A comparison of fish population estimates for two pothole lakes in Montana

by Dennis Lyle Workman

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
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Abstract:
Population estimates were made of the fish populations in two pothole lakes during the summers of 1969 and 1970 using three methods. Pumpkinseeds and largemouth bass were present in Plummers Lake and yellow perch in Cabin Lake. Trap nets were used to capture pumpkin-seeds and perch while hook-and-line was used to capture most bass.

Data collected by trap netting and angling were used to make population estimates using the method of Schnabel and DeLury. During the summer of 1970, after the estimates based on the Schnabel and DeLury methods were completed, the lakes were rehabilitated and the populations of all species were estimated using the Petersen method. The total estimated number of pumpkinseeds over 2.7 inches long was 52,911 with a standing crop of 142.8 lb/acre. Estimates based on the method of Petersen and that of Schnabel were in close agreement for all but fish in the smallest size group. The annual survival rate for pumpkinseeds in age groups III through VIII was 51 percent. The total number of perch over 2.8 inches long was estimated at 29,150 with a standing crop of 82.6 lb/acre. The number of perch estimated by the Schnabel method was lower than by the Petersen method for all size groups with a range in differences from 9 to 23 percent. The standing crop for a total estimated population of 2,239 largemouth bass from 2.7 to 11.0 inches long was 13.4 lb/acre. The survival rate for bass was estimated as 50 percent. Estimates based on the DeLury method were not satisfactory. Population estimates using the Schnabel method for 1969 are compared to those for 1970. Net selectivity for large fish, nonrandom distribution of marked fish and other factors affecting the accuracy of the estimates are discussed.

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Approved:

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ABSTRACT

Population estimates were made of the fish populations in two pothole lakes during the summers of 1969 and 1970 using three methods. Pumpkinseeds and largemouth bass were present in Plummers Lake and yellow perch in Cabin Lake. Trap nets were used to capture pumpkinseeds and perch while hook-and-line was used to capture most bass. Data collected by trap netting and angling were used to make population estimates using the method of Schnabel and DeLury. During the summer of 1970, after the estimates based on the Schnabel and DeLury methods were completed, the lakes were rehabilitated and the populations of all species were estimated using the Petersen method. The total estimated number of pumpkinseeds over 2.7 inches long was 52,911 with a standing crop of 142.8 lb/acre. Estimates based on the method of Petersen and that of Schnabel were in close agreement for all but fish in the smallest size group. The annual survival rate for pumpkinseeds in age groups III through VIII was 51 percent. The total number of perch over 2.8 inches long was estimated at 29,150 with a standing crop of 82.6 lb/acre. The number of perch estimated by the Schnabel method was lower than by the Petersen method for all size groups with a range in differences from 9 to 23 percent. The standing crop for a total estimated population of 2,239 largemouth bass from 2.7 to 11.0 inches long was 13.4 lb/acre. The survival rate for bass was estimated as 50 percent. Estimates based on the DeLury method were not satisfactory. Population estimates using the Schnabel method for 1969 are compared to those for 1970. Net selectivity for large fish, nonrandom distribution of marked fish and other factors affecting the accuracy of the estimates are discussed.

INTRODUCTION

Estimates of fish populations are an integral part of fisheries investigations and there are several methods available for making estimates. This study compares the results of three methods on the same populations.

Yellow perch *(Perca flavescens)* from Cabin Lake and pumpkinseeds *(Lepomis gibbosus)* from Plummers Lake were collected with trap nets. Largemouth bass *(Micropterus salmoides)*, in Plummers Lake, were captured by angling and trap netting. Data collected by trap netting and angling were used to make population estimates using the method of Schnabel and of DeLury. During the summer of 1970, after the estimates based on the Schnabel and DeLury methods were completed, the lakes were rehabilitated and the populations of all species were estimated using the Petersen method. Trapping and angling were done during the summers of 1969 and 1970. Estimates based on the method of Petersen and that of Schnabel were in close agreement but those based on the DeLury method were not.

DESCRIPTION OF STUDY AREA

Cabin and Plummers Lakes are two of more than 30 pothole lakes in the kame and kettle area on the east Kalispell Valley terrace, about 15 miles east of Kalispell, Montana. The terrace was formed from glacial deposits (Konizeski *et al.* 1968). The lakes are in steep-sided hollows surrounded by ridges covered with conifer trees and shrubs.

Cabin and Plummers are closed lakes receiving most of their water from subsurface springs. Water levels in the lakes rise during the summer and recede during the winter. In 1965, the water level in Cabin Lake was highest in September; Plummers was highest in August (Konizeski *et al.* 1968). Similar water level fluctuations occurred during 1969 and 1970.

Some physical and chemical characteristics of Cabin and Plummers Lakes are presented in Table 1. Cabin Lake is L-shaped with steep irregular shores. A small island, less than one acre, lies in the bend of the "L". The west shore descends abruptly to the deepest area in the lake. Plummers Lake is kidney-shaped with smooth, steep shores. A small island, visible in early summer and late fall, is located about one-third the length of the lake from the northeast end. The bottom of the northeast one-third of the lake slopes sharply to form a deep cone.

Chara sp. and *Drepanocladus* sp. were the predominant plants in Cabin Lake and covered most of the bottom. Other aquatic vegetation

Table 1. Some physical and chemical characteristics of Cabin and Plummers Lakes, during the summers of 1969 and 1970.

LAKE	Surface acres	Mean depth, feet (maximum depth, feet)	Shoreline development	Range & (average) minimum surface temperatures °C	Range & (average) maximum surface temperatures °C	pH Range (number of samples)	Average standard conductance (micromhos/cm)	Average ppm total alkalinity (number of samples)
CABIN	18.9	14 (18)	5.1	16-25 (21)	17-30 (23)	7.9-8.6 (10)	256.5	140.1 (10)
PLUMMERS	14.7	15 (22)	3.7	16-26 (20)	18-26 (23)	7.9-8.2 (10)	236.5	143.3 (10)

consisted of sparse stands of *Polygonium amphibium*, *Potamogeton amphifolius*, *P. gramineus*, and *Nuphar vareigatum*. The composition in Plummers Lake appeared similar to that in Cabin Lake in 1969 but no collection was made in that year. In 1970 all rooted aquatic plants in Plummers Lake were dead. Bottom mats loosened and rose to the surface forming islands of decomposing plant matter. The water in both lakes was clear with the bottom visible in all portions of Cabin Lake and in all but the bottom of the deep northeast end of Plummers.

METHODS

Four trap nets were used to capture yellow perch and pumpkinseeds each year. In 1969, two fyke nets of one-inch square mesh were used. Each was about 10 feet long, with a 3-foot diameter opening, and two 25 foot wings. In addition, two modified fyke nets of one-half inch square mesh were used. Each consisted of a 12 foot long hoop net with a 3-foot diameter opening, preceded by a 3 x 6 x 2 foot box of mesh-covered steel frames. Extending from this box was a four foot high lead. In 1970 only modified fyke nets were used, each differing only in length of lead (range 35 to 50 feet). Most bass were captured by angling but a few from 2.7 to 4.7 inches long were captured in the traps.

All trap nets were lifted and moved a short distance each day. Trapping was not complete until the entire perimeter of each lake had received approximately equal netting pressure. A record was made of marked and unmarked fish, and all unmarked fish were fin clipped. Measurements (length and weight) were made of a large sample of yellow perch and pumpkinseeds and on all largemouth bass. For age-growth analysis of each species, scales from approximately 50 fish were collected for each inch group, except for large fish where sample size was small. All fish were returned to the lake near the point of capture.

A single mark was used for all fish of a species captured during 1969. In 1970 each lake was arbitrarily divided into four areas of approximately equal shore length and numbered consecutively. A different fin clip was used to mark fish caught in each area and dorsal spine clips were used to indicate the number of times a fish had been recaptured in a particular area. Each lake was rehabilitated using Pro-Nox Fish toxicant sprayed from a boat at a concentration of approximately 1.0 ppm immediately after trapping was completed in 1970. As many fish as possible were checked for marks and additional measurements and scales were taken at that time. Estimates of the populations based on the Petersen method (Bailey modification) were made using formula 5 of the Michigan Institute for Fisheries Research (1960):

$$\text{population estimate} = \frac{N_1\ (N_2+1)}{(N_{12}+1)}$$

Confidence intervals were calculated using formula 6 of the Michigan Institute for Fisheries Research (1960):

$$\text{variance of population} = \frac{(\text{pop. est.})^2\ (N_2-N_{12})}{(N_2+1)\ (N_{12}+2)}$$

where N_1 is the number of fish caught, marked and released in the first sample

N_2 is the total number of fish caught in the second sample.

N_{12} is the number of recaptures in the second sample.

Population estimates based on the Schnabel method were made using formula 3.12 of Ricker (1958):

$$N = \frac{S(C_t M_t)}{R}$$

Confidence intervals were set for 1/N and then inverted using the following equation:

$$CI = \frac{1}{1/N \pm (t_{.95,n-1})(\sqrt{\text{var. of } 1/N})}$$

where $1/N = \frac{R}{S(C_t M_t)}$ and the variance of $1/N = \frac{R}{S(C_t M_t)^2}$, formulae 3.13 and 3.14, respectively, of Ricker (1958). The symbols are:

N the population estimate

C_t the total number of fish captured during time t

M_t the total marked at large at the beginning of the interval of time t

R the total number of recaptures during the experiment and

S is the summation of terms.

Population estimates based on the DeLury method were made using formulae 2.4 and 2.5 of DeLury (1951). Confidence intervals were calculated using formulae 2.6 and 2.7 of DeLury (1951).

Survival was estimated from the abundance of successive age groups, using the method of Jackson (1939):

$$s= \frac{N_2 + N_3 + N_4 \ldots N_r}{N_1 + N_2 + N_3 \ldots N_{r-1}}$$

where N is the abundance of each age group.

RESULTS

Trap netting of pumpkinseeds in Plummers Lake was carried out for 11 days between June 16 and July 3, 1970. A total of 8,345 pumpkinseeds were captured in 36 net sets during that time. On July 7th the lake was rehabilitated. Thirty people, including a high school biology class of about 20 students, collected fish. A total of 6,271 pumpkinseeds was collected and examined on July 7th and 8th and length measurements were obtained for 33 percent of those collected.

Pumpkinseeds were grouped into size intervals to avoid bias in population estimates due to net selectivity for larger fish and to facilitate estimates of the abundance of fish in each age group. Increasing rates of recapture of fish in the larger size groups indicated that the basic assumption of equal vulnerability of all fish to the trap netting was not met. The rates of recaptures (recaptures/marked at large) were 1.6 percent for 2.8-3.5 inch fish; 14 percent for fish 3.6-4.5 inches long; 26 percent for 4.6-5.5 inch fish and 35 percent for those larger than 5.5 inches long. Rates obtained from rehabilitation were 1.3 percent for the 2.8-3.5 inch fish and 24 percent for each of the next three larger size groups. These data substantiate the suggestion by Latta (1959) that estimates of total population numbers, where trap nets are used, should be made by estimating the abundance of each size group separately.

Another basic assumption in making population estimates is that marked fish distribute themselves randomly throughout the entire population being estimated (Ricker 1958). An indication of nonrandom mixing of marked fish throughout the entire population was obtained by comparing the number of fish recaptured in the area of initial marking to the number recaptured in other areas (Carlander 1970; Lawrence 1952). The percent of recaptures occurring in the area of initial marking ranged from 49 to 69 (Table 2). In three out of four cases the area with the fewest recaptures was also the farthest from the area of marking. The potential bias due to nonrandom mixing in this study was offset by systematically applying approximately equal fishing pressure to all portions of the lake perimeter.

An example of data tabulation for making a Schnabel estimate of a size group is presented in Table 3. Catch statistics, population numbers, and confidence limits for Petersen and Schnabel estimates were computed for each size group (Table 4). Estimates for the three largest size groups given by the two independent methods are in close agreement, with differences ranging from 3 to 18 percent. The Petersen estimate for 2.8-3.5 inch fish is 40 percent higher than that given by the Schnabel method. The confidence intervals for both types of estimates are relatively large reflecting the low rates of recapture noted previously for this size group. The possibility of the Schnabel estimates being biased due to net selectivity and the nonrandom mixing

Table 2. A comparison between the numbers of pumpkinseeds recaptured in and outside the area of initial marking (percent in parentheses).

Area of Marking	Area of Recapture 1	2	3	4
1	310 (69)	42 (9)	55 (12)	43 (10)
2	78 (26)	160 (55)	46 (16)	9 (3)
3	57 (15)	63 (16)	187 (49)	76 (20)
4	22 (9)	18 (8)	68 (28)	131 (55)

Table 3. Trap net data used for estimating the number of pumpkinseeds 4.6-5.5 inches long by the Schnabel method.

Date	Number Captured (C_t)	Number Recaptured (R_t)	Number Marked (C_t-R_t)	Marked At Large (M_t)	(C_tM_t)
June 17	440	0	440	0	0
June 18	774	37	737	440	340,560
June 19	378	66	312	1,177	444,906
June 23	328	83	245	1,489	488,392
June 24	197	54	143	1,734	341,598
June 25	187	50	137	1,877	350,999
June 26	248	61	187	2,014	499,472
June 30	293	55	238	2,201	644,893
July 1	269	97	172	2,439	656,091
July 2	369	137	232	2,611	963,459
July 3	303	97	...	2,843	861,429
Totals		737			5,591,799

Table 4. A summary of 1970 pumpkinseed catch statistics with Petersen and Schnabel population estimates, confidence intervals (CI) and standing crop for each size group.

Size Group	Type Estimate	Total Capture	Total Recapture	Marked at Large	Estimated Numbers (CI)	Total weight pounds	Standing Crop lb/acre
2.8-3.5	Petersen	405	8	626	28,239 (31,853-24,625)	564.8	38.4
	Schnabel	590	9	568	16,988 (42,900-10,592)	339.8	23.1
3.6-4.5	Petersen	3,971	842	3,546	16,708 (17,220-16,196)	835.4	56.8
	Schnabel	3,872	451	3,193	13,670 (13,833-13,504)	638.5	46.5
4.6-5.5	Petersen	1,865	690	2,905	7,845 (8,082-7,608)	682.5	46.4
	Schnabel	3,786	737	2,843	7,587 (7,638-7,537)	660.1	44.9
5.6+	Petersen	30	12	50	119 (148- 90)	17.5	1.2
	Schnabel	97	25	71	137 (154-123)	20.1	1.4
TOTALS	Petersen	6,271	1,552	7,127	52,911	2100.2	142.8
	Schnabel	8,345	1,222	6,675	38,382	1703.5	115.9

of marked with unmarked fish make it probable that the Petersen estimates are the most accurate.

DeLury estimates are dependent on the application of uniform effort and catching a large portion of the population. In addition, there must be no competition between units of gear and the catchability of fish must remain constant throughout the trapping period. Calculations are accomplished by determining the regression between the two variables: catch of unmarked fish per unit effort and accumulated catch of unmarked fish. The catch must be of sufficient magnitude to cause a decline in the numbers of unmarked fish captured over the study period, which results in a negative regression. Negative regressions were obtained for all size groups estimated but it was found that none of the regression coefficients were significantly different from zero at the 95 percent level of significance so the population estimates could not be made. Although 6,600 pumpkinseeds were marked, this represented only 12.6 percent of the total population estimated by the Petersen method which was not of sufficient magnitude to obtain an estimate by the DeLury method.

The age of 153 pumpkinseeds was determined, and length at each annulus was calculated (Table 5). About 90 percent of fish 2.8-3.5 inches long were in age group III. Fish 3.6-4.5 inches long were predominantly in age groups IV and V, 43 and 53 percent, respectively. The percentages of 4.6-5.5 inch fish in age groups V and VI were 53 and

Table 5. Average calculated lengths at each annulus for pumpkinseeds collected in 1970.

Year Class	Age Group	No. of Fish	Ave. Length	Calculated length at each annulus 1	2	3	4	5	6	7	8
1969	I	23	1.7	1.1							
1968	II	8	2.5	0.8	2.0						
1967	III	47	3.0	0.7	1.5	2.7					
1966	IV	23	3.8	0.6	1.5	2.3	3.4				
1965	V	55	4.6	0.6	1.7	2.7	3.5	4.4			
1964	VI	23	5.2	0.6	1.5	2.4	3.4	4.2	5.0		
1963	VII	11	5.8	0.7	1.6	2.6	3.5	4.2	5.0	5.6	
1962	VIII	2	6.3	0.8	1.8	2.4	3.1	3.8	4.6	5.4	5.9

43, respectively, while 62 percent of fish larger than 5.6 inches were older than VI years.

The age distribution of each size group in the sample was projected to the entire population using estimates obtained by the Petersen method. The projected distribution was as follows: age group III, 26,165; age group IV, 9,917; age group V, 13,053; age group VI, 3,368; age group VII, 393; age group VIII, 15. Using the Jackson method the annual survival rate was estimated as: $s = \frac{15 + 393 + 3,368 + 13,053 + 9,917}{393 + 3,368 + 13,053 + 9,917 + 26,165} \times 100 = 51$ percent. Thus, the total annual mortality rate was estimated as 100-51 = 49 percent. The total annual mortality rate based on data obtained from the Schnabel population estimate was 41 percent.

The total standing crop of pumpkinseeds over 2.7 inches long based on population estimates using the Petersen method was 142.8 lb/acre;

using the Schnabel method it was 20 percent less (Table 4).

Forty net sets in Cabin Lake over 11 days between July 21st and August 7, 1970 yielded a total catch of 6,133 yellow perch. The lake was rehabilitated on August 11th. Ten people collected 4,838 perch which were examined for marks on August 12th and lengths were obtained from 71 percent of those collected.

Perch were grouped into size intervals to compensate for possible bias due to net selectivity for large fish. Recapture rates obtained for various size groups were: 13 percent (3.6-4.5 inches), 10 percent (4.6-5.5 inches), 11 percent (5.6-6.5 inches) and 18 percent for those 6.6 inches and longer. Rates from the rehabilitation were 9 percent for the smallest size group, 19, 18, and 18 percent for each of the next three larger size groups, respectively. These data do not suggest strong net selectivity for large perch. Nonrandom mixing of marked fish throughout the entire population was suggested for perch (Table 6). The percent of recaptures from the area of initial marking ranged from 45 to 82. The combined percent of fish recaptured in the area in which they were initially marked and in one of the two adjacent areas ranged from 85 to 96. This source of bias was compensated for by systematically applying approximately equal fishing pressure to all portions of the lake perimeter.

Perch statistics were summarized and population estimates calculated for each size group by the Petersen and Schnabel methods (Table 7).

Table 6. A comparison between the numbers of yellow perch recaptured in and outside the area of initial marking (percent in parentheses).

Area of Marking	Area of Recapture 1	2	3	4
1	101 (68)	42 (28)	5 (3)	1 (0.7)
2	26 (10)	219 (82)	20 (7)	2 (0.7)
3	8 (5)	40 (25)	107 (67)	4 (3)
4	33 (40)	8 (10)	4 (5)	37 (45)

Schnabel estimates were lower than Petersen estimates for each size group; the differences ranged from 9 to 23 percent. In this situation, as with pumpkinseeds, the Petersen estimates are probably least vulnerable to bias.

Age was determined and length at each annulus was calculated for 194 yellow perch collected in 1970 (Table 8). Difficulty was experienced in accurately aging fish past age group II due to slow growth, dense compaction and erosion on the edges of the scales. The age distribution projected from the sample on the basis of data obtained from the Petersen population estimates was: age group I, 6,076; age group II, 700; age group III, 14,282; age group IV, 7,903; and age group V, 189.

The estimated number of fish in age group I is undoubtedly low since only the larger individuals in this age group were captured. Age group II perch accounted for only 3 percent of the total estimated population of fish over 3.5 inches long, which suggests a weak (1968)

Table 7. A summary of 1970 perch catch statistics with Petersen and Schnabel population estimates, confidence intervals (CI), and standing crop for each size group.

Size Group	Type Estimate	Total Capture	Total Recapture	Marked at Large	Estimated Numbers (CI)	Total weight pounds	Standing Crop lb/acre
3.6-4.5	Petersen	593	128	1,407	6,479 (6,991- 5,967)	194.4	10.3
	Schnabel	1,597	190	1,375	5,487 (4,851- 6,319)	164.6	8.7
4.6-5.5	Petersen	3,422	602	3,185	18,080 (18,750-17,410)	904.0	47.8
	Schnabel	3,496	311	3,037	16,468 (14,934-18,356)	823.4	43.6
5.6-6.5	Petersen	763	150	845	4,275 (4,590- 3,960)	384.7	20.3
	Schnabel	942	97	813	3,666 (3,097- 4,494)	329.9	17.4
6.6+	Petersen	60	15	83	316 (393-239)	79.0	4.2
	Schnabel	98	15	79	243 (166-458)	60.7	3.2
TOTALS	Petersen	4,838	895	5,520	29,150	1,562.1	82.6
	Schnabel	6,133	613	5,304	25,864	1,378.6	72.9

Table 8. Average calculated lengths at each annulus for yellow perch collected in 1970.

Year Class	Age Group	No. of Fish	Ave. Length	Calculated length at each annulus 1	2	3	4	5
1970	0	29	2.7					
1969	I	46	4.1	2.8				
1968	II	3	4.5	1.8	3.2			
1967	III	69	5.6	1.3	3.1	4.4		
1966	IV	71	6.3	1.2	3.1	4.4	5.4	
1965	V	4	6.8	1.5	2.9	4.0	5.1	6.0

year class. This weak year class was also observed for pumpkinseeds (Table 5) and largemouth bass (Table 10) from Plummers Lake. Over 48 percent of the population was made up of fish in age group III. Difficulties experienced in aging larger perch probably resulted in underaging many fish since one or more annuli on the edge may not have been distinguishable. The wide range of sizes (3.6-8.3 inches) classified as age III also suggests underaging. The above reasons probably accounted for a questionable calculated annual survival of 70 percent using the Jackson method.

The total standing crop of yellow perch over 2.8 inches long based on population estimates using the Petersen method was 82.6 lb/acre; using the Schnabel method it was 12 percent less (Table 7).

Eleven days of trap netting and approximately 110 man-hours of hook-and-line fishing in Plummers Lake between June 16th and July 3, 1970 yielded a total catch of 250 largemouth bass. The trap nets captured only bass from 2.7 to 4.7 inches long while hook-and-line fishing caught only those 5.6 inches and longer. Plummers Lake was rehabilitated on July 7th and 462 largemouth were collected and processed. Bass were arbitrarily divided into two size groups. Small sample size and the relatively small number of recaptures prevented the determination of gear selectivity and distribution pattern of marked fish.

The Petersen estimate of 2.7 to 6.9 inch bass is 44 percent higher than the Schnabel estimate of this size group and 12 percent lower than the Schnabel estimate of the 7.0 to 11.0 inch fish (Table 9). The small sample size of bass less than 7.0 inches long is conceivably the principle cause for the differences between the two estimates. The Petersen estimate should be relatively free from bias, and since it was based on nearly twice the sample size and had a 7 percent higher recapture rate, as compared to the Schnabel estimate, it is probably the most accurate.

Age was determined and length at each annulus was calculated for 223 largemouth bass from scales collected in 1970 (Table 10). The projected age distribution of the population based on the Petersen estimate is: age group I, 1,125; age group II, 59; age group III, 647; age group IV, 376; age group V, 32. Only 3 percent of the total estimated population of bass between 2.7 and 11.0 inches long were placed in age group II, indicating a weak (1968) year class. Using the Jackson

Table 9. A summary of 1970 largemouth bass catch statistics with Petersen and Schnabel population estimates and confidence intervals (CI) for each size group.

Size Group	Type Estimate	Total Capture	Total Recapture	Marked at Large	Estimated Numbers (CI)
2.7-6.9	Petersen	263	20	157	1,974 (2,422-1,526)
	Schnabel	168	11	157	1,110 (2,241- 720)
7.0-11.0	Petersen	199	54	73	265 (166-364)
	Schnabel	82	9	73	300 (750-188)
TOTALS	Petersen	462	74	230	2,239
	Schnabel	250	20	230	1,410

Table 10. Average calculated lengths at each annulus for largemouth bass collected in 1970.

Year Class	Age Group	No. of Fish	Ave. Length	Calculated length at each annulus 1	2	3	4	5	6	7	8
1969	I	67	3.6	2.7							
1968	II	3	4.4	1.8	3.7						
1967	III	63	6.8	1.9	3.7	5.9					
1966	IV	79	7.9	1.6	3.7	5.1	6.9				
1965	V	18	10.3	1.9	4.1	5.9	7.5	9.2			
1964	VI	0									
1963	VII	1	12.4	1.8	3.1	4.4	5.6	6.7	8.0	10.6	
1962	VIII	2	14.0	1.8	3.1	4.0	5.0	6.6	8.1	9.9	12.3

method the estimated annual survival rate through age group V was:

$$s = \frac{32 + 376 + 647 + 59}{376 + 647 + 59 + 1125} \times 100 = 50 \text{ percent.}$$

Using the Schnabel population estimate the annual mortality rate is calculated as 44 percent.

The total standing crop of bass 2.7 to 11.0 inches long based on the Petersen population estimate was 13.4 lb/acre; using data obtained from the Schnabel estimate it was 8.0 lb/acre. The combined standing crop of pumpkinseeds and largemouth bass in Plummers Lake based on the Petersen estimate was 155 lb/acre.

Schnabel estimates were made for all three species in 1969. Fish captured were grouped into the same size intervals as in 1970 to facilitate comparison of the estimates for the two years. Trapping for pumpkinseeds was conducted for 17 days between July 10th and August 8th and included 56 net sets. Trapping for perch was conducted for 9 days between June 23rd and July 9th and for 3 days between August 12th and 15th. A total of 28 net sets were made during the 12 days. Although the total effort expended in capturing pumpkinseeds in 1969 was considerably more than in 1970 (11 days and 36 net sets) the total catch was 62 percent less in 1969 (Table 11). Effort expended in capturing perch was slightly greater in 1970 (11 days and 40 net sets) with a 50 percent greater catch in 1970. The fyke nets used in 1969 captured 76 percent fewer pumpkinseeds, on the average, than the modified fyke nets and 95 percent fewer yellow perch. Part of this difference in catch

Table 11. A comparison of 1969 and 1970 population estimates calculated using the Schnabel method (confidence intervals in parentheses).

Species	1969 Total Capture	Size Group	1969 Estimates (CI)	1970 Estimates (CI)
Pumpkinseed	3,217	2.8-3.5	3,053 (5,882-2,044)	16,988 (42,900-10,592)
		3.6-4.5	6,243 (7,634-5,280)	13,670 (13,833-13,504)
		4.6-5.5	5,944 (6,766-5,302)	7,587 (7,638-7,537)
		5.6+	255 (611-179)	137 (154-123)
		TOTALS	15,477	38,433
Yellow perch	3,094	3.6-4.5	10,432 (15,188-7,841)	5,487 (4,851-6,319)
		4.6-5.5	14,177 (33,704-8,976)	16,468 (18,750-17,410)
		5.6-6.5	1,881 (3,312-1,313)	3,666 (3,097-4,494)
		6.6+	267 (481-185)	243 (166-458)
		TOTALS	26,667	25,864
Largemouth Bass	221	2.7-6.9[1]	1,277 (4,159-755)	1,110 (2,421-720)
		7.0-11.0	244 (581-155)	300 (750-188)
		TOTALS	1,521	1,410

[1]No bass smaller than 4.9 inches long were captured in 1969.

was due to the one-inch mesh size of the fyke nets which captured no pumpkinseeds smaller than 4.0 inches long and no yellow perch smaller than 4.8 inches long. The average catch per net of pumpkinseed in 1969 was 57 compared to 232 in 1970 when only modified fyke nets were used. The catch per net of perch in 1969 was 110 compared to 153 in 1970.

The total pumpkinseed population estimated in 1969 was 60 percent lower than in 1970. The principle difference was in the numbers estimated for 2.8 to 4.5 inch fish. The total number of perch estimated in 1969 was only 5 percent higher than in 1970 but for fish in the 3.6 to 4.5 inch group it was 53 percent higher (Table 11).

The distribution of net sets also differed between 1969 and 1970. In 1969 several locations were sampled as many as three times. In 1970 no net was ever set in a location that had been previously sampled.

Approximately equal effort was expended in fishing for bass in 1969 and 1970 but there was a 12 percent greater total catch in 1970. The estimates of the total population differed by only 7 percent with the highest estimate for 1969.

DISCUSSION

Cabin and Plummers Lakes had favorable characteristics for making population estimates. The relatively small surface area made possible adequate sampling in a short time reducing the chances of bias due to mortality or recruitment through growth. Being closed lakes and relatively shallow, additions to and losses from the population through migration were minimal. The lack of fishing pressure precluded the chance of significant error due to fishing mortality.

Some sources of bias can be offset through careful planning of procedures. The use of fin clips made identification easy and lessened the chance of tag loss. Differential vulnerability to trapping and nonrandom mixing of marked with unmarked fish were suspected in 1969 and were considered when planning the 1970 sampling procedures.

The differences between 1969 and 1970 estimates of pumpkinseeds and perch were probably due either to the use of two different types of nets in 1969 or to a less systematic sampling procedure. The use of one-inch square mesh nets in 1969 could have caused a misrepresentation of small fish in the sample in relation to large fish which were caught by both mesh sizes. Repeated sampling of certain locations in 1969 could have resulted in an underestimation of the total populations of pumpkinseeds and perch.

Another interesting point to consider is that if the 1969 estimates had been the only ones available the relatively narrow confidence limits could have instilled false confidence in the accuracy of the estimates (Table 11). When interpreting the results of population estimates it is important to know that confidence limits measure accuracy mainly as it is affected by the number of recaptures and that sample size and proportion of fish marked are important only as they affect the number of recaptures (DeLury 1951). The relatively good recapture rates of pumpkinseeds and perch (range 4 to 19 percent in 1969) in relation to total catches was probably due to repeatedly sampling certain locations.

Age information collected in 1970 on pumpkinseeds, perch and largemouth bass show disproportionately small numbers of age group II fish (Tables 5, 8, and 10, respectively). The appearance of a weak year class in three different species from two separate lakes suggests something more than coincidence or sampling error. Some environmental factor probably affected either spawning or survival of young in 1968.

The survival values calculated using the Jackson method are affected by the relative strengths of the year classes. Ricker (1958) suggests that the principle source of error in this type of survival estimate is the variable initial size of the broods involved. The small numbers of both largemouth bass and pumpkinseeds classified in age group II would influence the accuracy of the survival rates calculated.

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