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POPULATION DEVELOPMENT OF RE-INTRODUCED SMALLMOUTH BASS AND YELLOW PERCH IN NEBISH LAKE

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ABSTRACT

The population development of re-introduced smallmouth bass (Micropterus dolomieui) and yellow perch (Perca flavescens) in Nebish Lake was studied from 1967 to 1976. Nebish Lake was chemically treated in 1966 to remove a multi-species fish community that had replaced the native limited-species association. Mature smallmouth bass and yellow perch were restocked in the spring of 1967, and both species reproduced that year. Population estimates of fingerlings and adults were attempted every year, as were estimates of biomass, mortality, and survival.

Yellow perch became the more abundant of the 2 species by number and by biomass. The 1969 year class was the largest produced in the 10-year period, and overcrowding apparently caused severe mortality in 1971. The 1st 2 yellow perch year classes grew faster than succeeding year classes; later maturity was observed along with the slower growth.

Population estimates of adult smallmouth bass were higher than the single pretreatment estimate and higher than those for 2 other lakes in the region. The strongest year class was produced in 1970 and it was more abundant than any other year class at Ages 0 and II-IV. Growth rates were exceptional for the 1st 3 year classes, then declined to levels comparable to other northern Wisconsin lakes. The 1967 and 1970 year classes of smallmouth bass contributed 20 and 30%, respectively, of their estimated numbers to the harvest at Ages II-VI. However, total survival was much higher for the 1970 year class.

Exploitation rates during the study period averaged 0.40 for bass and 0.14 for perch. Age III smallmouth bass were more heavily exploited than older fish. Natural and fishing mortality were about equal for smallmouth bass for all ages and years combined. Natural mortality was considerably higher than angling mortality for the 1967 yellow perch year class at Ages I-IV.

CONTENTS

Department of Natural Resources • Madison, Wisconsin

INTRODUCTION

Chemical reclamation and restocking of lakes is an established fish management practice in Wisconsin, but its evaluation has been limited to subjective observations. The obvious successes have supported program expansion and obscured the need for further study (Kempinger and Christenson 1978). This omission is shared with many other resource agencies; as stated by Lennon et al. (1970), "Objective evaluations of subsequent management are conspicuously absent in much of the reclamation literature."

The history of the Nebish Lake (Vilas County) fish community is typical of many of our northern Wisconsin lakes. Its native limited-species community (Hile and Juday 1941) was altered during a statewide fish introduction program that began in the 1930's. By the time Nebish Lake was selected for chemical treatment research in the 1960's, its native populations of smallmouth bass, Micropterus dolomieui; rock bass, Ambloplites rupestris; yellow perch, Perca flavescens; and "minnows", had been supplemented with 3 stocked species (walleye, Stizostedion vitreum vitreum; northern pike, Esox lucius; and largemouth bass, Micropterus salmoides) and 6 species that were probably introduced but for which there are no stocking records (green sunfish, Lepomis cyanellus; pumpkinseed, Lepomis gibbosus; bluegill, Lepomis macrochirus; white sucker, Catostomus commersoni; black crappie, Poxomis nigromaculatus; and black bullhead, Ictalurus melas) (Christenson et al. 1982).

Nebish Lake was chemically treated in 1966 (Kempinger and Christenson 1978) and restocked in 1967 to compare angling quality before and after the manipulation and to describe the population development of the re-introduced smallmouth bass and yellow perch. The former objective has been met; angling quality, in terms of catch, yield, and catch rate, greatly improved following chemical treatment and restocking (Christenson et al. 1982). This paper presents the findings pertaining to population development for the period, 1967-76. Population size, biomass, growth, and mortality of the 2 re-introduced species are described, and harvest and survival of the 2 largest smallmouth bass year classes are discussed.

STUDY AREA

Nebish Lake, 1 of 5 lakes in the Northern Highland Fishery Research Area, is located on undeveloped, state-owned land in the Northern Highland State Forest in central Vilas County (Fig. 1). Access to the lake is provided at an unimproved boat landing with parking facilities for approximately 10 cars and boat trailers. The lake has a surface area of 94 acres, a shoreline of 3.2 miles, and a maximum depth of 50 ft. The bottom contour is irregular, with a sharp dropoff along most of the perimeter which limits the abundance of rooted aquatic plants.

Nebish is an infertile seepage lake, with a total alkalinity of 8.0-16.0 ppm. Other water quality characteristics are shown in Table 1. Fish species composition at the time of the chemical treatment consisted of 12 warm water species representing 5 families (Table 2). At that time, the standing crop was estimated to be 210.4 lb/acre (Kempinger and Christenson 1978).

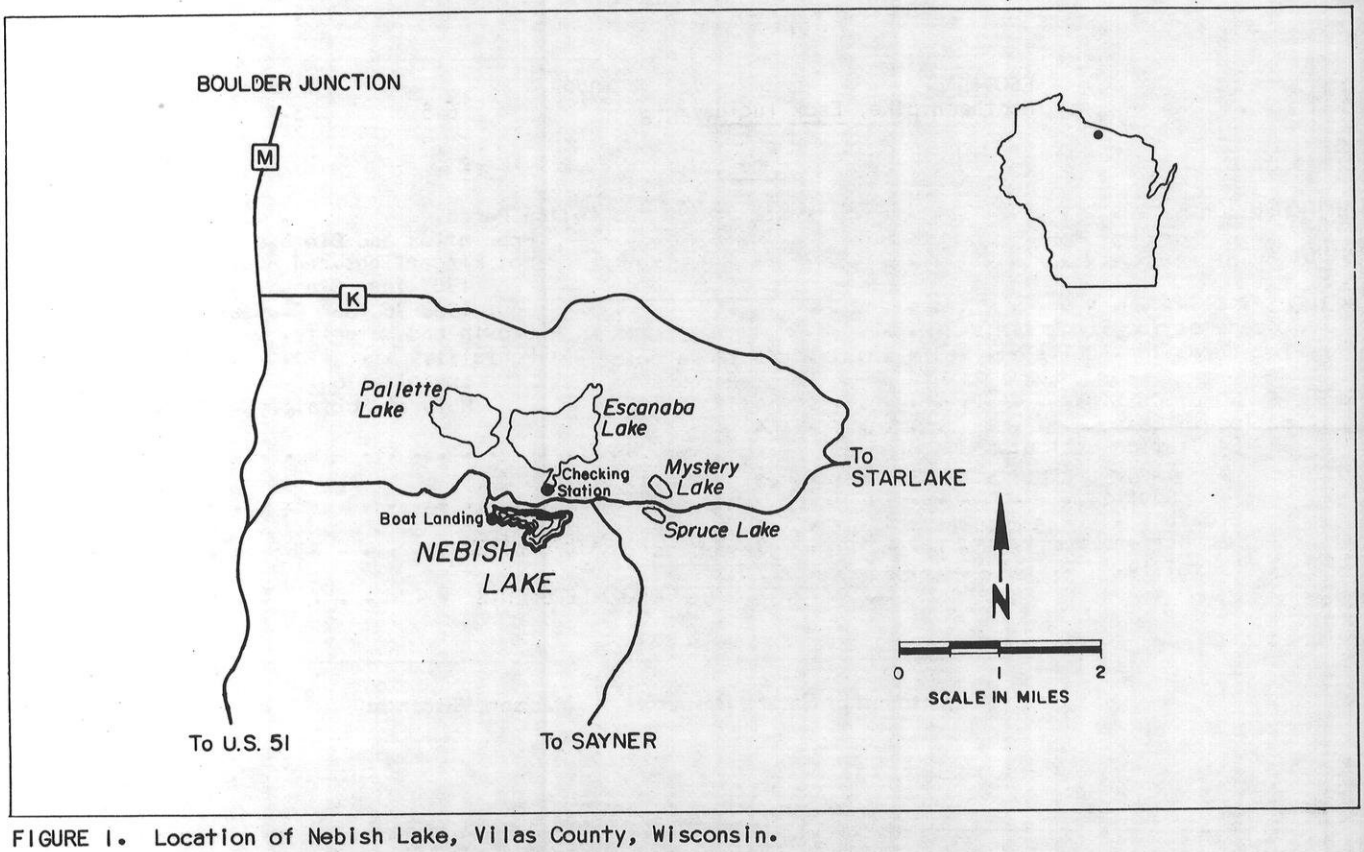

FIGURE 1. Location of Nebish Lake, Vilas County, Wisconsin.

TABLE 1. Chemical and physical characteristics of Nebish Lake at the surface and bottom during spring and summer.[a]

Parameter	Spring		Summer	
	Surface	Bottom	Surface	Bottom
Total alkalinity (mg/l CaC)$_3$	10.0	11.0	8.0	16.0
pH	6.9	6.8	7.1	6.1
Nitrite (mg/l N)	0.005	0.003	0.0	0.002
Nitrate (mg/l N)	0.1	0.1	<0.1	0.1
Ammonia (mg/l N)	0.0	0.0	<0.03	0.46
Organic nitrogen (mg/l N)	0.43	0.43	0.67	0.97
Dissolved phosphate (mg/l)	<0.03	0.0	0.0	0.07
Total phosphate (mg/l)	0.2	0.2	0.1	0.4
Sulphate (mg/l)	<2.0	<2.0	8.0	9.0
Chloride (mg/l)	<0.5	<0.5	<0.5	<0.5
Calcium (mg/l)	2.3	2.2	1.9	2.6
Magnesium (mg/l)	1.55	1.6	1.12	1.25
Sodium (mg/l)	0.42	0.45	0.45	0.55
Potassium (mg/l)	0.52	0.55	0.45	0.63
Dissolved oxygen (mg/l)	9.6	8.7	7.9	0.0
Specific conductance (micromhos/cm at 25 C)	--	--	30	45
Temperature (C)	5.5	5.5	22.2	7.2
Secchi disk (m)	4.25		4.0	

[a]Spring and summer sampling dates were 28 April 1969 and 28 July 1969, respectively.

TABLE 2. Standing crop of fish species present in Nebish Lake at the time of chemical treatment, October 1966.[a]

Family and Species	Standing Crop	
	Lb/Acre	Percent
ESOCIDAE		
Northern pike, *Esox lucius*	6.5	3.1
CYPRINIDAE		
Bluntnose minnow, *Pimephales notatus*		
Mimic shiner, *Notropis volucellus*	135.2[b]	64.3[b]
CATOSTOMIDAE		
White sucker, *Catostomus commersoni*	13.1	6.2
CENTRARCHIDAE		
Smallmouth bass, *Micropterus dolomieui*	6.1	2.9
Largemouth bass, *Micropterus salmoides*	0.4	0.2
Green sunfish, *Lepomis cyanellus*	0.6	0.3
Pumpkinseed, *Lepomis gibbosus*	0.3	0.1
Bluegill, *Lepomis macrochirus*	2.5	1.2
Rock bass, *Ambloplites rupestris*	5.9	2.8
PERCIDAE		
Yellow perch, *Perca flavescens*	29.0	13.8
Walleye, *Stizostedion vitreum vitreum*	10.8	5.1
Total	210.4	100.0

[a]From Kempinger and Christenson (1978).

[b]Both minnow species combined.

METHODS

PROCEDURES FOR FINGERLINGS

Smallmouth bass and yellow perch fingerlings in Nebish Lake were sampled each fall from 1967 through 1976. The entire 3.2 miles of shoreline were electrofished with a 230-volt, 3,000-watt AC boom shocker on 3-5 nights between 5 September and 19 November. The fingerlings were captured with a dip net and marked by fin removal; the population size was estimated using the Schnabel method. A yellow perch fingerling estimate was possible only in 1967; in the following years, there were no recaptures. Biomass of the smallmouth bass fingerlings was estimated only in the fall of 1967.

In some years, only a few fingerling smallmouth bass were recaptured, and fingerling abundance was evaluated from catch/unit effort (CPE) rather than from a population estimate. CPE was calculated as the number of fingerlings caught/mile of shoreline on the 1st night of sampling. In order to calculate fingerling densities in years when population estimates were not possible, we determined the regression equation for CPE and density for the years when population estimates were done (see Table 3).

PROCEDURES FOR ADULTS

Adult smallmouth bass and yellow perch were captured during the spawning periods using 4-ft fyke nets (3/8- and 3/4-inch square mesh). Yellow perch were sampled for a 6- to 17-day period at "ice out" which occurred as early as 17 April and as late as 5 May during the 1967-76 period. As many as 6 or 8 nets were used in the early years, but after 1970, only 3 nets were needed to obtain a very large sample. Smallmouth bass were collected in 8 fyke nets which were set as early as 14 May and as late as 4 June for periods of 9-15 days.

Scale samples were obtained below the lateral line at the terminus of the pectoral fin from all bass and from 10 yellow perch of each sex in each 1/2-inch size group. All bass and a sample (contents of 1 fyke net) of yellow perch were measured and weighed. Yellow perch were marked by fin removal. Smallmouth bass were marked with individually numbered Floy FD-67C anchor tags.

The standing stock (population estimate) and biomass of adult fish were calculated by year class for yellow perch from 1967 to 1971 and for bass each year. From 1972 to 1976, yellow perch were estimated by 1/2-inch size groups rather than year class. Petersen population estimates were determined from the recapture of marked and unmarked fish by anglers during the open water season following the marking period. Growth and recruitment between the time of marking and recapture were not considered. A complete creel census provided data on the total number and weight of fish harvested (Christenson et al. 1982).

There were some exceptions to the use of the Petersen method for yellow perch; a few year classes were estimated by Schnabel estimates, from catch curves, or by subtracting an estimate for 1 age group from an estimate of 2 groups combined (see Table 10).

Exploitation rates were calculated as the proportions of marked fish harvested by anglers. Survival of smallmouth bass and of the 1967 year class of yellow perch was computed from spring population estimates of 1 year to spring estimates of the next year. For example, annual survival from Age II to Age III was computed by dividing the spring Age II population estimate into the Age III population estimate for the next year.

RESULTS AND DISCUSSION

SMALLMOUTH BASS

Population Estimates and Biomass

Fingerlings. Fingerling smallmouth bass were found in Nebish Lake every fall from 1967 to 1976 although there was considerable variation in numbers (Table 3). In 1967, the 1st year after chemical reclamation and the restocking of 38 brood stock smallmouth bass, a sizeable year class estimated at 84.3 fingerlings/acre was produced. Fingerling densities were estimated for 6 of the 10 years of study. During these 6 years, there was a 9-fold range from a low of 12.5 to a high of 111.5 fingerlings/acre. The estimated biomass of the 1967 fall fingerling population, based on 40 fingerlings/lb, was 188 lb or 2.0 lb/acre.

The largest fingerling year class of the 10-year period was produced in 1970 when progeny from the 1967 brood stock reached Age III; the fall fingerling density was 111.5/acre (Table 3). The success of the 1970 year class was attributed both to the large number of nesting adults and to the exceptionally warm growing season. In the spring of 1970, a total of 62 bass nests were observed between the shoreline and depths of 13 ft. Nest counts for the 2 succeeding years in which small year classes were produced were 15 and 11 in 1971 and 1972, respectively. However, probably more important to the success of the 1970 cohort was the temperature of the 1st growing season; the June-August noon water temperature in Nebish Lake in 1970 averaged 73.4 F, 1 of the 2 highest values observed during the 10-year period (Table 4). In continuing studies on Nebish Lake (Serns 1982), the number of fall fingerlings in 1974-81 was positively correlated with water and air temperatures during June and June-August combined and not with the number of adults or the number of fingerlings in previous years.

The 3rd largest year class was produced in 1976; there were 82.6 fingerlings/acre in the fall (Table 3). The fact that the 1976 year class was subjected to the warmest growing season of the 10-year period (Table 4) adds credence to the importance of temperature to 1st year survival.

It is interesting that the 1967 fall fingerling density was high even though summer water temperatures that year were among the lowest observed from 1967 to 1976 (Table 4). It seems that the advantage of entering an environment of reduced competition outweighed the disadvantage of cooler temperatures in this 1st year.

Numbers of fingerlings captured on the 1st night of electroshocking (CPE) ranged from 1.8 to 284.5/mile (Table 3). The 9.0 and 11.9 fingerlings/mile captured in 1971 and 1972 were estimated to represent 25.3 and 26.4/acre, respectively, on the basis of the regression between CPE and density. Since the percent

TABLE 3. Smallmouth bass fingerling catch/effort (CPE), population estimates, and density in Nebish Lake in the fall, 1967-76. The regression between CPE and density was used to calculate fingerling density in years when recapture rates were too low for population estimates.

Sampling Year	CPE (no./mile shoreline)	Population Estimate *N*	95% Confidence Interval	Density (no./acre)	Calculated Density (no./acre)[a]	Percent Error[b] (Sign Ignored)
1967	189.9	7,923	5,110-17,153	84.3	89.0	5.6
1968	1.8				c	
1969	2.2				c	
1970	284.5	10,477	8,403-14,306	111.5	122.3	9.7
1971	9.0				25.3	
1972	11.9				26.4	
1973	8.3	1,495	208- 7,475	15.9	25.1	69.6
1974	20.2	1,174	705-14,493	12.5	29.3	134.4
1975	78.7	5,718	3,185-17,241	60.8	49.9	17.9
1976	91.3	7,764	5,405-11,236	82.6	54.3	34.3
Mean	69.8			61.2	52.7	45.3

[a]Regression formula used to calculate smallmouth bass fingerling density from CPE is: $Y = 22.17 + 0.352\ X$ ($r = 0.914$, df = 4, $P < 0.05$), where Y = estimated fingerling density (no./acre) and X = fingerling CPE.

[b]Between density and calculated density.

[c]CPE values were outside the range of observed densities; for this reason the density was not calculated.

error between fingerling density and density calculated by regression was variable and often high (Table 3), the calculated densities for 1971 and 1972 should be used with caution. The lowest CPE's were observed in 1968 and 1969; population estimates were not possible due to lack of recaptures, but these years probably represent the smallest year classes produced during the 10-year period.

The poor 1968 year class cannot be attributed to angler removal of the brood stock, as only 7 bass, or 18% of the brood stock, were caught by anglers during the 1968 spawning period (prior to 1 Jul). During the entire 1968 open water fishing season (May-Nov), anglers caught 28 bass, or 74% of the brood stock, which may have had a detrimental effect on the 1969 year class. The 1st season growing temperatures for 1968 and 1969 were among the lowest observed for 1967-76 (Table 4), and therefore, the absence of strong year classes was not surprising.

The range of fingerling densities observed in Nebish Lake (too few to estimate to a maximum of 111.5/acre) was broader than that in 48-acre Katherine Lake in upper Michigan where Clady (1975) reported a range of 36-87/acre over a 3-year period. The average number of about 61/acre was the same in both studies.

Adults. Population estimates for adult smallmouth bass began at Age II (Table 5). In the absence of size limits, bass entered the creel as yearlings. However, few of these fish had been marked since they were not yet vulnerable to capture in fyke nets. Standing

TABLE 4. Mean noon June-August water temperatures in Nebish Lake, 1967-76.

Year	Temperature (F)
1967[a]	70.8
1968[a]	70.4
1969[a]	70.8
1970	73.4
1971	71.6
1972	70.9
1973	71.9
1974	70.6
1975	72.6
1976	73.5

[a]1967-69 temperatures determined from the relationship between mean 7:00 a.m. water temperature at Escanaba Lake (X) and mean noon water temperature at Nebish Lake (Y) in 1970-76. $Y = -2.65 + 1.07\ X$; $r = 0.961$, $P < 0.01$, 5 df.

TABLE 5. Estimated number of adult smallmouth bass in Nebish Lake in the spring, 1969-76.

Sampling Year	Number in Each Age Group[a] (95% Confidence Intervals)						
	II	III	IV	V	VI	VII	
1969	2,225 (1,900-2,599)						
1970	865 (636-1,172)	345 (267-427)					
1971		115 (79-173)	45 (26-95)				
1972	4,770 (4,121-5,512)	745 (545-1,049)	85 (23-840)	40 (14-200)			
1973		3,350 (2,864-3,921)	250 (166-398)	60 (23-238)	25 (8-117)		
1974		475 (162-2,380)	470 (330-699)	75 (41-149)	25 (9-125)		
1975	1,450 (767-3,280)	250 (143-484)	55 (24-175)	115 (45-459)			
1976		880 (672-1,152)	120 (64-251)	15 (3-160)	20 (3-56)	25 (7-245)	
Averages							Totals
No.	2,328	880	171	61	23	25	3,488
No./acre	24.7	9.4	1.8	0.6	0.2	0.3	37.0

[a]Numbers are rounded to the nearest 5 fish.

TABLE 6. Biomass estimates of smallmouth bass in Nebish Lake in the spring, 1969-76.

Sampling Year	Weight of Each Age Group (lb)						
	II	III	IV	V	VI	VII	
1969	378						
1970	130	141					
1971		51	55				
1972	429	164	143	78			
1973		469	115	79	61		
1974		67	122	40	40		
1975	87	53	20	78			
1976		387	118	16	18	48	
Averages							Totals
lbs	256	190	96	58	40	48	688
lb/acre	2.7	2.0	1.0	0.6	0.4	0.5	7.2

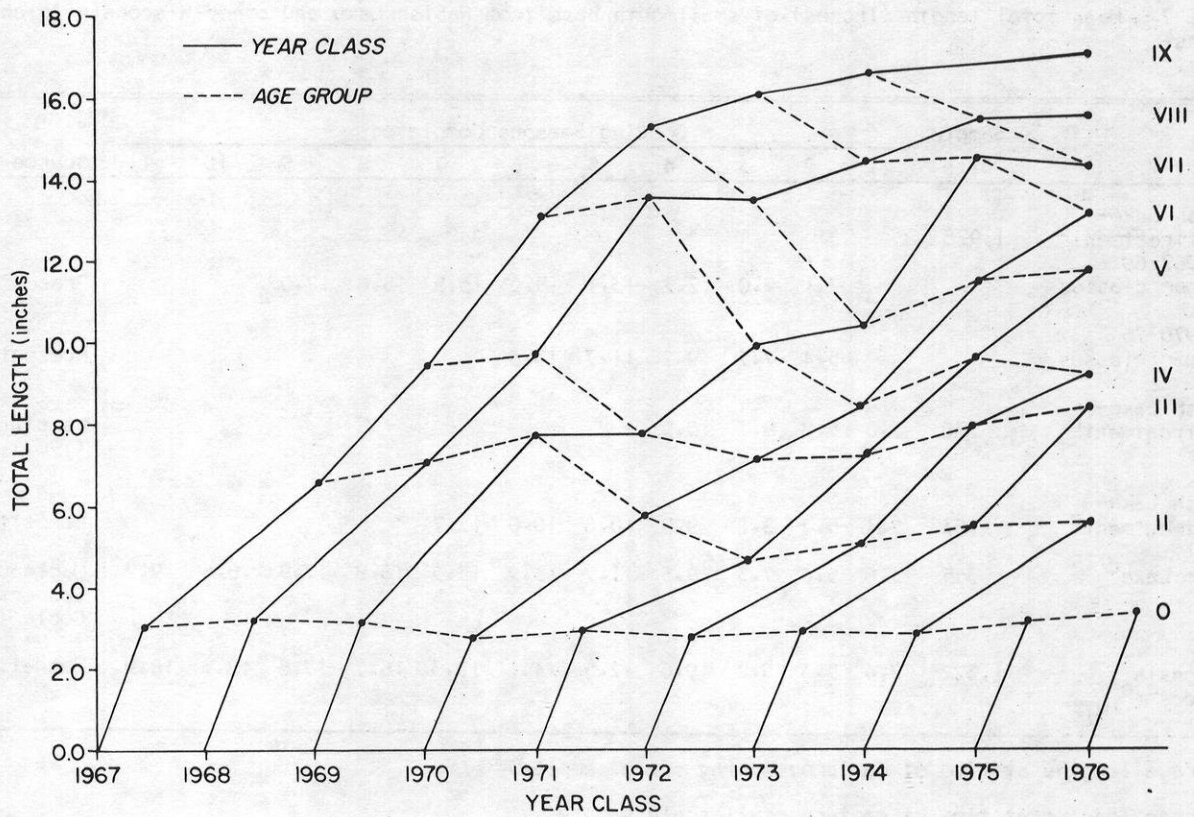

FIGURE 2. Average length of smallmouth bass at time of capture in Nebish Lake by year class and age group, 1967-76. The solid lines show the annual increase in average length of the individual year classes. The dashed lines connect the average length of each age group. Age 0 fish were measured in the fall; all other ages were measured in the spring.

stock estimates for Age II fish were achieved for only 4 of 8 years. Populations of the 4 year classes not estimated at Age II were estimated at Age III.

The average numbers of smallmouth bass in age groups II-VII in spring were 24.7, 9.4, 1.8, 0.6, 0.2, and 0.3 fish/acre, respectively (Table 5). The strongest year class observed was that of 1970. It had the highest fingerling density and was more abundant than any other year class at Ages II, III, IV, and V. The average spring biomass of age groups II-VII was calculated at 2.7, 2.0, 1.0, 0.6, 0.4, and 0.5 lb/acre, respectively (Table 6).

The re-introduced smallmouth bass population in Nebish Lake achieved a greater density and biomass than the population which was present in 1966 when the lake was chemically treated. The re-introduced population of Age II and older bass averaged 37.0 fish/acre and 7.2 lb/acre over 8 years (Tables 5 and 6). At the time of chemical reclamation, Nebish Lake supported a population of Age I and older smallmouth bass that numbered 15 fish/acre and weighed 3.0 lb/acre (Kempinger and Christenson 1978). We have only this single 1966 fall estimate to use for before and after treatment comparisons of bass production in Nebish Lake.

Estimates of adult smallmouth bass for Nebish Lake were higher than in 2 other lakes in the region. Marinac-Sanders and Coble (1981) found a smallmouth bass population of 3.5/acre that weighed 1.0 lb/acre in Clear Lake, Wisconsin (using fish ≥8.9 inches). Clady (1975) reported 5.1 smallmouth bass/acre in Katherine Lake, upper Michigan (using fish ≥9.0 inches). The best posttreatment comparison of data from Clear and Katherine lakes to Nebish Lake would be by using Age III (which averaged 8.2 inches) and older smallmouth bass which represented an estimated 12.3 bass/acre and 4.5 lb/acre. If we consider only the last year of sampling in Nebish Lake (1976) when estimates through Age VII were possible, the population of Age III (which averaged 8.5 inches) and older bass numbered 11.3 fish/acre and weighed 6.2 lb/acre.

Growth

As might be expected, the early year classes of smallmouth bass grew rapidly (Fig. 2) in the

TABLE 7. Mean total length (inches) of smallmouth bass from Nebish Lake and other Wisconsin inland waters.

Water	Sample Size	Growing Seasons Completed 1	2	3	4	5	6	7	8	9	10	11	Source
Nebish Lake--posttreatment[a]	1,928												
1967-69 year classes			7.1	9.0	12.2	13.1	15.0	15.5	15.6	17.0			Present Study
1970-76 year classes			5.4	7.7	9.2	11.7	13.3						Present Study
Nebish Lake--pretreatment[b]	170	3.0	5.8	8.7	10.5	--[d]							Kempinger (1967)
Nebish Lake--pretreatment[c]	183	2.4	5.4	8.1	9.9	10.6	10.0	12.2					Bennett (1938)
Clear Lake[c]	355	3.6	5.6	7.3	9.5	11.7	13.9	15.5	16.8	17.9	18.6	19.2	Marinac-Sanders and Coble (1981)
Wisconsin waters[c,e]	1,322	2.4	5.3	8.2	10.6	12.5	14.1	15.3	16.7	17.6	18.3	18.9	Bennett (1938)

[a]Average lengths at time of capture; spring scale samples.

[b]Average lengths at time of capture; fall scale samples.

[c]Back-calculated lengths.

[d]Older fish were kept in holding ponds for re-introduction and were not aged.

[e]Average of 19 lakes and 1 stream.

TABLE 8. Population, harvest, and survival of the 1967 and 1970 year classes of smallmouth bass in Nebish Lake.

Parameter	Year Class 1967	1970
Population Estimate		
Fingerling	7,923	10,477
Age II	2,225	4,770
Total Harvest (Ages II-VI)		
Number	1,575	3,155
Percent fingerling estimate	20	30
Percent Age II estimate	71	66
Survival		
Percent of Fingerling Estimate at Present Age:		
II	28.1	45.5
III	4.4	31.9
IV	0.6	4.5
V	0.5	1.1
VI	0.3	0.2

TABLE 9. Total annual mortality (A) and exploitation rates (u) for smallmouth bass in Nebish Lake, 1969-76.

Sampling Year[a]	Age Group II		Age Group III		Age Group IV		Age Group V		Weighted Mean III+	
	A	u	A	u	A	u	A	u	A	u
1969-70	0.84	0.57							--	--
1970-71	0.87	0.37	0.87	0.52					0.87	0.52
1971-72	--	--	0.26[b]	0.58	0.12[b]	0.41			0.22[b]	0.52
1972-73	0.30	0.28	0.66	0.23	0.29	0.29	0.38	0.25	0.61	0.24
1973-74			0.86	0.45	0.70	0.47	0.59	0.58	0.84	0.46
1974-75			0.88	0.43	0.74	0.38	--	0.25	0.82	0.33
1975-76	0.40	--	0.52[b]	0.80	0.73	0.36	0.83	0.13	0.79	0.35
Means										
1969-76	0.60	0.41	0.82	0.50	0.62	0.38	0.60	0.30	0.79	0.40
1972-76	0.35	0.28	0.80	0.48	0.62	0.38	0.60	0.30	0.76	0.34

[a]Mortality for age group indicated from spring to the following spring.

[b]Total annual mortality (A) not included in calculation of mean when u is greater than A, an impossible situation due to small sample size and/or sampling variation.

presence of only limited competition with older bass and yellow perch. This was least dramatic for fingerlings, which averaged 3.1 inches in length for the 1967-69 year classes and 2.8 inches for the 1970-76 year classes (Appendix Table 1). Good fingerling growth in the early years can be attributed to the advantage of entering an environment of reduced competition following chemical treatment. However, after the population was re-established, 1st season growth was positively correlated to August air and water temperatures for 1974-81 samples (Serns 1982).

The 1st 3 year classes of bass at Age I and older also grew faster than the succeeding year classes; the average length of 1967-69 year classes at comparative ages was from 1.3 to 3.0 inches larger than the average for the 1970-76 year classes (Table 7, Appendix Table 1). Growth of the 1st 3 year classes (1967-69) was exceptional when compared to pretreatment Nebish Lake and through the 1st 6 growing seasons when compared to other Wisconsin waters (Table 7). Growth rates for the succeeding year classes (1970-76) were similar to those observed by other Wisconsin investigators.

Harvest and Survival

The abundance of smallmouth bass fingerlings in fall should be a good indication of the quality of the prospective fishery. The 1967 and 1970 year classes, estimated at 7,923 and 10,477 fingerlings, respectively, were of a large enough magnitude to trace the cohorts throughout most of their life. Through the complete creel census, the contribution of these 2 year classes to the harvest was determined, and year-to-year survival was calculated from successive population estimates. Cumulative harvest of the 1967 and 1970 year classes between Ages II and VI was 1,575 and 3,155 or 20 and 30% of the fingerling estimates and 71 and 66% of the Age II estimates, respectively (Table 8). Although the above harvest percentages were similar for the 1967 and 1970 year classes, total survival to Age II-V was much higher for the 1970 year class (Table 8).

The higher survival of the 1970 year class may have been influenced by the warmer temperatures experienced during the 1st growing season. The June-August noon water temperature in Nebish Lake averaged 73.4 F in 1970 and only 70.8 F in 1967 (Table 4). Numerous authors have shown a positive correlation between temperature of the 1st growing season and year class strength at Age IV or V (Forbes 1982).

Although other investigators have correlated overwinter survival of smallmouth bass fingerlings with 1st year growth (Forbes 1982), we have not attempted such discussion for the 1967 and 1970 year classes because: (1) the average length of 1967 fall fingerlings was high in spite of a cool growing season, and (2) we have no actual data on 1st year survival.

Mortality

Estimates of total annual mortality (A) averaged 0.79 for all years and varied from 0.61 to 0.87 for Age III and older smallmouth bass combined (Table 9). Mean total mortality by age group generally declined with increasing age; values for ages III, IV, and V averaged 0.82, 0.62, and 0.60, respectively. These averages changed only slightly when the 1st 3 year classes were excluded. Age II fish did not fit this pattern; mortality was 0.60 for all years combined and 0.35 with the 1st 3 cohorts excluded, but there were few estimates on which to base these averages.

Exploitation rate (u) followed the same trend as total mortality, averaging 0.40 for all ages combined and varying annually from 0.24 to 0.52 (Table 9). Mean exploitation for Ages III, IV, and V were 0.50, 0.38, and 0.30, respectively, while mean exploitation for Age II was 0.41. When the 1st 3 year classes were excluded from the means, the values for Ages III, IV, and V did not substantially change; the value for Age II was much lower, 0.28.

Total mortality (A) for all ages combined (0.79) was about equally divided between natural mortality (0.39) and fishing mortality (0.40) in Nebish Lake (Table 9). For the years 1972-76 (when more older age groups were present), total mortality was 0.76 of which 0.34 was from fishing and 0.42 from natural causes.

There were no consistent yearly trends for either increasing or decreasing total mortality or exploitation as the smallmouth bass population developed. However, the 1972-73 sampling year was the most unusual. With few exceptions, total mortality and exploitation were lower than in any other year for all age groups. This difference in the 1972-73 mortality estimates may be related to: (1) the

TABLE 10. Yellow perch population estimates in Nebish Lake, 1967-76.

Year Class	Date of Estimate	Age or Size (Inches)	Population Estimate N	95% Confidence Interval	Method
1967	9/12/67	0	22,776	15,456 - 51,813	a
	4/17/68	I	13,964	13,454 - 14,953	b
	4/28/69	II	8,200	7,732 - 8,729	b
	5/3/70	III	2,500	--	c
	5/6/71	IV	447	(females only)	b
1968	5/3/70	II	15,864	--	e
	5/6/71	III	3,571	--	f
1967 & 1968	5/3/70	II-III	18,364	16,514 - 20,424	b
	5/6/71	III-IV	4,465	3,989 - 4,999	b
1969	5/3/70	I	199,500	163,381 - 243,616	d-1
	5/6/71	II	564,628	531,317 - 594,443	d-2
--	5/12/72	≥3.0	139,670	135,776 - 143,389	d-3
--	5/12/72	≥5.5	42,764	35,572 - 51,411	b
--	5/3/73	>5.5	129,300	105,201 - 158,927	b
--	5/9/74	>5.5	116,617	98,474 - 138,100	b
--	5/9/75	>6.0	34,146	31,625 - 36,867	b
--	4/29/76	>6.0	25,137	23,409 - 26,992	b

[a]Electroshocker; Schnabel estimate.

[b]Marked from fyke nets, recaptured in creel; Petersen estimate.

[c]Spring fyke net catch; estimate using catch curve $\ln \underline{Y} = 10.75 - 0.941 \ln \underline{X}$, $\underline{r} = 0.989$.

[d]Spring fyke net catch; Schnabel estimates
(1) - Recaptures as Age II the following spring.
(2) - Recaptures as 4.0- to 5.5-inch fish the following spring.
(3) - Recaptures as ≥3.0-inch fish the following spring.

[e]18,364 Age II-III minus 2,500 Age III from the 1967 year class.

[f]4,465 Age III-IV minus 894 Age IV from the 1967 year class (assuming 1:1 ratio of males to females).

relatively low fishing pressure (Christenson et al. 1982), (2) the highest population density of smallmouth bass during the study (Table 5), and/or (3) higher prey densities than in other years.

YELLOW PERCH

Population and Biomass of Fingerlings and Adults

1967 Year Class. The 1967 year class was the 1st one produced after re-introduction of 31 adult yellow perch, and it was the only year class we were able to estimate at Age 0 or follow in successive years by age group (Table 10). In the fall of 1967, the estimated fingerling standing stock and biomass were 242/acre and 8.7 lb/acre, respectively (Appendix Tables 2 and 3). Males were mature as yearlings in the spring of 1968, and in the following year, both sexes were mature at Age II. The standing stock estimate of Age I and Age II yellow perch was 149/acre and 87/acre, respectively. Corresponding biomass estimates were 10.2 lb/acre and 15.7 lb/acre, respectively.

At Age III, males overlapped in length with Age II females precluding separate population estimates of age groups. By applying a catch curve (Ricker 1975) from spring 1970 fyke nets, the standing stock and biomass of Age III yellow perch was calculated at 2,500 (27/acre) and 825 lb (8.8 lb/acre), respectively (Appendix Tables 2 and 3).

Through the creel census the density of Age IV females was estimated at 447; Age III females overlapped in size with Age IV males, making a total Age IV estimate impossible. Assuming a 1:1 male-female ratio, the total Age IV population was calculated at 894 (9.5 perch/acre). [Thorpe (1977) reported that a 1:1 sex ratio was usually found for yellow perch, except among older age groups or among populations exhibiting very fast or very slow growth.]

1968-76 Year Classes. Although yellow perch population estimates were attempted from 1967 to 1976, the data are difficult to interpret because of variations in age and size groupings and in methods (Table 10). Fingerlings of the 1968-76 year classes were smaller in size than in 1967 which made them difficult to see and capture using the electroshocker. Fall sampling produced from 9 to 245 fingerlings each year; there were no recaptures, and therefore, no population estimates.

The 1st estimate of the 1968 year class took place in 1970 at Age II when an estimated 15,864 yellow perch (169/acre) were present (Table 10). The Age III population from the 1968 year class was estimated at 3,571 or 38 perch/acre.

The 1969 year class was the largest observed in 10 years, appearing at Age I with an estimated 199,500 individuals and at Age II with a considerably larger estimate of 564,628 (Table 10, Appendix Table 4). The smaller Age I estimate excluded the females which did not mature and enter the fyke nets until Age II.

Beginning in 1972, population estimates were calculated for 1/2-inch size groups. Estimates now included Age III and IV fish from the 1968-69 year classes and Age II and older fish from the succeeding year classes. The yellow perch populations (>5.5 inches) ranged from a high of 129,300 (1,376/acre) in 1973 to a low of 25,137 (267/acre) in 1976 (Table 10, Appendix Table 5). Biomass during these years ranged from a high of 214 lb/acre in 1974 to a low of 33 lb/acre in 1976 (Appendix Table 6).

Growth and Maturity

Growth rates of yellow perch fingerlings were highest for the 1st 2 year classes after re-introduction. Thereafter, growth of young of the year declined beginning with the large 1969 year class and continuing through 1976 (Fig. 3). The faster growth of these 1st 2 year classes was evident through Age VII for males and through Age VI for females (Table 11, Appendix Tables 7 and 8). Growth of the 1967-68 year classes was comparable to growth of yellow perch in Escanaba Lake through Age IV, but growth of the 1969-76 year classes was considerably slower than in Escanaba (Table 11). Growth rates were exceptional for the 1967-68 cohorts, compared to 10 northern Wisconsin lakes (Snow 1969), but males and females were not separated in the latter study.

The tremendous 1969 year class dominated the yellow perch population; slower growth and later maturity, particularly of females, were subsequently observed (Appendix Tables 7 and 8). The age at which yellow perch were 1st caught in fyke nets was used as an indication of age of maturity. The 1971-74 female cohorts did not mature until Age III or IV; the earlier year classes matured at Age II. Late maturity was less prominent in males; the 1970 year class matured 2 years late at Age III and the 1971 and 1974 year classes matured 1 year late at Age II. The Age I fish were not sexed in 1968-71, but it is not likely that females matured that soon.

Mortality

Exploitation. Compared to smallmouth bass, yellow perch exploitation rates were quite low in most years. Exploitation rate of the 1967 year class was 0.07 in 1968 and 0.26 in 1969 (Table 12). From 1970 to 1976, age or size groups were combined and annual exploitation rates ranged from 0.02 to 0.25 (mean = 0.14). On Escanaba Lake (Kempinger et al. 1975), annual exploitation rates of yellow perch were also low, ranging from 0.05 to 0.34 (mean = 0.16). The relatively low exploitation of yellow perch was probably related to their pelagic distribution and schooling behavior which can make them difficult for anglers to locate.

Natural Mortality. The 1967 year class of yellow perch was the only one monitored to determine natural and fishing mortality throughout most of its life (Table 13). With no fishing during the 1967 ice fishing season, the fingerling to yearling population declined 38.7% over winter; all mortality was due to natural causes. Natural mortality remained higher than angling mortality in each succeeding year. Anglers began fishing yearling yellow perch in the spring of 1968 and caught 1,118 or 8.0% of the estimated population; natural mortality was 33.2% from Age I to Age II. Natural mortality from Age II to III and III to IV was 38.8% and 44.7%, while mortality from fishing was 30.7% and 20.2%, respectively.

TABLE II. Mean total length (inches) of yellow perch in spring from Nebish and Escanaba lakes.

Sex and Lake	Age Group II	III	IV	V	VI	VII	VIII	Source
Males								
Nebish Lake 1967-68 year classes	6.8	7.8	7.7	8.5	9.4	9.6	9.4	Present Study
Nebish Lake 1969-76 year classes	3.9	4.9	6.4	7.3	8.1	8.7	--	Present Study
Escanaba Lake	6.6	7.7	8.6	9.3	10.0			Kempinger (1966)
Females								
Nebish Lake 1967-68 year classes	7.4	8.9	9.2	8.6	9.6	9.7	10.1	Present Study
Nebish Lake 1969-76 year classes	5.6	5.8	6.7	7.7	8.7	9.8	--	Present Study
Escanaba Lake	7.1	8.3	9.5	10.1	11.3			Kempinger (1966)

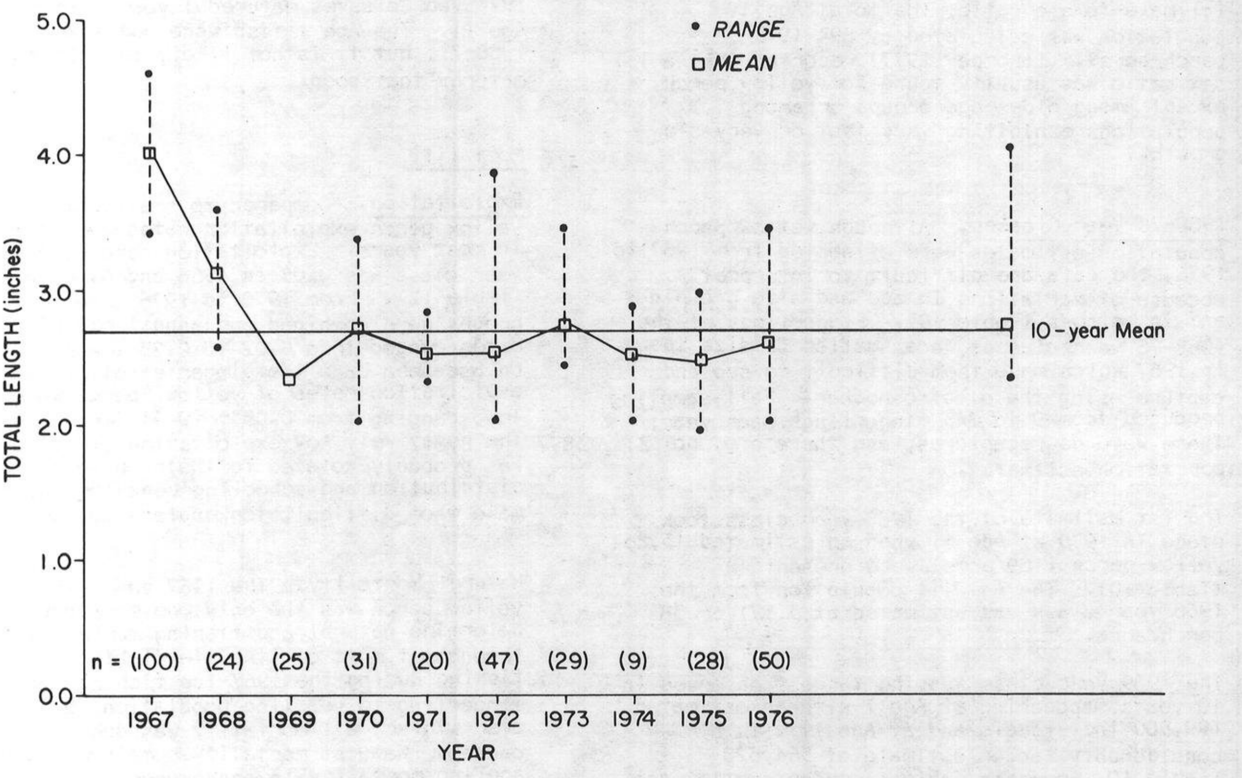

FIGURE 3. Average length (in inches) in fall of yellow perch fingerlings, 1967-76.

In the spring of 1971, the yellow perch population in Nebish Lake was estimated to exceed 1/2 million (Table 10), comprising 99% of the biomass (Table 14) in the fish community. Overcrowding was apparent and many of the fyke-net-captured perch were heavily fungused. In June 1971, thousands of dead perch were found along the shoreline and many others were observed swimming erratically. A sample was sent to the Bureau of Sport Fisheries and Wildlife Laboratory in Genoa, Wisconsin. The fungus was identified as Saprolegnia sp., and lesions were full of large Gram-negative bacteria (Dennis E. Anderson, pers. comm.). Tricodina sp. (a ciliated protozoan) were found on the skin of the fish, and a few Ambiphrya sp. (a stalked ciliated protozoan) were clinging to the gills.

Although the yellow perch population estimates never reached the 1971 levels again during the study period, the biomass exceeded the 1971 level several times (Table 14). Thus, the cause of the mortality observed in 1971 must have been related to numbers of individuals, not to the total population biomass.

TABLE 12. Exploitation rate (u) of yellow perch in Nebish Lake, 1968-76.

Sampling Year	Age or Size Groups	Exploitation Rate
1968	I	0.07
1969	II	0.26
1970	II & III	0.13
1971	III & IV	0.25
1972	>7.0 inches	0.15
1973	>7.0 inches	0.14
1974	>5.5 inches	0.02
1975	>5.5 inches	0.15
1976	>5.5 inches	0.12
Mean		0.14

TABLE 14. Estimated biomass and relative percent of biomass for smallmouth bass as compared to yellow perch in Nebish Lake in the spring, 1969-76.

Sampling	Smallmouth Bass		Yellow Perch	
Year	lb	%	lb	%
1969	378	20	1,479	80
1970	271	4	6,575	96
1971	106	1	9,341	99
1972	814	9	8,159	91
1973	724	5	14,852	95
1974	269	1	20,116	99
1975	238	4	5,865	96
1976	587	16	3,092	84
Mean	423	5	8,685	95

TABLE 13. Population size, mortality, and harvest of the 1967 year class of yellow perch in Nebish Lake.

			Annual Mortality					
			Total Mortality[a]		Natural Mortality		Harvest[b]	
Sampling Year	Age	Population Estimate	No.	% of Pop. Est.	No.	% of Pop. Est.	No.	% of Pop. Est.
1967	0	22,776[c]						
			8,812	38.7	8,812	38.7	0	0
1968	I	13,964						
			5,748	41.2	4,630	33.2	1,118	8.0
1969	II	8,200						
			5,700	69.5	3,185	38.8	2,515	30.7
1970	III	2,500						
			1,621	64.8	1,117	44.7	504[d]	20.2
1971	IV	894						

[a]Total mortality from successive population estimates.

[b]Total harvest from complete creel census.

[c]Fall estimate; others are spring estimates.

[d]Age II females from the 1968 year class overlapped in size with Age III males in the 1967 year class. Therefore, harvest of the 1968 year class at Age III was calculated by doubling the known catch of 252 Age III females. The total of 504 assumes a 1:1 sex ratio.

SUMMARY

(1) The re-introduction of adult stocks of smallmouth bass and yellow perch in Nebish Lake after chemical reclamation resulted in the successful establishment of both populations.

(2) Population estimates of adult smallmouth bass were higher than the single pretreatment estimate and higher than those for 2 other lakes in the region. Mean annual density of smallmouth bass Age II and older, 1969-76, was calculated at 37.0/acre and mean annual biomass was estimated at 7.2 lb/acre.

(3) Yellow perch was the more abundant of the 2 re-introduced species by number and by biomass. Adult yellow perch averaged 95% of the mean annual fish biomass estimated from 1969 to 1976.

(4) With only 2 fish species in the lake, yellow perch became very numerous, dominating the fishery and dying in large numbers in 1971. The tremendous 1969 year class was the primary cause of the high population densities.

(5) Smallmouth bass fall fingerling densities during the 10 years ranged from too few to estimate to 111.5/acre. Strong fingerling year classes were attributed to introduction into an environment of reduced competition (1967 year class) and, after re-establishment, to warm growing seasons (1970 and 1976 year classes).

(6) The contribution of the 1967 and 1970 year classes of smallmouth bass to the harvest at Ages II-VI was 20 and 30%, respectively, of the estimated number of fingerlings. Although these harvest percentages were similar, total survival was much higher for the 1970 year class.

(7) Growth rates of smallmouth bass were exceptional for the 1st 3 year classes and then dropped to levels comparable to pretreatment Nebish Lake and several other regional lakes. Yellow perch followed a similar pattern, with the 1st 2 year classes showing very fast growth. Later maturity, especially of females, accompanied the slower growth of yellow perch.

(8) Age III smallmouth bass were more heavily exploited and suffered greater total mortality than Age IV and older fish. Natural mortality for all ages combined was about equal to fishing mortality; total mortality was 0.79, of which natural mortality was 0.39 and the exploitation rate was 0.40.

(9) Natural mortality of the 1967 yellow perch year class was considerably higher than angling mortality. Annual exploitation of all yellow perch year classes was low (mean = 0.14); this was probably due to their pelagic distribution and schooling behavior, which makes them difficult to locate while fishing.

APPENDIX

APPENDIX TABLE I. Mean total length (inches) and age of smallmouth bass at time of capture in Nebish Lake, 1967-76.[a]

Year Class Group	Sampling Year	Age Group 0[b]	I	II	III	IV	V	VI	VII	VIII	IX
	1967	3.1 (100)									
1967-69 Year Classes	1968	3.1 (46)	5.8[c] (81)								
	1969	3.1 (17)		6.5 (283)							
	1970	2.7 (62)	6.9[c] (20)	7.0 (129)	9.4 (131)						
	1971	2.8 (25)	4.1 (73)	7.7 (51)	9.8 (47)	13.0 (27)					
1970-76 Year Classes	1972	2.7 (33)	3.4 (7)	5.9 (652)	7.8 (169)	13.5 (7)	15.2 (6)				
	1973	2.8 (63)		4.7 (40)	7.1 (336)	10.0 (47)	13.5 (6)	16.0 (6)			
	1974	2.7 (56)		5.1 (3)	7.1 (7)	8.6 (79)	10.5 (37)	14.4 (15)	16.6 (6)		
	1975	3.0 (72)	3.3 (8)	5.5 (179)	8.0 (14)	9.7 (15)	11.5 (28)	14.7 (1)	15.5 (3)		
	1976	3.2 (144)	3.1 (4)	5.6 (56)	8.5 (108)	9.3 (21)	11.9 (4)	13.3 (9)	14.5 (7)	15.6 (10)	17.0 (1)
Means											
1967-69 Year Classes		3.1	6.4	7.1	9.0	12.2	13.1	15.0	15.5	15.6	17.0
1970-76 Year Classes		2.8	3.5	5.4	7.7	9.2	11.7	13.3	--	--	--
Total Mean		2.9	4.4	6.0	8.2	10.7	12.5	14.6	15.5	15.6	17.0

[a] Sample size in parenthesis.

[b] Fingerlings were captured in fall using an electroshocker.

[c] Age I smallmouth bass were measured in late August in 1968 and 1970. Age I bass in other years and all Age II and older bass were measured in the spring (19 May-10 Jun) from fyke net samples.

APPENDIX TABLE 2. Estimated number of the 1967 yellow perch year class by length and age in Nebish Lake.

Total Length (inches)		Sampling Year 1967[a]		1968		1969 Male	1969 Female		1970 Male	1970 Female		1971 Female
3.0												
3.5	Age	2,733										
4.0	0	17,538										
4.5		2,505		1,955								
5.0			Age	9,775								
5.5			I	2,234		57						
6.0						500						
6.5					Age	1,164						
7.0					II	1,223	385					
7.5						935	1,546					
8.0						221	2,013		455			
8.5							156		739			
9.0								Age	56	460		
9.5								III		593		
10.0										197		
10.5												
11.0											Age	358
11.5											IV	89
Total no.		22,776		13,964		4,100	4,100		1,250	1,250		447
No./acre		242		149		87			27			5

[a]Fall population estimates. Estimates determined in spring in other years.

APPENDIX TABLE 3. Biomass estimates (lb) for the 1967 yellow perch year class in Nebish Lake.

Total Length (inches)		Sampling Year 1967[a]		1968		1969 Male	1969 Female		1970 Male	1970 Female		1971 Female
3.0												
3.5	Age	98										
4.0	0	632										
4.5		90		134								
5.0			Age	672								
5.5			I	154		8						
6.0						72						
6.5					Age	169						
7.0					II	76	83					
7.5						135	334					
8.0						32	436		120			
8.5							34		195			
9.0								Age	15	182		
9.5								III		235		
10.0										78		
10.5												
11.0											Age	90
11.5											IV	23
Total lb		820		960		592	887		330	495		113
Lb/acre		8.7		10.2		15.7			8.8			1.0

[a]Biomass determined in fall. Estimates determined in spring in other years.

APPENDIX TABLE 4. Spring standing stock and biomass estimates for the 1969 yellow perch year class in Nebish Lake.

Total Length (inches)	Age I Number	Age I Weight (lb)	Age II Number	Age II Weight (lb)
3.0	64,239	840		
3.5	96,558	1,276	5,044	660
4.0	38,703	512	155,700	2,146
4.5			238,169	3,272
5.0			146,171	2,012
5.5			19,534	308
Total	199,500	2,637	564,628	8,398
No./acre	2,122		6,000	
Lb/acre		28		89

APPENDIX TABLE 5. Spring standing stock estimates by 1/2-inch group for yellow perch in Nebish Lake, 1972-76.

Total Length (inches)	Sampling Year 1972	1973	1974	1975	1976
3.0	560				
3.5	7,276				
4.0	25,130				
4.5	37,195[a]				
5.0	32,523[a]				
5.5	17,416	72,231	600		
6.0	11,884	39,067	3,881	3,892	2,363
6.5	11,869	13,888[b]	15,094	1,537	2,539
7.0	3,586	2,466	26,199	1,571	3,645
7.5	2,880	1,168	29,125	3,824	3,469
8.0	770	260	27,872[c]	8,503	5,531
8.5	225	129	9,061[c]	5,805	4,122
9.0	115	78	3,114	4,985	1,433
9.5	110	13	1,596	2,800	1,583
10.0			75	1,093	251
10.5				136	201
Total	139,670	129,300	116,617	34,146	25,137
No./acre	1,486	1,376	1,241	363	267

[a]Mean size of Age III males and females was 4.4 and 5.3 inches, respectively.

[b]Mean size of Age IV for both sexes was 6.7 inches.

[c]Mean size of Age V females and males was 8.0 and 8.5
inches, respectively.

APPENDIX TABLE 6. Biomass estimates (lb) by 1/2-inch group for yellow perch in Nebish Lake in the spring, 1972-76.

Total Length (inches)	Sampling Year 1972	1973	1974	1975	1976
3.0	7				
3.5	96				
4.0	332				
4.5	1,074[a]				
5.0	1,976[a]				
5.5	1,118	6,868	47		
6.0	1,010	4,883	310	164	110
6.5	1,234	2,129[b]	1,509	80	157
7.0	455	505	3,467	149	282
7.5	449	296	5,121	488	376
8.0	298	82	5,958[c]	1,652	723
8.5	51	46	2,265[c]	1,078	633
9.0	30	33	841	1,137	275
9.5	35	8	559	672	388
10.0			31	382	75
10.5				62	69
Total	8,159	14,852	20,116	5,865	3,092
Lb/acre	87	158	214	62	33

[a]Mean size of Age III males and females was 4.4 and 5.3 inches, respectively.

[b]Mean size of Age IV for both sexes was 6.7 inches.

[c]Mean size of Age V females and males was 8.0 and 8.5 inches, respectively.

APPENDIX TABLE 7. Mean total length (inches) and age of male yellow perch captured at "ice out" in Nebish Lake, 1967-76[a].

Year Class Group	Sampling Year	Age Group I	II	III	IV	V	VI	VII	VIII
	1968	5.0[b] (57)							
1967-68 Year Classes	1969		6.9 (74)						
	1970	3.7[b] (56)	6.6 (44)	8.3 (44)					
	1971	3.5[b] (34)	4.6 (34)	7.3 (43)	8.7 (33)				
	1972			4.4 (52)	6.7 (33)	8.7 (42)			
1969-75 Year Classes	1973	3.2 (8)	3.8 (18)	4.9 (55)	6.7 (48)	8.3 (12)	9.1 (16)		
	1974	3.3 (17)	4.2 (19)	5.1 (16)	6.5 (56)	8.5 (34)	9.7 (4)		
	1975		3.4 (10)	4.8 (35)	5.8 (8)	6.8 (28)	8.4 (27)	9.6 (2)	
	1976	3.0 (3)	3.7 (40)	5.1 (28)	6.5 (17)	6.7 (19)	7.8 (52)	8.7 (13)	9.4 (2)
Means									
1967-68 Year Classes		5.0	6.8	7.8	7.7	8.5	9.4	9.6	9.4
1969-75 Year Classes		3.2[c]	3.9	4.9	6.4	7.3	8.1	8.7	--
Total Mean		3.2[c]	4.7	5.7	6.8	7.8	8.8	9.2	9.4

[a]Number in parenthesis is sample size.

[b]Sexes combined.

[c]Males only.

APPENDIX TABLE 8. Mean total length (inches) and age of female yellow perch captured at "ice out" in Nebish Lake, 1967-76.[a]

Year Class Group	Sampling Year	Age Group II	III	IV	V	VI	VII	VIII
1967-68 Year Classes	1969	7.7 (52)						
	1970	7.0 (25)	9.4 (19)					
1969-75 Year Classes	1971	6.3 (8)	8.5 (5)	11.1 (5)				
	1972	4.8 (14)	5.3 (19)	7.2 (34)	9.1 (10)			
	1973		5.5 (21)	6.8 (40)	8.2 (13)			
	1974			7.0 (46)	8.0 (15)	9.6 (1)		
	1975			5.8 (21)	6.9 (17)	8.4 (15)	9.7 (5)	
	1976		6.5 (6)	7.3 (22)	8.1 (6)	9.0 (34)	9.8 (8)	10.1 (2)
Means								
1967-68 Year Classes		7.4	8.9	9.2	8.6	9.6	9.7	10.1
1969-75 Year Classes		5.6	5.8	6.7	7.7	8.7	9.8	--
Total Mean		6.5	7.0	7.5	8.1	9.0	9.7	10.1

[a]Number in parenthesis is sample size.

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