# An 8-inch length limit on smallmouth bass: effects on the sport fisheries and populations of smallmouth bass and yellow perch in Nebish Lake, Wisconsin. No. 148 1984

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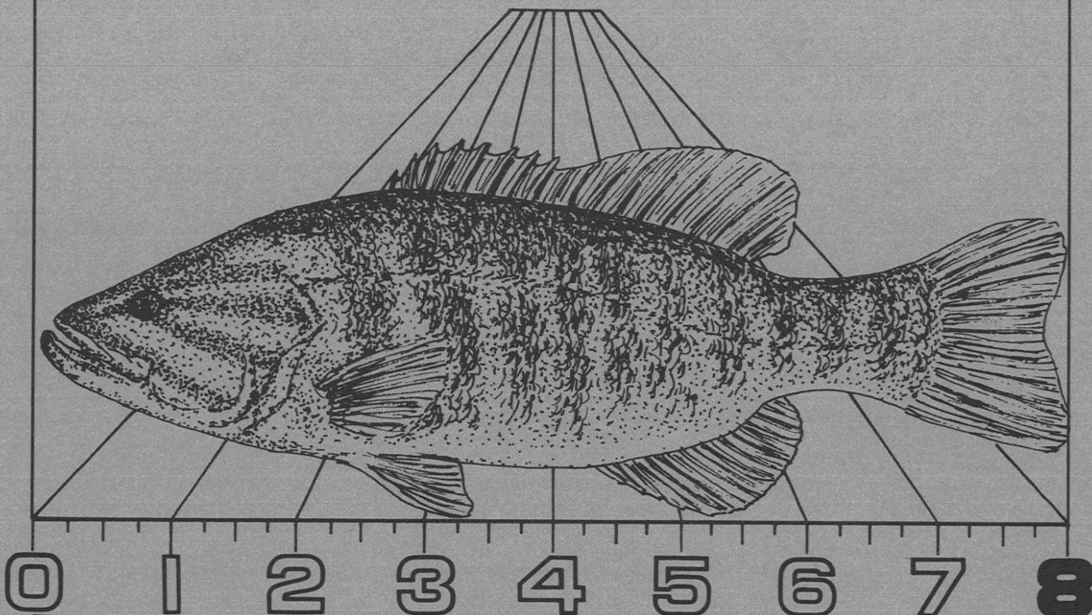


## Effects on the Sport Fisheries and Populations of Smallmouth Bass and Yellow Perch in Nebish Lake, Wisconsin

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# ABSTRACT

One of the more effective and most frequently used methods of regulating harvest to improve a fishery is the use of a minimum length limit. To determine the effects of an 8-inch minimum length limit on smallmouth bass (*Micropterus dolomieui*) in Nebish Lake, Wisconsin, the sport fishery was studied for 5 years (1977-81) and contrasted to the previous 5-year period (1972-76) when there was no minimum length limit. The sport fishery included smallmouth bass and yellow perch (*Perca flavescens*). Population characteristics of smallmouth bass and yellow perch were compared for the 4-year periods of 1974-77 (pre-length limit) vs. 1978-81 (post-length limit), because the length limit imposed on 1 January 1977 would not have affected these parameters when measured in spring 1977.

After the imposition of the 8-inch length limit on smallmouth bass in Nebish Lake, the following changes in the sport fishery occurred:

1) the average number of anglers per year was 33% higher.
2) the average number of hours fished per year was 27% higher.
3) the harvest (no.) of smallmouth bass was 8% lower, but the yield (lb) was 30% higher.
4) the mean length of smallmouth bass harvested increased from 8.2 inches to 9.4 inches.
5) the harvest rate of smallmouth bass declined 29% but the harvest rate of those $\geq$ 8.0 inches increased 27%.
6) the harvest, yield, and harvest rate of yellow perch all declined substantially.

After the establishment of an 8-inch length limit on smallmouth bass in Nebish Lake, the following changes in population characteristics occurred:

1) the mean annual density and biomass of age III+ smallmouth bass was 77% and 79% higher, respectively.
2) the production of fingerling smallmouth bass was 21% lower.
3) adult (ages III-V) smallmouth bass total annual mortality rates were slightly higher, because of higher rates of angler exploitation and possibly higher bass densities (increased intraspecific competition).
4) smallmouth bass growth increased slightly.
5) production of age III and IV smallmouth bass nearly doubled.
6) the mean annual density and biomass of adult yellow perch decreased substantially.
7) the angler exploitation rates of yellow perch increased, while the annual rates of total mortality decreased markedly.
8) yellow perch growth increased.

With the 8-inch length limit in effect, the trade-off of 8% fewer bass in the creel was more than offset by the 30% increase in yield and the 1.2-inch increase in average length of bass creeled.

An equilibrium yield model predicted that by increasing the entry level into the sport fishery from age III (8-inch length limit) to age IV (approximately an 11-inch length limit), yield would increase 5% and harvest would decrease by 45%, assuming no resultant changes in growth or natural mortality. To test this hypothesis, the Wisconsin Department of Natural Resources set the length limit at 10 inches beginning on 1 January 1982 and will monitor the fishery and populations of smallmouth bass and yellow perch through at least 1986.


KEY WORDS: Angler Harvest, Growth, Length Limit, Mortality, Population Density, Smallmouth Bass, Wisconsin, Yellow Perch.

# An 8-Inch Length Limit on Smallmouth Bass: Effects on the Sport Fisheries and Populations of Smallmouth Bass and Yellow Perch in Nebish Lake, Wisconsin

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# INTRODUCTION

With the increase in fishing pressure nationally in recent years (Anonymous 1982) and angler sophistication and efficiency because of advanced technology and "how-to" clinics and magazines, many state natural resource agencies are investigating ways to regulate sport fishing to protect more vulnerable species from overharvest. Among natural resource agencies, there also appears to be a move away from the philosophy of maximum sustained yield (MSY) management toward one of optimum sustained yield (OSY), in which the "quality" (the definition can be quite varied) of the fish harvested is considered (Carlton 1975).

One of the more effective and most frequently used methods of regulating harvest in order to improve a fishery is the use of a minimum length limit (Fox 1975). The purpose of this study was to contrast the sport fishery and life history parameters for smallmouth bass (*Micropterus dolomieui*) and yellow perch (*Perca flavescens*) before and after an 8-inch minimum length limit on smallmouth bass in Nebish Lake, Wisconsin. Another objective was to determine whether an 8-inch length limit would increase the angling yield of smallmouth bass by an estimated 22% (Kempinger 1978).

Nebish Lake was chemically treated in 1966 (Kempinger and Christenson 1978) and restocked in 1967 to compare angling quality before and after the manipulation (Christenson et al. 1982) and to describe the population development of reintroduced smallmouth bass and yellow perch (Kempinger et al. 1982). During the 1972-81 period, neither species was regulated by a bag limit or a closed season.

# THE STUDY AREA

Nebish Lake, one of five 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 about 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 Lake is an infertile seepage lake with a total alkalinity of 8.0-16.0 ppm. Other water quality characteristics are shown in Table 1.

**TABLE 1.** *Chemical and physical characteristics of Nebish Lake during spring and summer, 1969.**

| | Spring** | | Summer** | |
|---|---|---|---|---|
| Parameter | Surface | Bottom | Surface | Bottom |
| Alkalinity (mg/L $CaCO_3$) | 10.0 | 11.0 | 8.0 | 16.0 |
| pH | 6.9 | 6.8 | 7.1 | 6.1 |
| Nitrite (mg/L) | 0.005 | 0.003 | 0.0 | 0.002 |
| Nitrate (mg/L) | 0.1 | 0.1 | <0.1 | 0.1 |
| Ammonia (mg/L) | 0.0 | 0.0 | <0.03 | 0.46 |
| Organic nitrogen (mg/L) | 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 |
| Sulfate (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 | 0.55 |
| Dissolved oxygen (mg/L) | 9.6 | 8.7 | 7.9 | 0.0 |
| Specific conductance (μmhos/cm) | — | — | 30 | 45 |
| Temperature (C) | 5.5 | 5.5 | 22.2 | 7.2 |
| Secchi disk (m) | 4.25 | | 4.0 | |

* From Kempinger et al. 1982.

** Spring and summer sampling dates were 28 April 1969 and 28 July 1969, respectively.

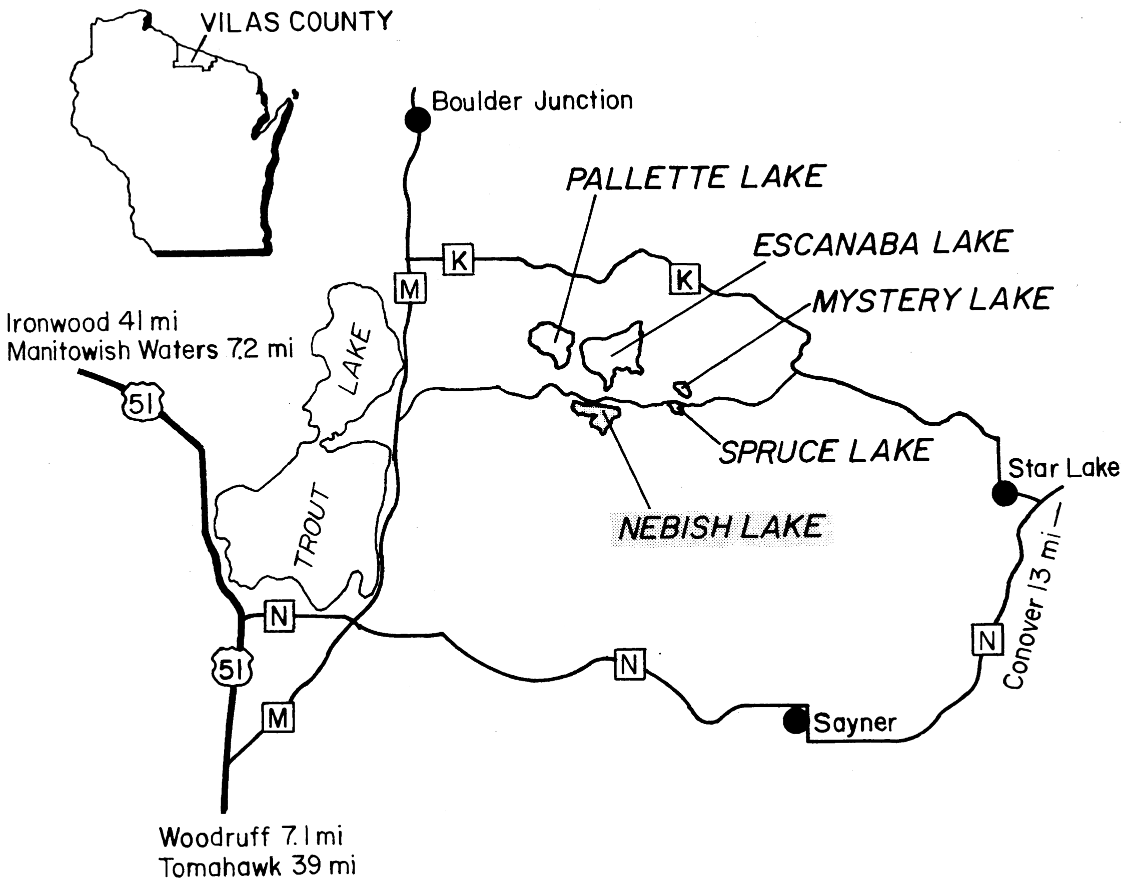



**FIGURE 1.** *Location of Nebish Lake in the Northern Highland Fishery Research Area, Vilas County.*

# METHODS

Smallmouth bass fingerlings were collected each fall using a 230-volt, 3,000-watt AC boom shocker. The entire shoreline was electrofished on each of 3 to 5 nights between early September and mid-October. Stunned fingerlings were captured with a dipnet and marked with a distinctive fin clip, and a sample was measured to determine first summer growth. Population size was estimated using the Schnabel method (Ricker 1975).

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). Four 3/8-inch mesh nets were fished for approximately 4 to 6 days after ice-out to capture the yellow perch, and 8 or 10 (4 or 5, 3/8-inch mesh and 4 or 5, 3/4-inch mesh) nets were fished for approximately one week in late May to collect smallmouth bass. In addition to using fyke nets, the entire shoreline was electrofished on 2 or 3 nights in late May and early June to capture smallmouth.

Scale samples were collected below the lateral line at the tip of the pectoral fin from all smallmouth bass and from 10 yellow perch of each sex in each 1/2-inch size group. All bass were measured (to nearest 0.1 inch) and weighed (to the nearest 0.01 lb), and a sample of perch (contents of one fyke net) was measured. Yellow perch and smallmouth bass less than 6 inches were marked by fin removal; bass 6 inches and larger were marked with numbered Floy® FD-67C anchor tags.

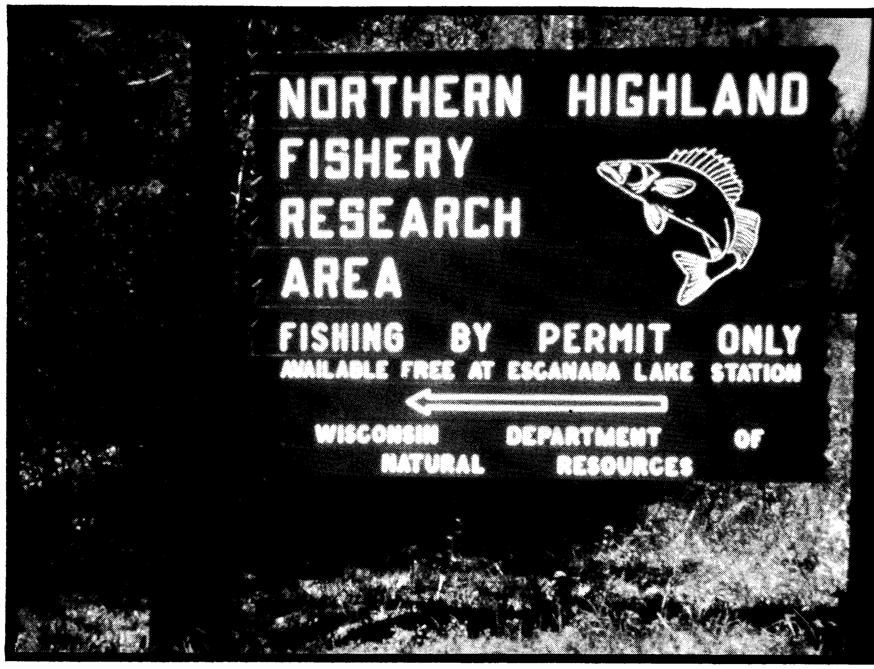
The population and biomass of adult fish were calculated by age group for smallmouth bass and by 1/2-inch group (usually greater than 5.5 inches total length) for yellow perch. Petersen population estimates (Ricker 1975) were determined from the recapture of marked and unmarked fish by anglers during the open water season following the marking period (the entire season for smallmouth bass and usually the period through 30 June for yellow perch). A complete mandatory permit-type creel census (described in detail by Christenson et al. 1982) provided data on fishing pressure and number, length, and weight of fish harvested each year (from ice-out one year to ice-out the following year).

Exploitation rates were calculated as the proportions of marked fish harvested by anglers during that year. Estimates of total instantaneous mortality (Z), annual rates of mortality (A), and annual rates of survival (S) were determined from catch curve analyses of aged smallmouth bass and yellow perch caught in fyke nets in spring. Estimates of annual mortality rates (A) of smallmouth bass were also made by dividing the population estimate of fish of age $N+1$ in one year by the estimated number in age N the previous year.

For the various age groups, mean lengths (for smallmouth bass and yellow perch) and mean weights (for smallmouth bass) were calculated from data collected during the spring fyke netting and electrofishing periods. Length-weight regression formulae were calculated for smallmouth bass captured in fyke nets in spring.

Equilibrium yield calculations (Ricker 1975) were made using smallmouth bass data during 1980 and 1981, the last two years of the 8-inch length limit. Estimates of smallmouth bass production (ages III and IV) were made for the last three years with no length limit (1974-76) and the last three years with an 8-inch length limit (1979-81).

When possible in this report, comparisons were made between data from 1972-76 and data from 1977-81. Much of the data from 1972-76 have been published in two reports (Christenson et al. 1982 and Kempinger et al. 1982). These describe the smallmouth bass and yellow perch sport fishery and populations in Nebish Lake after they had stabilized following chemical treatment in fall 1966 and reintroduction in 1967. (These data were collected before the length limit on smallmouth bass harvest was in effect.) The data from 1977-81 describe the fishery for these two species under an 8-inch minimum length limit on smallmouth bass. Because the length limit (which began on 1 January 1977) would not have affected the smallmouth bass and yellow perch populations when sampled in spring 1977*, comparisons of data on population density, biomass, mortality, and growth were made for the 4-year periods 1974-77 vs. 1978-81, respectively.




*This sign on County Trunk Highway "M" points to the permanent year-round research station in the Northern Highland State Forest.*

*Only 5 smallmouth bass were caught during the 1977 ice fishing period.

# RESULTS

## FISHING PRESSURE

Annual fishing pressure during 1977-81, with an 8-inch minimum length limit on smallmouth bass, was higher than during 1972-76 when there was no length limit (Table 2). The mean number of anglers/year fishing Nebish Lake after the length limit was 1,459 compared with 1,099 anglers before the length limit. Mean annual pressure, both in total number of hours fished and hours fished/acre, was higher after the length limit (5,343 hours; 57 hours/acre) than before the length limit (4,214 hours; 45 hours/acre). The mean hours fished/angler was 3.86 before the length limit compared to 3.66 after the length limit.

## EFFECTS ON SMALLMOUTH BASS

### Density and Biomass

The estimated density of smallmouth bass age III+ varied from 7.3-24.6/acre (mean = 12.9) during the period with the 8-inch length limit (Table 3). When there was no minimum length limit (1972-76), the range was 4.5-39.2/acre (mean = 15.1). Because the length limit (which began on 1 January 1977) would have had little effect on the density of bass in spring 1977, a comparison of the densities of bass from 1978-81 with those of 1974-77 was considered to yield a better comparison of the density of age III+ bass. This comparison indicated a 77% increase in the mean annual density of age III+ bass during 1978-81 (14.6/acre) compared to 1974-77 (8.2/acre). (See Table 3.)

Mean annual biomass estimates of adult smallmouth bass were 96% higher at age III, 87% higher at age IV, and 124% higher at age V during 1977-81 (Table 4). Mean total biomass estimates (ages III+) were 79% higher during 1978-81 (Table 4).

Estimated densities of fingerling smallmouth bass in fall were more variable during 1974-77 than during 1978-81, and the mean densities were also highest before the length limit (Table 5).The overall mean lengths of fingerlings in fall were identical during both periods, indicating similar first season growth.

### Angler Harvest, Yield, and Harvest Rate

After the 8-inch minimum length limit, the mean annual harvest of smallmouth bass decreased 8% (1,436 to 1,326) while yield increased by 30% (4.7 to 6.1 lb/acre). (See Table 6.) The harvest rate for smallmouth was lower when the limit was in effect (24.9/100 angler hours compared to 35.0/100 angler hours). However, the harvest rate for bass ≥8 inches was higher with the length limit (23.9 vs. 18.8/100 angler hours). (See Table 6.) There were no significant ($P$ < 0.05) correlations between fishing pressure (see Table 2) and the angler harvest of smallmouth bass (Table 6) during the 5-year periods of 1972-76 ($r$ = -0.103) and 1977-81 ($r$ = 0.161), or the 10-year period of 1972-81 ($r$ = -0.162).

**TABLE 2.** *Annual fishing pressure before and after an 8-inch length limit on smallmouth bass.*

| Year | Total No. Anglers | Total Hours of Fishing | Angler Hours/ Acre |
|---|---|---|---|
| **Before Limit** | | | |
| 1972 | 907 | 3,320 | 35 |
| 1973 | 1,034 | 4,087 | 43 |
| 1974 | 981 | 3,962 | 42 |
| 1975 | 1,232 | 4,616 | 49 |
| 1976 | 1,339 | 5,085 | 54 |
| **After Limit** | | | |
| 1977 | 1,387 | 5,170 | 55 |
| 1978 | 1,514 | 4,542 | 58 |
| 1979 | 1,392 | 5,076 | 54 |
| 1980 | 1,558 | 5,927 | 63 |
| 1981 | 1,436 | 5,092 | 54 |
| **Means ± SD** | | | |
| 1972-76 | 1,099 ± 180 | 4,214 ± 671 | 45 ± 7 |
| 1977-81 | 1,459 ± 74 | 5,343 ± 360 | 57 ± 4 |

**TABLE 3.** *Estimated number of adult smallmouth bass in the spring, before and after an 8-inch length limit.**

| | Age | | | | | Total (Age ≥ III) | |
|---|---|---|---|---|---|---|---|
| Year | III | IV | V | VI[a] | VII[a] | (no.) | (no./acre) |
| **Before Limit** | | | | | | | |
| 1972 | 745 (545-1,049)* | 85 (23-840) | 40 (14-200) | | | 870 | 9.3 |
| 1973 | 3,350 (2,874-3,921) | 250 (166-398) | 60 (23-238) | 25 (8-117) | | 3,685 | 39.2 |
| 1974 | 475 (162-2,380) | 470 (330-699) | 75 (41-149) | 25 (9-125) | | 1,045 | 11.1 |
| 1975 | 250 (143-484) | 55 (24-175) | 115 (45-459) | | | 420 | 4.5 |
| 1976 | 880 (672-1,152) | 120 (64-251) | 15 (3-160) | 20 (3-56) | 25 (7-245) | 1,060 | 11.3 |
| **After Limit** | | | | | | | |
| 1977 | 529 (**) | 116 (56-290) | 5 | | 16 (4-160) | 568 | 6.0 |
| 1978 | 838 (**) | 155 (71-422) | 72 (20-720) | 9 (2-90) | 10 3-50) | 1,084 | 11.5 |
| 1979 | 1,216 (**) | 115 (80-160) | 9 (5-35) | 11 (5-35) | | 1,401 | 14.9 |
| 1980 | 1,708 (**) | 495 (352-720) | 105 (19-1,050) | | | 2,308 | 24.6 |
| 1981 | 436 (**) | 172 (128-237) | 75 (32-234) | | | 683 | 7.3 |
| **Means ± SD** | | | | | | | |
| 1974-77 | 534 ± 261 | 190 ± 189 | 53 ± 52 | | | 773 ± 328 | 8.2 ± 3.5 |
| 1978-81 | 1,050 ± 542 | 234 ± 175 | 65 ± 40 | | | 1,369 ± 692 | 14.6 ± 7.4 |

* 95% confidence intervals are shown in parentheses.

** Confidence intervals not available because the total number of age III bass was estimated by expanding the estimated number of bass 7.8 inches and greater by the percentage of all age III fish that were 7.8 inches and larger in the spring net catch.

[a] Blank spaces in column indicate insufficient sample size for population estimate or mean and standard deviation calculations.

**TABLE 4.** *Estimated biomass of smallmouth bass in the spring, before and after an 8-inch length limit.**

| Year | Age | | | | | Total (Age ≥ III) | |
|---|---|---|---|---|---|---|---|
| | III | IV | V | VI** | VII** | (lb) | (lb/acre) |
| **Before Limit** | | | | | | | |
| 1972 | 164 | 122 | 78 | | | 364 | 3.9 |
| 1973 | 469 | 150 | 79 | 61 | | 759 | 8.1 |
| 1974 | 67 | 122 | 40 | 40 | | 269 | 2.9 |
| 1975 | 53 | 20 | 78 | | | 151 | 1.6 |
| 1976 | 211 | 43 | 12 | 24 | 37 | 327 | 3.4 |
| **After Limit** | | | | | | | |
| 1977 | 164 | 86 | 5 | | 35 | 290 | 3.1 |
| 1978 | 210 | 84 | 93 | 17 | 30 | 434 | 4.6 |
| 1979 | 280 | 74 | 14 | 26 | | 394 | 4.2 |
| 1980 | 376 | 247 | 104 | | | 727 | 7.7 |
| 1981 | 105 | 103 | 92 | | | 300 | 3.2 |
| **Means ± SD** | | | | | | | |
| 1974-77 | 124 ± 76 | 68 ± 45 | 34 ± 33 | | | 259 ± 76 | 2.8 ± 0.8 |
| (lb/acre) | (1.3) | (0.7) | (0.4) | | | | |
| 1978-81 | 243 ± 114 | 127 ± 81 | 76 ± 42 | | | 464 ± 184 | 4.9 ± 1.9 |
| (lb/acre) | (2.6) | (1.4) | (0.8) | | | | |

* Units in lb.
** Blank spaces in column indicate insufficient sample size for biomass estimate.

**TABLE 5.** *Smallmouth bass young-of-the-year densities and mean lengths in fall, before and after an 8-inch length limit.*

| Year | Total Number | 95% Confidence Interval | Density (no./acre) | Mean Length ± Stand. Dev. (inches) | |
|---|---|---|---|---|---|
| **Before Limit** | | | | | |
| 1972 | 2,482* | | 26.4* | 2.7 ± 0.4 | (33)** |
| 1973 | 1,495 | 208- 7,475 | 15.9 | 2.8 ± 0.3 | (86) |
| 1974 | 1,174 | 705-14,483 | 12.5 | 2.7 ± 0.4 | (56) |
| 1975 | 5,718 | 3,185-17,241 | 60.8 | 3.0 ± 0.3 | (72) |
| 1976 | 7,764 | 5,405-11,236 | 82.6 | 3.2 ± 0.3 | (253) |
| **After Limit** | | | | | |
| 1977 | 3,410 | 2,212- 6,667 | 36.3 | 2.8 ± 0.3 | (125) |
| 1978 | 2,168 | 1,560- 4,655 | 23.1 | 2.8 ± 0.3 | (70) |
| 1979 | 4,183 | 3,202- 5,627 | 44.5 | 2.8 ± 0.3 | (63) |
| 1980 | 3,006 | 2,882- 3,366 | 32.0 | 3.1 ± 0.2 | (100) |
| 1981 | 4,952 | 4,454- 5,510 | 52.7 | 3.1 ± 0.3 | (100) |
| **Means ± SD** | | | | | |
| 1974-77 | 3,727 ± 2,886 | | 39.6 ± 30.7 | 2.9 | |
| 1978-81 | 3,544 ± 1,071 | | 37.7 ± 11.4 | 2.9 | |

* Calculated from regression formula developed for relationship between catch/unit effort and density from 1967-76 (Kempinger et al. 1982); therefore, confidence interval data could not be determined.
** Sample size in parentheses.

The mean total length of harvested smallmouth bass was 1.2 inches longer during the period with the length limit (9.4 inches vs. 8.2 inches), and the mean number of bass ≥8 inches in the annual creel was higher (1,278 vs. 783). (See Table 7.)

The mean annual harvest of smallmouth bass that were ≥10.0 and ≥12.0 inches was also higher in the years with an 8-inch length limit. The percentage of bass ≥8 inches that were ≥10 inches was also higher with the length limit in effect (26% vs. 22%). However, the percentage of bass ≥8 inches that were ≥12 inches was slightly higher during the period without the length limit (7% vs. 5%). (See Table 6.)

When the length limit was in effect, the harvest of smallmouth bass from Nebish Lake was dominated in both number and weight by fish in age groups II and III (Table 8). Age II fish comprised an average of 48% (by number) and 34% (by weight) of the total yield, while age III fish comprised an average of 43% (by number) and 44% (by weight) of the total yield (Table 7). Only one yearling (1977) was harvested during the period of the 8-inch minimum length limit.

With no length limit in effect (1972-76), anglers began harvesting bass at age I. An average of 4% (by number) and 1% (by weight) of the entire smallmouth yield during this period were age I. Age groups II and III comprised the majority of the yield. From 1972-

**TABLE 6.** *Harvest, yield, and harvest rate of smallmouth bass, before and after an 8-inch length limit.**

| Year | Harvest | | Yield | | Harvest Rate (no./100 angler hours) | No. ≥8.0 Inches Caught/100 angler hours |
|---|---|---|---|---|---|---|
| | Number | Weight (lb) | (no./acre) | (lb/acre) | | |
| **Before Limit** | | | | | | |
| 1972 | 1,617 | 439 | 17 | 4.7 | 48.7 | 19.5 |
| 1973 | 2,106 | 568 | 22 | 6.0 | 51.5 | 29.2 |
| 1974 | 808 | 268 | 9 | 2.9 | 20.4 | 11.8 |
| 1975 | 1,228 | 371 | 13 | 4.0 | 26.6 | 21.6 |
| 1976 | 1,420 | 549 | 15 | 5.8 | 27.9 | 12.1 |
| **After Limit** | | | | | | |
| 1977 | 1,332 | 568 | 14 | 6.0 | 25.8 | 25.2 |
| 1978 | 1,599 | 701 | 17 | 7.5 | 29.3 | 28.7 |
| 1979 | 1,460 | 673 | 16 | 7.2 | 28.8 | 27.2 |
| 1980 | 1,301 | 543 | 14 | 5.8 | 22.0 | 21.3 |
| 1981 | 938 | 357 | 10 | 3.8 | 18.4 | 17.2 |
| **Means ± SD** | | | | | | |
| 1972-76 | 1,436 ± 479 | 439 ± 125 | 15 ± 5 | 4.7 ± 1.3 | 35.0 ± 14.1 | 18.8 ± 7.3 |
| 1977-81 | 1,326 ± 247 | 568 ± 136 | 14 ± 3 | 6.1 ± 1.5 | 24.9 ± 4.6 | 23.9 ± 4.7 |

* Smallmouth bass 7.8 inches and larger were considered "legal" when brought into the checking station to allow for differences in measurement between angler and creel clerk and to allow for possible length loss due to shrinkage.

**TABLE 7.** *Size distribution of harvested smallmouth bass, before and after an 8-inch length limit.*

| Year | Total Number | Mean Length (inches) | No. and % ≥8.0 inches | No. and % ≥10.0 inches | No. and % ≥12.0 inches |
|---|---|---|---|---|---|
| **Before Limit** | | | | | |
| 1972 | 1,617 | 8.0 | 648 (40)* | 156 (24)* | 45 (7)* |
| 1973 | 2,106 | 8.2 | 1,193 (57) | 144 (12) | 55 (5) |
| 1974 | 808 | 8.4 | 466 (58) | 141 (30) | 35 (8) |
| 1975 | 1,228 | 8.2 | 997 (81) | 231 (23) | 49 (5) |
| 1976 | 1,420 | 8.1 | 613 (43) | 119 (19) | 52 (9) |
| **After Limit** | | | | | |
| 1977 | 1,332 | 9.4 | 1,304 (98) | 297 (23) | 71 (5) |
| 1978 | 1,599 | 9.4 | 1,562 (98) | 360 (23) | 103 (7) |
| 1979 | 1,460 | 9.5 | 1,382 (95) | 402 (29) | 54 (4) |
| 1980 | 1,301 | 9.6 | 1,264 (97) | 392 (31) | 66 (5) |
| 1981 | 938 | 9.2 | 878 (94) | 213 (24) | 51 (6) |
| **Means ± SD** | | | | | |
| 1972-76 | 1,436 ± 479 | 8.2 ± 0.2 | 783 ± 301 (56 ± 16) | 158 ± 43 (22 ± 7) | 47 ± 8 (7 ± 2) |
| 1977-81 | 1,326 ± 247 | 9.4 ± 0.1 | 1,278 ± 251 (92 ± 2) | 333 ± 79 (26 ± 4) | 69 ± 21 (5 ± 1) |

* Percent is shown in parentheses.

76, age II fish comprised an average of 53% (by number) and 38% (by weight) of the total smallmouth harvest. Both these figures were higher than during 1977-81, the period with the length limit. Age III fish comprised 32% (by number) and 34% (by weight) of the harvest during 1972-76. These values were lower than during 1977-81 (Table 9).

Of the 6,630 smallmouth bass caught by anglers during 1977-81, only 43 (0.6%) were caught during the period of ice cover (usually mid-November to mid-late April), indicating low vulnerability to angling during the winter months (5.6% of the anglers fishing Nebish Lake from 1977-81 fished during the period of ice cover).

## Mortality and Exploitation Rate

Estimates of instantaneous and annual mortality rates from catch curve analyses of the age frequency distribution in the spring fyke net catches indicated higher mortality rates for age III+ bass when the length limit was in effect (Table 10). Estimates of total annual mortality calculated for ages III, IV, and V from successive population estimates were higher for both periods than those calculated from catch curves (Table 10). The estimates determined from successive population estimates of the same year class also indicated slightly lower rates at ages III-V when the length limit was in effect (Table 11).

Mean annual angler exploitation rates ($\mu$) of smallmouth averaged 0.43, 0.49, and 0.43 for ages III-V during 1978-81 (Table 11). The rates were similar to those for smallmouth of age III during 1974-77. However, the rates for ages IV and V smallmouth before the length limit were lower (0.37 and 0.21, respectively) than after the length limit (0.49 and 0.43, respectively). There was a trend toward reduced angler exploitation with increasing age during 1974-77. However, this trend was not evident during 1978-81 (Table 11).

**TABLE 8.** *Angler harvest and yield of smallmouth bass ≥7.8 inches after an 8-inch length limit.*

| Year | Age | Harvest (no.) | Harvest (lb) | Yield (no./acre) | Yield (% of total) | Yield (lb/acre) | Yield (% of total) |
|---|---|---|---|---|---|---|---|
| 1977 | I | 1 | * | | | | |
| | II | 1,036 | 360 | 11.0 | 77 | 3.8 | 63 |
| | III | 223 | 123 | 2.4 | 17 | 1.3 | 22 |
| | IV | 62 | 64 | 0.7 | 5 | 0.7 | 12 |
| | V | 4 | 5 | * | ** | 0.1 | 1 |
| | VI | 0 | 0 | 0 | 0 | 0 | 0 |
| | VII | 5 | 14 | * | 1 | 0.1 | 1 |
| | VIII | 2 | 5 | * | ** | * | ** |
| Total | | 1,332 | 568 | 14.2 | | 6.0 | |
| 1978 | II | 965 | 296 | 10.3 | 61 | 3.1 | 41 |
| | III | 536 | 268 | 5.7 | 34 | 2.9 | 39 |
| | IV | 61 | 62 | 0.6 | 4 | 0.6 | 8 |
| | V | 23 | 37 | 0.2 | 1 | 0.4 | 5 |
| | VI | 3 | 6 | * | ** | * | ** |
| | VII | 2 | 6 | * | ** | * | ** |
| | VIII | 4 | 11 | * | ** | 0.1 | 1 |
| | IX | 5 | 15 | * | ** | 0.2 | 3 |
| Total | | 1,599 | 701 | 16.9 | | 7.5 | |
| 1979 | II | 398 | 115 | 4.2 | 27 | 1.2 | 17 |
| | III | 973 | 456 | 10.4 | 67 | 4.9 | 68 |
| | IV | 72 | 61 | 0.8 | 5 | 0.6 | 8 |
| | V | 8 | 15 | 0.1 | 1 | 0.2 | 3 |
| | VI | 6 | 14 | 0.1 | 1 | 0.1 | 1 |
| | VII | 2 | 7 | * | ** | * | ** |
| | X | 1 | 5 | * | ** | * | ** |
| Total | | 1,460 | 673 | 15.5 | | 7.2 | |
| 1980 | II | 288 | 75 | 3.1 | 22 | 0.8 | 14 |
| | III | 768 | 287 | 8.1 | 59 | 3.0 | 52 |
| | IV | 223 | 149 | 2.4 | 17 | 1.6 | 28 |
| | V | 20 | 26 | 0.2 | 1 | 0.3 | 5 |
| | VI | 2 | 6 | * | ** | 0.1 | 2 |
| Total | | 1,301 | 543 | 13.8 | | 5.8 | |
| 1981 | II | 501 | 126 | 5.3 | 53 | 1.4 | 37 |
| | III | 331 | 135 | 3.6 | 36 | 1.4 | 37 |
| | IV | 89 | 68 | 0.9 | 9 | 0.7 | 18 |
| | V | 17 | 28 | 0.2 | 2 | 0.3 | 8 |
| Total | | 938 | 357 | 10.0 | | 3.8 | |
| Means | II | | | | 48 | | 34 |
| | III | | | | 43 | | 44 |
| | IV | | | | 8 | | 15 |
| | V | | | | 1 | | 4 |

* Less than 0.1.
** Less than 1.0%.

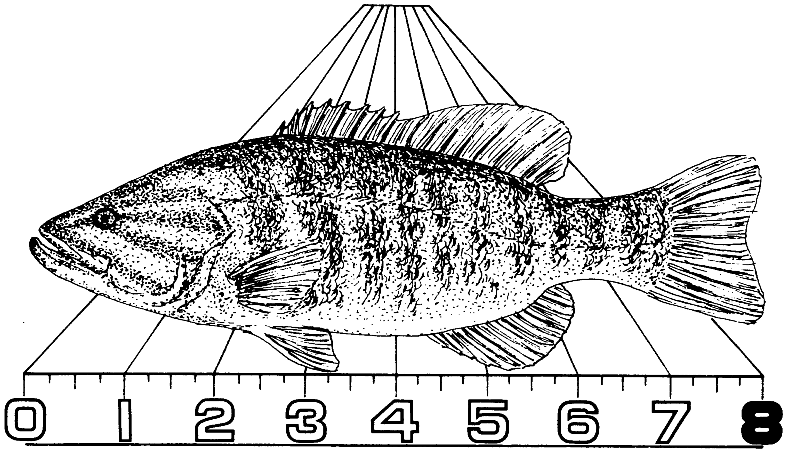


**TABLE 9.** *Angler harvest and yield of smallmouth bass before an 8-inch length limit.*

| Year | Age | Harvest (no.) | Harvest (lb) | Yield (no./acre) | Yield (% of total) | Yield (lb/acre) | Yield (% of total) |
|---|---|---|---|---|---|---|---|
| 1972 | I | 49 | 5 | 0.5 | 3 | 0.1 | 2 |
| | II | 1,356 | 286 | 14.4 | 84 | 3.0 | 64 |
| | III | 171 | 83 | 1.8 | 11 | 0.9 | 19 |
| | IV | 28 | 39 | 0.3 | ** | 0.4 | 9 |
| | V | 13 | 26 | 0.1 | ** | 0.3 | 6 |
| Total | | 1,617 | 439 | 17.1 | | 4.7 | |
| 1973 | I | 11 | 1 | 0.1 | ** | * | ** |
| | II | 401 | 55 | 4.3 | 19 | 0.6 | 10 |
| | III | 1,536 | 387 | 16.3 | 73 | 4.1 | 68 |
| | IV | 112 | 60 | 1.2 | 5 | 0.6 | 10 |
| | V | 34 | 39 | 0.4 | 2 | 0.4 | 7 |
| | VI | 12 | 26 | 0.1 | ** | 0.3 | 5 |
| Total | | 2,106 | 568 | 22.4 | | 6.0 | |
| 1974 | I | 85 | 9 | 0.9 | 10 | 0.1 | 3 |
| | II | 264 | 52 | 2.8 | 33 | 0.6 | 21 |
| | III | 209 | 62 | 2.2 | 26 | 0.7 | 24 |
| | IV | 212 | 96 | 2.3 | 27 | 1.0 | 34 |
| | V | 29 | 30 | 0.3 | 3 | 0.3 | 10 |
| | VI | 7 | 14 | 0.1 | 1 | 0.1 | 3 |
| | VII | 2 | 5 | * | ** | 0.1 | 3 |
| Total | | 808 | 268 | 8.6 | | 2.9 | |
| 1975 | I | 21 | 2 | 0.2 | 2 | * | ** |
| | II | 905 | 198 | 9.6 | 73 | 2.1 | 53 |
| | III | 209 | 69 | 2.2 | 17 | 0.7 | 18 |
| | IV | 26 | 18 | 0.3 | 2 | 0.2 | 5 |
| | V | 43 | 36 | 0.5 | 4 | 0.4 | 10 |
| | VI | 5 | 2 | 0.1 | 1 | * | ** |
| | VII | 13 | 28 | 0.1 | 1 | 0.3 | 8 |
| | VIII | 6 | 18 | 0.1 | 1 | 0.2 | 5 |
| Total | | 1,228 | 371 | 13.1 | | 4.0 | |
| 1976 | I | 102 | 13 | 1.1 | 7 | 0.1 | 2 |
| | II | 758 | 225 | 8.1 | 54 | 2.4 | 41 |
| | III | 470 | 220 | 5.0 | 33 | 2.3 | 40 |
| | IV | 60 | 41 | 0.6 | 4 | 0.4 | 7 |
| | V | 5 | 5 | 0.1 | 1 | 0.1 | 2 |
| | VI | 13 | 19 | 0.1 | 1 | 0.2 | 3 |
| | VII | 9 | 17 | 0.1 | 1 | 0.2 | 3 |
| | VIII | 3 | 9 | * | ** | 0.1 | 2 |
| Total | | 1,420 | 549 | 15.1 | | 5.8 | |
| Means | I | | | | 4 | | 1 |
| | II | | | | 53 | | 38 |
| | III | | | | 32 | | 34 |
| | IV | | | | 8 | | 13 |
| | V | | | | 2 | | 7 |
| | VI | | | | 1 | | 2 |

* Less than 0.1.
** Less than 1.0%.

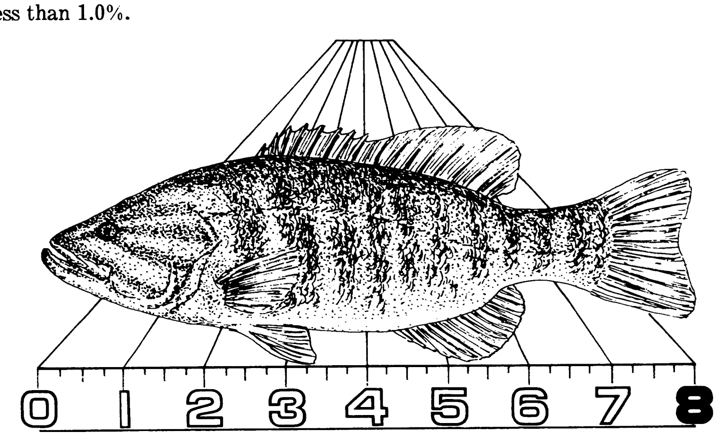


**TABLE 10.** *Instantaneous (Z) and annual (A) mortality rates, survival rates (S), and correlation coefficient (r) for smallmouth bass, before and after an 8-inch length limit.**

| Year | Age | Z | A | S | r |
|---|---|---|---|---|---|
| **Before Limit** | | | | | |
| 1972 | ≥III | 1.322 | 0.734 | 0.266 | -0.776 |
| 1973 | ≥III | 0.994 | 0.630 | 0.370 | -0.915 |
| 1974 | ≥IV | 0.854 | 0.574 | 0.426 | -0.999 |
| 1975 | ≥II | 0.792 | 0.547 | 0.453 | -0.824 |
| 1976 | ≥III | 0.405 | 0.333 | 0.667 | -0.660 |
| **After Limit** | | | | | |
| 1977 | ≥III | 0.676 | 0.491 | 0.509 | -0.602 |
| 1978 | ≥III | 0.500 | 0.393 | 0.607 | -0.841 |
| 1979 | ≥III | 1.062 | 0.653 | 0.347 | -0.910 |
| 1980 | ≥III | 1.490 | 0.775 | 0.225 | -0.960 |
| 1981 | ≥III | 1.441 | 0.763 | 0.237 | -0.955 |
| **Means** | | | | | |
| 1974-77 | ≥age III | 0.692 | 0.486 | 0.514 | |
| 1978-81 | ≥age III | 1.123 | 0.646 | 0.354 | |

* Based on catch curve analyses of the age distribution of the spring fyke net catches.

**TABLE 11.** *Total annual mortality rates (A)* and exploitation rates (μ) for smallmouth bass before and after an 8-inch length limit.*

| | III | | IV | | V | | VI | VII+ | Mean III-V | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | A | μ | A | μ | A | μ | μ | μ | A | μ |
| **Before Limit** | | | | | | | | | | |
| 1972 | 0.66 | 0.23 | 0.29** | 0.29 | 0.38 | 0.25 | — | — | 0.52 | 0.26 |
| 1973 | 0.86 | 0.45 | 0.70 | 0.47 | 0.59 | 0.58 | — | — | 0.72 | 0.50 |
| 1974 | 0.88 | 0.43 | 0.74 | 0.38 | — | 0.25 | — | — | 0.81 | 0.35 |
| 1975 | 0.52** | 0.80 | 0.73 | 0.36 | 0.83 | 0.13 | — | — | 0.78 | 0.43 |
| 1976 | 0.87 | 0.51 | 0.96 | 0.50 | — | 0.25 | 0.56 | 0.29 | 0.92 | 0.42 |
| **After Limit** | | | | | | | | | | |
| 1977 | 0.71 | 0.46 | 0.38 | 0.25 | — | — | — | 0.38 | 0.55 | 0.44 |
| 1978 | 0.86 | 0.21 | 0.94 | 0.38 | 0.85 | 0.25 | 0.33 | 0.60 | 0.88 | 0.28 |
| 1979 | 0.61 | 0.59 | 0.09** | 0.63 | — | 0.80 | 0.67 | — | 0.61** | 0.67 |
| 1980 | 0.90 | 0.42 | 0.85 | 0.45 | — | — | — | — | 0.88 | 0.44 |
| 1981[a] | 0.84 | 0.50 | 0.74 | 0.51 | 0.80 | 0.23 | — | — | 0.79 | 0.41 |
| **Means** | | | | | | | | | | |
| 1974-77 | 0.82 | 0.47 | 0.70 | 0.37 | 0.83 | 0.21 | — | — | 0.77 | 0.41 |
| 1978-81 | 0.80 | 0.43 | 0.84 | 0.49 | 0.83 | 0.43 | — | — | 0.85 | 0.45 |

* Mortality for age group calculated using estimates (Table 2) from spring of one year to spring the following year.

** Total annual mortality (A) not included in calculation of mean when μ is equal to or greater than A, an impossible situation probably the result of small sample size and/or sampling variation.

[a] Population estimates in spring 1982 used to calculate total annual mortality from spring 1981 to spring 1982 are presented in Serns, 1983.

## Growth

For each age except age I, the mean lengths of smallmouth bass captured in Nebish Lake by fyke netting and electrofishing were higher when the length limit was in effect (1978-81) than for the previous four years (1974-77). (See Table 12.)

Mean weights for smallmouth captured by fyke netting and electrofishing from 1978-81 were higher at ages II-IX than the mean weights of smallmouth collected in the springs of 1974-77 (Table 13). Although the 8-inch length limit on smallmouth bass began on 1 January 1977, there was little fishing prior to spring ice-out and only 5 smallmouth bass were caught through the ice in 1977. Therefore, the mean weight of bass collected in the spring of 1977 would not have been influenced by the length limit. Mean calculated weights for a given length, using length-weight regression formulae for smallmouth collected in spring during two years with no length limit (1974 and 1975) and two years with the length limit (1979 and 1980), indicated no obvious differences (Table 14).

Annual smallmouth bass reproduction (lb/acre) was more than twice as high during 1979-81 than during 1974-76 (Table 15). Annual production of age III and IV bass combined ranged from 0.6-1.5 lb/acre (mean = 1.17) from 1974-76 and from 1.7-4.3 lb/acre (mean = 2.9) during 1979-81 (Table 15).

Equilibrium yield calculations for Nebish Lake smallmouth bass indicated that if instantaneous rates of growth, natural mortality, and annual angler exploitation rates remain unchanged from 1980 and 1981, the highest yield of bass would occur if bass were protected until age IV (Table 16). This increased protection from age III (approximately 8 inches total length) to age IV (approximately 11 inches) would increase the theoretical yield per given weight of recruits by slightly more than 5%. The total number of fish harvested, however, would decrease by 45% (from 2,232 to 1,235).

Protection until age V (about 13 inches) would cause a reduction in yield of about 19% and a reduction in harvest of 75% (compared to protection up to age III). With slight decreases in the instantaneous growth rate or increases in the natural mortality rate, yield would increase less than 5% by increasing the protection of smallmouth bass from age III to age IV, and in some cases yield would decline with increased protection.

*Biologist measures an adult smallmouth bass during spring netting and tagging operations.*

TABLE 12. *Mean total length at various ages of smallmouth bass collected in the spring, before and after an 8-inch length limit.**

| Year | 0** | I | II | III | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Age | | | | | |
| **Before Limit** | | | | | | | | | | |
| 1972 | 2.8 | 3.4 | 5.9 | 7.8 | 13.5 | 15.2 | — | — | — | — |
| | (25)[a] | (7) | (652) | (169) | (7) | (6) | | | | |
| 1973 | 2.7 | — | 4.7 | 7.1 | 10.0 | 13.5 | 16.0 | — | — | — |
| | (33) | | (40) | (336) | (47) | (6) | (6) | | | |
| 1974 | 2.8 | — | 5.1 | 7.1 | 8.6 | 10.5 | 14.4 | 16.6 | — | — |
| | (86) | | (3) | (7) | (79) | (37) | (15) | (6) | | |
| 1975 | 2.7 | 3.3 | 5.5 | 8.0 | 9.7 | 11.5 | 14.7 | 15.5 | — | — |
| | (56) | (8) | (179) | (14) | (15) | (28) | (1) | (3) | | |
| 1976 | 3.0 | 3.1 | 5.6 | 8.5 | 9.3 | 11.9 | 13.3 | 14.5 | 15.6 | 17.0 |
| | (72) | (4) | (56) | (108) | (21) | (4) | (9) | (7) | (10) | (1) |
| **After Limit** | | | | | | | | | | |
| 1977 | 3.2 | 3.8 | 6.5 | 9.1 | 11.8 | 12.2 | — | 16.3 | — | — |
| | (253) | (557) | (697) | (105) | (28) | (1) | | (8) | | |
| 1978 | 2.8 | 3.4 | 6.2 | 8.4 | 10.5 | 13.6 | 14.8 | — | — | 17.8 |
| | (125) | (73) | (1,015) | (146) | (24) | (10) | (5) | | | (4) |
| 1979 | 2.8 | 3.6 | 5.9 | 8.4 | 11.3 | 14.4 | 16.4 | 16.9 | 16.9 | — |
| | (70) | (2) | (172) | (522) | (59) | (5) | (9) | (1) | (2) | |
| 1980 | 2.8 | 3.3 | 6.1 | 8.2 | 10.4 | 13.1 | — | 17.6 | — | — |
| | (63) | (142) | (297) | (407) | (75) | (5) | | (1) | | |
| 1981 | 3.1 | 3.3 | 5.5 | 8.5 | 11.0 | 13.4 | 16.4 | 17.6 | — | — |
| | (100) | (55) | (547) | (155) | (86) | (22) | (1) | (1) | | |
| **Means** | | | | | | | | | | |
| 1974-77 | 2.9 | 3.4 | 5.7 | 8.2 | 9.9 | 11.5 | 14.1 | 15.7 | 15.6 | 17.0 |
| 1978-81 | 2.9 | 3.4 | 5.9 | 8.4 | 10.8 | 13.6 | 15.9 | 17.4 | 16.9 | 17.8 |

* Units in inches.
** Fingerlings were captured in previous fall using an electroshocker.
a Sample size in parentheses.

TABLE 13. *Mean weight of smallmouth bass collected in spring, before and after an 8-inch length limit.**

| Year | I | II | III | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Age | | | | |
| **Before Limit** | | | | | | | | | |
| 1972 | 0.01 | 0.09 | 0.22 | 1.43 | 1.96 | — | — | — | — |
| | (7)** | (652) | (169) | (7) | (12) | | | | |
| 1973 | — | 0.04 | 0.14 | 0.46 | 1.31 | 2.43 | — | — | — |
| | | (39) | (334) | (49) | (5) | (6) | | | |
| 1974 | — | 0.05 | 0.14 | 0.26 | 0.53 | 1.58 | 2.59 | — | — |
| | | (3) | (7) | (80) | (37) | (15) | (60) | | |
| 1975 | 0.04 | 0.07 | 0.21 | 0.37 | 0.68 | 1.02 | 1.69 | — | — |
| | (62) | (242) | (15) | (15) | (27) | (1) | (3) | | |
| 1976 | 0.01 | 0.06 | 0.24 | 0.36 | 0.78 | 1.20 | 1.48 | 2.03 | 2.81 |
| | (4) | (56) | (108) | (21) | (4) | (9) | (7) | (10) | (1) |
| **After Limit** | | | | | | | | | |
| 1977 | 0.03 | 0.13 | 0.31 | 0.74 | 0.93 | — | 2.20 | — | — |
| | (557) | (697) | (105) | (28) | (1) | | (8) | | |
| 1978 | 0.02 | 0.09 | 0.25 | 0.53 | 1.27 | 1.80 | — | — | 2.97 |
| | (73) | (977) | (140) | (24) | (10) | (5) | | | (4) |
| 1979 | 0.04 | 0.08 | 0.23 | 0.66 | 1.59 | 2.40 | 2.88 | 2.88 | — |
| | (2) | (172) | (522) | (59) | (5) | (6) | (1) | (2) | |
| 1980 | 0.01 | 0.09 | 0.22 | 0.50 | 0.99 | — | 1.85 | — | — |
| | (142) | (298) | (410) | (77) | (4) | | (1) | | |
| 1981 | 0.01 | 0.06 | 0.24 | 0.60 | 1.22 | 2.69 | 3.00 | — | — |
| | (55) | (549) | (156) | (85) | (22) | (1) | (1) | | |
| **Means** | | | | | | | | | |
| 1974-77 | 0.03 | 0.08 | 0.23 | 0.43 | 0.73 | 1.27 | 1.99 | 2.03 | 2.81 |
| 1978-81 | 0.02 | 0.08 | 0.24 | 0.57 | 1.27 | 2.30 | 2.58 | 2.88 | 2.97 |

* Units in lb.
** Sample size in parentheses.

**TABLE 14.** *Mean calculated weights and length-weight regression formulae of smallmouth bass collected in the spring, before and after an 8-inch length limit.*

| Total Length | Weight Before Limit (lb) 1974 | 1975 | Weight After Limit (lb) 1979 | 1980 |
|---|---|---|---|---|
| 6.0 | 0.08 | 0.08 | 0.07 | 0.08 |
| 8.0 | 0.20 | 0.20 | 0.19 | 0.19 |
| 10.0 | 0.43 | 0.41 | 0.41 | 0.39 |
| 12.0 | 0.78 | 0.74 | 0.75 | 0.69 |
| 14.0 | 1.31 | 1.22 | 1.24 | 1.12 |
| 16.0 | 2.03 | 1.89 | 1.94 | 1.69 |
| Length-Weight Relationship | $\log_{10}W = -3.682 + 3.314 \log_{10}L$ | $\log_{10}W = -3.629 + 3.243 \log_{10}L$ | $\log_{10}W = -3.710 + 3.320 \log_{10}L$ | $\log_{10}W = -3.532 + 3.123 \log_{10}L$ |
| N | 151 | 245 | 511 | 601 |
| r | 0.991 | 0.991 | 0.990 | 0.981 |

**TABLE 15.** *Annual instantaneous growth rates (G), mean biomass (B), and production (P) of age III and IV smallmouth bass, for selected years before and after an 8-inch length limit.*

| Year | III | IV | Total | Total (lb/acre) | $P/\overline{B}$ |
|---|---|---|---|---|---|
| **Before Limit** | | | | | |
| 1974 | | | | | |
| G | 0.97 | 0.60 | | | |
| $\overline{B}$ | 44 | 100 | 144 | 1.5 | 0.72 |
| P | 43 | 60 | 103 | 1.1 | |
| 1975 | | | | | |
| G | 0.54 | 0.75 | | | |
| $\overline{B}$ | 86 | 18 | 84 | 1.0 | 0.64 |
| P | 46 | 14 | 60 | 0.6 | |
| 1976 | | | | | |
| G | 0.38 | 0.49 | | | |
| $\overline{B}$ | 254 | 89 | 343 | 3.6 | 0.41 |
| P | 87 | 44 | 141 | 1.5 | |
| **After Limit** | | | | | |
| 1979 | | | | | |
| G | 0.78 | 0.41 | | | |
| $\overline{B}$ | 276 | 97 | 373 | 4.0 | 0.68 |
| P | 97 | 40 | 255 | 2.7 | |
| 1980 | | | | | |
| G | 1.00 | 0.89 | | | |
| $\overline{B}$ | 257 | 170 | 427 | 4.5 | 0.96 |
| P | 257 | 151 | 408 | 4.3 | |
| 1981 | | | | | |
| G | 1.15 | 0.85 | | | |
| $\overline{B}$ | 79 | 83 | 162 | 1.7 | 0.98 |
| P | 91 | 71 | 162 | 1.7 | |

**TABLE 16.** *Equilibrium yield calculations for smallmouth bass in relation to changing assumptions on instantaneous growth rates (G) and natural mortality rates (M).**

| Age of Recruits to Fishery | Approx. Size Limit (inches) | Yield (lb) | Harvest (no.) | Mean Weight of Harvest (lb) | Population Biomass (lb) |
|---|---|---|---|---|---|
| | | **G and M unchanged** | | | |
| I | 3 | 766 | 4,706 | 0.2 | 1,090 |
| II | 6 | 831 | 3,888 | 0.2 | 1,232 |
| III | 8 | 1,078 | 2,232 | 0.5 | 2,205 |
| IV | 11 | 1,136 | 1,235 | 0.9 | 3,309 |
| V | 13 | 872 | 569 | 1.5 | 4,283 |
| | | **G decreased by 5%** | | | |
| I | 3 | 655 | 4,308 | 0.2 | 948 |
| II | 6 | 708 | 3,481 | 0.2 | 1,071 |
| III | 8 | 889 | 1,899 | 0.5 | 1,881 |
| IV | 11 | 910 | 1,011 | 0.9 | 2,771 |
| V | 13 | 683 | 453 | 1.5 | 3,536 |
| | | **G decreased by 10%** | | | |
| I | 3 | 562 | 3,955 | 0.1 | 909 |
| II | 6 | 672 | 3,351 | 0.2 | 1,026 |
| III | 8 | 827 | 1,780 | 0.5 | 1,785 |
| IV | 11 | 829 | 924 | 0.9 | 2,600 |
| V | 13 | 610 | 404 | 1.5 | 3,286 |
| | | **G decreased by 5%, M increased by 5%** | | | |
| I | 3 | 623 | 4,175 | 0.1 | 909 |
| II | 6 | 672 | 3,351 | 0.2 | 1,026 |
| III | 8 | 827 | 1,781 | 0.5 | 1,785 |
| IV | 11 | 829 | 924 | 0.9 | 2,600 |
| V | 13 | 610 | 404 | 1.5 | 3,286 |
| | | **G decreased by 5%, M increased by 10%** | | | |
| I | 3 | 594 | 4,048 | 0.1 | 872 |
| II | 6 | 639 | 3,227 | 0.2 | 985 |
| III | 8 | 769 | 1,670 | 0.5 | 1,696 |
| IV | 11 | 755 | 844 | 0.9 | 2,442 |
| V | 13 | 544 | 361 | 1.5 | 3,057 |
| | | **G decreased by 10%, M increased by 10%** | | | |
| I | 3 | 510 | 3,724 | 0.1 | 764 |
| II | 6 | 547 | 2,899 | 0.2 | 861 |
| III | 8 | 635 | 1,424 | 0.4 | 1,455 |
| IV | 11 | 606 | 692 | 0.9 | 2,058 |
| V | 13 | 426 | 287 | 1.5 | 2,540 |
| | | **G decreased by 15%, M increased by 10%** | | | |
| I | 3 | 483 | 3,642 | 0.1 | 724 |
| II | 6 | 518 | 2,803 | 0.2 | 816 |
| III | 8 | 606 | 1,379 | 0.4 | 1,380 |
| IV | 11 | 585 | 678 | 0.9 | 1,960 |
| V | 13 | 419 | 287 | 1.5 | 2,433 |

* Assumes 100 lb of annual recruits. Total annual mortality for age I fish was set at 40% and exploitation was 10%. For age II and older bass, annual mortality rate was 77% and annual rate of exploitation 47%. Instantaneous growth rates (G) were calculated from mean weight-at-age data for 1980 and 1981, as listed in Table 13.

# EFFECTS ON YELLOW PERCH

## Density and Biomass

Mark-recapture estimates of the number of adult yellow perch in Nebish Lake in spring indicated a much higher density during the 4-year period before the length limit on smallmouth bass (Table 17). The mean density of perch ≥5.5 inches was over 2 times greater during the 1974-77 period (514/acre) than the subsequent 5 years (219/acre). The density of perch ≥7.0 inches during 1974-77 was more than triple (415/acre) the density observed when the length limit was in effect (128/acre). (See Table 17.)

Spring biomass estimates of yellow perch in Nebish Lake were also much greater during the period before the length limit. The estimated mean annual biomass of perch ≥5.5 inches during 1974-77 was 86 lb/acre compared with 38 lb/acre during the subsequent 4-year period (Table 18). Also, the mean biomass for perch ≥7 inches during the 4 years before the length limit (78 lb/acre) was more than double the biomass of perch of equal length after the length limit (28 lb/acre).

## Angler Harvest, Yield, and Harvest Rate

The harvest, yield, and harvest rate of yellow perch was higher during 1972-76 than during the subsequent 5 years (Table 19). The annual harvest of yellow perch averaged 4,167 fish weighing 810 lb during 1972-76, compared with 3,036 fish weighing 678 lb from 1977-81. The mean annual yield of perch before the length limit was 44/acre and 8.6 lb/acre compared to 32/acre and 7.2 lb/acre after the length limit (Table 19). No significant ($\underline{P} < 0.05$) correlations were found for the relationship between fishing pressure (Table 2) and the angler harvest of yellow perch (Table 19) during 1972-76 ($\underline{r} = 0.534$) and 1977-81 ($\underline{r} = -0.333$), or the 10-year period of 1972-81 ($\underline{r} = -0.019$).

Mean annual harvest rates were nearly twice as high (96 vs. 58 per 100 angler hours) in the 5 years before the length limit (Table 19). Harvest rates for yellow perch ranged from 42-184 per 100 angler hours from 1972-76 and from 29-96 during the subsequent 5 years.

Of the 15,180 yellow perch harvested by anglers during 1977-81, 32% were caught when the lake was ice-covered. The annual percentage of perch harvested during the winters of 1977-81 ranged from a low of 13% in 1980 to a high of 60% in 1981. Of the 7,287 anglers fishing Nebish Lake from 1977-81, only 408 (5.6%) fished during the period of ice cover.

## Mortality and Exploitation Rate

Instantaneous and annual mortality rates were calculated for yellow perch from catch curves of fish captured in fyke nets in spring. Mortality rate estimates for adult (age III+, IV+, and VI+) perch were considerably higher during 1974-77 than during 1978-81 (Table 20).

Annual exploitation rates for adult yellow perch were higher generally during 1978-81 than 1974-77 (Table 21). The mean annual exploitation rates for perch from 1974-77 were 0.13 (perch ≥5.5 inches) and 0.31 (perch ≥7 inches) compared with the annual rates of 0.20 (perch ≥6 inches) and 0.24 (perch ≥7 inches) for 1978-81.

## Growth

Mean total lengths were greater at each age for both male and female yellow perch collected during 1978-81 than during 1974-77. Mean lengths were over 1 inch greater for males ages III and IV collected from 1978-81, compared with mean lengths of those collected from 1974-77 (Table 22). Mean lengths of females at each of ages IV-VII were also over 1 inch greater during 1978-81 than during 1974-77 (Table 23).

**TABLE 17.** *Estimated number of yellow perch, by 1/2-inch group, before and after an 8-inch length limit on smallmouth bass.**

| Total Length (inches) | Before Limit 1972 | 1973 | 1974 | 1975 | 1976 | After Limit 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.5 | 17,400 | 72,200 | 600 | | | 2,700 | 4,400 | | | |
| 6.0 | 11,900 | 39,100 | 3,900 | 3,900 | 2,400 | 2,900 | 3,600 | | 3,100 | 16,200 |
| 6.5 | 11,900 | 13,900 | 15,100 | 1,500 | 2,500 | 1,500 | 900 | | 1,500 | 4,500 |
| 7.0 | 3,600 | 2,500 | 26,200 | 1,600 | 3,600 | 1,400 | 2,000 | 4,400 | 400 | 4,100 |
| 7.5 | 2,900 | 1,200 | 29,100 | 3,800 | 3,500 | 2,100 | 1,500 | 5,900 | 1,200 | 1,600 |
| 8.0 | 800 | 300 | 27,900 | 8,500 | 5,500 | 1,900 | 1,600 | 8,000 | 1,200 | 1,100 |
| 8.5 | 200 | 100 | 9,000 | 5,800 | 4,100 | 1,800 | 1,300 | 4,000 | 800 | 1,200 |
| 9.0 | 100 | 80 | 3,100 | 5,000 | 1,400 | 2,600 | 700 | 1,200 | 800 | 1,700 |
| 9.5 | 100 | 10 | 1,600 | 2,800 | 1,600 | 400 | | 500 | 500 | |
| 10.0 | | | 80 | 1,000 | 300 | 200 | 300 | 400 | 500 | |
| 10.5 | | | | 100 | 200 | | 300 | | 200 | |
| 11.0 | | | | | | | 500 | | 100 | |
| Total | | | | | | | | | | |
| ≥5.5 (no.) | 48,900 | 129,390 | 116,580 | 34,000 | 25,100 | 17,500 | 17,100 | 24,400 | 10,300 | 30,400 |
| ≥7.0 (no.) | 7,700 | 4,190 | 96,980 | 28,600 | 20,200 | 10,400 | 8,200 | 24,400 | 5,700 | 9,700 |
| ≥5.5 (no./acre) | 520 | 1,376 | 1,240 | 362 | 267 | 186 | 182 | 260 | 110 | 323 |
| ≥7.0 (no./acre) | 82 | 46 | 1,032 | 304 | 215 | 111 | 87 | 260 | 61 | 103 |

Means
1974-77
≥5.5 48,295 (514/acre)
≥7.0 39,045 (415/acre)
1978-81
≥5.5 20,550 (219/acre)
≥7.0 12,000 (128/acre)

* Rounded to the nearest 100 if ≥100 or 10 if <100.

**TABLE 18.** *Estimated spring biomass of yellow perch, by 1/2 inch group, before and after an 8-inch length limit on smallmouth bass.**

| Total Length (inches) | Before Limit 1972 | 1973 | 1974 | 1975 | 1976 | After Limit 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.5 | 1,118 | 6,868 | 47 | | | 163 | 443 | | | |
| 6.0 | 1,010 | 4,883 | 310 | 164 | 110 | 229 | 360 | | 312 | 1,787 |
| 6.5 | 1,234 | 2,129 | 1,509 | 80 | 157 | 166 | 103 | | 198 | 539 |
| 7.0 | 455 | 505 | 3,467 | 149 | 282 | 202 | 304 | 667 | 67 | 567 |
| 7.5 | 449 | 296 | 5,121 | 488 | 376 | 377 | 269 | 1,060 | 198 | 267 |
| 8.0 | 298 | 82 | 5,958 | 1,652 | 723 | 427 | 339 | 1,674 | 252 | 212 |
| 8.5 | 51 | 46 | 2,265 | 1,078 | 633 | 460 | 317 | 970 | 198 | 287 |
| 9.0 | 30 | 33 | 841 | 1,137 | 275 | 833 | 198 | 335 | 237 | 499 |
| 9.5 | 35 | 8 | 559 | 672 | 388 | 162 | | 168 | 154 | 231 |
| 10.0 | | | 31 | 382 | 75 | 105 | 112 | 134 | 197 | |
| 10.5 | | | | 62 | 69 | | 154 | | 95 | |
| 11.0 | | | | | | | 241 | | 58 | |
| Totals | | | | | | | | | | |
| $\geq$5.5 (lb.) | 4,680 | 14,850 | 20,108 | 5,864 | 3,088 | 3,124 | 2,840 | 5,008 | 1,966 | 4,389 |
| $\geq$7.0 (lb.) | 1,318 | 970 | 18,242 | 5,620 | 2,821 | 2,566 | 1,934 | 5,008 | 1,456 | 2,063 |
| $\geq$5.5 (lb/acre) | 50 | 158 | 214 | 62 | 33 | 33 | 30 | 53 | 21 | 47 |
| $\geq$7.0 (lb/acre) | 14 | 10 | 194 | 60 | 30 | 27 | 21 | 53 | 15 | 22 |

Means

1974-77
- $\geq$5.5 8,046 lb; 86 lb/acre
- $\geq$7.0 7,312 lb; 78 lb/acre

1978-81
- $\geq$5.5 3,551 lb; 38 lb/acre
- $\geq$7.0 2,615 lb; 28 lb/acre

* Units in lb.

**TABLE 19.** *Harvest, yield, and harvest rate of yellow perch, before and after an 8-inch length limit on smallmouth bass.*

| Year | Harvest Number | Harvest Weight (lb) | Yield (no./acre) | Yield (lb/acre) | Harvest Rate (no./100 angler hours) |
|---|---|---|---|---|---|
| **Before Limit** | | | | | |
| 1972 | 1,918 | 266 | 20 | 2.8 | 57 |
| 1973 | 1,724 | 227 | 18 | 2.4 | 42 |
| 1974 | 4,708 | 893 | 50 | 9.5 | 119 |
| 1975 | 8,505 | 1,716 | 90 | 18.3 | 184 |
| 1976 | 3,981 | 947 | 42 | 10.1 | 78 |
| **After Limit** | | | | | |
| 1977 | 3,596 | 896 | 38 | 9.2 | 71 |
| 1978 | 3,074 | 746 | 33 | 7.9 | 56 |
| 1979 | 1,898 | 469 | 20 | 5.0 | 38 |
| 1980 | 1,748 | 427 | 19 | 4.5 | 29 |
| 1981 | 4,864 | 881 | 52 | 9.4 | 96 |
| **Means ± SD** | | | | | |
| 1972-76 | 4,167 ± 2,746 | 810 ± 609 | 44 ± 29 | 8.6 ± 6.5 | 96 ± 57 |
| 1977-81 | 3,306 ± 1,286 | 678 ± 217 | 32 ± 14 | 7.2 ± 2.3 | 58 ± 27 |

**TABLE 20.** *Instantaneous (Z) and annual (A) mortality rates and survival (S) rates for yellow perch, before and after an 8-inch length limit on smallmouth bass.**

| Year | Age | Z | A | S | r |
|---|---|---|---|---|---|
| **Before Limit** | | | | | |
| 1972 | ≥III | 1.703 | 0.818 | 0.182 | -0.949 |
| 1973 | ≥III | 2.679 | 0.931 | 0.069 | -0.976 |
| 1974 | ≥IV | 2.272 | 0.897 | 0.103 | -0.938 |
| 1975 | ≥V | 3.173 | 0.959 | 0.041 | -0.900 |
| 1976 | ≥VI | 3.023 | 0.956 | 0.044 | -0.980 |
| **After Limit** | | | | | |
| 1977 | ≥III | 0.994 | 0.626 | 0.374 | -0.990 |
| 1978 | ≥III | 0.761 | 0.533 | 0.467 | -0.963 |
| 1979 | ≥III | 1.110 | 0.670 | 0.330 | -0.993 |
| 1980 | ≥III | 0.630 | 0.467 | 0.533 | -0.992 |
| 1981 | ≥III | 0.808 | 0.554 | 0.446 | -0.941 |
| **Means** | | | | | |
| 1974-77 | ≥III, IV and VI | 2.366 | 0.860 | 0.140 | |
| 1977-81 | ≥III | 0.827 | 0.556 | 0.444 | |

* Based on catch curve analyses of the age distribution of perch in the spring fyke net catches.

**TABLE 21.** *Annual angler exploitation rates (μ) of yellow perch, before and after an 8-inch length limit on smallmouth bass.*

| Year | Length Group (inches) | Annual Rate of Exploitation (μ) |
|---|---|---|
| **Before Limit** | | |
| 1972 | ≥7.0 | 0.15 |
| 1973 | ≥7.0 | 0.14 |
| 1974 | ≥5.5 | 0.02 |
| 1975 | ≥5.5 | 0.15 |
| 1976 | ≥5.5 | 0.12 |
| **After Limit** | | |
| 1977 | ≥6.0; ≥7.0 | 0.23; 0.31 |
| 1978 | ≥6.0; ≥7.0 | 0.37; 0.35 |
| 1979 | ≥6.0; ≥7.0 | 0.07; 0.09 |
| 1980 | ≥6.0; ≥7.0 | 0.16; 0.25 |
| 1981 | ≥6.0; ≥7.0 | 0.20; 0.27 |
| **Means ± SD** | | |
| 1974-77 | ≥5.5, ≥6.0 | 0.13 ± 0.09 |
| | ≥7.0 | 0.31 |
| 1978-81 | ≥6.0 | 0.20 ± 0.13 |
| | ≥7.0 | 0.24 ± 0.11 |

**TABLE 22.** *Mean total length and age of male yellow perch captured at ice-out, before and after an 8-inch length limit on smallmouth bass.**

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | I | II | III | IV | V | VI | VII | VIII |
| **Before Limit** | | | | | | | | |
| 1972 | — | — | 4.4 (52)** | 6.7 (33) | 8.7 (42) | — | — | — |
| 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) |
| **After Limit** | | | | | | | | |
| 1977 | 3.5 (44) | 4.9 (18) | 6.0 (51) | 7.7 (34) | 8.6 (17) | 9.1 (13) | 9.5 (7) | — |
| 1978 | 3.3 (16) | 4.4 (37) | 6.3 (32) | 7.1 (24) | 8.3 (12) | 8.8 (9) | 9.3 (16) | 10.1 (12) |
| 1979 | 3.6 (31) | 5.1 (34) | 6.7 (33) | 8.2 (27) | 8.7 (10) | 9.2 (6) | 9.5 (6) | 9.8 (2) |
| 1980 | 3.3 (19) | 4.7 (40) | 6.6 (51) | 7.5 (37) | 8.5 (31) | 9.0 (34) | 9.6 (15) | 10.0 (9) |
| 1981 | 3.9 (20) | 5.0 (48) | 6.8 (25) | 8.2 (23) | 8.8 (16) | 10.0 (6) | 10.2 (4) | 9.5 (8) |
| **Means** | | | | | | | | |
| 1974-77 | 3.3 | 4.1 | 5.3 | 6.6 | 7.7 | 8.8 | 9.3 | 9.4 |
| 1978-81 | 3.5 | 4.8 | 6.6 | 7.8 | 8.6 | 9.3 | 9.7 | 9.9 |

* Units in inches.
** Sample size in parentheses.

**TABLE 23.** *Mean total length and age of female yellow perch captured at ice-out, before and after an 8-inch length limit on smallmouth bass.**

| Year | Age II | Age III | Age IV | Age V | Age VI | Age VII | Age VIII |
|---|---|---|---|---|---|---|---|
| **Before Limit** | | | | | | | |
| 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) | 8.9 (8) | 10.1 (2) |
| **After Limit** | | | | | | | |
| 1977 | — | 7.2 (42) | 8.5 (34) | 9.6 (15) | 9.6 (5) | 10.6 (23) | 11.2 (7) |
| 1978 | — | 6.9 (35) | 7.9 (31) | 9.4 (3) | 9.9 (5) | 10.5 (6) | 10.9 (5) |
| 1979 | 5.8 (2) | 7.7 (45) | 9.4 (18) | 9.7 (2) | 11.6 (2) | 11.9 (2) | — |
| 1980 | — | 7.3 (45) | 8.2 (18) | 9.9 (2) | 10.6 (2) | 11.0 (2) | — |
| 1981 | 5.6 (15) | 7.3 (40) | 8.5 (26) | 9.7 (10) | 9.7 (2) | — | — |
| **Means** | | | | | | | |
| 1974-77 | | 6.9 | 7.2 | 8.2 | 9.2 | 9.7 | 10.7 |
| 1978-81 | | 7.3 | 8.5 | 9.7 | 10.5 | 11.1 | 10.9 |

* Units in inches.
** Sample size in parentheses.

# DISCUSSION

## FISHING PRESSURE

Mean annual fishing pressure was higher during the period with the 8-inch length limit on smallmouth bass than during the previous 5-year period. The mean annual number of anglers was 33% higher and the mean annual hours fished was 27% higher.

Ming and McDannold (1975) reported that fishing pressure (hours/acre) and number of fishermen increased after a minimum length limit was imposed on largemouth bass in Pony Express Lake, Missouri. However, fishing pressure at Limpp Lake, Missouri changed little after a 12-inch length limit on largemouth bass was implemented (Rasmussen and Michaelson 1974). Surber (1968) reported a decrease in fishing pressure on the Shenandoah River, Virginia after the implementation of a 12-inch length limit on smallmouth bass.

Mean annual fishing pressure (45 and 57 hours/acre before and after the 8-inch length limit, respectively) was considerably higher than during the 21 years before chemical reclamation in 1966 (mean = 21 hours/acre) and is indicative of the increase in the quality and quantity of the fishery after chemical treatment (Christenson et al. 1982). Fishing pressure on nearby Escanaba Lake (mostly a walleye and yellow perch lake) averaged 49 hours/acre during 1972-81 (unpublished DNR files).

There was no correlation between fishing pressure and the number of smallmouth bass and yellow perch harvested in Nebish Lake during 1972-76, 1977-81, or for the entire period of 1972-81. Fleener et al. (1974) reported similar results for smallmouth bass in the Big Piney River, Missouri for the period 1951-58. However, data collected from Murphy Flowage, Wisconsin indicated a significant ($\underline{P} < 0.05$) positive relationship between fishing pressure and largemouth bass harvest (Snow 1971).

## EFFECTS ON SMALLMOUTH BASS

### Density and Biomass

The mean annual density and biomass of age III+ smallmouth bass increased 77% and 79%, respectively, after the length limit. By delaying harvest of the smallmouth until they were 8 inches (attained during the 3rd summer of life), the length limit positively influenced the density and biomass of age III+ bass. Surber (1968) reported an increase in the density of intermediate-sized smallmouth in the Shenandoah River after a 12-inch length limit.

Mean densities of fingerling smallmouth bass in the fall during the 4-year period before the length limit (1974-77) were 21% higher than the densities after the length limit (1978-81). Summer water temperatures (June-August) averaged 72.3 F during 1974-77 and 71.4 F during 1978-81 (Serns 1982).

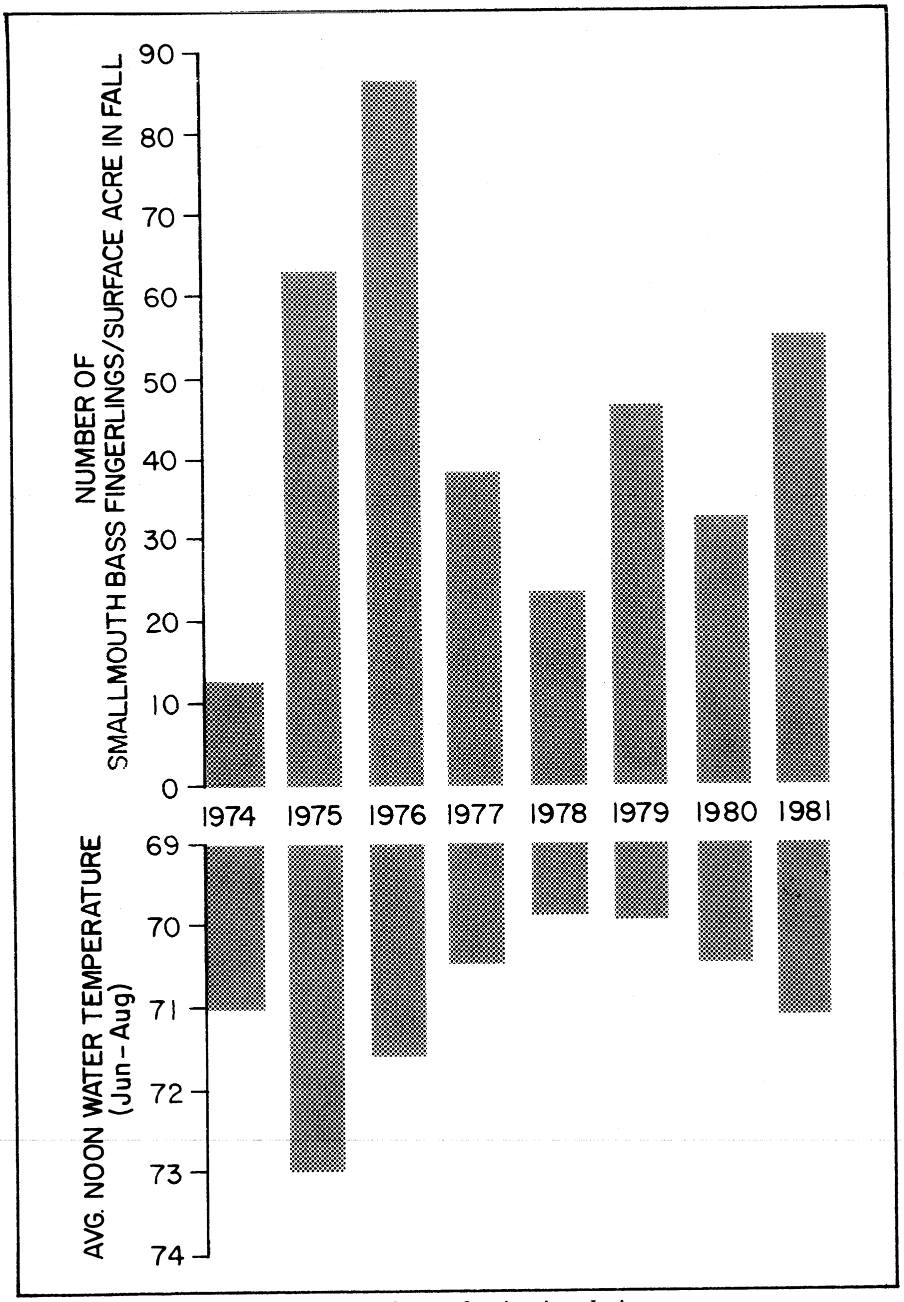



**FIGURE 2.** *Smallmouth bass natural reproduction in relation to summer water temperature in Nebish Lake, 1974-81.*

(See Fig. 2.) Previous research on Nebish Lake indicated that summer water temperature was the major determinant of young-of-the-year densities in fall, and no apparent correlation between adult ($\geq$age III) densities and year class strength was found (Serns 1982).

## Harvest, Yield, and Harvest Rate

The angler harvest (no.) of smallmouth was 8% less during the years with the length limit than during the previous 5-year period, but the yield (lb) was 30% greater. The length limit prevented the harvest of smallmouth until they reached age II, and most of the age II fish probably did not recruit into the legal length range until midway through their 3rd growing season. During the period without a length limit, some age I fish were harvested each year, while age II smallmouth contributed the highest percentage to both the mean total annual harvest (number) and yield (weight). After the length limit, age III smallmouth bass comprised the highest percentage of the mean annual yield.

The increased yield of smallmouth after the length limit was imposed cannot be attributed to the higher fishing pressure during those years, as there was no correlation between fishing pressure and smallmouth angling yield ($r = 0.49$, $df = 8$, $P > 0.10$). Jones (1968) reported that the harvest (no.) of smallmouth bass from Elkins Creek, Kentucky declined after an 11-inch minimum length limit, but the mean weight of bass harvested increased substantially.

The mean length of smallmouth harvested before the length limit was 8.2 inches contrasted with 9.4 inches during the period with the length limit. During the period with no length limit, an average of 44% of the bass harvested by anglers were less than 8 inches, while during the period with the length limit only 4% of the creeled bass were less than 8 inches (fish $\geq$7.8 inches were considered legal). However, the length limit did not result in a marked increase in the percentage of 10- and 12-inch fish in the angler's creel. The percentage of bass $\geq$8 inches that were $\geq$10 inches was slightly higher during the years with the length limit, but the percentage of bass $\geq$8 inches that were $\geq$12 inches was slightly higher before the length limit. Most of the increased harvest of bass $\geq$8.0 inches after the length limit was comprised of fish in the 8.0-9.9 inch range.

The harvest rate of smallmouth (all sizes) declined 29% after the length limit. There was, however, a 27% increase in the angler harvest rate of bass $\geq$8 inches after the length limit. After a 12-inch length limit on smallmouth bass in the Big Piney River in Missouri, Fleener (1974) reported an increase of 25% in the harvest of bass $\geq$12 inches. Unfortunately, data on harvest rates were not reported.

The length limit protected bass from harvest until late in their 2nd or early in their 3rd year of life. The percentage of age III bass in the creel increased from 32% with no length limit to 43% after the length limit, and the total yield of age III bass increased from 34% before the length limit to 44% after the length limit.

## Mortality Rate

Bass mortality rates as indicated by catch curves and population estimates by age group in successive years were higher during the years with the length limit than the period without the length limit. Mean estimated total annual mortality (A) from 1978-81 for age III+ bass was 61.5% (calculated from catch curves) compared with 48.6% for age III+ bass from 1974-77. Mean annual mortality rates for bass between ages III and V determined from population estimates of age groups in successive years also were higher with the length limit in effect.

Mortality rates calculated from the population estimates were higher in each period than those determined from catch curves, perhaps because of the biases inherent in using catch curves (influence of large year classes and incomplete vulnerability of all year classes included in the calculations) or because of the wide confidence intervals on some of the population estimates. Nonetheless, because both methods of calculation indicated that the total annual mortality of bass was higher with the length limit, those results appear real. A possible reason for the higher total mortality rates with the length limit in effect is the higher mean annual rate of exploitation during that period (45% vs. 41%). Another reason could be the higher density and biomass of age III+ bass after the length limit was imposed. The higher density of these older, mature fish may have increased competition for food and space, although these effects were not evident in reduced growth of smallmouth bass after the length limit was imposed.

## Growth

For smallmouth bass, mean lengths and weights at the various ages collected before and after the length limit indicated that growth improved slightly when the length limit was in effect. The growth of smallmouth during that period may have been influenced by a reduction in adult yellow perch during this period. Food habit studies of smallmouth bass and yellow perch in Nebish Lake (Serns and Hoff 1984) suggested some interspecific competition for various aquatic insects. Also, few yellow perch were found in smallmouth stomachs, indicating that they were not a major food item for smallmouth.

The mean annual production (lb) of smallmouth was higher after the length limit. The higher biomass of age III and IV bass along with higher instantaneous growth rates were responsible for this greater production.

Equilibrium yield calculations indicate that the length limit, given the instantaneous rates of growth and natural mortality exhibited by the population in 1980 and 1981, may be the best regulation for maximizing yield of Nebish Lake smallmouth bass. Indications are that yield would increase about 5% by protecting the bass from harvest until age IV (about 11 inches); however, with decreases in the instantaneous rate of growth or increases in natural mortality, yield would increase less than 5% and may actually decline from yield levels that assume entry to the fishery at age III (about 8 inches). Large reductions in the bass harvest would also result from increased protection from age III to age IV.

Greater production of age III and IV bass during 1979-81 than during 1974-76 was probably due to higher mean biomass estimates and greater instantaneous rates of growth.

## EFFECTS ON YELLOW PERCH

The lower density and biomass of yellow perch during the length limit period was probably a reflection of the extremely large 1969 year class influencing perch densities and biomass in the years before the length limit (Kempinger et al. 1982). After the effect of this large cohort had passed (1973 and 1974), the density and biomass of adult yellow perch remained fairly stable throughout the ensuing years (through 1981). The increase in age III+ bass during the years with the length limit probably had little impact on the population density or biomass of adult yellow perch. Food habit studies of adult smallmouth bass from Nebish Lake indicated they ate few yellow perch (Serns and Hoff 1984).

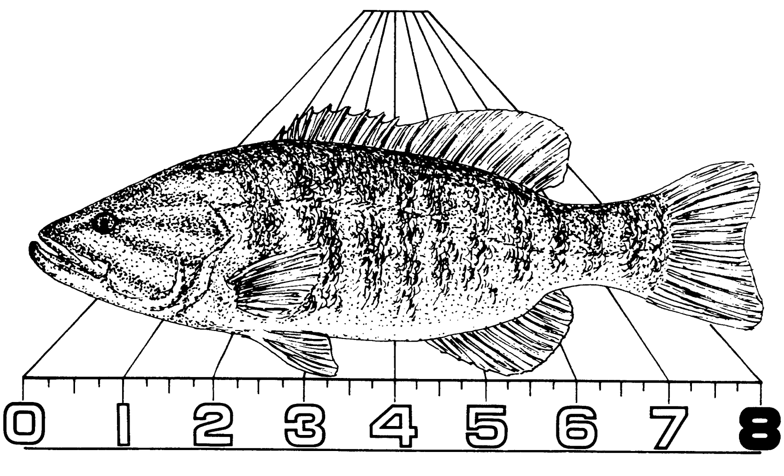
Before the length limit, the angler harvest, yield, and harvest rate for yellow perch were 27%, 16%, and 40% higher, respectively. These factors were probably influenced by the large 1969 year class of yellow perch, which affected the sport fishery at the time, particularly in 1973 and 1974.

Total instantaneous and annual mortality rates for adult yellow perch were considerably higher during 1974-77 when compared with 1978-81. Values of total annual mortality of adult yellow perch range "normally" between 45% and 70% (Thorpe 1977). Rates for adult yellow perch were within this range during 1978-81, but considerably higher during 1974-77.

Thorpe (1977) reported that the survival of adult yellow perch was inversely related to density. The higher rates of mortality for yellow perch before the length limit were quite possibly the result of the high densities and increased intraspecific competition for food and space among yellow perch during 1974-77.

The exploitation of yellow perch was lower before the length limit, even though densities were higher during that time. Higher fishing pressure during 1977-81 may have resulted in increased exploitation rates for adult perch when contrasted with 1972-76.

The growth of yellow perch of both sexes was better during the years with the length limit. These results may be a function of the lower densities of adult yellow perch during 1978-81. Other authors (Schneberger 1935, Eschmeyer 1938) reported the growth of yellow perch was inversely related to abundance. The higher growth rate of females than males in Nebish Lake both before and after the length limit is typical of yellow perch populations in other waters (Scott and Crossman 1973).



# SUMMARY AND MANAGEMENT CONSIDERATIONS

**TABLE 24.** *Comparison of fishery and population statistics, before and after an 8-inch size limit on smallmouth bass.*

| | Smallmouth Bass | | | Yellow Perch | |
|---|---|---|---|---|---|
| Parameter | Before Limit | After Limit | Parameter | Before Limit | After Limit |
| Fishing Pressure (hours/acre) | 45 | 57 | Fishing Pressure (hours/acre) | 45 | 57 |
| Harvest | | | Harvest | | |
| No./acre | 15 | 14 | No./acre | 44 | 32 |
| Lb/acre | 4.7 | 6.1 | Lb/acre | 8.6 | 7.2 |
| Mean length (inches) | 8.2 | 9.4 | Mean Length (inches) | 7.5 | 8.0 |
| Harvest | | | | | |
| $\geq$8 inches | 783 | 1,278 | | | |
| % $\geq$ 10 inches | 22 | 26 | | | |
| % $\geq$ 12 inches | 7 | 5 | | | |
| Harvest/100 hours ($\geq$8 inches) | 18.8 | 23.9 | Harvest/100 hours (all sizes) | 96 | 58 |
| Standing Crop | | | Standing Crop | | |
| Age III+ | | | $\geq$5.5 inches | | |
| No./acre | 8.2 | 14.6 | No./acre | 514 | 219 |
| Lb/acre | 2.8 | 4.9 | Lb/acre | 86 | 38 |
| Age 0 | | | | | |
| no./acre | 48.1 | 38.1 | | | |

An analysis of the smallmouth bass and yellow perch population and sport fishery in Nebish Lake before and after the 8-inch minimum length limit on smallmouth bass indicates the following changes occurred during the period after the length limit:

1) annual number of anglers increased 33% and fishing pressure increased 27%.
2) the density and biomass of age III+ smallmouth bass were 77% and 79% higher, respectively, while biomass increased slightly.
3) smallmouth bass reproductive success was 21% lower, presumably because of lower mean annual summer water temperatures.
4) the smallmouth bass harvest decreased by 8% but the yield (lb) increased by 30%.
5) the harvest rate of all smallmouth bass declined 29%, but the harvest rate of smallmouth bass $\geq$8.0 inches increased 27%.
6) the age of smallmouth bass contributing the greatest percent of both total harvest (no.) and yield (lb) increased from age II to age III.
7) the average total length of angler-caught bass increased from 8.2 to 9.4 inches.
8) the rate of total mortality of age III+ bass increased and was attributed to higher angler exploitation rates and possibly higher bass densities, which resulted in increased intraspecific competition.
9) the growth rate of smallmouth bass increased slightly.
10) production of age III and IV bass nearly doubled.
11) the average density of adult yellow perch decreased 3-fold and biomass decreased about 2-fold, because of the impact of the large 1969 year class on densities before the length limit.
12) angler harvest (no.), yield (lb), and harvest rate of yellow perch decreased 27%, 16%, and 40%, respectively.
13) the annual rate of total mortality of yellow perch declined substantially even though exploitation rates increased (natural mortality declined markedly), probably as a result of decreased intraspecific competition related to decreased density.
14) growth of yellow perch increased.

With the 8-inch length limit in effect for Nebish Lake smallmouth bass, the trade-off of 8% fewer bass in the creel was more than offset by the 30% increase in weight harvested and the 1.2-inch increase in the average length of bass creeled. It was estimated that yield of smallmouth bass would increase by 22% if an 8-inch length limit was implemented and if there were no resultant changes in instantaneous rates of growth and natural mortality of smallmouth (Kempinger 1978). However, during the 5-year period after the length limit, the smallmouth bass yield was actually 30% higher than during the 5 years before the length limit. Actual yield was probably higher than predicted yield because smallmouth bass growth was better during the period of the 8-inch length limit.

An equilibrium yield model was again used to estimate harvest and yield of smallmouth bass using various assumptions on length or age at entry to fishery, as well as instantaneous growth rates, natural mortality rates, and annual exploitation rate of the population in 1980 and 1981. The model predicted that by increasing the entry level from age III (8-inch length limit) to age IV (approximately an 11-inch length limit), yield (lb) would increase 5% and harvest (no.) would decrease by 45%, assuming no resultant changes in growth or natural mortality. However, if growth rates decreased or natural mortality increased, the increase in yield would be less than 5% and may actually decline, while the harvest would decrease by more than 45%.

To test the hypothesis that yield would increase by raising the length limit above 8 inches, the smallmouth bass length limit in Nebish Lake was set at 10 inches in 1982. The Department of Natural Resources will monitor both the smallmouth bass and yellow perch populations and sport fishery through at least 1986 to determine the impact of this higher length limit.

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## ENGLISH-METRIC MEASURE AND WEIGHT EQUIVALENTS

1 inch = 2.54 cm
1 ft = 30.48 cm or 0.3048 m
1 mile = 1.609 km
1 cfs = 0.028 cms
1 acre = 0.405 ha or 4.047 $m^2$
1 oz = 31.103 g
1 lb = 0.373 kg
1 $cm^2$ = 0.155 $inch^2$
1 g = 0.035 oz
1 liter = 33.83 oz


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