range of the confidence limits, all bass caught by anglers in the last week of May (the first week of the bass season) were added together and entered as the final recapture runs for the estimates. This included bass caught in opening week bass tournaments

Table 12.--Back-calculated mean lengths (mm) at age for tagged largemouth bass caught by anglers at Pontiac, Whitmore, and Kent lakes.

Lake	Number of bass	Age								
		1	2	3	4	5	6	7	8	9
Pontiac	46	108	177	241	293	334	373	410	436	
Whitmore	45	105	169	230	284	322	361	408	469	492
Kent	31	109	197	278	342	386	417	448	468	480

as well as those caught by non-tournament anglers. It was felt the last week in May was close enough to the conclusion of the tagging process, (2, 3, and 22 days at Pontiac, Kent, and Whitmore lakes, respectively) that the assumptions of the multiple census procedure could still be closely met. The values obtained for the population estimates seemed to confirm this as estimates made using angler caught bass differed only slightly from those excluding bass caught by anglers, yet they significantly reduced the confidence limit range. The addition of angler caught bass changed the population estimate of legal size bass in Pontiac Lake from 2,293 to 2,390, a difference of only 6%, while decreasing the 95% confidence limit range from 3,996 to 2,854, a reduction of 29% (Table 13).

The Petersen population estimates computed from bass collected during the August electrofishing recapture runs were not very useful. No estimate was possible at Whitmore Lake because of 115 largemouth bass collected, only 7 would have been large enough in May to tag and none were recaptures. The larger bass had apparently moved into deeper water away from the shoreline areas and therefore were not subjected to the electrical field. Support for this assumption was obtained through the creel census with anglers questioned at the time confirming that the bass they had caught had come from water 4.5 to 6 m in depth.

Since a Petersen estimate is an estimate of the population at the time of tagging and not at the time of recapture (Everhart et al. 1975), such population estimates at Kent and Pontiac lakes could only be made for the bass populations 254 mm and larger. This was because at least two recaptures at each lake had lost their tags and it was therefore impossible to determine how many recaptured bass were legal size at the time of tagging.

The Petersen population estimate at Kent Lake of 2,758 (Table 14) lies above the 95% confidence interval upper bound value of 2,113 determined by

Table 13.--Modified Schnabel population estimates for largemouth bass as determined from spring electrofishing and trap net collections at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Minimum size of bass (mm)	Number tagged	Number recaptured	Population estimate	95% confidence interval	Number per hectare
Pontiac	254	304	14	2,897	1,849- 5,644	12.2
	304	230	16	2,390	1,563- 4,417	10.1
Whitmore	254	408	11	5,531	3,369-12,290	20.2
	304	187	7	1,959	1,088- 5,596	7.1
Kent	254	352	40	1,514	1,140- 2,113	3.7
	304	226	32	969	708- 1,411	2.4

Table 14.--Modified Petersen population estimates for largemouth bass as determined from August electrofishing and May angling captures at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Method sample obtained	Minimum size of bass (mm)	Population estimate	95% confidence interval	Number recaptured
Pontiac	AC	254	1,390	811-3,243	6
	Angling	304	2,312	1,235-7,356	6
Whitmore	AC	254			0
	Angling	304	1,002	501-4,009	3
Kent	AC	254	2,758	1,609-9,653	6
	Angling	304	1,262	701-6,312	4

the Schnabel method and is about twice the Schnabel estimate of 1,514 (Table 13). This could be the result of several factors but there is no finite answer. First, it may be due to simple random error in the sample as the confidence intervals for the estimates overlap. Also the Petersen estimate is probably less accurate than the Schnabel (it has a 95% confidence interval range eight times larger) because it was based on only 6 recaptures as opposed to the Schnabel estimate which was based on 40 recaptures. Second, marked fish may not have become randomly distributed during the spring mark-and-recapture process, and tagged bass were caught disproportionately. This would produce a spring population estimate lower than the true population size. Third, the occurrence of differential mortality as a result of the tagging process would cause the estimate obtained from the August recapture runs to be higher than the true population size. However, only one tagged bass was found dead at any of the three lakes and it had been noted that this particular bass had suffered exceptional stress at the time of tagging. If many tagged bass had died, they probably would have been reported either by anglers or the creel census clerks.

The Petersen population estimate from largemouth bass collected during the August electroshocking period at Pontiac Lake was 1,390 (Table 14). Though this value is below the lower bound of the 95% confidence interval determined from the Schnabel spring estimate of 1,849 (Table 13), this again may be due to simple random error in the sample as the confidence limits for the estimates overlap. Also, the Schnabel estimate, based on 14 recaptures, is more reliable than the Petersen estimate based on 6 recaptures.

A second explanation for the low Petersen estimate at Pontiac Lake involves the possibility that some unmarked bass were erroneously identified as recaptures by field crews. This question arose because 4 of the 6 bass identified as recaptures had no tags but were judged to have fin clips. This seems to be an unusually high proportion of bass with lost tags as the creel census clerks who were instructed to check for fin clips reported only a 9.5% rate of tag loss from bass seen in the census. The tag loss rate reported by the clerks agrees more closely with the results of Ager (1979) who reported a loss of less than 10% of Floy FD-68BC anchor tags over an annual period.

Largemouth bass caught by anglers during the last week of May (the first week of the bass season) were used to produce a Petersen estimate of the population of legal size bass ($\geq$ 304 mm) in each lake (Table 14) for comparison to the spring Schnabel estimates (Table 13). The Petersen estimates for Pontiac and Kent lakes were fairly close to the Schnabel estimates but had much larger 95% confidence intervals due to the small number of recaptures used of 4 and 6 bass, respectively. At Whitmore Lake the Petersen estimate was low and this was probably the result of the small sample size.

Largemouth bass population estimates from five other Michigan studies are presented for comparison in Table 15. It is believed that the population estimates compiled for Sugarloaf and Whitmore (1953 and 1953-1956) lakes are conservative due to the methods used to collect the bass and perform the computations. Latta (1959) observed that trap nets are size selective for larger fish and that population estimates based on such collections have a systematic bias unless they are calculated for relatively small size groups and then summed. Bass were collected solely by trap nets in these three studies, and a stratification by size was not made; the size-selective bias therefore probably exists producing a tendency to underestimate population size.

Table 15.--Population estimates of largemouth bass 254 mm and larger for some Michigan lakes.

Lake	Year	Area (ha)	Population estimate	Number per hectare
Pontiac	1980	237	2,897	12.2
Whitmore	1980	274	5,531	20.2
Kent	1980	405	1,514	3.7
Whitmore[a]	1953	274	4,532	16.5
Whitmore[b]	1953-1956	274	3,025	11.0
Sugarloaf[c]	1948-1952	73	759	10.4
Mill[d]	1964-1969	55	1,276	23.2[f]
Third Sister[e]	1941	38	1,125	29.6[f]

[a] Cooper and Schafer (1954)

[b] Cooper, Latta, and Schafer (1957)

[c] Cooper and Latta (1954)

[d] Schneider (1971)

[e] Brown and Ball (1942)

[f] Unexploited population

The population densities of largemouth bass at Pontiac and Whitmore lakes in 1980, appear to be about average for Michigan lakes of this size when compared to past studies (Table 15). But though Whitmore Lake had the largest population of largemouth bass 254 mm and larger (20.2/ha), only 35% of this population was legal size or greater as opposed to 64% and 82% at Kent and Pontiac lakes, respectively (Table 13). The low population density of largemouth bass in Kent Lake may be the result of a low Schnabel population estimate as was indicated by the higher Petersen estimates for each size group. Even if the apparently less reliable Petersen estimate for bass 254 mm and larger was taken at face value, it would still indicate only 6.8 bass per hectare, one-half the density determined for Pontiac Lake and only one-third the concentration observed at Whitmore Lake. Regardless of which estimate is used, both indicate a largemouth bass population at Kent Lake significantly smaller than those at Pontiac or Whitmore lakes.

For Whitmore Lake there are both recent and past data on largemouth bass populations and a comparison shows that there are now more bass per hectare than previously (Table 15). Latta (1974) predicted a 29% increase in the number of bass 254 mm and larger with a size limit change from 254 mm to 304 mm. The data for Whitmore Lake show a 22% increase from 16.5 bass per hectare in 1953, to 20.2 bass per hectare in 1980. The numerical difference between the actual increase and the predicted rise could be due to the fact that the 0.22 exploitation rate on bass of Whitmore Lake in 1953 was less than the 0.35 rate of exploitation used in Latta's yield model. If the average population estimate for the years 1953-1956 is used instead of the 1953 year alone, then there is an 83% increase in the number of bass 254 mm and larger at Whitmore Lake. However, if the past population estimates are low as previously discussed, there would be less of a difference in numbers between the studies with the actual difference approaching the predicted 29% increase.

Standing Crop

Length and weight data were collected from nearly 100 largemouth bass in each lake from mid-April through August 1980. The logarithm of the weight in grams was plotted against the logarithm of the length in millimeters and a length-weight regression computed for each lake by the method of least squares (Table 16). These equations were used to calculate the weight of bass in each 5-mm size group in the population and to generate estimates of 1980 standing crops in each lake (Table 17).

The standing crops of 8.9 kg/ha and 8.7 kg/ha for the largemouth bass populations 254 mm and larger at Pontiac and Whitmore lakes, respectively, compare favorably with values obtained in previous studies for exploited lakes (Table 17). At both lakes the standing crops of the 254-mm and larger size group are only slightly below the 9.4 kg/ha reported for an unexploited population at Mill Lake. The Pontiac Lake value of 8.7 kg/ha for the bass population 304 mm and larger also compares well with the 8.8 kg/ha standing crop of unexploited bass 304 mm and larger at Mill Lake.

Though Kent Lake had the lowest bass population density, the weight of an average bass (0.76 kg for the 254-mm and larger size group and 0.95 kg for the 304-mm and larger group) was the largest of the three study lakes for both size groups and nearly twice as great as the 0.43 kg and 0.59 kg values at Whitmore Lake for the two respective size groups.

Harvest

Estimates of the number of largemouth bass harvested at each lake in 1980 (Table 18) were almost as high as the population estimates of legal size bass present at the beginning of the bass fishing season. This is due to the continual recruitment of bass from the 254- to 304-mm size class into

Table 16.--Length-weight equations for largemouth bass at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	$\text{Length}_{(mm)}$ - $\text{Weight}_{(gm)}$ Equation
Pontiac	Log W = -6.0408 + 3.4697 Log L
Whitmore	Log W = -6.4271 + 3.6157 Log L
Kent	Log W = -5.7093 + 3.3512 Log L
Michigan average[a]	Log W = -5.1689 + 3.1274 Log L

[a] Latta (1974)

Table 17.--Standing crops of largemouth bass in selected lakes.

Lake	Year	Area (ha)	Minimum size of bass (mm)	kg/ha	kg per bass
Pontiac, MI	1980	237	254	8.9	0.72
			304	8.7	0.86
Whitmore, MI	1980	274	254	8.7	0.43
			304	4.4	0.59
Kent, MI	1980	405	254	2.8	0.76
			304	2.4	0.95
Whitmore, MI [a]	1953	274	254	9.1	0.55
Whitmore, MI [b]	1953-1956	274	254	6.6	
Sugarloaf, MI [c]	1948-1950	73	254	7.4	0.71
Mill, MI [d]	1964-1969	55	254	9.4 [g]	0.41
Mill, MI [d]	1964-1969	55	304	8.8 [g]	
Avg. 55 Minnesota lakes [e]	1950	202 avg.	All sizes	9.6	
Avg. 170 U.S. reservoirs [f]	1975	6,070 avg.	All sizes	10.0	

[a] Cooper and Schafer (1954)

[b] Cooper, Schafer, and Latta (1957)

[c] Cooper (1952)

[d] Schneider (1971)

[e] Moyle et al. (1950)

[f] Jenkins (1975)

[g] Unexploited population

Table 18.--Harvest estimates for largemouth bass at selected lakes.

Lake	Year	Minimum size of bass (mm)	Harvest estimate	Number per ha	kg/ha	kg/bass
Pontiac	1980	304	2,076	8.8	6.3	0.72
Whitmore	1980	304	1,518	5.5	3.2	0.58
Kent	1980	304	833	2.1	1.6	0.76
Pontiac [a]	1946-1960	254	2,820	11.9	7.2	0.60
Whitmore [b]	1952-1953	254	1,769	7.7	3.5	0.54
Whitmore [c]	1953-1956	254		6.7	3.9	
Sugarloaf [d]	1948-1950	254			7.2	
Average 170 U.S. reservoirs	1975	various			5.6	

[a] Schneider and Lockwood (1979)

[b] Cooper and Schafer (1954)

[c] Cooper, Schafer, and Latta (1957)

[d] Cooper (1952)

[e] Jenkins (1975)

the harvestable population during the course of the fishing season. The lower weight of the average bass caught by anglers at Pontiac and Kent lakes compared to the average weights from the spring electrofishing collections may reflect this recruitment. As expected as a result of the less numerous population, Kent Lake had the smallest harvest, but the size of an average bass harvested was larger than from the other two lakes.

Past harvest rates of largemouth bass 254 mm and larger in Michigan have ranged from about 1.1 kg/ha to 8.9 kg/ha, and averaged 3.8 kg/ha or about one-third the average standing crop of 10.1 kg/ha (Latta 1974). Harvest at Pontiac Lake was above the Michigan average and Whitmore Lake was close to average. The harvest at Kent Lake was well below the mean.

Latta (1974) predicted there would be a 33% decrease in the number of bass harvested as a result of changing the minimum size limit from 254 mm to 304 mm. Compared with previous harvest data, Pontiac Lake showed a decrease of 26% whereas Whitmore Lake exhibited a drop in number of bass harvested of from 18% to 29% (Table 18). Total estimated bass catch from all Michigan waters fell from 4.2 million in 1975 to 3.9 million in 1976, a 7% decrease, due to the size limit change (Michigan Sport Fishing Survey 1975; 1976).

Latta (1974) also predicted that the change in weight of largemouth bass harvested would be negligible. At an annual exploitation rate of 0.35 the predicted decrease in weight was only 5%. Whitmore Lake had a decrease of 9% to 18% in weight of harvested bass and Pontiac Lake had a decrease of 13% (Table 18).

Although the number of largemouth bass harvested has apparently decreased about 25% in the study lakes, there were large catch-and-release fisheries (Table 19). These fisheries consisted mainly of bass 200 mm to 304 mm in length. Bass at these sizes are susceptible to angler lures yet

Table 19.--Estimated number of largemouth bass at all sizes caught and released at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Number of bass	95% confidence interval	Number per hectare
Pontiac	6,297	5,044-7,550	26.6
Whitmore	2,455	1,487-3,423	9.0
Kent	5,555	3,884-7,226	13.7

are below the legal minimum size limit. However, these estimates also include some bass below 200 mm and many above the legal size of 304 mm.

It is apparent that there was a great amount of catch-and-release fishing in each lake. For each bass creeled at Pontiac Lake, there were three more that were caught and released. At Whitmore Lake there were almost two bass caught and released for every one creeled. And at Kent Lake there were over six bass caught and released for each bass harvested. There is no comparable information on any of the three lakes to determine whether or not this is a significant increase over the number of bass caught and released in the past.

From creel census data it was found that of the total number of largemouth bass creeled by anglers, 7.9% were sublegal at Pontiac Lake, 11.5% at Kent Lake, and 36.5% at Whitmore Lake. Of the remaining number of legal bass caught by anglers, 60% to 70% were in the 304- to 355-mm size group (Table 20). The heavy catch of sublegal bass at Whitmore Lake may be one reason so few large bass were caught there.

When the size of bass harvested by the general public was compared to that of those caught by anglers participating in competitive bass tournaments, in both Pontiac and Whitmore lakes, the former caught a greater percentage of large bass than did the latter (Table 20). But when the percentages of all three lakes were averaged there was little difference in the size of bass caught by general anglers or bass tournament fishermen.

There are past data on the number of largemouth bass 406 mm and larger harvested at Pontiac Lake for the period 1946-1961 (Schneider and Lockwood 1979). Until 1954, the bass season was closed from January 1 to the third Saturday in June, but from 1954 through 1961, year-round fishing was allowed for bass at Pontiac Lake. With the opening of year-long bass fishing there was a substantial increase in the number of large bass

Table 20.--Percentage of legal size largemouth bass in each 50-mm size group collected by various methods at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Method collected	Number of bass	Size group (mm) 304-355	356-406	Larger than 406
Pontiac	AC [a]	230	46.6	24.4	29.0
	General angling [b]	186	59.4	22.4	18.2
	Tournament angling [c]	60	71.4	17.9	10.7
Whitmore	AC	187	75.4	14.8	9.8
	General angling	153	71.9	22.2	5.9
	Tournament angling	62	71.7	24.5	3.8
Kent	AC	226	45.5	18.0	36.5
	General angling	101	62.0	25.0	13.0
	Tournament angling	28	57.7	23.1	19.2

[a] Bass collected and released during the spring tagging operation with electrofishing gear and trap nets.

[b] Bass harvested by the general public.

[c] Bass caught and released by bass tournament anglers.

harvested followed by a drop to below previous levels. From 1946 through 1953, with no bass fishing allowed until the third Saturday in June, 20% of the harvested bass were 406 mm and larger. During the first 5 years of the year-round open season, 1954-1958, the catch of bass 406 mm and larger increased by 36%. However, the harvest of bass in the same size range fell to only 13% of the total catch from 1959 through 1961. In 1980, with a minimum size limit of 304 mm and a bass season closed from January 1 to the Saturday preceding Memorial Day, 18.2% of the bass harvested from Pontiac Lake were 406 mm and larger. This is close to the 20% value reported before the season was opened year-round in 1954 and is greater than the 13% figure obtained for the years 1959-1961.

The seasonal distribution of largemouth bass catch shows the largest number of bass were caught in June and July at Whitmore Lake, July and August at Pontiac Lake, and August and September at Kent Lake (Table 21). The greatest bass catch did not always occur during the months with the most fishing pressure (Table 22).

The estimated total catches of all species from May 15 to October 31, 1980, are given in Table 23. Of the other game fish harvested, walleye were caught only in Kent Lake, smallmouth bass were creeled in Kent and Whitmore lakes, tiger muskellunge were present in Pontiac and Whitmore lakes, and northern pike were harvested in all three lakes. The bluegill (Lepomis macrochirus) was the most numerous member of the catch at Pontiac and Whitmore lakes followed by other sunfish species, mostly the pumpkinseed (Lepomis gibbosus). At Kent Lake the black crappie (Pomoxis nigromaculatus) was by far the most prominent member of the catch with the bluegill being next in abundance. At both Pontiac and Whitmore lakes, catches of all panfish species (but especially bluegills) were low in 1980 compared to the years 1946-1961 (Schneider and Lockwood

Table 21.--Estimated angler harvest of legal size largemouth bass by month from Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Month						Season total
	May[a]	June	July	August	September	October	
Pontiac	292	789	640	224	110	17	2,072
Whitmore	300	277	346	361	203	31	1,518
Kent	81	82	106	301	205	58	833

[a] May 24th and after.

Table 22.--Total fishing pressure (angler hours) by month at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Month						Season total
	May[a]	June	July	August	September	October	
Pontiac	12,478	11,305	12,082	8,095	3,091	308	47,359
Whitmore	9,936	19,031	14,599	11,984	7,877	1,093	64,520
Kent	42,281	42,024	48,335	37,242	18,800	2,452	191,134

[a] May 15th and after.

Table 23.--Estimated numbers of fish harvested by anglers during the period May 15 through October 31, 1980, from Pontiac, Whitmore, and Kent lakes.

Species	Lake		
	Pontiac	Whitmore	Kent
Largemouth bass (*Micropterus salmoides*)	2,072	1,518	833
Smallmouth bass (*Micropterus dolomieui*)	0	93	66
Walleye (*Stizostedion vitreum*)	0	0	81
Northern pike (*Esox lucius*)	356	95	1,050
Tiger muskellunge (*Esox masquinongy* X *E. lucius*)	74	40	0
Yellow perch (*Perca flavescens*)	854	2,545	5,176
Rock bass (*Ambloplites rupestris*)	2,609	1,142	36
Black crappie (*Pomoxis nigromaculatus*)	563	112	94,529
Bluegill (*Lepomis macrochirus*)	8,937	8,791	19,435
Other sunfish (*Lepomis* spp.)	5,164	4,256	4,526
Bowfin (*Amia calva*)	13	115	601
Bullhead spp. (*Ictalurus* spp.)	305	246	502
Carp (*Cyprinus carpio*)	0	0	1,979
Total	20,947	18,953	128,814

1979). Contributing to the depressed catches was a decrease in the amount of fishing pressure applied towards panfish.

Fishing Pressure

The 1980 estimates of fishing pressure at each lake include only fishing activity from May 15 through October 31. The greatest amount of fishing pressure at all three lakes occurred during the last 2 weeks of May, followed by June and July, with fishing activity rapidly decreasing thereafter (Table 22). Anglers fishing from shore accounted for 7.7% of the total angler hours at Whitmore Lake, 11.3% at Pontiac Lake, and 60.6% at Kent Lake.

Partly because of the large amount of shore fishing activity, Kent Lake had the highest total fishing pressure of the three lakes with 472 hours per hectare (Table 24). Whitmore and Pontiac lakes had fishing pressures of 235 hours per hectare and 200 hours per hectare, respectively, only half the level received by Kent Lake. However, though Pontiac Lake had the lowest total angler hours per hectare, more fishing pressure was exerted on bass at this lake than either of the other two. Fishing pressure for bass at Pontiac Lake was 100 hours per hectare, slightly above the 96 hours per hectare at Whitmore Lake and the 76 hours per hectare at Kent Lake.

At Whitmore Lake total fishing pressure for the May-through-October time frame has increased only 2% from the 7-year average reported for this period in 1946-1952 (Christensen 1953a), but fishing pressure on bass has increased 200% (Table 24). Despite this 200% increase in bass fishing pressure and an increase of the minimum size limit from 254 mm to 304 mm, bass catch per hour, based on total angler hours for the lake, has decreased only 21% from 0.029 bass per hour to 0.023 bass per hour. But largemouth bass catch per hour based on bass angler hours (fishing

Table 24.--Fishing pressure (angler hours) and catch rates of largemouth bass from selected lakes.

Lake	Year	Bass minimum size limit (mm)	Total angler hours	Total hours/ ha	Bass hours/ ha	Bass/ bass hour	Bass hours/ bass
Pontiac, MI	1980	304	47,359	200	100	0.087	11.5
Whitmore, MI	1980	304	64,520	235	96	0.056	17.9
Kent, MI	1980	304	191,134	472	76	0.027	37.0
Pontiac, MI	1960[a,b]	254	42,494	179	68	0.050	20.0
	1952[a]	254	68,537	289	58	0.250	4.0
Whitmore, MI	1946-1952[c]	254	63,020	230	32[d]	0.208	4.8
Merle Collins Reservoir, CA	1970[e]	≈204	52,860	131		0.040	25.0

[a] Schneider and Lockwood (1979)

[b] No closed season from 1954-1960

[c] Christensen (1953a)

[d] Derived from Schneider and Lockwood (1979)

[e] Rawstron and Hashagen (1972)

pressure exerted directly towards bass) has declined by 73% from 0.208 bass per hour to 0.056 bass per hour.

Total fishing pressure at Pontiac Lake was up 12% from 1960 levels while bass fishing pressure has increased 47% from 1960, and is 72% higher than in 1952 (Table 24). The largemouth bass catch per hour for bass anglers of 0.087 bass per hour has decreased 43% from the 1952 figure but increased 188% over the 1960 level when there was year-round fishing.

It has been estimated that 126 legal bass per hectare would be needed to provide an average catch of 1 bass per hour (Lagler and DeRoth 1952). If one assumes that catch per hour increases directly with population size, a population of 127 legal bass per hectare would be required at Whitmore Lake to increase the catch rate to 1 bass per hour. Likewise, it would require 116 bass per hectare at Pontiac Lake and 88 bass per hectare at Kent Lake to provide a catch of 1 bass per hour.

It was noted earlier that there seemed to be little difference between the size of bass caught by bass tournament anglers when compared to the general public. But bass tournament anglers did catch bass at a faster rate than general anglers. It took tournament anglers only 7.3 hours to catch a legal bass at Pontiac Lake compared to 11.5 hours for non-tournament bass fishermen, a 36% faster rate (Table 25). Similarly, at Kent Lake tournament fishermen caught bass at a 42% faster rate than the general angler, while at Whitmore Lake tournament fishermen caught bass 17% faster. These results agree with those of Holbrook (1975) who reported that national tournament fishermen catch bass at a slightly faster rate than do non-tournament anglers.

An analysis of angler residency showed that the majority of anglers came from Wayne and Oakland counties (Table 26). The percentage of local anglers (Oakland County) fishing Pontiac Lake has increased from 13% in

Table 25.--Catch rates of largemouth bass 304 mm and larger by bass tournament anglers at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Angler hours	Angler hours/ hectare	Bass/ bass hour	Bass hours/ bass
Pontiac	440	1.9	0.136	7.3
Whitmore	859	3.1	0.067	14.8
Kent	603	1.5	0.046	21.5

Table 26.--Residency as a percentage of anglers interviewed at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	County						
	Wayne	Oak-land	Wash-tenaw	Living-ston	Macomb	Out-of-state	Other
Pontiac	23	64	<1	<1	12	<1	1
Whitmore	54	10	24	7	1	3	1
Kent	64	24	1	4	2	1	4
Lakes combined	47	33	8	4	5	1	2

1946 and 36% in 1954 (Schneider and Lockwood 1979) to 64% in 1980. In 1947, 93% of the anglers fishing Whitmore Lake were local anglers, 67% were from Washtenaw County and 26% from Livingston County (Predmore 1947). In 1980, the percentages changed to only 24% from Washtenaw County, 7% from Livingston County, and 54% from Wayne County.

About 60% of the anglers fishing the three lakes were seeking panfish or anything they could catch (Table 27). The remaining 40% were fishing specifically for bass or some combination of game fish, usually bass and pike. About half the anglers interviewed said they had been still fishing (Table 28). Only 20% had exclusively used the casting method of fishing and only 4% said they had been trolling. The remainder, about 30%, used a combination of two or more of the three methods. In keeping with the 46% of the anglers who were still fishing, 50% said they had used only live bait (Table 29). Artificial lures alone were used by 22% of the anglers and 28% said they used both live and artificial baits.

Each angler interviewed was asked to give his opinion of the fishing quality for that day's trip in terms of the number and size of fish caught and in terms of overall quality (both number and size). From 59% to 74% of the anglers at all three lakes rated fishing "poor" in each category (Table 30).

Exploitation Rates

Largemouth bass exploitation rates were calculated from the angler catch of tagged bass using a direct proportion procedure. A ratio of the number of tagged bass caught by anglers to the number of untagged bass caught was determined separately at each lake from creel census data of bass actually seen by the creel census clerks. The estimated total harvest was multiplied by this ratio to calculate the total number of tagged bass

Table 27.--Species sought (as a percentage of anglers interviewed) at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Species					
	Black bass	Northern pike	Tiger muskellunge	Various game fish	Pan-fish	Any
Pontiac	39	2	1	8	16	34
Whitmore	22	2	2	20	8	46
Kent	15	1	0	7	31	46
Lakes combined	25	2	1	11	19	42

Table 28.--Fishing methods (as a percentage of anglers interviewed) used at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Fishing method			
	Still fishing	Casting	Trolling	Combination
Pontiac	54	22	2	22
Whitmore	30	15	3	52
Kent	53	24	5	18
Lakes combined	46	20	4	30

Table 29.--Bait used (as a percentage of anglers interviewed) at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Bait		
	Live	Artificial	Both
Pontiac	58	20	22
Whitmore	33	21	46
Kent	57	26	17
Lakes combined	50	22	28

Table 30.--Angler opinions (as a percentage of anglers interviewed) on three aspects of fishing quality at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Fishing quality								
	Number of fish caught			Size of fish caught			Both size and number of fish caught		
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Pontiac	19	22	59	12	18	70	15	23	62
Whitmore	16	22	62	9	17	74	13	21	66
Kent	14	16	70	13	19	68	13	18	69
Lakes combined	16	20	64	11	18	71	14	20	66

caught. The estimated number of tagged bass caught, divided by the number of tagged bass in the population susceptible to capture, produced an estimated exploitation rate.

Annual exploitation rates of 0.18, 0.34, and 0.48 were computed for Kent, Pontiac, and Whitmore lakes, respectively (Table 31). These estimates should be regarded as approximations only as they were calculated from the small number of recaptures seen in the creel census and have large statistical variances. However, the calculated exploitation rates remained the same regardless of whether annual totals were used to compute the estimates or individual monthly estimates were summed.

A second method to determine the rate of exploitation would be to use the total number of tags returned by anglers. The validity of this method depends on fishermen reporting all tagged fish caught. Exploitation rates based on such data may vary considerably for a given population due to the non-reporting of tags by anglers (Heidinger 1976). For this procedure to be successful, it is therefore necessary to know what percentage of tagged fish caught by anglers are actually reported. It was not known what percentage of tagged bass caught in this study were reported and, as a result, reliable estimates of the exploitation rates could not be made using this method. It was determined, however, that in addition to tags seen by the creel census clerks, tags from 13% of the exploitable tagged population were returned by anglers at Pontiac Lake, and 11% were returned at both Kent and Whitmore lakes. Working backwards from the exploitation rates calculated above, 29% of the estimated number of tagged bass caught were not reported at Kent Lake, 53% were not reported at Pontiac Lake, and 66% were not returned at Whitmore Lake. This suggests that choosing some average tag non-return rate based on previous studies, or some estimated rate, to calculate exploitation rates would probably not produce accurate

Table 31.--Exploitation rates of largemouth bass at Pontiac, Whitmore, and Kent lakes in 1980.

Lake	Minimum size of bass tagged (mm)	Number of bass tagged	Number of tags returned	Number of tags in census	Estimated number of tagged bass harvested	Exploi-tation rate (u)
Pontiac	254	304	47	9		
	304	230	37	7	78	0.34
Whitmore	254	408	47	12		
	304	187	30	9	89	0.48
Kent	254	352	39	6		
	304	226	29	5	41	0.18

estimates as the non-return rate appears to differ from lake to lake. Combining angler tag returns with creel census records of tags returned, the minimum rates of exploitation had to be 16% for Pontiac Lake, 14% for Whitmore Lake, and 13% for Kent Lake.

A third way to calculate exploitation rates would be to divide the estimated harvest by the estimated population size. This method requires that an adjustment be made in the harvest estimate to compensate for the harvest of bass which were not of legal size when the population estimate was made. The recruitment adjustment was made by taking the growth of bass into account in the monthly harvest estimates. Latta (1974) determined the average amount of largemouth bass growth in each month for each age group in Michigan waters. The yearly growth increments of the age groups recruiting into the exploitable bass population at each lake were multiplied by the monthly growth percentages to determine the amount of growth having taken place each month. The exploitation rates so calculated were 0.51 for Whitmore Lake, 0.45 for Pontiac Lake, and 0.35 for Kent Lake. These are close to the previous estimates and the difference is probably due to the actual monthly growth increments being slightly greater than those calculated.

It was hoped that voluntary angler records of fishing activity recorded in the fishing diaries passed out at the beginning of the study to interested anglers would provide an additional means of calculating exploitation rates. Unfortunately the data obtained in this manner were sparse. As mentioned previously, anglers receiving the diaries were instructed by the creel census clerks to return them when they finished fishing for the year or by November 1. These instructions and the return address were also printed on the first page of the diary. During September and October the creel census clerks reminded those anglers with diaries, to whom they spoke, to remember to return the diaries by

November 1. In the first week of November a letter was sent to each diary holder reminding him to return the diary, even if he had made no entries at all. A pre-addressed, stamped envelope was provided for their mailing convenience.

A total of 48 diaries were given out to interested anglers who said they fished one of the study lakes at least once a week. Only 23 of the diaries (48% of the total) were returned. Green (1980) reported a similar response rate over a 3-year period with participation ranging from only 45% to 52% of cooperators receiving diaries, despite personal contacts, training sessions, review meetings, letters, telephone calls, and a mailed semi-annual progress report. Of the 23 diaries returned in this study, 12 diaries (52%) had six entry dates or more. Only five diaries, or 10% of those given out, had 10 entries or more. The poor response rate and low amount of information received from those anglers who did return diaries made the information of little use for purposes of determining exploitation rates.

Mortality Rates

When the annual mortality rate cannot be determined by sampling year classes from one year to the next, the best estimate is obtained from a catch curve (Ricker 1975). Catch curves were calculated from the number of largemouth bass of each age collected with electrofishing gear and trap nets during the spring tagging operation in April and May (Table 32). Natural logarithms ($\log_e x$) for the number of bass of each age were computed and plotted against age to generate a catch curve for each lake (Figs. 2-4). Total annual mortality (A) was calculated for ages at the peak and along the descending leg portion of the catch curve from a least squares linear regression. When the peak of the curve is used as part of the regression it is assumed that the age class representing the apex is

Table 32.--Numbers of largemouth bass of each age collected with electrofishing equipment and trap nets in April and May 1980, at Pontiac, Whitmore, and Kent lakes.

Lake	Age											Total
	1	2	3	4	5	6	7	8	9	10	11	
Pontiac	0	10	59	66	96	40	24	20	16	7	4	342
Whitmore	13	20	129	207	96	57	14	11	5	1	0	553
Kent	1	22	113	123	28	28	24	12	16	7	2	376

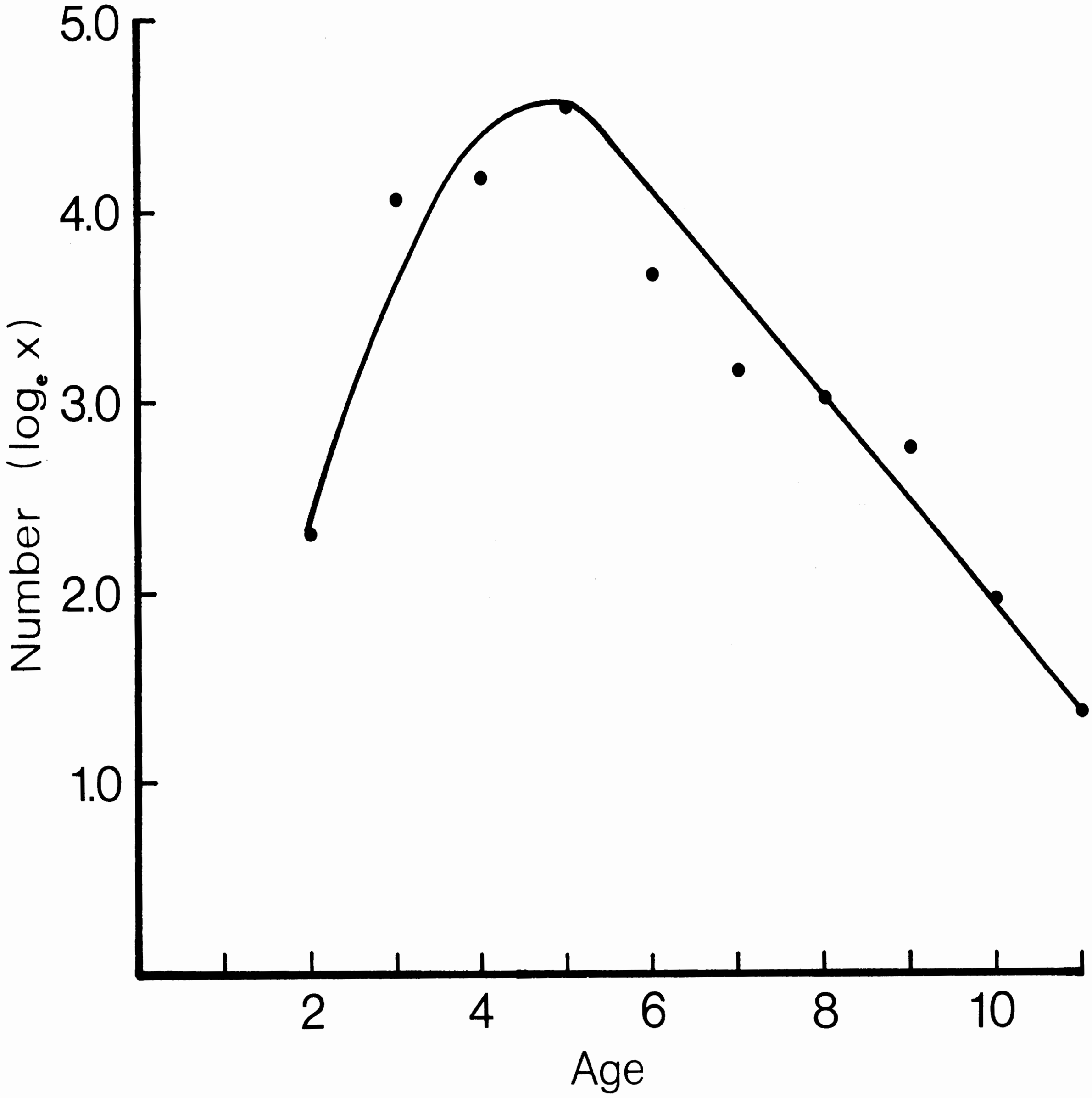

Figure 2.--Catch curve for largemouth bass collected with electrofishing equipment and trap nets in April and May 1980, at Pontiac Lake.

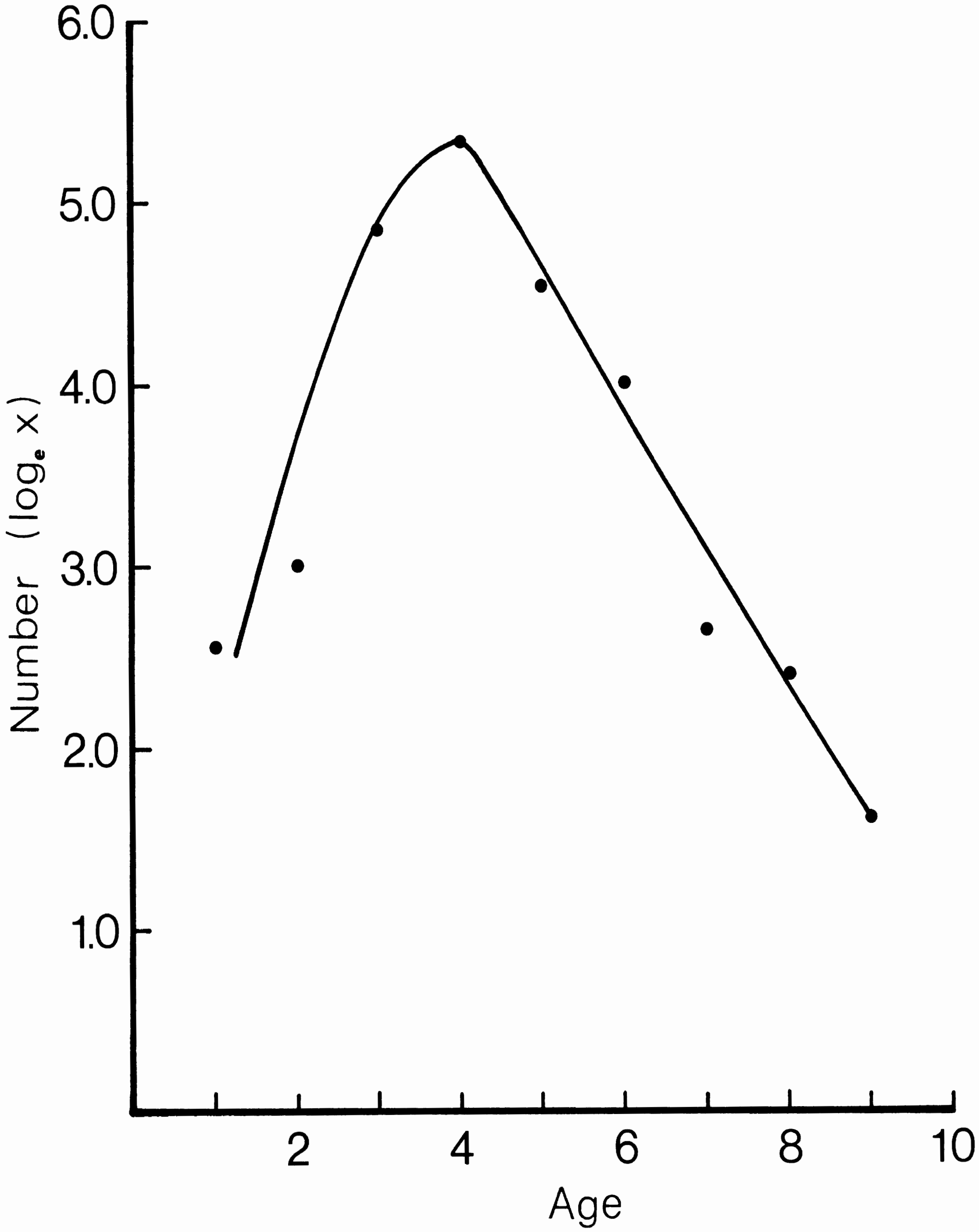

Figure 3.--Catch curve for largemouth bass collected with electrofishing equipment and trap nets in April and May 1980, at Whitmore Lake.

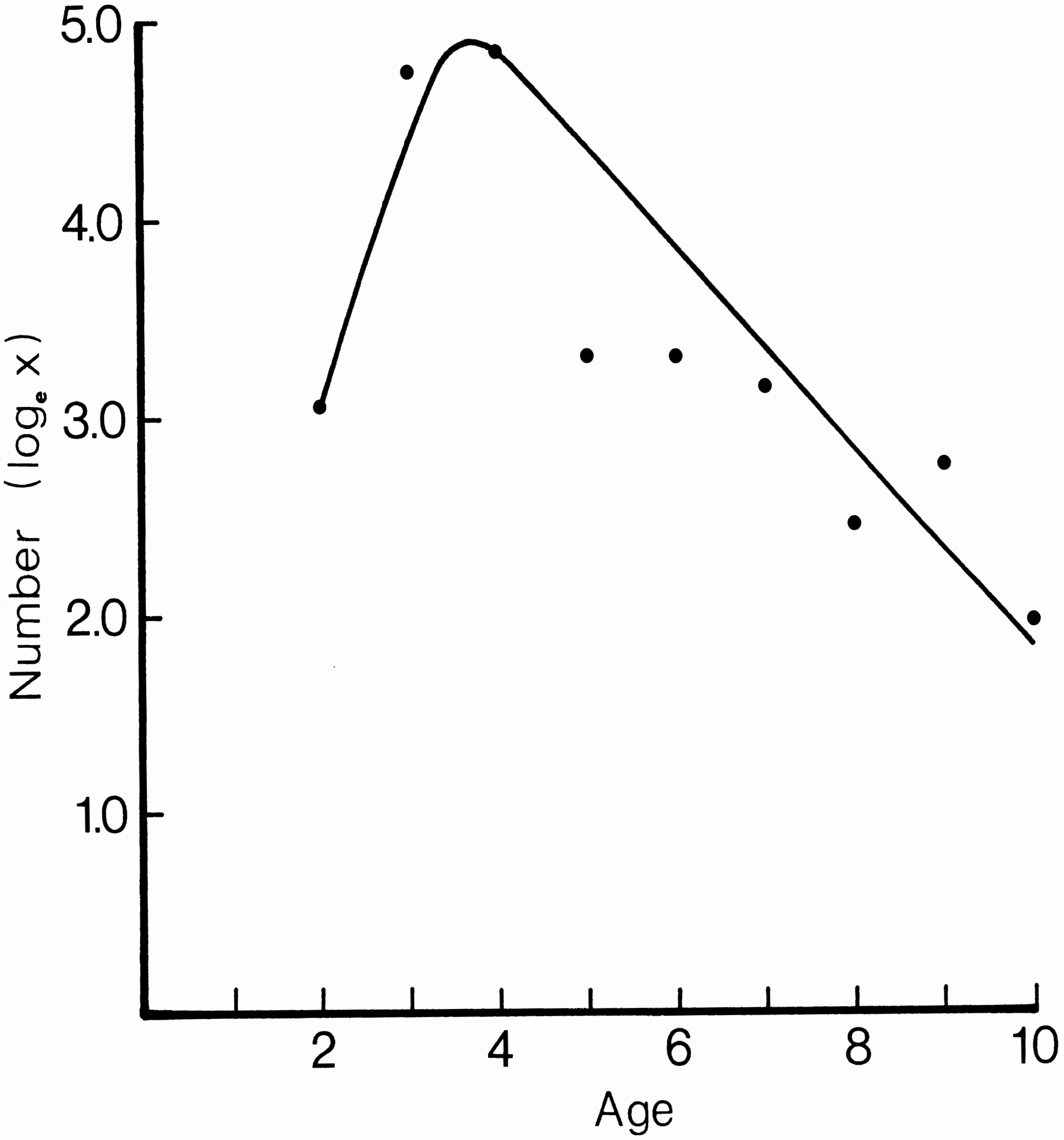

Figure 4.--Catch curve for largemouth bass collected with electrofishing equipment and trap nets in April and May 1980, at Kent Lake.

completely vulnerable to the sampling gear (Everhart et al. 1975). Usually older age groups containing less than five fish are not included in the estimate since statistical variation in small samples is quite large and could cause large changes in the slope of the regression lines (Everhart et al. 1975). Therefore regressions were run for ages 4 through 9 at Whitmore Lake ($r^2 = 0.96$), 5 through 11 at Pontiac Lake ($r^2 = 0.96$), and 4 through 10 at Kent Lake ($r^2 = 0.82$). The total annual mortality rates computed from the catch curves were 0.31 for Kent Lake, 0.38 for Pontiac Lake, and 0.53 for Whitmore Lake (Table 33). These rates are well within the range reported previously for lakes in Michigan and across the nation of 0.24 to 0.92 (Table 33). All three values are at or below the 0.52 average of all lakes in Table 33.

Bass fishing mortalities (exploitation rates, u, from Table 31) were likewise within the 0.08 to 0.65 previously reported range for U.S. lakes (Table 33). Both Pontiac and Whitmore lakes had fishing mortalities above the 0.26 average rate of exploitation for the lakes in Table 33 while exploitation at Kent Lake was below that mean.

Since total mortality is equal to the sum of fishing mortality and natural mortality (v), natural mortality was determined for largemouth bass in the study lakes by subtracting fishing mortality from total mortality (Table 33). In the past, natural mortalities for bass in Michigan lakes receiving average fishing pressure have generally been about half the total mortality with the remainder resulting from harvest by fishermen (Table 33). It is believed natural mortality at Sugarloaf Lake in 1962 is higher than half the total because of a high minimum size limit (Laarman and Schneider 1979). Of the three lakes studied, only Kent Lake displayed this 50:50 pattern with a 0.13 natural mortality rate and fishing mortality of 0.18. Both Pontiac and Whitmore lakes had minimal mortality due to natural causes, 0.04 and 0.05, respectively. The Pontiac and Whitmore

Table 33.--Mortality rates of adult largemouth bass from selected lakes.

Lake	Year	Mortality Total A	Mortality Fishing u	Mortality Natural v	Instantaneous total Z
Pontiac, MI	1980	0.38	0.34	0.04	0.479
Whitmore, MI	1980	0.53	0.48	0.05	0.754
Kent, MI	1980	0.31	0.18	0.13	0.377
Whitmore, MI	1953-1956[a]	0.35			
	1953[b]	0.42	0.22	0.20	
Sugarloaf, MI	1962[c]	0.43	0.10	0.33	
	1948-1952[d]	0.70	0.35	0.35	
Mill, MI	1965-1967[e]	0.40	0.00	0.40	
Average of 12 U.S. lakes	1942-1974[f]	0.55	0.27	0.28	
		(0.24-0.92)[g]	(0.08-0.65)	(0.06-0.56)	

[a] Cooper, Schafer, and Latta (1957)

[b] Cooper and Schafer (1954)

[c] Laarman and Schneider (1979)

[d] Cooper and Latta (1954)

[e] Schneider (1971)

[f] Latta (1974)

[g] Range of values reported

lake figures are only about 10% of the total mortality, the bulk of bass deaths coming from angler harvest. This indicates that either anglers are efficiently utilizing a healthy bass population, with few fish being lost to natural causes, or that the estimated exploitation rates are too high. Though it is possible that the exploitation rate estimates for these two lakes may be higher than actual fishing mortality, one should remember that an adult largemouth bass has few natural enemies and if death due to disease is minimal, natural mortality should be low except in the older ages. Also, with increasing fishing pressure fishing mortality tends to rise and natural mortality decrease (Heidinger 1976).

At Whitmore Lake, fishing mortality more than doubled from 1953 to 1980, going from 0.22 to 0.48 (Table 33). But during the same period, there was a corresponding decline in natural mortality of 75% dropping from 0.20 to 0.05, resulting in only a 26% increase in total mortality from 0.42 to 0.53.

By examining the mortality rates (Table 33) it was possible to arrive at limited conclusions about the current levels of exploitation in Pontiac, Whitmore, and Kent lakes. Basically a high proportion of total mortality was due to exploitation in two of the lakes, but the fishing mortality appeared to be countered by corresponding low natural mortality rates such that the level of exploitation did not seem to be creating adversely high total mortalities. Total mortality at all three lakes was either equal to or below the 0.52 average of the lakes presented (Table 33). Also, total mortality for bass in a Michigan lake with no fishing mortality was 0.40 (Schneider 1971). Both Pontiac and Kent lakes had total mortality rates below 0.40 despite exploitation rates as high as 0.34.

Bass Fishing Questionnaire

A total of 1,113 anglers from the three lakes responded to the questionnaire about bass fishing in Michigan (Fig. 1). Of these respondents, 23% said they never fish for bass in Michigan (question 1). The remaining questions were asked of the 862 anglers who said they fish for bass in Michigan at least once a year.

When asked if they usually keep the bass they catch or release them (question 2), 27% of the bass anglers said they release their bass. Anglers who fish often were more likely to say they release the bass. Older fishermen were also slightly more likely to release their bass.

Angler response to question 5--how would you feel if the lake was designated as a catch-and-release bass fishing lake, such that no bass of any size could be kept?--was 36% approved, 8% did not care, and 56% disapproved. As expected, catch-and-release fishermen (those who said they usually released their bass in question 2) were twice as likely to approve of this idea as anglers who preferred to keep and eat their catch--51% versus 28%. There was no difference in the response of anglers who spent more than 50% of their fishing time on the lake compared to those fishermen that spent less than 50% of their fishing activity at the lake. Similarly, answers did not differ between anglers who fish often and anglers who fish only once or twice a year. However, the more years an angler had been fishing, the more likely he was to approve. Many anglers who disapproved said they would approve if they could keep a trophy bass if they caught one; in effect opting for a high minimum size or weight limit to produce a trophy fishing lake where exceptional bass could be harvested.

Questions 4 and 6 dealt with angler response to extending the closed season in order to improve bass populations and fishing. Question 4 asked, "suppose you were required to throw back all the bass you caught in this lake before June 30, so that you might catch and keep more large bass during the rest of the season?" This would be a July 1 opening of the bass season at the lake. No fish could be kept during the entire spring fishing season when the greatest amount of bass fishing pressure and harvest now occurs. However, catch-and-release bass fishing would be allowed. Over 70% of the anglers approved, 12% did not care and 18% disapproved. But many anglers that approved said they would fish elsewhere during the spring. Catch-and-release fishermen were least likely to disapprove--only 10%, versus 22% of those who keep their catch. Again there was no difference in response to this question between anglers who spend more than 50% of their bass angling time at the lake compared to those who are at the lake less than half their angling hours. However, the more often an angler said he fished the lake, the more likely he was to disapprove of such a regulation. In contrast to their response to question 5, older fishermen were more likely to disapprove of this change than younger anglers.

Question 6 is similar to question 4 except that it involves all Michigan waters instead of only the particular lake where the angler was interviewed. Now only 58% of the anglers approved (though still a majority) and the number disapproving nearly doubled, increasing from 18% in question 4 to 31%; 11% did not care. There was no difference in the answer to this question between anglers who fish often and those who fish occasionally, or between older anglers and young anglers, or between anglers who keep their catch and those who release it.

Twenty-two percent of the bass anglers had fished for bass in Michigan 5 years or less, 25% had fished 6 to 11 years, and 53% had fished 12 or more years. Nine percent of these anglers were unaware of the minimum size limit change from 254 mm to 304 mm in 1976. It is believed that this number would have been higher if question 7 had been rephrased so that it read, "can you tell me what the minimum size limit for bass is now?" instead of stating the current size limit and asking the angler if he had been aware of the fact.

When asked how the minimum size limit change has affected their catch, only 14% of the bass anglers felt they caught fewer bass and 22% thought they caught more. However, 37% believed they kept fewer bass now than in the past and only 11% said they kept more. The trend of these figures agrees closely with the 33% decline in catch predicted by Latta (1974) at an exploitation rate of 0.35, and with the 18% to 29% drop in number of bass harvested at Pontiac and Whitmore lakes (Table 17). There was no difference in opinion between anglers who fish a lot and those who fish only rarely.

Though many anglers felt they were keeping fewer bass, they approved of the size limit change saying they were keeping larger bass than before the change was made. This observation agreed with the increase in the number of large bass harvested at Pontiac Lake recorded in this study. This indication that many anglers would rather catch fewer bass if the bass they did catch were larger, seems to be borne out by the response to question 11. Fishermen were asked, "in one fishing trip, would you prefer to catch and keep 4 bass 12 inches long, 3 bass 13 inches long, or 1 bass 16 inches long?" Over half the anglers, 52%, would like to catch the one 16-inch bass, 32% preferred catching four 12-inch bass, and 14% chose the three 13-inch bass. Weithman et al. (1979) obtained similar results when they asked anglers if they would rather catch 6 bass 300 mm long (12 inches) or 3 bass 370 mm long (14 1/2 inches) and 60% chose the three large bass. Along the same line, Brown (1968) listed size as the most important quality picked by anglers for a quality trout fishery. Similarly, in this bass study, preference for the one 16-inch bass was expressed by both anglers that fished often and those who released their catch.

To determine if anglers choosing to catch and keep the four bass 12 inches long would like to catch the larger bass if they could also catch, but then release, several smaller bass, question 11 was rephrased in question 12. The categories of question 12 were: 4 bass 12 inches long with no additional bass caught, 3 bass 13 inches long and 2 more bass 10 to 12 inches long were caught and released, and 1 bass 16 inches long with 5 more bass 10 to 14 inches long being released. So that no confusion would occur as a result of the long categories, the angler was given an index card with the choices printed on it to read while the question was recited to him. There was only a very slight increase in the number of anglers choosing the third category, changing from the 52% in question 11 to 55% in question 12. There was a shift in response from the first category to the second with the first declining from 32% to 20% and the second rising from 14% to 23%. Apparently many of the anglers choosing the first category do so because the most fish can be kept. They do not choose the other options, despite the additional fishing action provided by the bass that are caught and released, because they cannot keep the additional fish caught. As with question 11, both catch-and-release anglers and older fishermen were more likely to pick the third category.

Management Implications

As previously mentioned, the minimum size limit for bass in Michigan was raised in 1976 from 254 mm to 304 mm, as a result of increasing fishing pressure, in an attempt to maximize yield and protect spawning stocks (Latta 1974). The imposition of restrictive fishing regulations is generally made on the assumption that a relatively high mortality rate can be reduced or avoided by decreasing fishing mortality in the population (Anderson 1974). Minimum length limit restrictions have been found to be the most effective means of controlling bass harvest (Redmond 1974).

The increase in the bass minimum size limit from 254 mm to 304 mm in 1976 seems to have accomplished its objective in Michigan. Despite a 200% increase in bass fishing pressure since 1953 at Whitmore Lake, the bass population 254 mm and larger there has increased 22% above the 1953 levels under the 304-mm limit. At Pontiac Lake in addition to a probable similar increase in population size, there was a greater percentage of large bass caught by anglers than in the past. Increased minimum length limits have had success in other states as well. A 306-mm size limit was influential in nearly doubling the size of bass populations in less than 1 year in small northwest Missouri lakes receiving heavy fishing pressure (Rasmussen and Michaelson 1974). In another Missouri lake which was heavily fished, a 306-mm size limit on largemouth bass doubled the pounds of bass harvested after the first year (Ming and McDonald 1975).

Two assumptions must be met for a 304-mm minimum size limit to be effective in accomplishing its goal of reducing fishing mortality. The first is that losses from hooking are minimal, and second, that the released bass are reasonably recatchable (Anderson 1974; Latta 1974; Rutledge and Pritchard 1980; Wydoski 1980).

Hooking stress does not cause significant mortality in fish that are in good physiological condition (Wydoski 1980). Three years of data from a recent New York study indicated that angler released bass were not suffering increased mortality as a result of the angling experience (Schonhoff 1980). Angling studies at the Missouri Cooperative Fishery Research Unit found hooking mortality to amount to less than 5% of the largemouth bass caught (Weithman et al. 1980). And Redmond (1974) recovered only five dead bass in daily checks during a 16-day catch-and-release fishing season on a 6-ha lake when 1,550 bass were caught and released. However, in experiments conducted by Rutledge and Pritchard (1980), 38% of 1,351 bass hooked, died within 6 days.

Initial mortalities in 25 national bass tournaments averaged 21% and delayed mortality determined in 8 of the tournaments was an additional 12% (Holbrook 1975). High mortalities were associated with high water temperatures, long fishing days, and deeply swallowed hooks. Seidensticker (1980) observed 31% initial mortality during a 10-hour bass tournament fishing day whereas only 11% mortality was observed the second day with only 7 hours of angling. May (1973) found 67% of the bass that had swallowed the hook died versus only 7% of those hooked in the mouth.

Careful handling of bass during the catching, hook removing, and releasing process can greatly increase the chances for survival after being released. As a result of refined handling techniques, bass tournament fishermen have been able to reduce the high mortalities of released bass prevalent in the early years of competitive tournaments (Shupp 1978).

Susceptibility of bass to recapture, the second assumption that must be met for the success of the 304-mm minimum size limit, has been found to decrease with previous angling experience. Aldrich (1939) postulated that bass may learn to avoid angler lures by observation of the trauma accompanying the struggle of another hooked bass. Hackney and Linkous (1978) reported some conditioning or learning occurred among largemouth bass exposed to live bait angling for the first time. During a 6-week period most of the bass were captured at least once but relatively few could be provoked into striking a second time. In another experiment Anderson and Heman (1969) found bass released into Little Dixie Lake from fished and unfished experimental ponds were caught at different rates. For the first 2 weeks of spring fishing, bass stocked from the unfished ponds were caught three times as fast as those stocked from the fished ponds (16% versus 5%). When Mill Lake, Michigan, was opened to fishing after a 5-year closure, population density was 35 bass per hectare. In the first 3 days of fishing with pressure at 96 hours per hectare, 35% of the bass were removed (Schneider 1973). Catch statistics showed 481 bass caught on opening day, 155 the second day, and only 49 the third day. The drop in catch was found to be mostly due to a decline in catchability rather than a significant decrease in number of bass present. Brown and Ball (1942) and Westers (1963) have noted this decrease in angling susceptibility in other Michigan lakes. These studies indicate a definite decrease in bass vulnerability to anglers' efforts, but it may be that after a certain recovery period these bass would again be susceptible (Hackney and Linkous 1978). Periodicity of recapture of tagged bass (most larger than 1 kg) in a 10-ha impoundment ranged from three times in 1 day and nine times in 1 year, to once in 5 years with an average of once every 24 weeks in a 39-week fishing season (Weithman and Anderson 1980).

Two management possibilities should be discussed as a result of information gained in this study on bass populations and angler opinions on bass fishing in Michigan. First, since the 304-mm size limit has succeeded in increasing both the overall number of bass and the number of large bass in Michigan waters, it should be possible to shorten the length of the closed season, if desired, without harmful effects on the bass population. A year-round open season for bass was allowed on several experimental lakes in Michigan from 1954-1961 (Schneider and Lockwood 1979). The additional fishing activity during the normally closed season, from January 1 to the third Saturday in June, increased fishing pressure and catch substantially. Between 21% and 51% of the annual bass harvest was made during this time. However, it was found that bass catch was negligible between January 1 and April 30, the additional harvest being recorded in the 6 to 7 weeks from May 1 to the third week in June. Redmond (1974) found similar winter angling results and concluded that largemouth bass are essentially invulnerable to sport fishing during cold weather and that a mid-winter bass season opening provided some early spring fishing with no harmful effects. The few bass saved from winter anglers are apparently exploited by summer anglers anyway (Hackney 1974).

The additional spring catch in the experimental Michigan lakes was about equally divided between May 1-31 and June 1-24 (Schneider and Lockwood 1979). In 1972, the opening date of the bass season was advanced to the Saturday preceding May 30 (Memorial Day) thereby essentially providing protection of bass stocks for only a 3-week period in early May since catch is negligible before May 1. Then in 1976, it was decided more protection was needed and rather than increasing the length of the closed season again, the minimum size limit was raised from 254 mm to 304 mm, in effect protecting the bass for an additional year. If the closed season were removed entirely, bass populations would essentially lose only 3 weeks of protection from the additional year provided by the size limit change. However, by advancing opening day to May 1 instead of completely removing the closed season, angling opportunity is provided during the entire period bass are vulnerable to capture, yet the psychological factor of an opening day is retained, providing anglers a goal to look forward to in the spring. With a May 1 opening of the bass season, the opening week-end bass fishing crowd, which usually creates the highest bass fishing pressure of the season, would fall during a time when bass are only beginning to become susceptible to angler lures, rather than near the peak of the spawning period as is the case now.

There is little reason to suspect that with a shorter closed season recruitment might be diminished due to exploitation of spawning stocks. Several authors have noted there appears to be no obvious relationship between number of adult bass and numbers of young produced (Bennett 1954; Johnson and McCrimmon 1967; Schneider 1971; Bennett 1974; Hackney 1974; Latta 1975; Summerfelt 1975). When spring fishing was allowed during the spawning season for 5 years on experimental lakes in Michigan, almost as many young bass were produced at the conclusion of the study as at the start (Christensen 1953b). Even with annual exploitation rates as high as 60% in Ridge Lake, Illinois, bass were capable of replacing their numbers and weights during a single season (Bennett 1974). Only a few bass need to spawn successfully to furnish enough young to maintain the population (Fox 1975). The young of one pair of bass can overpopulate an acre of water (Bennett 1974). Even if a direct relationship between spawning stock and young is assumed, largemouth bass in Michigan lakes, with a size limit of 304 mm and exploitation rates as high as 70%, would be able to produce more than twice the number of fall fingerlings needed to replace the population (Latta 1974).

Instead of recruitment depending directly on the size of the spawning stock (above a certain minimum), year-class strength is strongly influenced by events occurring within the first month of egg deposition (Kramer and Smith 1962; Miller and Kramer 1971; Summerfelt 1975). These events include predation, competition for food, disease, parasitism, and variation in abiotic environmental factors including water level, wave action, temperature, dissolved oxygen concentration, and turbidity (Eipper 1975; Heidinger 1976). Much of the year-to-year variation in largemouth bass recruitment is not due to the number of spawners, but is a result of environmental conditions during the egg and larval periods of life.

A second possible management adjustment would be the creation of a few trophy bass fishing waters. Many anglers interviewed in this study expressed a desire for the establishment of a trophy bass fishing lake with a high minimum size or weight limit. Latta's (1974) largemouth bass modeling study, as well as others, showed that with a decrease in fishing pressure, which usually results from more restrictive or special regulations, the number of large bass in the population increases. This would provide increased angler opportunity to catch large bass. However, natural mortality would take its toll on bass saved from the angler's creel; indeed, natural mortality at Mill Lake, Michigan, with no angler exploitation at all, was higher than the total mortality at two of the lakes in this study (Schneider 1973). Previous studies with size limits as high as 406 mm in Michigan have shown negligible improvement in the number of large bass in the population (Schneider and Lockwood 1979). There would be the hazard of additional mortality due to catch-and-release handling practices. The problem addressed earlier of bass learning from prior angling experience and becoming less vulnerable to capture would exist. And there would be the enforcement difficulty of preventing undersized bass from being harvested. But if the population did improve in terms of the number of large bass, a trophy bass fishing water would provide enjoyment for bass anglers as they would have fishing access to a lake where they know there are large bass available to be caught.

CONCLUSION

The combination of more anglers and escalating angler interest in bass fishing has produced an increase in bass fishing pressure of up to 200% over the levels sustained by Michigan waters 30 years ago. During the same period largemouth bass exploitation rates have as much as doubled. Yet despite this large increase in angling pressure, total mortality rates have risen only about 26%. This appears to be the result of two factors, a compensatory decrease in natural mortality rates and an increase in the minimum size limit from 254 mm to 304 mm.

These two factors, one biological and one regulatory, have combined to produce bass populations with around 22% more bass 254 mm and larger and a greater percentage of large bass than in the past. Though a larger catch-and-release fishery is provided by the increased number of bass, the total number of bass harvested has decreased about 25% and catch rates for harvested bass have dropped considerably to an average of 0.06 bass per hour due to the higher size limit. However, the majority of anglers approve of the size limit change. Though they believe they are catching fewer legal size bass, they enjoy both the increased catch-and-release activity provided by the greater number of sublegal bass, and the larger size of the bass they are able to keep.

Though fishing pressure is high, exploitation rates are at acceptable levels and the bass populations appear to be doing well in both overall population density and the size-age structure. This is even the case at Kent Lake which had the smallest population density of the three study lakes and might be expected to be the most vulnerable to heavy fishing pressure. Yet this lake had the lowest exploitation rate, the most large bass, and the fastest bass growth rate of the three lakes.

Even though anglers would be willing to absorb more restrictive legislation if it would provide better bass fishing quality, it is felt increased fishing opportunity could best be provided, without harm to the bass population, by reducing the length of the closed season by 3 weeks rather than imposing more angling restrictions. Also, the establishment of trophy bass fishing waters, whether or not there was a dramatic increase in the number of large bass, would provide anglers an opportunity to fish waters where they know large bass are available to be caught.

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