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Evaluating a Smallmouth Bass Slot Length and Daily Bag Limit on Nebish Lake, Wisconsin

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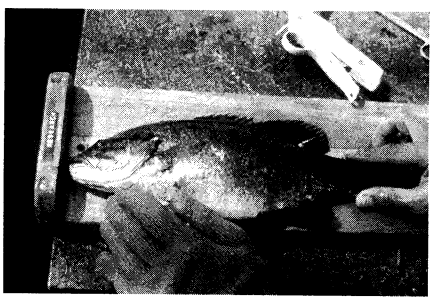


Abstract

Fishing pressure, angling harvest, and the population dynamics of smallmouth bass (*Micropterus dolomieui*) and yellow perch (*Perca flavescens*) were studied to evaluate smallmouth bass angling regulations in a 94-acre softwater lake in northern Wisconsin. The study was conducted when smallmouth bass fishing was subject to no bag, length, or season restrictions (1972–76); only a minimum length limit of 8 inches (1977–81); only a minimum length limit of 10 inches (1982–88); and both a protective slot length limit of 9 to 12 inches and a daily bag limit of 5 smallmouth bass/angler (1989–93).

During the 17 years of length limits (1977–93), mean annual fishing pressure increased 1.3 times (44.8 hours fished/acre under no limits to 58.8 hours/acre under the slot and bag limits), though fishing trips became 12% (24 minutes) shorter.

Mean annual harvest, meanwhile, decreased 3.3 times for all smallmouth bass (15.3/acre to 4.7/acre) and 5.5 times for all yellow perch (44.3/acre to 8.0/acre). Anglers, however, increased their harvest of smallmouth bass 12.0–14.0 inches long from 8% under the 8-inch limit to 55% under the slot and bag limits. The mean total length of all harvested smallmouth bass increased 1.3 times (8.2 inches to 10.8 inches), though anglers under the slot and bag limits kept almost as many smallmouth bass under the slot (42%) as above it (52%).

Among study periods in spring, the mean annual abundance of combined ages 3–8 smallmouth bass increased from 13.6/acre to 20.6/acre, while that of yellow perch decreased from 751.8/acre to 91.3/acre. Total annual mortality and open-water angling exploitation significantly decreased for age-3 smallmouth bass when the 10-inch limit was imposed. Growth of smallmouth bass has stayed well below the North Central District and "statewide" averages since at least 1972, while their population density has stayed above average at (mean ± 1 SE) 16.2 ± 1.8 smallmouth bass/acre.

Each new bass regulation reduced the overall harvest of smallmouth bass and yellow perch, though few spawning-age smallmouth bass were protected from harvest until the 10-inch limit and especially the slot and bag limits were imposed. Yet more anglers came to Nebish Lake and, under the slot and bag limits, their harvest of smallmouth bass 12.0–14.0 inches long increased.

Cover Photo
Smallmouth bass from Nebish Lake being measured for total length.

Introduction

To maintain stocks and prevent overharvest, smallmouth bass (*Micropterus dolomieu*) angling in North America (Anderson 1978), including Wisconsin (Hoff 1995), has increasingly been regulated with minimum or slot length limits. Yet setting the proper length limits can be critical to balancing stock size against growth rate (Anderson and Weithman 1978, Keith 1978). Setting them too low reduces spawning stock, leading to reduced overall harvest; setting them too high reduces growth, leading to harvest of fewer but larger fish (Novinger 1984, 1988). When recruitment is high, slot limits could stack bass within the slot if growth is slow or anglers harvest mainly at the upper slot limit (Kauffman 1983, Austen and Orth 1988). Failing to harvest below the slot, however, could turn a slot into a minimum length limit (Gabelhouse 1984).

Our objectives were to assess the effects of a combined slot length and daily bag limit on the fishing pressure and angling harvest, the fish community structure and mortality, and the growth of smallmouth bass and yellow perch stocked in a northern Wisconsin lake after removing the previous fish community. Before imposing slot and bag limits in 1989–92, angling took place under successive periods of no limits (1972–76), an 8-inch minimum limit (1977–81), and a 10-inch minimum limit (1982–88) (Kempinger and Christenson 1978, Serns 1984, Hoff 1995). In this report we compare fishing pressure; angling harvest; and fish abundance, biomass, mortality, exploitation, and growth under the slot and bag limits to those of earlier no limit and minimum length limit periods.

This experimental design had limitations. The four study periods lasted only 5–7 years, hardly long enough to stabilize the fishery and complete year classes before starting a new regulation. Regulations after the 8-inch limit were not separated by control periods, when all fish would be eradicated and brood stock introduced. Mixing a protective slot limit with a daily bag limit after 1988 added difficulty in separating treatment effects. Finally, this study lacked a control lake to help evaluate the smallmouth bass regulations.

Study Area

Located in Wisconsin's Vilas County, Nebish Lake (46°03' N latitude, 89°35' W longitude) lies about 13 miles south of Upper Peninsula Michigan and 40 miles south of Lake Superior, putting it near the probable northern limit of the smallmouth bass native range but well within its naturalized range (MacCrimmon and Robbins 1975).

Nebish Lake covers 94 acres to a maximum depth of 52 ft and a mean depth of 18.4 ft (Table 1). The lake has clear, infertile softwater that thermally stratifies from mid-May to early September (Serns 1984, Hoff 1995). In June 1946, it became one of five experimental lakes in the Northern Highlands Fishery Research Area (Fig. 1). Anglers in the late 1940s caught many undersized fish, including smallmouth bass shorter than the "statewide" limit of 10 inches (Threinen 1951). A smallmouth bass and yellow perch fishery dominated until the early 1960s, when a walleye fishery was developed (Kempinger and Christenson 1978).

All fish in Nebish Lake were killed in October 1966 with 550 gallons of about 1.0 mg/L emulsifiable rotenone (Table 2), to create an interim fishery for trout and a sustained fishery for smallmouth bass and yellow perch (Kempinger and Morsell 1969, Kempinger and Christenson 1978). The following spring the lake was stocked with 33 adult yellow perch (5.7–8.3 inches long) from Buckatabon Lake in Vilas County, 38 smallmouth

PHOTO S. SERNS

Nebish Lake and its forested watershed in May 1970.

PHOTO: S. ENGEL

Nebish Lake revealing one of many sunken logs, viewed from the southwest shore during fyke netting in October 1992.

bass (5.4–20.9 inches long) from Nebish Lake or McGrath Lake in Oneida County and held during winter in a hatchery pond, 4,500 hatchery brown trout (*Salmo trutta*), and 4,500 hatchery rainbow trout (*Oncorhynchus mykiss*) (Brynildson and Kempinger 1973, Serns and Hoff 1984). After chemical treatment, anglers could no longer use fish or crayfish as live bait and the lake was closed to all fishing until 28 May 1968, when anglers could fish under special permit for brown trout, rainbow trout, smallmouth bass, and yellow perch.

Both smallmouth bass and yellow perch spawned within weeks of stocking, producing fingerling densities of 84 smallmouth bass/acre and 242 yellow perch/acre in fall 1967 (Kempinger et al. 1982). But anglers next year caught 28 smallmouth bass, leaving only 26% of the brood stock, and the fall fingerling (age-0) density became too low to estimate. Male progeny from these stocked fish, maturing a year earlier than female progeny, could first spawn in 1968 (yellow perch) or 1970 (smallmouth bass). The smallmouth bass population was estimated at 111 fish/acre in 1970—a fall fingerling density not exceeded until 1991.

Table 1. *Area, depth, length, and volume of Nebish Lake.*

Variable[a]	Measurement
Watershed (acres)	512
Lake surface (acres)	94
Maximum depth (ft)	52.0
Mean depth (ft)	18.4
Relative depth (maximum/mean depth)	2.8
Island shorelines (miles)	0.17
Lake shoreline, excluding islands (miles)	2.53
Maximum lake fetch (miles)	0.8
Maximum lake width (miles)	0.4
Shoreline development factor	1.90
Lake volume (acre-ft)	1,731
Volume development factor	1.06

[a] Definitions and calculations follow Welch (1948).

Methods

Creel Census

A compulsory creel census on Nebish Lake began in June 1946 to measure fishing pressure and angling harvest (Patterson 1952; Churchill 1957; Williamson 1947, 1948). Before each fishing trip, anglers of all ages had to obtain a free angling permit from the nearby Escanaba Lake Station, open nearly every day. A clerk at the station recorded the date and each angler's name, address, sex, age group (<16, 16–65, or >65 years old), and distance traveled to the lake. Every angler had to return to the station, whether or not fish were caught, to record the time fished and the manner of fishing. All harvested fish were identified, sexed, examined for fin clips and tags, and measured for total length (nearest 0.1 inches) and body weight (nearest 0.01 lb). Harvested smallmouth bass also had scales removed for aging.

Creel data for 1972–93 were analyzed for the entire angling year (ice-out of one year to ice-out of the subsequent year, noted by the year ice-up occurred) and open water alone (ice-out to ice-up). Ice cover averaged 210 days and varied yearly

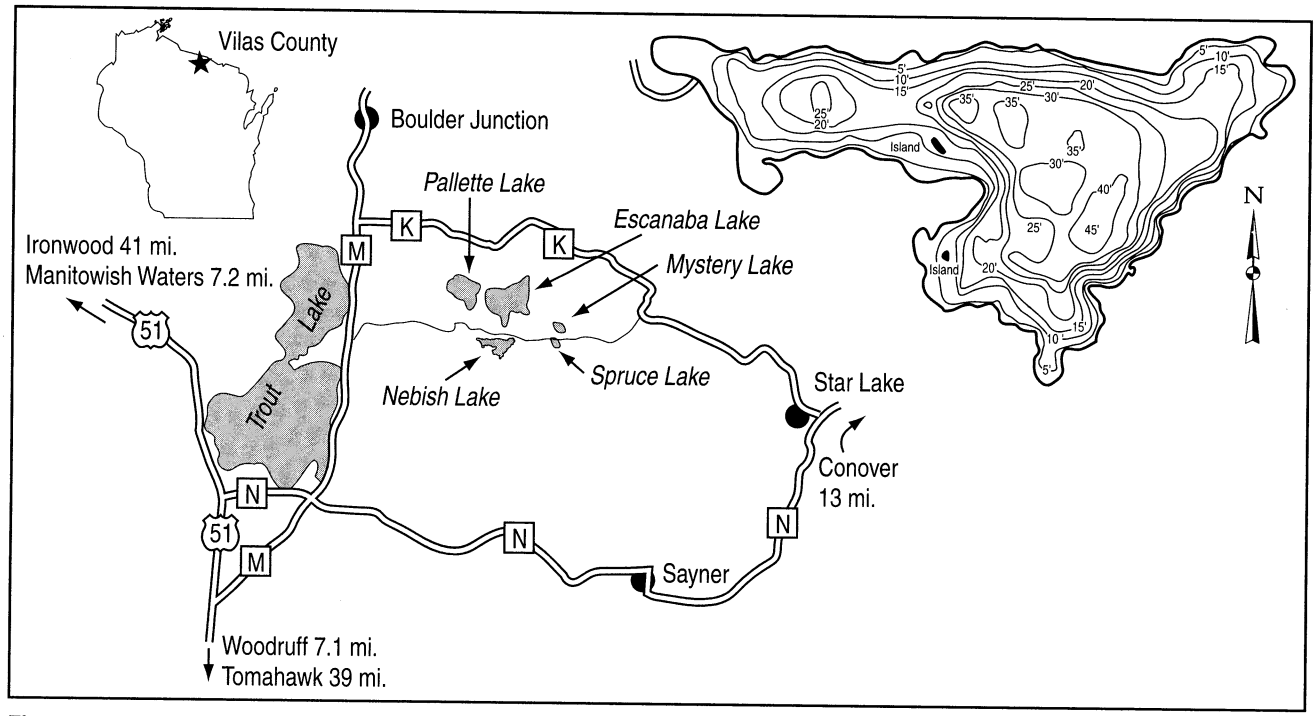
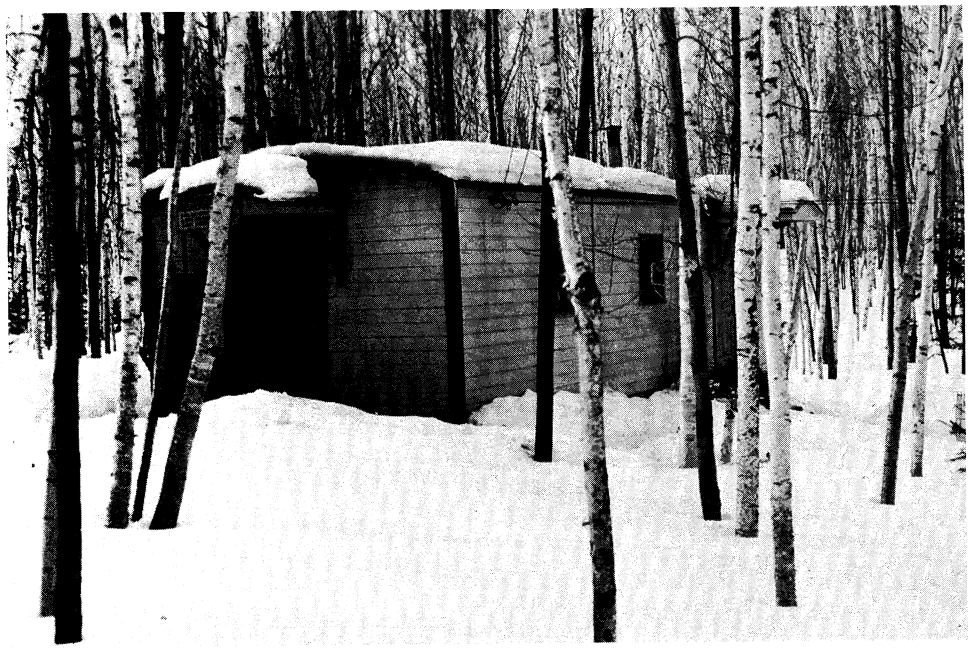


Figure 1. *The five lakes of the Northern Highlands Fishery Research Area located 3.2–4.0 miles east of Trout Lake (left), and 5-foot depth contours echosounded August 1976 in Nebish Lake (right).*

Table 2. *Chronology of fishery regulations and stocking at Nebish Lake.*

Date	Description of Fishery Practice
1966 September	Removed 150 smallmouth bass (4.4-14.5 inches long) to hatchery ponds and McGrath Lake, Oneida County, for return to Nebish Lake in spring 1967; removed 4,500 yellow perch (36 lbs, age 0) as hatchery forage (Kempinger et al. 1982)
1966 October 3	Applied 550 gallons of 1.0 mg/L emulsifiable rotenone to eradicate all fish, and closed Nebish Lake to angling until 28 May 1968 (Kempinger and Christenson 1978, Christenson et al. 1982)
1967 April 27	Stocked 12 female (6.0-7.8 inches long) and 19 male (5.7-8.3 inches long) yellow perch from Buckatabon Lake, Vilas County, Wisconsin (Kempinger 1967)
1967 June 7-8	Stocked 38 unsexed brood-stock smallmouth bass (5.4-20.9 inches long), 4,500 fall-hatched brown trout (3.0-3.9 inches long), and 4,500 fall-hatched rainbow trout (3.2-3.9 inches long) (Kempinger 1967, Kempinger et al. 1982)
1968 May 28	Opened Nebish Lake to angling, unrestricted except for daily bag limit of 10 trout/person and no bait fish allowed (Kempinger and Christenson 1978, Kempinger et al. 1982)
1973 May 31	Stocked 4,500 (3.0-3.9 inches long) brown trout and 4,500 (3.1-4.2 inches long) rainbow trout (Avery 1975); continued unrestricted angling except for daily bag limit of 10 trout/person and no bait fish allowed
1977 January 1	Imposed an 8-inch minimum length limit on smallmouth bass angling (no bait fish allowed) until 31 December 1981 (Serns 1984, Hoff 1995)
1982 January 1	Imposed a 10-inch minimum length limit on smallmouth bass angling (no bait fish allowed) until 31 December 1988 (Hoff 1995)
1989 April 2	Imposed a 9- to 12-inch protective slot length limit and a daily bag limit of 5 bass/person on smallmouth bass angling (no bait fish allowed) until present
1992 December	Ended fish sampling to assess population size, biomass, mortality, and growth; creel census, slot length limit, and daily bag limit on smallmouth bass continues



PHOTOGRAPHER UNKNOWN

The Escanaba Lake Station in the 1960s: open daily to anglers despite snow cover.

between 193 and 231 days. The median date for ice-out was 21 April and for ice-up was 17 November.

Response variables—calculated according to Ricker (1975) and Larscheid (1992)—included angling yield (the weight of fish removed/acre), catch (the combined number of all fish released and harvested), fishing effort (the number of hours fished/angling permit), fishing pressure (the number of angling permits issued or hours fished), harvest (the combined number or weight of all fish removed from the lake, including dead confiscated fish), harvest rate (the number of fish removed/angling permit issued or hour fished), and release (the number of smallmouth bass returned alive to the lake).

Abundance and Biomass Estimates

The population size of smallmouth bass and yellow perch was estimated each spring of 1972–92 by the Bailey-modified Petersen method (Ricker 1975). The population biomass of smallmouth bass was then computed from mean body weight-at-age. Starting at ice-out, 4–8 fyke nets of 3/8-inch or 3/4-inch square mesh were set for 3–16 days (12–64 net-days) to catch spawning yellow perch for marking; a few weeks later 4–10 fyke nets, about half with 3/8-inch square mesh and half with 3/4-inch square mesh, were similarly set for 5–14 days (40–112 net-days) to catch prespawning smallmouth bass for marking. All smallmouth bass were measured for total length (nearest 0.1 inches) and body weight (nearest 0.01 lb), whereas yellow perch from only several nets, set on different days, were measured for total length alone.

Smallmouth bass under 6.0 inches long and yellow perch 4.8 inches or longer were marked with a different fin clip each year, repeated every 4–7 years. For example, the soft dorsal fin of smallmouth bass was clipped in 1973, 1979, 1983, 1987, and 1991. Smallmouth bass 6.0 inches and longer were marked with Floy® FT-2, FD-67C, or FD-68BC dart or anchor tags attached below the soft or spiny dorsal fin. To assess tag loss, a different dorsal spine was removed.

Smallmouth bass were recaptured along the entire lake and island shorelines by AC-electrofishing for 1–3 evenings, starting 7–10 days after fyke netting. Smallmouth bass of legal length and yellow perch 5.5 inches and longer were recaptured by open-water anglers as part of the creel census.

Age-at-capture in spring was determined from scales of all smallmouth bass and of 10 male and 10 female yellow perch in each 0.5-inch group. Recaptured smallmouth bass marked in previous years with numbered tags, clipped spines, or clipped fins helped validate our estimation of smallmouth bass ages from scales. Abundance (population size) was calculated from estimates apportioned by scale ages (both species) or 1.0-inch groups (smallmouth bass). Biomass was estimated by multiplying mean weight by population size for each scale age or length group. These estimates were divided by lake surface area to give population density (number/acre) and standing crop (lb/acre).

The population size of fall fingerling (age-0) smallmouth bass was estimated by the Schnabel method and multiplied by mean weight to estimate standing crop (Ricker 1975). Fish were caught by AC-electrofishing (230-V) for 3-7 evenings and marked by fin clipping.

Mortality, Exploitation, and Growth

Mortality, exploitation, and growth were calculated each year for age-specific smallmouth bass, regardless of legal length. Total annual mortality (A) was computed by sequential computations of stock size (Ricker 1975), using spring population size estimates instead of catch numbers (Hoff 1995). We computed the mortality of cohorts in successive years by dividing the population size of fish age x + 1 (say, age 4) by that of fish age x (say, age 3) until each cohort disappeared from the spring catch.

PHOTO: S. ENGEL

The Escanaba Lake Station in October 1992 with solar panel on roof.

Angling exploitation (μ) was computed for fyke-netted or electrofished smallmouth bass that were marked with Floy® anchor or dart tags in spring and harvested by anglers during open water of the same year. Fish with numbered tags from previous years were counted as marked only for years we caught them in spring. Fish tagged in 1972 and harvested in 1976, for example, would be considered marked in 1972 but not in 1976 unless we caught them again in spring 1976 and noted their tag number.

Growth was calculated each spring from the mean total lengths or body weights of smallmouth bass aged from scales by counting annuli (no back calculations). Scales were removed from an area ventral to the dorsal fin and posterior to the pectoral fin. Missing weights for some year classes of smallmouth bass were estimated from length-weight regressions (Serns 1984).

Statistical Analysis

Sample means, standard deviations, and standard errors of the mean (SE) were calculated for each study period from yearly counts (such as harvest number) or averages (such as mean total length). Percent changes in response variables were calculated from the mean differences between adjacent length limit periods (such as the mean hours fished yearly from no limits to the 8-inch limit). The first year of each new regulation was included with the previous regulation to calculate average population size, population biomass, total annual mortality, and total length-at-age.

Null hypotheses were examined with nonparametric tests of inference (Conover 1980, Siegel and Castellan 1988), using Statistix® version 4.1 computer software to compute test statistics and associated P-values (Anonymous 1994). Means of response variables for the four study periods were compared with Kruskal-Wallis one-way analysis of variance-by-ranks H-tests (Conover 1980), followed by Tukey's HSD pairwise comparisons of mean-ranks ω-test (Anonymous 1994) to distinguish unusual sample means when null hypotheses were rejected. Means of response variables for just two length limit periods (smallmouth bass catch and release records, for example, were kept only after 1981) were compared with Mann-Whitney U-tests. Correlations between response variables (such as the number of angling permits versus the number of smallmouth bass harvested) were tested with Spearman's rank-order correlation r_s-tests (Siegel and Castellan 1988). Null hypotheses for all tests were rejected at $P < 0.05$.

Results and Discussion

Fishing Pressure

The number of anglers fishing Nebish Lake significantly increased during the study while their fishing trips became shorter (Table 3). Most of the increased fishing pressure came during open water when the mean annual number of angling permits increased 36% from no limits to the 8-inch limit. Although the mean annual number of angling permits increased 54% ($H = 11.2$, $P = 0.01$), the

Table 3. *Annual fishing pressure on smallmouth bass or yellow perch during open water and entire angling year of each bass regulation.*

Bass Regulation	Angling Year	Open Water			Angling Year		
		Hours Fished	Number of Angling Permits	Hours Fished Per Permit	Hours Fished	Number of Angling Permits	Hours Fished Per Permit
No limit							
	1972	3,234	891	3.63	3,320	907	3.66
	1973	4,067	1,029	3.95	4,087	1,034	3.95
	1974	3,334	827	4.03	3,964	981	4.04
	1975	4,179	1,104	3.79	4,616	1,222	3.78
	1976	4,645	1,218	3.81	5,085	1,339	3.80
8-inch limit							
	1977	4,790	1,286	3.72	5,148	1,397	3.69
	1978	5,239	1,462	3.58	5,456	1,514	3.60
	1979	4,866	1,351	3.60	4,920	1,380	3.57
	1980	5,872	1,546	3.80	5,927	1,558	3.80
	1981	4,386	1,256	3.49	5,092	1,436	3.55
10-inch limit							
	1982	3,414	996	3.43	4,086	1,154	3.54
	1983	4,541	1,287	3.53	5,360	1,485	3.61
	1984	7,585	2,286	3.32	7,884	2,357	3.34
	1985	5,324	1,573	3.38	5,434	1,607	3.38
	1986	4,446	1,389	3.20	4,459	1,396	3.19
	1987	5,389	1,624	3.32	5,466	1,648	3.32
	1988	4,670	1,427	3.27	4,784	1,458	3.28
9- to 12-inch slot							
	1989	5,044	1,512	3.34	5,371	1,617	3.32
	1990	6,615	1,842	3.59	7,029	1,984	3.54
	1991	5,620	1,614	3.48	5,821	1,681	3.46
	1992	4,565	1,353	3.37	4,655	1,390	3.35
	1993	4,704	1,490	3.16	4,763	1,520	3.13
Mean (±1 SE)							
No limit		3,892 (267)	1,014 (71)	3.84 (0.07)	4,214 (300)	1,097 (80)	3.84 (0.07)
8-inch limit		5,031 (250)	1,380 (54)	3.64 (0.05)	5,309 (177)	1,457 (34)	3.64 (0.04)
10-inch limit		5,053 (489)	1,512 (151)	3.35 (0.04)	5,353 (467)	1,586 (142)	3.38 (0.06)
9- to 12-inch slot		5,310 (374)	1,562 (81)	3.39 (0.07)	5,528 (431)	1,638 (99)	3.36 (0.07)
All years (1972-93)		4,842 (216)	1,380 (69)	3.54 (0.05)	5,124 (212)	1,458 (68)	3.54 (0.05)

hours fished per angling permit decreased 12% ($H = 15.4$, $P < 0.01$) from no limits to the slot and bag limits. Open-water anglers, for example, fished an average of 24 min/angling permit or 625 hours/year less under the slot and bag limits than under no limits. Had such shorter trips prevailed throughout the study, 9% fewer fish would have been harvested under no limits.

The heaviest fishing pressure during the study came in May–August 1984 (Fig. 2), after a magazine article was published on fishing Escanaba and Nebish Lakes (Kulpa 1984). About 2,350 year-round angling permits were issued in 1984—62% more than the 22-year annual average—yet 42% fewer smallmouth bass and 43% fewer yellow perch than average were harvested that year.

PHOTO: S. ENGEL

Lifting a fyke net of yellow perch in April 1992. Michael T. Vogelsang Jr., left, and Daniel E. Jacobi, right

Fishing pressure changed little during ice cover. No significant differences were found in the total number of angling permits issued ($H = 0.1$, $P = 0.99$) or hours fished ($H = 0.2$, $P = 0.97$) among study periods. Only 5% of all angling permits and hours fished were logged during ice cover, when 0.4% of all smallmouth bass were harvested. Anglers fished smallmouth bass mainly from late May through September.

Angling Harvest

Smallmouth Bass. Anglers harvested significantly larger but fewer smallmouth bass with each new bass regulation (Table 4). The mean annual total length of all harvested smallmouth bass increased 32% or 2.6 inches ($H = 17.2$, $P < 0.01$) from no limits to the slot and bag limits. Despite increased fishing pressure, the mean annual number of all legal-length smallmouth bass harvested year-round decreased 69% in number ($H = 15.9$, $P < 0.01$) and 34% in biomass ($H = 8.0$, $P = 0.047$) among study periods. The harvest rate, as a result, decreased 80% in mean annual number/angling permit ($H = 16.5$, $P < 0.01$) and 77% in mean annual number/hour fished ($H = 16.3$, $P < 0.01$). The smallest year-round harvest for smallmouth bass came in 1982, when 28% fewer anglers took 83% fewer smallmouth bass than the 22-year average.

Although the harvested number and biomass of smallmouth bass declined overall during the study (Fig. 3), the harvested biomass increased 29% from no limits to the 8-inch limit and then decreased 32% to the 10-inch limit. The mean body weight of all harvested smallmouth bass increased 2.0 oz under the 8-inch limit and 3.5 oz under the 10-inch limit, yet the total number of harvested smallmouth bass dropped so much under the 8-inch limit that total harvested biomass also decreased.

Despite reduced overall harvest with each change in bass regulation, anglers took more smallmouth bass 12.0 inches or longer ($H = 12.7$, $P < 0.01$) after length limits were imposed (Table 5). The mean annual harvest of these bass increased 4.9 times in the 22 years since 1972. Yet Hoff (1995) found no significant increase in mean annual harvest of bass 12.0 inches or longer, because their harvest increased mainly after 1986: 1,443 of them were harvested in 1987–93, a significant increase from the 345 such bass harvested in the previous seven years ($H = 9.8$, $P < 0.01$). But no significant difference was found in the mean annual harvest of smallmouth bass 14.0 inches or longer ($H = 3.3$, $P = 0.35$). Anglers thus increased their harvest of smallmouth bass mainly between 12.0 and 14.0 inches long, starting

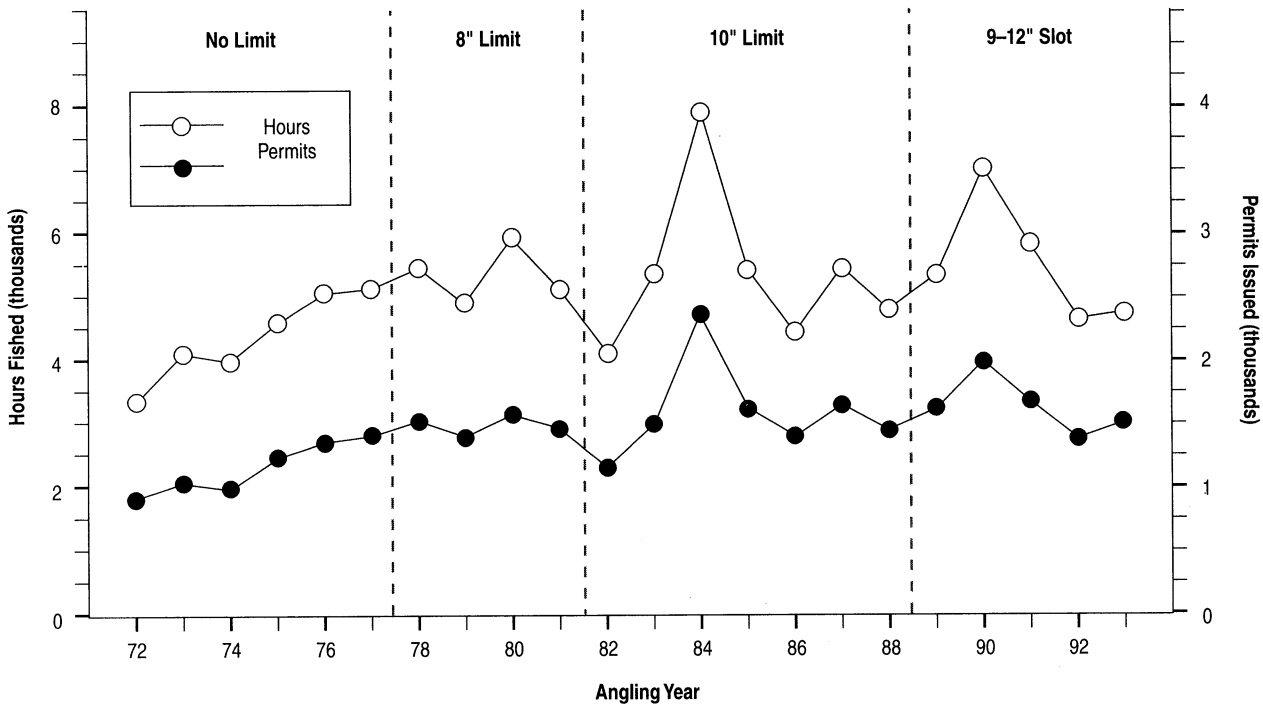


Figure 2. *The total number of hours fished and angling permits issued year-round in Nebish Lake.*

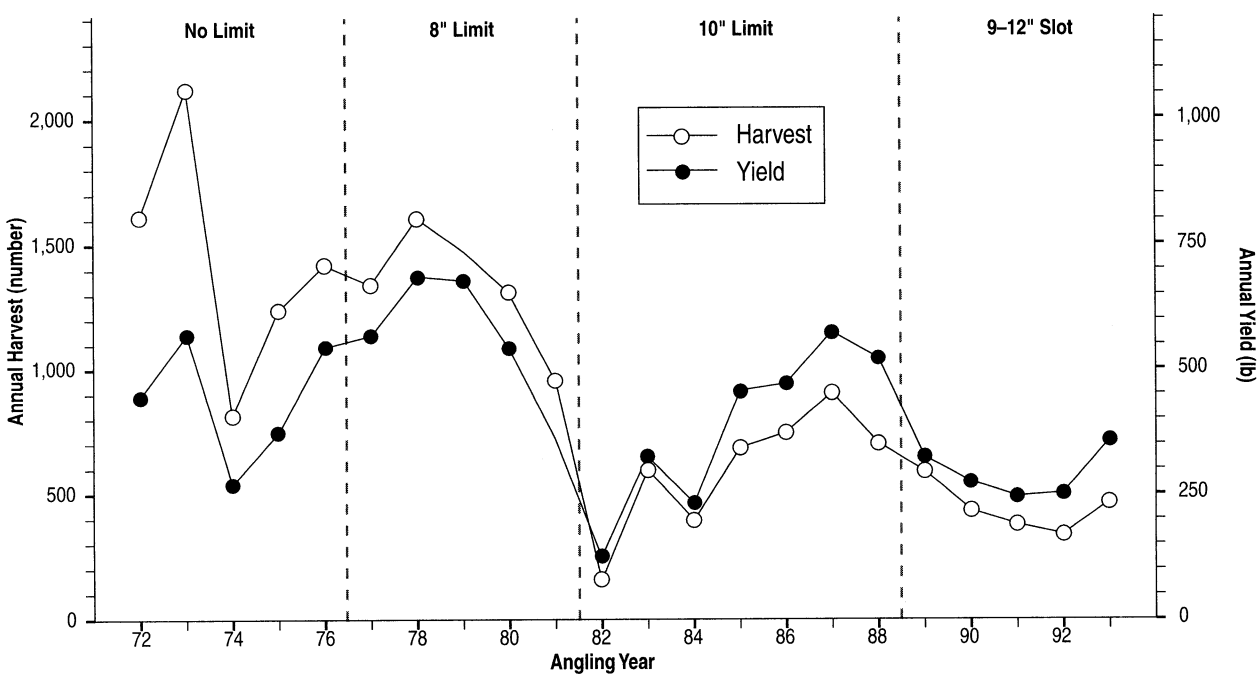


Figure 3. *The number and biomass of all smallmouth bass harvested year-round in Nebish Lake.*

Table 4. *Total length, abundance, biomass, and rate of smallmouth bass harvested year-round during each bass regulation.*

Bass Regulation	Angling Year	Bass 4.1 – 20.6 Inches Long					Bass 12.0 –20.6 Inches Long				
		Mean Total Length (in)	Number	Number/ Permit	Number/ Hour	Biomass (lb)	Mean Total Length (in)	Number	Number/ Permit	Number/ Hour	Biomass (lb)
No limit											
	1972	8.0	1,617	1.78	0.49	439	14.0	45	0.05	0.07	67
	1973	8.2	2,106	2.04	0.52	568	13.7	55	0.05	0.05	77
	1974	8.4	808	0.82	0.20	268	13.9	35	0.04	0.06	52
	1975	8.2	1,228	1.00	0.27	371	14.1	52	0.05	0.05	80
	1976	8.1	1,420	1.06	0.28	543	13.6	49	0.04	0.05	67
8-inch limit											
	1977	9.4	1,332	0.95	0.26	568	13.4	71	0.06	0.04	91
	1978	9.4	1,599	1.06	0.29	687	13.9	103	0.07	0.04	153
	1979	9.5	1,459	1.06	0.30	673	14.3	54	0.04	0.04	86
	1980	9.6	1,301	0.84	0.22	543	13.2	66	0.04	0.04	79
	1981	9.2	941	0.66	0.18	357	13.5	53	0.04	0.05	67
10-inch limit											
	1982	11.5	159	0.14	0.38	122	14.0	46	0.05	0.06	63
	1983	10.6	598	0.40	0.11	321	14.2	29	0.02	0.05	44
	1984	10.7	389	0.17	0.05	230	13.8	24	0.01	0.03	36
	1985	10.9	684	0.43	0.12	452	13.0	88	0.06	0.04	100
	1986	10.8	744	0.53	0.17	468	13.0	79	0.06	0.05	89
	1987	10.9	902	0.55	0.17	573	12.9	118	0.07	0.04	122
	1988	11.3	700	0.48	0.15	519	13.0	166	0.12	0.05	186
9- to 12-inch slot											
	1989	9.8	582	0.36	0.11	321	13.2	178	0.12	0.04	208
	1990	10.6	435	0.22	0.06	274	12.9	222	0.12	0.03	216
	1991	11.0	374	0.22	0.06	244	12.6	227	0.14	0.04	208
	1992	11.2	338	0.24	0.07	252	12.7	225	0.17	0.05	219
	1993	11.2	471	0.31	0.10	358	12.9	307	0.21	0.05	317
Mean (±1 SE)											
No limit		8.2 (0.1)	1,436 (214)	1.34 (0.24)	0.35 (0.06)	438 (55)	13.9 (0.1)	47 (3)	0.05 (<0.01)	0.06 (0.004)	69 (5)
8-inch limit		9.4 (0.1)	1,326 (110)	0.91 (0.08)	0.25 (0.02)	566 (59)	13.6 (0.2)	69 (9)	0.05 (<0.01)	0.04 (0.002)	95 (15)
10-inch limit		11.0 (0.1)	597 (94)	0.38 (0.06)	0.16 (0.04)	384 (62)	13.4 (0.2)	79 (19)	0.05 (0.01)	0.04 (0.004)	91 (20)
9- to 12-inch slot		10.8 (0.3)	440 (42)	0.27 (0.03)	0.08 (0.01)	290 (22)	12.8 (0.1)	232 (21)	0.15 (0.02)	0.04 (0.003)	234 (21)
All years (1972-93)		9.9 (0.3)	918 (110)	0.70 (0.11)	0.21 (0.03)	416 (33)	13.4 (0.1)	104 (17)	0.07 (0.01)	0.05 (0.002)	119 (16)

Table 5. *Abundance and biomass by total length of smallmouth bass 12.0 inches or longer harvested year-round during each bass regulation.*

Bass Regulation	Angling Year	Abundance (number) by Length Interval				Biomass (lb) by Length Interval			
		≥12.0 Inches	≥14.0 Inches	≥16.0 Inches	≥18.0 Inches	≥12.0 Inches	≥14.0 Inches	≥16.0 Inches	≥18.0 Inches
No limit									
	1972	45	25	4	0	70	48	10	0
	1973	55	19	10	0	77	42	25	0
	1974	35	16	4	0	52	32	11	0
	1975	52	26	7	2	80	55	20	7
	1976	49	15	4	1	67	32	12	4
8-inch limit									
	1977	71	18	5	0	91	36	14	0
	1978	103	46	11	2	153	92	33	10
	1979	54	25	11	1	86	56	33	8
	1980	66	13	2	0	78	25	6	0
	1981	53	17	2	0	67	29	5	0
10-inch limit									
	1982	46	22	4	1	67	58	8	4
	1983	29	14	5	0	44	29	12	0
	1984	24	5	5	3	36	19	19	10
	1985	88	14	1	1	100	25	4	4
	1986	79	12	0	0	89	19	0	0
	1987	118	14	3	0	122	25	7	0
	1988	166	21	4	1	186	40	13	5
9- to 12-inch slot									
	1989	178	38	10	0	208	75	25	0
	1990	222	20	11	3	216	33	22	0
	1991	227	5	2	2	208	12	7	7
	1992	225	9	0	0	219	14	0	0
	1993	307	26	0	0	317	40	0	0
Mean (±1 SE)									
	No limit	47 (3)	20 (2)	6 (1)	0.6 (0.4)	69 (5)	42 (5)	16 (3)	2.2 (1.4)
	8-inch limit	69 (9)	24 (6)	6 (2)	0.6 (0.4)	95 (15)	48 (12)	18 (6)	3.6 (2.2)
	10-inch limit	79 (19)	15 (2)	3 (1)	0.9 (0.4)	92 (19)	30 (5)	9 (2)	3.2 (1.4)
	9- to 12-inch slot	232 (21)	20 (6)	4 (2)	1.0 (0.6)	234 (21)	35 (11)	11 (5)	1.4 (1.4)
	All years (1972-93)	104 (17)	19 (2)	5 (1)	0.8 (0.2)	120 (16)	38 (4)	14 (2)	2.7 (0.8)

two years before the slot and bag limits were imposed.

By cropping smallmouth bass near the upper slot limit, anglers harvested more smallmouth bass between 12.0 and 14.0 inches long, though of smaller average size. The mean total length of smallmouth bass 12.0 inches or longer decreased 1.1 inches ($H = 10.4$, $P = 0.02$), while their mean body weight decreased 0.47 lb ($H = 10.6$, $P = 0.01$) under the slot and bag limits. No significant difference among study periods, however, was found in the mean total length ($H = 0.6$, $P = 0.90$) or mean body weight ($H = 3.4$, $P = 0.34$) of smallmouth bass 14.0 inches or longer. The increased harvest, therefore, extended only to smallmouth bass within two inches of the upper slot limit.

PHOTO: C. HORNUNG

AC-electrofishing gear used to sample fall fingerling smallmouth bass. Sandy Engel, left, and Gary R. Kubenik, right.

The largest smallmouth bass harvested yearly ranged from 15.0 inches in 1991 to 20.6 inches in 1984. Yet maximum total length ($H = 2.7$, $P = 0.43$) and body weight ($H = 1.9$, $P = 0.59$) were not found to differ significantly among study periods.

Catch and release records (kept only after 1981) show anglers released more than 95% of their smallmouth bass catch, mostly fish shorter than the 10-inch limit, protected by the 9- to 12-inch slot, or caught after filling the daily limit. The release rate stayed high under both the 10-inch limit and the slot and bag limits. No significant difference among study periods was found, therefore, in the mean annual number ($U = 0.6$, $P = 0.52$) or rate ($U = 0.0$, $P = 1.00$) of smallmouth bass released.

During open water, when 99% of all smallmouth bass were harvested, no significant correlation was found between the annual total number of angling permits and total smallmouth bass harvested under the no limits ($r_s = 0.20$, $P = 0.75$), 8-inch limit ($r_s = 0.40$, $P = 0.50$), 10-inch limit ($r_s = 0.32$, $P = 0.48$), or slot and bag limits ($r_s = 0.20$, $P = 0.75$). Nor was a significant correlation found between the annual number of hours fished and the rate of smallmouth bass harvested under the no limits ($r_s = -0.10$, $P = 0.87$), 8-inch limit ($r_s = 0.40$, $P = 0.50$), 10-inch limit ($r_s = 0.14$, $P = 0.76$), or slot and bag limits ($r_s = -0.60$, $P = 0.28$).

The open-water harvest of smallmouth bass between years of the slot and bag limits (Table 6) decreased 25% from 1989–90, 14% from 1990–91, and 10% from 1991–92 before increasing 39% from 1992–93; open-water fishing pressure between these years increased 22%, decreased 12% and 16%, and then increased 10%. Anglers harvested almost as many smallmouth bass below (42%) as above (52%) the slot, with 6% of smallmouth bass illegally harvested within the slot. The slot limit, therefore, failed to act like a minimum limit, as occurred with largemouth bass (*Micropterus salmoides*) in Kansas (Gabelhouse 1984) and Missouri (Eder 1984).

Anglers kept as many as 34 smallmouth bass/angling permit in the 17 years before bag limits were imposed, yet fewer than 10% of them harvested more than 5 smallmouth bass/angling permit (Table 7). The mean annual number of smallmouth bass harvested/angling permit averaged 0.87 ± 0.10 (mean ±1 SE) for all years and was not found to differ significantly between 1977–88 and 1989–93 ($H = 0.19$, $P = 0.67$), though a significant 38% decrease occurred between 1984–88 (0.46 ± 0.05 smallmouth bass/angling permit) and 1989–93 ($H = 4.8$, $P = 0.03$). Few anglers in any study period, however, kept more than 2 smallmouth bass/angling permit. Most fishing trips ended with no smallmouth bass harvested.

Anglers harvested fewer smallmouth bass ages 1–3 combined ($H = 15.7$, $P < 0.01$), about as many smallmouth bass age 4 ($H = 6.6$, $P = 0.09$), and

more smallmouth bass ages 5–12 combined ($H = 8.6$, $P = 0.03$) with each successive bass regulation (Table 8). The mean annual biomass of these bass (Table 9) likewise decreased for smallmouth bass ages 1–3 ($H = 14.2$, $P < 0.01$), changed little for smallmouth bass age 4 ($H = 6.9$, $P = 0.08$), and increased for smallmouth bass ages 5–12 ($H = 6.6$, $P = 0.09$). Smallmouth bass ages 5–12 made up 10% of the total bass harvest in 1972–88 and 29% in 1989–92. Only 31 of 20,187 smallmouth bass harvested in all years were older than age 7.

Yellow Perch. Anglers also harvested significantly fewer yellow perch with each new bass regulation (Table 10). The mean annual number of yellow perch harvested year-round decreased from no limits to the slot and bag limits ($H = 11.0$, $P < 0.01$), despite an unusually large open-water harvest of 6,870 yellow perch in 1975 (4.3 times the 22-year average of 1,597 yellow perch harvested). Although the mean annual biomass of harvested yellow perch also decreased, differences among study periods were not found to be significant ($H = 5.7$, $P = 0.13$).

Two-thirds of all 52,198 yellow perch harvested in 22 angling years were caught during open water compared to 99.6% of 20,187 smallmouth bass harvested. Less than 50 yellow perch, weighing 8 lb, were harvested during the 1992 angling year despite 1,520 angling permits issued and over 4,760 hours fished year-round for yellow perch or smallmouth bass.

Despite increased fishing pressure, the mean annual harvest rate of yellow perch decreased in number/angling permit ($H = 11.8$, $P = 0.01$) and number/hour fished ($H = 11.6$, $P = 0.01$) when averaged year-round by study period. Combining all years studied, yellow perch still made up 64% of the total open-water harvest and 72% of the total year-round harvest.

No significant correlation was found between the number of angling permits issued and yellow perch harvested during open water under the no limit ($r_s = 0.50$, $P = 0.39$), 8-inch limit ($r_s = -0.50$, $P = 0.39$), or 10-inch limit ($r_s = -0.46$, $P = 0.29$). Nor were the number of hours fished and rate of yellow perch harvested during open water found to correlate significantly under the no limit ($r_s = 0.60$, $P = 0.28$), 8-inch limit ($r_s = -0.50$, $P = 0.39$), or 10-inch limit ($r_s = -0.43$, $P = 0.34$). But these response variables were positively correlated under the slot and bag limits ($r_s = 0.90$, $P = 0.04$), despite overall increased fishing pressure and decreased yellow perch harvest. Yearly fluctuations in yellow perch abundance, as well as catch and release fishing for smallmouth bass or yellow

Table 6. *Number of smallmouth bass harvested year-round below, within, or above the 9- to 12-inch protective slot. (Percentages are in brackets; standard errors of the mean are in parentheses.)*

	Number [%] Harvested				
Angling Year	Below Slot ≤9.0 Inches	Within Slot 9.1–11.9 Inches	Above Slot ≥12.0 Inches	Number Confiscated 9.3–11.7 Inches	Total
1989	365 [63]	40 [7]	177 [30]	3	585
1990	180 [41]	34 [8]	221 [51]	2	437
1991	122 [33]	27 [7]	225 [60]	5	379
1992	99 [29]	15 [4]	224 [66]	2	340
1993	151 [32]	13 [3]	307 [65]	1	472
Sum	917 [42]	129 [6]	1,154 [52]	13	2,213
Mean (±1 SE)	183 (47)	26 (5)	231 (21)	2.6 (0.7)	443 (42)

Table 7. *Distribution of year-round angling permits by the number of bass harvested during each bass regulation.*

Bass Regulation	Angling Year	Number of Angling Permits by Number of Bass Harvested							Maximum Bass/ Permit	Total Permits Issued
		0	1	2	3	4	5	≥6		
No limit										
	1972	439	147	80	65	46	33	81	32	891
	1973	448	122	144	97	77	48	93	21	1,029
	1974	501	117	104	40	26	16	23	12	827
	1975	731	124	98	47	36	27	51	17	1,114
	1976	709	157	132	102	57	30	31	14	1,218
8-inch limit										
	1977	760	231	126	68	33	28	40	34	1,286
	1978	819	229	198	96	47	27	45	12	1,461
	1979	875	115	152	78	51	29	51	36	1,351
	1980	970	245	175	74	36	17	29	28	1,546
	1981	839	207	97	49	23	10	31	28	1,256
10-inch limit										
	1982	877	94	22	0	1	1	1	6	996
	1983	941	199	92	29	14	10	2	12	1,287
	1984	2,058	134	51	25	11	7	0	5	2,286
	1985	1,176	196	144	40	16	2	1	6	1,575
	1986	1,001	160	141	63	19	3	2	6	1,389
	1987	1,166	210	159	50	24	8	7	14	1,624
	1988	1,090	155	102	46	16	8	13	11	1,430
9- to 12-inch slot										
	1989	1,212	158	73	31	17	20	1	6	1,512
	1990	1,615	126	62	31	11	7	0	5	1,852
	1991	1,400	122	63	11	10	7	1	8	1,614
	1992	1,173	76	62	30	9	3	0	5	1,353
	1993	1,242	123	70	33	13	9	0	5	1,490
Mean (±1 SE)										
No limit		566 (64)	133 (8)	112 (12)	70 (13)	48 (9)	31 (5)	56 (14)	19 (4)	1,016 (71)
8-inch limit		853 (35)	205 (23)	150 (18)	73 (8)	38 (5)	22 (4)	39 (4)	28 (4)	1,380 (54)
10-inch limit		1,187 (151)	164 (16)	102 (19)	36 (8)	14 (3)	6 (1)	4 (2)	9 (1)	1,512 (151)
9- to 12-inch slot		1,328 (81)	121 (13)	66 (2)	27 (4)	12 (1)	9 (3)	0.4 (0.2)	6 (1)	1,564 (83)
All years (1972-93)		1,002 (10)	157 (10)	107 (10)	50 (6)	27 (4)	16 (3)	23 (6)	15 (2)	1,381 (69)

Table 8. *Abundance by age of smallmouth bass harvested year-round during each bass regulation.*[a]

Bass Regulation	Angling Year	Abundance (number) by Scale Age at Capture								
		1	2	3	4	5	6	7	8	Total
No limit										
	1972	49	1,356	171	28	13	0	0	0	1,617
	1973	11	401	1,536	112	34	12	0	0	2,106
	1974	85	264	209	212	29	7	2	0	808
	1975	21	905	209	26	43	5	13	6	1,228
	1976	102	758	470	60	5	13	9	3	1,420
8-inch limit										
	1977	1	1,036	223	62	4	0	5	2	1,333
	1978	0	965	536	61	23	3	2	4	1,594
	1979	0	398	973	72	8	6	2	0	1,459
	1980	0	288	768	223	20	2	0	0	1,301
	1981	0	501	331	89	17	0	0	0	938
10-inch limit										
	1982	0	0	94	33	21	5	1	0	154
	1983	0	0	39	538	4	9	2	0	592
	1984	0	0	75	171	135	0	1	1	383
	1985	0	15	252	292	97	22	0	0	678
	1986	0	0	465	210	47	12	7	0	741
	1987	0	0	257	596	37	6	1	2	899
	1988	0	84	275	227	102	3	2	1	694
9- to 12-inch slot										
	1989	9	352	85	73	25	19	2	0	565
	1990	0	128	65	197	20	4	6	0	420
	1991	1	64	61	158	71	2	1	1	359
	1992	0	56	41	67	155	15	0	0	334
	1993	0	104	52	9	186	108	5	0	464
Mean (±1 SE)										
	No limit	54 (18)	737 (193)	519 (260)	88 (35)	25 (7)	7 (2)	5 (3)	1.8 (1.2)	1,436 (214)
	8-inch limit	<1	638 (152)	566 (138)	101 (31)	14 (4)	2 (1)	2 (1)	1.2 (0.8)	1,325 (110)
	10-inch limit	0	14 (12)	208 (57)	295 (76)	63 (18)	8 (3)	2 (1)	0.6 (0.3)	592 (94)
	9- to 12-inch slot	2 (2)	141 (54)	61 (7)	101 (34)	91 (34)	30 (20)	3 (1)	0.2 (0.2)	428 (41)
	All years (1972-93)	13 (6)	349 (86)	327 (78)	160 (33)	50 (11)	12 (5)	3 (1)	0.9 (0.3)	913 (111)

[a] Total harvest is given in Table 4, including some harvested bass not found in the above table because they were not aged.

Table 9. *Biomass by age of smallmouth bass harvested year-round during each bass regulation.*[a]

Bass Regulation	Angling Year	Biomass (lb) by Scale Age at Capture								
		1	2	3	4	5	6	7	8	Total
No limit										
	1972	5	286	83	39	26	0	0	0	439
	1973	1	55	387	60	39	26	0	0	568
	1974	9	52	62	96	30	14	5	0	268
	1975	2	198	69	18	36	2	28	18	371
	1976	13	225	220	41	5	19	17	9	549
8-inch limit										
	1977	<1	360	123	64	5	0	14	5	571
	1978	0	296	268	62	37	6	6	11	686
	1979	0	115	456	61	15	14	7	0	668
	1980	0	75	287	149	26	6	0	0	543
	1981	0	126	135	68	28	0	0	0	357
10-inch limit										
	1982	0	0	46	28	32	12	4	0	122
	1983	0	0	17	271	5	18	5	0	316
	1984	0	0	39	89	84	0	2	4	218
	1985	0	8	146	186	78	27	0	0	445
	1986	0	0	253	140	46	18	9	0	466
	1987	0	0	138	381	36	10	2	5	572
	1988	0	46	188	162	105	4	5	3	513
9- to 12-inch slot										
	1989	1	95	64	72	36	39	5	0	312
	1990	0	27	24	172	23	9	15	0	270
	1991	<1	14	18	136	66	2	2	4	242
	1992	0	12	12	60	150	17	0	0	251
	1993	0	23	15	7	179	121	8	0	353
Mean (±1 SE)										
	No limit	6 (2)	163 (47)	164 (63)	51 (13)	27 (6)	12 (5)	10 (5)	5 (4)	439 (56)
	8-inch limit	<1	194 (56)	254 (61)	81 (17)	22 (6)	5 (3)	5 (3)	3 (2)	565 (59)
	10-inch limit	0	8 (6)	118 (33)	180 (44)	55 (13)	13 (3)	4 (1)	2 (1)	379 (62)
	9- to 12-inch slot	<1	34 (15)	27 (10)	89 (29)	91 (31)	38 (22)	6 (3)	1 (1)	286 (21)
	All years (1972-93)	1 (<1)	92 (24)	139 (27)	107 (19)	49 (10)	17 (5)	6 (1)	3 (1)	414 (33)

[a] Total harvest is given in Table 4, including some harvested bass not found in the above table because they were not aged.

Table 10. *Abundance, biomass, and rate of all yellow perch harvested year-round during each bass regulation.*

Bass Regulation	Angling Year	Number	Number/Permit	Biomass (lb)	Number/Hour
No limit					
	1972	1,917	2.11	266	0.58
	1973	1,723	1.67	227	0.42
	1974	4,708	4.80	893	1.19
	1975	8,505	6.96	1,716	1.84
	1976	3,980	2.97	947	0.78
8-inch limit					
	1977	3,638	2.60	896	0.71
	1978	3,051	2.02	746	0.56
	1979	1,898	1.38	469	0.39
	1980	1,748	1.12	427	0.29
	1981	4,864	3.39	881	0.96
10-inch limit					
	1982	4,443	3.85	1,016[a]	1.09
	1983	3,361	2.26	968	0.63
	1984	1,021	0.43	329	0.13
	1985	525	0.33	150	0.10
	1986	245	0.18	38	0.05
	1987	1,414	0.86	361	0.26
	1988	1,416	0.97	378	0.30
9- to 12-inch slot					
	1989	1,539	0.95	407[a]	0.29
	1990	1,433	0.72	424[a]	0.20
	1991	582	0.35	195	0.10
	1992	140	0.10	52	0.03
	1993	47	0.03	8	0.01
Mean (±1 SE)					
	No limit	4,167 (1,228)	3.70 (0.98)	810 (272)	0.96 (0.25)
	8-inch limit	3,040 (577)	2.10 (0.41)	684 (100)	0.58 (0.12)
	10-inch limit	1,775 (585)	1.27 (0.50)	463 (144)	0.36 (0.14)
	9- to 12-inch slot	748 (315)	0.43 (0.18)	217 (87)	0.13 (0.05)
	All years (1972-93)	2,373 (434)	1.82 (0.37)	536 (90)	0.50 (0.10)

[a] Biomass was estimated from the mean annual weight of harvested yellow perch.

perch, could have masked an effect of fishing pressure on yellow perch harvest before slot and bag limits were imposed.

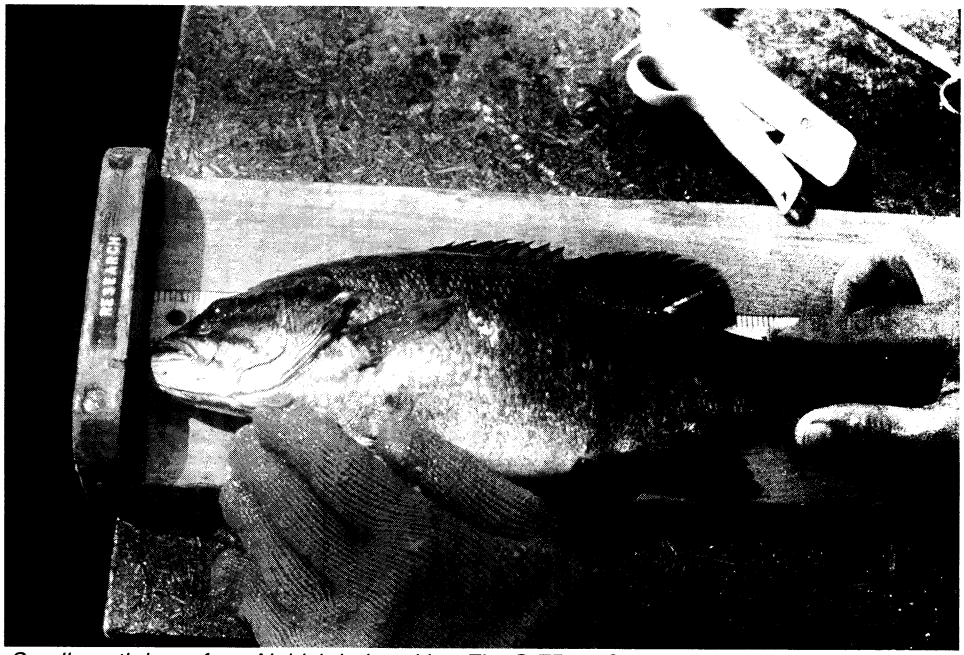


PHOTO: S. SERNS

Smallmouth bass from Nebish Lake with a Floy® FD-67C anchor tag attached below interneural rays of the soft dorsal fin.

Abundance and Biomass

Smallmouth Bass. The mean annual abundance of smallmouth bass (Table 11) was not found to differ significantly among study periods for combined ages 3–8 ($H = 4.0$, $P = 0.26$), age 3 alone ($H = 1.5$, $P = 0.68$), or age 5 alone ($H = 4.1$, $P = 0.25$) but did increase a significant 5.2 times for age 4 alone ($H = 10.3$, $P = 0.02$), especially after the 8-inch limit. Smallmouth bass abundance was highest in 1973 (2.4 times the 21-year average for combined ages 3–8), when age-3 smallmouth bass made up 91% of all smallmouth bass ages 3–8 marked that spring (Fig. 4). This strong year class resulted from many nesting smallmouth bass and a warm growing season in 1970 (Kempinger et al. 1982). Another strong year class hatched in 1983 and made up 80% of the total abundance in spring 1986.

Unlike estimated abundance, the mean annual biomass of smallmouth bass (Table 12) increased among study periods a significant 2.6 times for combined ages 3–8 ($H = 11.1$, $P = 0.01$) and 5.2 times for age 4 alone ($H = 11.3$, $P = 0.01$) but was not found to differ significantly for just age 3 ($H = 1.6$, $P = 0.65$) or age 5 ($H = 3.6$, $P = 0.30$). Smallmouth bass older than age 5 annually contributed up to 3% of estimated abundance but up to 19% of estimated biomass. The 1970 and 1983 year classes contributed more than 60% of the total biomass estimated three years later.

Fall fingerling smallmouth bass changed little in average size but varied widely in abundance among years (Table 13). No significant differences were found, therefore, among study periods in their mean annual total length ($H = 5.4$, $P = 0.14$), mean annual abundance ($H = 4.2$, $P = 0.24$), or mean annual biomass ($H = 0.3$, $P = 0.85$). Mean total length exceeded 3.0 inches in 1975 and 1976, when fingerling abundance was above the 21-year average, as well as in 1980, 1981, and 1988, when it was nearly average. Fall fingerling abundance was unusually high (Fig. 5) in 1976 (1.8 times the 21-year average) and especially 1991 (2.9 times this average).

Yellow Perch. With each new bass regulation, anglers had significantly fewer yellow perch to harvest (Table 14). The mean annual abundance of yellow perch in spring, averaged by study period, decreased 7.4 times for combined ages 3–8 ($H = 3.5$, $P < 0.01$), 16.1 times for age 4 alone ($H = 11.2$, $P = 0.01$), and 27.4 times for age 7 alone ($H = 10.9$, $P = 0.01$). No significant change, however, was found among study periods for yellow perch age 3 ($H = 4.5$, $P = 0.21$), age 5 ($H = 6.7$, $P = 0.08$), or age 6 ($H = 5.5$, $P = 0.14$). From the no limit period, the mean annual abundance of combined ages 3–8 yellow perch decreased 68% under the 8-inch limit and 63% under the 10-inch limit, then increased 13% under the slot and bag limits. Yellow perch abundance was high in spring 1973 (4.9 times the 21-year average) and 1974 (4.4 times this average) and too low to estimate in spring 1993. Despite declining abundance, yellow perch of combined ages 3–8 still averaged 282 fish/acre in the 21 years, 17.4 times the average abundance of smallmouth bass in this age range.

High population abundance can occur from a succession of strong year classes, caused by weather affecting hatching, fry survival, prey

availability, or a combination of factors (Stroud and Clepper 1975). Such year-class fluctuations can mask a response in smallmouth bass abundance to length limits (Ming and McDannold 1975, Paragamian 1982), though yellow perch abundance did significantly change with each new bass regulation.

Mortality and Exploitation of Smallmout h Bass

The total annual mortality (A) of combined ages 3–5 smallmouth bass varied widely among years and dropped 4.5 times from 1981 to 1982, when the 10-inch limit was imposed (Table 15). Averaged by study period, total annual mortality decreased 2.2 times for smallmouth bass age 3 ($H = 11.8$, $P = 0.01$) but was not found to change significantly for age 4 ($H = 2.5$, $P = 0.47$) or age 5 ($H = 3.5$, $P = 0.32$). The total annual mortality of age-3 smallmouth bass, however, gradually increased from 38.4% to 79.0% in 1982–88, when anglers increasingly harvested age-3 smallmouth bass longer than the 10-inch limit, and dropped to 17.5% in 1989, when anglers were restricted to mostly younger or older smallmouth bass outside the slot limit.

Mean annual angling exploitation (μ) during open water, likewise, significantly decreased for combined ages 3–5 smallmouth bass after the 10-inch limit was imposed ($H = 8.2$, $P = 0.045$), falling 1.4 times from the 8-inch to the 10-inch limits and 2.7 times from the 10-inch to the slot and bag limits. Averaged by study period, exploitation of smallmouth bass decreased 2.2 times for age 3 ($H = 13.1$, $P < 0.01$) and increased 1.5 times for age 5 ($H = 8.5$, $P = 0.035$) but was not found to change significantly for age 4 ($H = 3.9$, $P = 0.27$). Although angling exploitation during the slot and bag limits averaged only 4.3% for age-3 smallmouth bass, it was still 23.9% for age-4 and 38.5% for age-5 smallmouth bass. High angling exploitation in Nebish Lake (Hoff 1995) could keep smallmouth bass from growing much larger than the slot limit, a problem in continuing to improve the size of smallmouth bass harvested.

Annual changes (1972–91) in angling exploitation mirrored those of total annual mortality (Fig. 6), having a positive correlation with smallmouth bass age 3 ($r_s = 0.81$, $P < 0.01$) and age 4 ($r_s = 0.62$, $P = 0.01$) but not with smallmouth bass age 5 ($r_s = 0.29$, $P = 0.34$). A significant negative correlation was likewise found between annual exploitation and survival for age-3 smallmouth bass in 1972–88 (Hoff 1995).

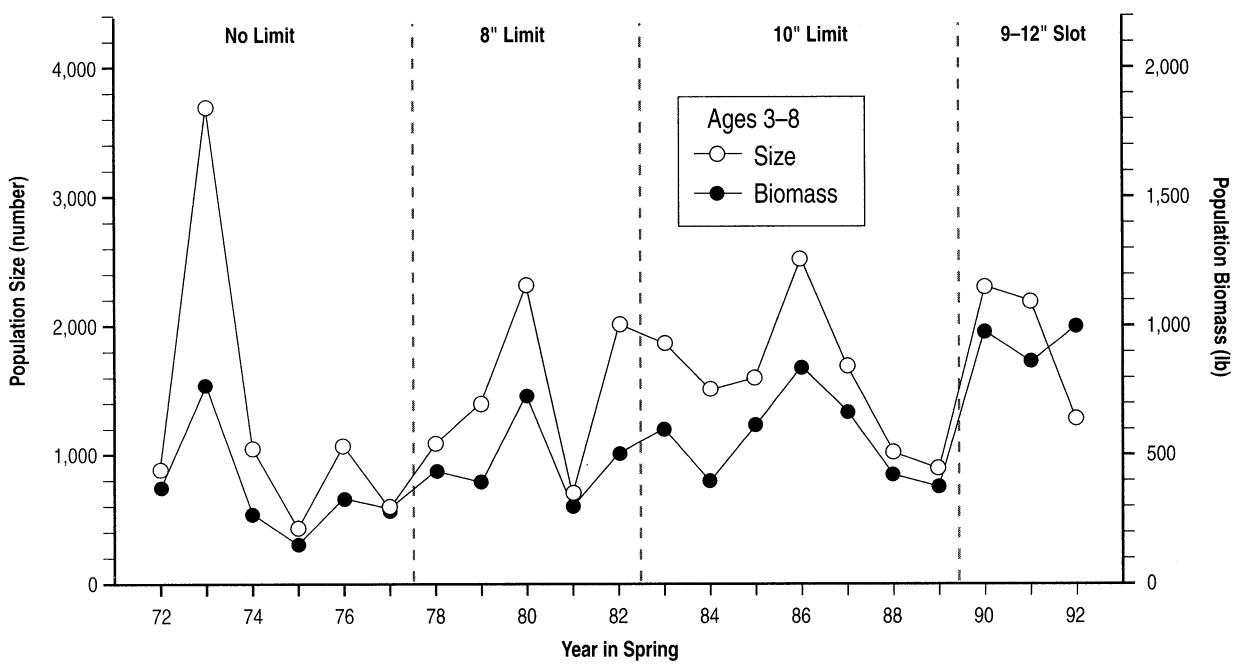


Figure 4. *Spring population size and biomass estimates of combined ages 3–8 smallmouth bass in Nebish Lake.*

Table 11. *Petersen population size estimates by age for adult smallmouth bass during the spring of each bass regulation.*

Bass Regulation	Spring	Abundance (number) by Scale Age at Capture						
		3	4	5	6	7	8	Total
No limit								
	1972	745	85	40	—	—	—	870
	1973	3,350	250	60	25	—	—	3,685
	1974	475	470	75	25	—	—	1,045
	1975	250	55	115	—	—	—	420
	1976	880	120	15	20	25	—	1,060
	1977	529	116	5	—	16	—	568
8-inch limit								
	1978	838	155	72	9	10	—	1,084
	1979	1,216	115	9	11	—	—	1,401
	1980	1,708	495	105	—	—	—	2,308
	1981	436	172	75	—	—	—	683
	1982	1,889	68	45	15	—	—	2,017
10-inch limit								
	1983	679	1,164[a]	—[b]	20	—	—	1,863
	1984	892	404	206	—	—	1	1,503
	1985	861	528	157	44	—	—	1,590
	1986	2,029	387	78	17	14	—	2,525
	1987	796	835	48	24	3	1	1,707
	1988	591	300	125	2	—	—	1,018
	1989	713	124	27	16	1	—	881
9- to 12-inch slot								
	1990	1,691	588	30	—	2	—	2,311
	1991	1,064	904	216	5	2	2	2,193
	1992	358	584	335	22	—	—	1,299
Mean (±1 SE)								
	No limit	1,038 (471)	183 (64)	52 (17)	23 (2)	20 (4)	0	1,275 (493)
	8-inch limit	1,217 (269)	201 (76)	61 (16)	12 (2)	10 (—)	0	1,499 (298)
	10-inch limit	937 (186)	430 (98)	107 (28)	20 (6)	6 (4)	1 (—)	1,584 (207)
	9- to 12-inch slot	1,038 (385)	692 (106)	194 (89)	14 (8)	2 (0)	2 (—)	1,934 (319)
	All years (1972-92)	1,047 (159)	338 (257)	92 (19)	18 (3)	9 (3)	0.3 (0.2)	1,525 (172)

[a] This population size was estimated for age-4 bass that were 10.0 inches or longer; it was not used to calculate any mean or standard error.

[b] Population size could not be estimated for age-5 bass, because only 1 bass was marked and then not recaptured.

Table 12. *Petersen population biomass estimates by age for adult smallmouth bass during the spring of each bass regulation.*

Bass Regulation	Spring	Biomass (lb) by Scale Age at Capture						
		3	4	5	6	7	8	Total
No limit								
	1972	164	122	78	—	—	—	364
	1973	469	150	79	61	—	—	759
	1974	67	122	40	40	—	—	269
	1975	53	20	78	—	—	—	151
	1976	211	43	12	24	37	—	327
	1977	164	86	5	—	35	—	290
8-inch limit								
	1978	210	84	93	17	30	—	434
	1979	280	74	14	26	—	—	394
	1980	376	247	104	—	—	—	727
	1981	105	103	92	—	—	—	300
	1982	359	52	63	30	—	—	504
10-inch limit								
	1983	122	431[a]	—[b]	45	—	—	598
	1984	152	137	109	—	—	—	398
	1985	215	248	105	42	—	—	611
	1986	528	205	64	21	17	—	835
	1987	167	426	38	32	5	2	670
	1988	142	162	116	3	—	—	423
	1989	242	77	31	30	—	—	380
9- to 12-inch slot								
	1990	524	412	33	—	6	5	975
	1991	213	470	166	4	6	—	864
	1992	107	520	344	25	—	996	
Mean (±1 SE)								
	No limit	188 (62)	90 (21)	49 (14)	42 (11)	36 (1)	0	360 (85)
	8-inch limit	266 (50)	112 (35)	73 (16)	24 (4)	30 (—)	0	472 (72)
	10-inch limit	224 (53)	241 (52)	77 (15)	29 (6)	11 (6)	1 (—)	559 (63)
	9- to 12-inch slot	281 (125)	467 (31)	181 (90)	14 (10)	6 (0)	5 (—)	945 (41)
	All years (1972-92)	232 (31)	200 (34)	83 (17)	29 (4)	19 (5)	4 (2)	537 (54)

[a] This population biomass was estimated for age-4 bass that were 10.0 inches or longer; it was not used to calculate any mean or standard error.

[b] Population biomass could not be estimated for age-5 bass, because only 1 bass was marked and then not recaptured.

Table 13. *Total length, body weight, and Schnabel estimates of abundance and biomass for fall fingerling smallmouth bass during each bass regulation.*[a]

Bass Regulation	Spring	Mean Length (in)	Mean Weight (lb)	Abundance (number)	Biomass (lb)
No limit					
	1972[b]	2.7	—	2,482	—
	1973	2.8	—	1,495	—
	1974	2.7	—	1,174	—
	1975	3.0	—	5,718	—
	1976	3.2	—	7,764	—
	1977	2.8	—	3,410	—
8-inch limit					
	1978	2.8	—	2,168	—
	1979	2.8	0.009	4,183	36.8
	1980	3.1	0.012	3,006	36.4
	1981	3.1	0.011	4,952	53.4
	1982	2.5	0.007	2,810	19.9
10-inch limit					
	1983	2.9	0.010	6,300	60.0
	1984	2.7	0.009	1,694	14.4
	1985	2.5	0.006	2,874	18.5
	1986	2.6	0.007	2,568	18.7
	1987	2.8	0.009	4,028	37.3
	1988	3.2	0.014	2,742	38.1
	1989	2.5	0.008	4,107	32.6
9- to 12-inch slot					
	1990	1.9	0.003	3,793	10.9
	1991	2.6	0.008	12,438	101.4
	1992	2.6	0.004	9,603	36.0
Mean (±1 SE)					
	No limit	2.9 (0.08)	—	3,674 (1,055)	—
	8-inch limit	2.9 (0.11)	0.008 (0.002)	3,424 (502)	36.6 (7)
	10-inch limit	2.7 (0.09)	0.009 (0.001)	3,473 (569)	31.4 (6)
	9- to 12-inch slot	2.4 (0.23)	0.005 (0.002)	8,611 (2,544)	49.4 (27)
	All years (1972-92)	2.8 (0.06)	0.006 (0.001)	4,253 (612)	36.7 (6)

[a] Fall fingerling smallmouth bass were not weighed before 1979.

[b] The 1972 abundance was calculated from a regression formula relating the 1967–76 catch/effort to density (Kempinger et al. 1982 in Serns 1984).

Table 14. *Petersen population size estimates by age for yellow perch during spring of each bass regulation.*[a]

Bass Regulation	Spring	Abundance (number) by Scale Age at Capture						
		3	4	5	6	7	8	Total
No limit								
	1972	16,973	30,513	1,414	—	—	—	48,900
	1973	70,814	57,982	492	82	—	—	129,370
	1974	—	78,888	36,326	766	—	—	115,980
	1975	—	3,012	7,918	21,746	1,324	—	32,676
	1976	903	5,496	3,816	11,620	2,928	337	21,835
	1977	8,817	5,099	1,742	921	178	—	16,579
8-inch limit								
	1978	9,415	4,277	727	791	692	539	15,210
	1979	13,476	6,961	3,372	319	189	83	24,128
	1980	4,306	2,163	931	270	225	115	7,670
	1981	15,951	3,326	1,242	35	—	75	20,554
	1982	13,762	9,648	5,638	1,283	522	379	30,331
10-inch limit								
	1983	4,354	4,955	1,360	275	24	24	10,944
	1984	—	1,784	1,611	190	149	—	3,585
	1985	2,691	1,288	591	552	83	36	5,122
	1986	3,726	1,120	380	114	154	30	5,340
	1987	6,312	932	203	187	63	179	7,634
	1988	6,795	2,475	274	47	99	102	9,591
	1989	5,936	1,686	1,296	185	—	23	9,103
9- to 12-inch slot								
	1990	10,455	527	516	92	13	—	11,590
	1991	835	3,232	752	93	95	5	4,912
	1992	—	—	—	—	—	—	—
Mean (±1 SE)								
	No limit	24,377 (15,823)	30,165 (13,066)	8,618 (5,647)	7,027 (4,257)	1,477 (798)	337 (—)	60,890 (20,127)
	8-inch limit	11,382 (2,060)	5,275 (1,350)	2,382 (941)	540 (223)	407 (121)	238 (94)	19,579 (3,861)
	10-inch limit	4,969 (663)	2,034 (524)	816 (222)	221 (61)	95 (21)	66 (26)	7,331 (1,027)
	9- to 12-inch slot	5,645 (4,810)	1,879 (1,352)	634 (118)	92 (1)	54 (41)	5 (—)	8,251 (3,339)
	All years (1972-92)	11,501 (3,900)	11,268 (4,665)	3,530 (1,782)	2,083 (1,245)	449 (198)	148 (46)	26,553 (7,795)

[a] Dashes indicate not enough yellow perch of this age group were marked or recaptured to estimate population size.

By restricting angling exploitation, the 10-inch limit and especially the slot and bag limits reduced mortality on most age-3, some age-4, and a few age-5 smallmouth bass. The mean annual total length of harvested smallmouth bass during the 10-inch limit averaged 10.4 ± 0.1 inches (mean ± 1 SE) for age-3, 11.1 ± 0.2 inches for age-4, and 12.6 ± 0.4 inches for age-5 smallmouth bass. But these bass are less effective at guarding nests (Wiegmann and Baylis 1995) and less apt to renest after inclement weather (Lukas and Orth 1995), because they spawn late. Yet protecting age-3 smallmouth bass permitted a significant increase in abundance and biomass of those age 4 (Hoff 1995). Older, more effective spawners, therefore, gained from protection of younger, less effective spawners.

Neither total annual mortality nor angling exploitation of age-3 smallmouth bass were found to correlate significantly with annual changes in total hours fished ($P > 0.36$), though hours fished/angling permit issued did correlate with mortality ($r_s = 0.61$, $P < 0.01$) and exploitation ($r_s = 0.48$, $P = 0.036$). Shorter fishing trips, therefore, contributed to reduced harvest and, indirectly, to increased protection of spawning-age bass.

Growth of Smallmouth Bass

The growth of Nebish Lake smallmouth bass stayed mostly below average for Wisconsin populations, despite successively stricter length regulations (Table 16). Of the 135 mean total lengths calculated for scale ages 1–7 in 1972–92, 83% were below the North Central District averages and 86% were below the "statewide" averages tabulated for May 1990 in the Department of Natural Resources (DNR) Fish Management Reference Book (Anonymous 1990). A fourth of the mean lengths by age of Nebish Lake smallmouth bass were more than 1 sample standard deviation below the North Central District and "statewide" averages. When data for all 21 years (1972–92) were combined, Nebish Lake smallmouth bass averaged 0.4 inches below the North Central District average (0.5 inches below the "statewide" average) after 1 growing season (age 1 in spring) and 1.5 inches below the district average (1.4 inches below the "statewide" average) after 5 growing seasons.

The mean annual total length of smallmouth bass in spring changed little for ages 2 and 3 but fluctuated among years for ages 4 and 5 (Fig. 7).

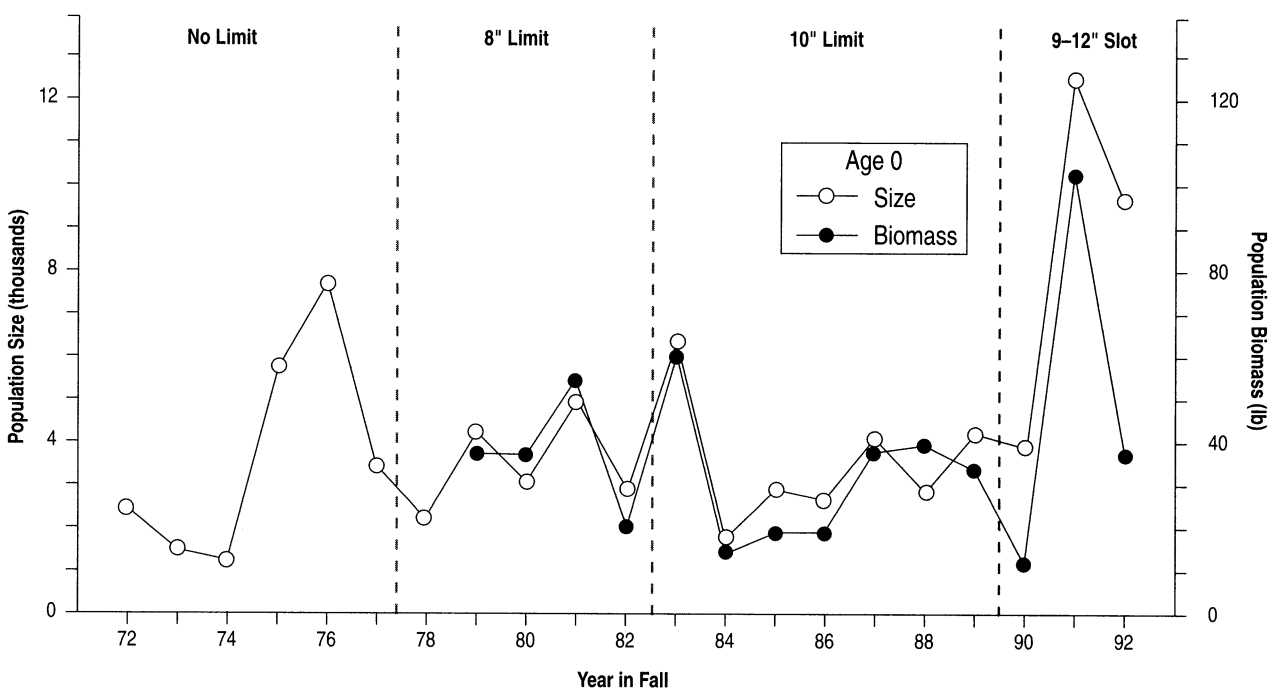


Figure 5. *Fall population size and biomass estimates of age-0 smallmouth bass in Nebish Lake.*

Table 15. *Percent total annual mortality (A) and open-water angling exploitation (μ) by age for smallmouth bass during each bass regulation.*[a]

Bass Regulation	Spring	Total Annual Mortality (%) by Scale Age at Capture				Angling Exploitation (%) Ages 3-5
		Age 3	Age 4	Age 5	Ages 3-5	
No limit						
	1972	66.4	— [b]	37.5	61.5	23.5
	1973	86.0	70.0	58.3	84.4	45.6
	1974	88.4	75.5	— [b]	83.3	36.7
	1975	— [b]	72.7	82.6	63.1	37.5
	1976	86.8	95.8	— [b]	88.1	50.4
8-inch limit						
	1977	70.7	37.9	— [b]	63.7	15.6
	1978	86.3	94.2	84.7	87.3	59.8
	1979	59.3	— [b]	— [b]	55.2	41.6
	1980	89.9	84.8	— [b]	89.3	36.8
	1981	84.4	73.8	80.0	81.3	51.5
10-inch limit						
	1982	38.4	— [b]	55.6	38.8	11.5
	1983	40.5	82.3	— [b]	66.9	28.6
	1984	40.8	61.1	78.6	51.5	30.3
	1985	55.1	85.2	89.2	68.8	40.1
	1986	58.8	87.6	69.2	63.6	27.4
	1987	62.3	85.0	95.8	74.6	40.1
	1988	79.0	91.0	87.2	83.6	27.7
9- to 12-inch slot						
	1989	17.5	75.8	— [b]	28.5	10.3
	1990	46.5	63.3	83.3	51.3	11.0
	1991	45.1	62.9	89.8	56.9	11.0
Mean (±1 SE)						
	No limit	81.9 (5.2)	78.5 (5.9)	59.5 (13.0)	76.1 (5.7)	38.7 (4.6)
	8-inch limit	78.1 (5.7)	72.7 (12.3)	82.4 (2.4)	75.4 (6.8)	41.1 (7.5)
	10-inch limit	53.6 (5.6)	82.0 (4.4)	79.3 (6.0)	64.0 (5.6)	29.4 (3.6)
	9- to 12-inch slot	36.4 (9.4)	67.3 (4.2)	86.6 (3.2)	45.6 (8.7)	10.8 (0.2)
	All years (1972-91)	63.3 (4.9)	76.4 (3.6)	76.3 (4.6)	67.1 (3.8)	31.9 (3.3)

[a] Without a population size estimate in 1993, mortality could not be calculated for 1992.

[b] Mortality and exploitation were not included in the mean or standard error, because small sample size precluded calculation of mortality or because exploitation equalled or exceeded mortality.

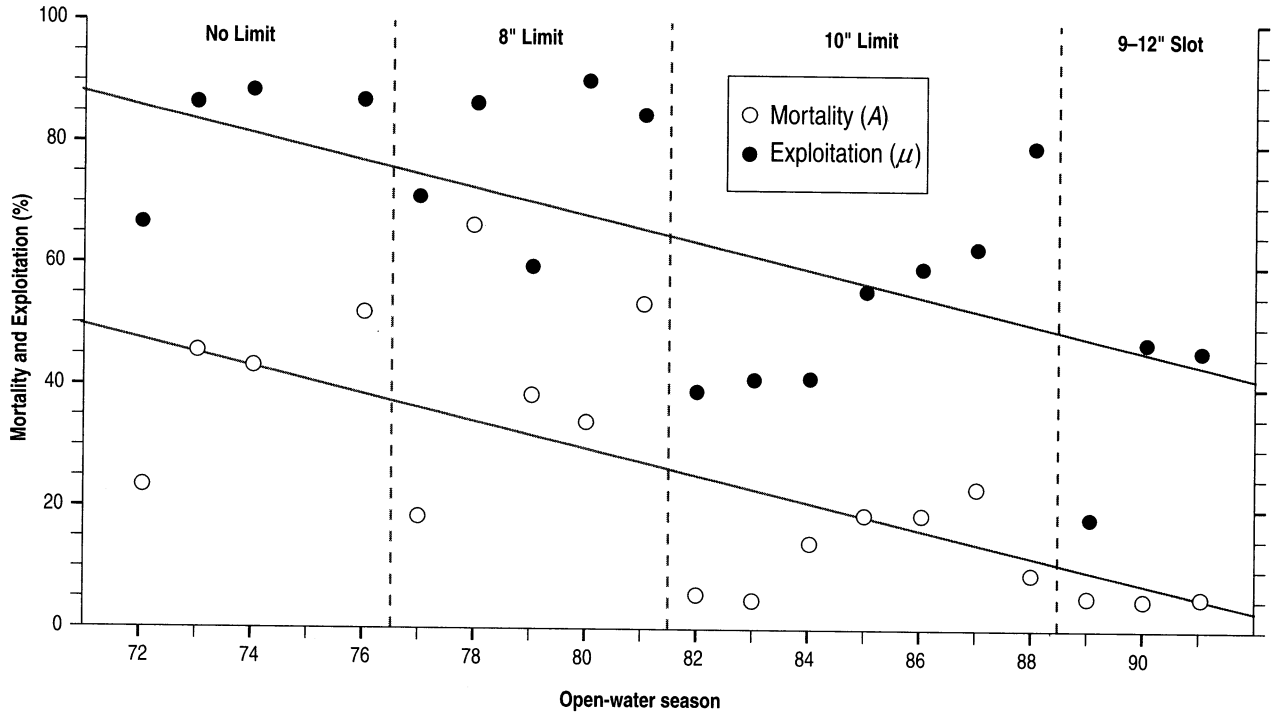


Figure 6. *Percent total annual mortality (A) and angling exploitation (μ) of smallmouth bass during open water in Nebish Lake. Not enough smallmouth bass were tagged in 1975 to estimate mortality or exploitation for that year.*

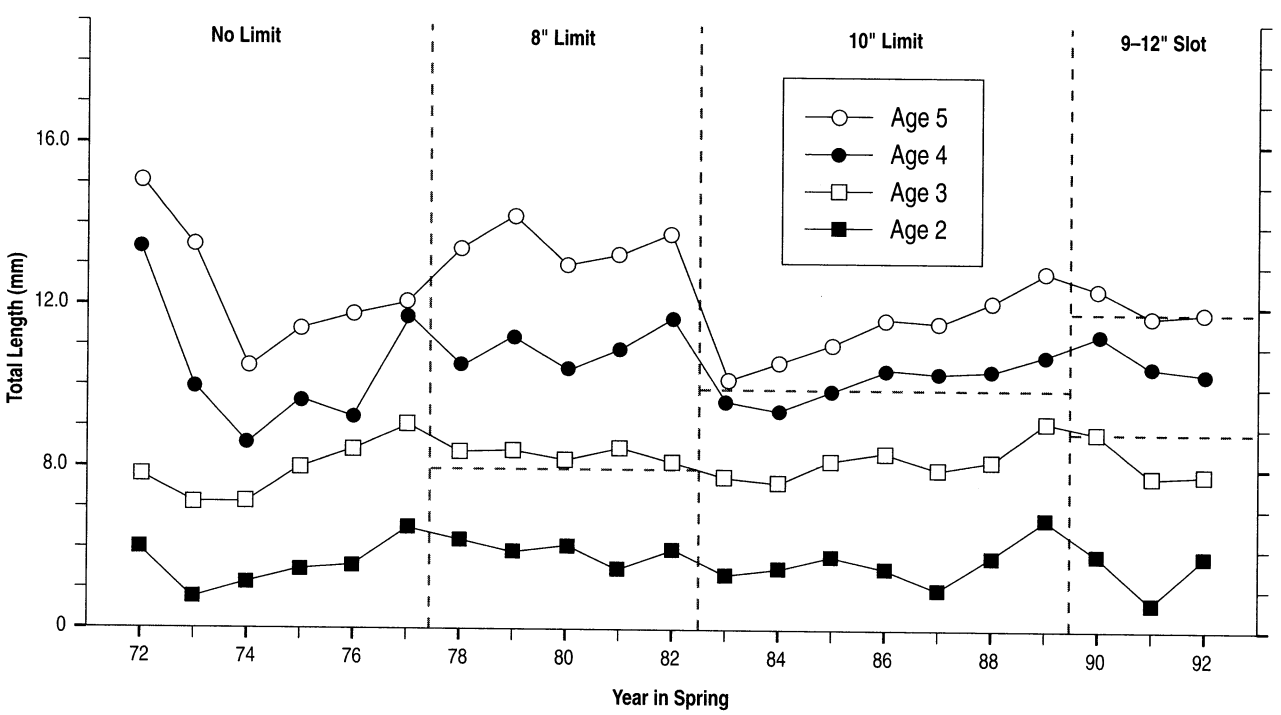


Figure 7. *The mean total length-at-age of smallmouth bass fyke netted or electrofished each spring in Nebish Lake. Dashes delimit study periods (vertical lines) or legal lengths (horizontal lines).*

Table 16. *Mean annual total length by age of smallmouth bass fyke netted or electrofished in spring compared with North Central District and "statewide" average lengths. (Few bass >age 7 were measured.)*

Bass Regulation	Spring	Mean Length (in) by Scale Age at Capture							
		1	2	3	4	5	6	7	8
No limit									
	1972	3.4	5.9	7.8	13.5	15.2	—	—	—
	1973	—	4.7	6.1	10.0	13.5	16.0	—	—
	1974	—	5.1	7.1	8.6	10.5	14.4	16.6	—
	1975	3.3	5.5	9.0	9.7	11.5	14.7	15.5	—
	1976	3.1	5.6	8.5	9.3	11.9	13.3	14.5	15.6
	1977	3.8	6.5	9.1	11.8	12.2	—	16.3	—
8-inch limit									
	1978	3.4	6.2	8.4	10.5	13.6	14.8	—	—
	1979	3.6	5.9	8.4	11.3	14.4	16.4	16.9	16.9
	1980	3.3	6.1	8.2	10.4	13.1	—	17.6	—
	1981	3.3	5.5	8.5	11.0	13.4	16.4	17.6	—
	1982	3.3	6.1	8.1	11.8	13.9	15.3	18.0	—
10-inch limit									
	1983	2.8	5.4	7.8	9.7	10.2	—	18.0	—
	1984	3.2	5.5	7.7	9.5	10.7	—	18.1	18.8
	1985	3.0	5.9	8.3	19.0	11.2	12.4	—	—
	1986	2.8	5.6	8.5	10.5	11.8	13.5	13.7	—
	1987	2.8	5.1	8.0	10.4	11.7	13.7	14.9	14.8
	1988	3.1	5.9	8.3	10.5	12.3	13.8	16.1	—
	1989	3.5	6.8	9.3	10.9	13.0	15.0	15.8	—
9- to 12-inch slot	1990	3.0	5.9	8.9	11.4	12.5	—	16.7	—
	1991	2.5	4.8	7.9	10.6	11.9	12.6	17.4	17.1
	1992	3.6	5.9	7.9	10.5	12.0	12.5	—	—

Table 16. *continued*

Bass Regulation	Mean Length (in) by Scale Age at Capture							
	1	2	3	4	5	6	7	8
Mean (±1 SE) lengths								
No limit	3.4 (0.15)	5.6 (0.26)	7.9 (0.32)	10.5 (0.74)	12.5 (0.68)	14.6 (0.56)	15.7 (0.47)	15.6 (—)
8-inch limit	3.4 (0.06)	6.0 (0.12)	8.3 (0.07)	11.0 (0.26)	13.7 (0.22)	15.7 (0.40)	17.5 (0.23)	16.9 (—)
10-inch limit	3.0 (0.10)	5.7 (0.21)	8.3 (0.20)	10.2 (0.19)	11.6 (0.36)	13.7 (0.41)	16.1 (0.70)	16.8 (2.00)
9- to 12-inch slot	3.0 (0.32)	5.5 (0.37)	8.2 (0.33)	10.8 (0.28)	12.1 (0.19)	12.6 (0.05)	17.0 (0.35)	17.1 (—)
All years (1972-92)	3.2 (0.08)	5.7 (0.11)	8.2 (0.12)	10.6 (0.23)	12.4 (0.28)	14.3 (0.35)	16.5 (0.33)	16.6 (0.69)
North Central District[a]	3.6 (0.20)	6.6 (0.21)	9.6 (0.30)	11.9 (0.32)	13.9 (0.45)	14.8 (0.46)	16.7 (0.33)	17.7 (0.49)
"Statewide"[a]	3.7 (0.13)	6.6 (0.13)	9.4 (0.18)	11.7 (0.25)	13.8 (0.25)	15.1 (0.26)	17.0 (0.22)	18.2 (0.38)
Mean (± SE) length differences of North Central District minus Nebish Lake								
No limit	0.20 (0.15)	1.05 (0.26)	1.67 (0.32)	1.42 (0.74)	1.43 (0.68)	0.20 (0.56)	0.98 (0.47)	2.10
8-inch limit	0.22 (0.06)	0.64 (0.12)	1.28 (0.07)	0.90 (0.26)	2.40 (0.21)	0.68 (0.54)	-0.82 (0.23)	0.80
10-inch limit	0.57 (0.10)	0.86 (0.21)	1.33 (0.20)	1.69 (0.19)	2.34 (0.36)	1.12 (0.41)	-0.60 (0.70)	0.90 (2.00)
9- to 12-inch slot	0.57 (0.32)	1.07 (0.21)	1.37 (0.33)	1.07 (0.28)	1.77 (0.19)	2.25 (0.05)	-0.35 (0.35)	0.60
All years (1972-92)	0.40 (0.08)	0.89 (0.11)	1.42 (0.12)	1.33 (0.23)	1.50 (0.28)	0.55 (0.34)	-0.22 (0.33)	1.06 (0.69)

[a] May 1990 data from the DNR Fish Management Reference Book (Anonymous 1990).

The mean length of these older bass first decreased and then increased under the no limit and 10-inch limit periods. Yet their mean length in the open-water harvest, averaged by study period, significantly increased under the minimum length limits for smallmouth bass age 3 ($H = 10.5$, $P = 0.01$) and age 4 ($H = 9.1$, $P = 0.03$) but not age 5 ($H = 6.3$, $P = 0.10$). Harvested smallmouth bass age 3, for example, averaged (mean $\pm$ 1 SE) 9.0 $\pm$ 0.3 inches under no limits, 9.7 $\pm$ 0.2 inches under the 8-inch limit, 10.4 $\pm$ 0.1 under the 10-inch limit, and 9.4 $\pm$ 0.7 under the slot and bag limits. Minimum length limits, therefore, led anglers to harvest larger smallmouth bass, though growth remained slow.

The growth of Nebish Lake smallmouth bass has long been below the state average (Threinen 1951) and 0.3–1.0 inches below smallmouth bass average lengths in more than 44 North American populations (Coble 1975). The mean total length of age-4 smallmouth bass, for example, was about 1.5 inches below the "statewide" average (Anonymous 1990) in the 22 years since 1972.

Yet growth of black bass can slow when abundance increases (Novinger 1987, Austen and Orth 1988) or quicken when abundance decreases (Newmann et al. 1993), indicating changes in trophic interactions. Nebish Lake smallmouth bass continued to grow slowly during our study while their abundance averaged 16.2 smallmouth bass/acre, a sign that food shortage could have limited their growth despite changes in angling regulations.

Summary

1. The number of angling permits issued and hours fished, averaged by angling year, increased with each new bass regulation: 33% by number (26% by hours) from no limits to the 8-inch limit, 9% by number (1% by hours) from the 8-inch limit to the 10-inch limit, and 3% by number (3% by hours) from the 10-inch limit to the slot and bag limits (Table 17). Anglers during 1972–92 fished an average of 54.5 hours/acre, accounting for 95% of angling permits issued during open water.
2. Anglers harvested 69% fewer smallmouth bass and 82% fewer yellow perch of all sizes from no limits to the slot and bag limits. The mean total length of harvested smallmouth bass increased about 2 inches under the 8-inch limit and 10-inch limit but only 0.2 inches under the slot and bag limits. The mean annual harvest of smallmouth bass 12.0 inches or longer, however, increased only 5% from no limits to the 8-inch limit and only 14% from the 8-inch limit to the 10-inch limit but increased 194% from the 10-inch limit to the slot and bag limits. Anglers under the slot and bag limits harvested almost as many smallmouth bass under the slot as above it.
3. Mean annual abundance in spring was not found to change significantly for smallmouth bass but increased 7.4 times for yellow perch of combined ages 3–8. Nor was the annual abundance of fall fingerling smallmouth bass found to change significantly among study periods until the slot and bag limits, when it increased 2.5 times from that under the 10-inch limit.
4. Angling exploitation, rather than total annual mortality, significantly decreased for smallmouth bass of combined ages 3–5, though total annual mortality dropped for those age 3 when the 10-inch limit was imposed. Mortality and exploitation, however, varied widely among years and were significantly correlated for age-3 smallmouth bass.
5. Smallmouth bass grew slowly throughout the study, with no evidence found for significant change in average length or weight of most age groups. The mean total length of age-4 spawners, for example, stayed almost identical with each new regulation.

Management Implications

We expected length limits to boost angling yield (lb/acre) of smallmouth bass while protecting spawning smallmouth bass. Assuming no change in growth or natural mortality, an equilibrium yield model for Nebish Lake smallmouth bass predicted mean annual angling yield would increase 22% under an 8-inch limit (Kempinger 1978) and another 5% under an 11-inch limit (Serns 1984) as larger smallmouth bass entered the harvest. The model also predicted a 45% fall in overall harvest, because anglers no longer could keep smallmouth bass shorter than 11 inches. (A 10-inch limit was imposed instead of the 11-inch limit modeled.)

We did find angling yield to increase 28% from no limits to the 8-inch limit, as the average size of harvested smallmouth bass increased. But then harvested biomass decreased 33% under the 10-inch limit and 25% under the slot and bag limits (Table 17) because of the protection afforded most juvenile smallmouth bass under the 10-inch limit and the subsequent daily bag limit.

Table 17. *Summary of the year-round creel census, spring population size, annual mortality, and angling exploitation of smallmouth bass and yellow perch, averaged yearly for each study period.*

	Bass Regulation				Kruskal-Wallis ANOVA		
Response Variable	**No Limit**	**8-inch Limit**	**10-inch Limit**	**9- to 12-inch Limit**	**All Years**	***H*-statistic**	***P*-value**
Fishing pressure							
Angling permits (number/acre)	11.7	15.5	16.9	17.4	15.5	11.2	0.01
Fishing effort (hours fished/acre)	44.8	56.5	56.9	58.8	54.5	7.2	0.07
Harvest number							
Bass all lengths (number/acre)	15.3	14.1	6.4	4.7	9.8	15.9	<0.01
Bass 12.0-20.6 inches (number/acre)	0.5	0.7	0.8	2.5	1.1	12.7	<0.01
Perch all lengths (number/acre)	44.3	32.3	18.9	8.0	25.2	11.0	0.01
Harvest biomass							
Bass all lengths (lb/acre)	4.7	6.0	4.0	3.0	4.4	8.0	0.05
Bass 12.0-20.6 inches (lb/acre)	0.7	1.0	1.0	2.5	1.3	12.5	<0.01
Harvest rates (all fish lengths)							
Bass (number/permit)	1.34	0.91	0.38	0.27	0.70	16.5	<0.01
Perch (number/permit)	3.70	2.10	0.00	0.43	1.82	11.8	<0.01
Bass (number/hours fished)	0.35	0.25	0.16	0.08	0.21	16.3	<0.01
Perch (number/hours fished)	0.96	0.58	0.36	0.13	0.50	11.6	<0.01
Spring abundance							
Bass fall age 0 (number/acre)	39.1	36.4	36.9	91.6	45.2	4.2	0.24
Bass ages 3-8 (number/acre)	13.6	15.9	16.9	20.6	16.2	4.0	0.26
Perch ages 3-8 (number/acre)	647.8	208.3	78.0	87.8	282.5	13.5	<0.01
Spring biomass							
Bass fall age 0 (lb/acre)	— [a]	0.39	0.33	0.53	0.39	0.3	0.85
Bass ages 3-8 (lb/acre)	3.8	5.0	5.9	10.1	5.7	11.1	0.01
Mortality (*A*) and exploitation (μ)							
Bass ages 3-5 (*A*, %)	76.1	75.4	64.0	45.6	67.1	6.8	0.08
Bass ages 3-5 (μ, %)	38.7	41.1	29.4	10.8	31.9	9.4	0.02

[a] Fall fingerling smallmouth bass were not weighed before 1979.

A daily bag limit on Nebish Lake smallmouth bass after 1988 dampened the effect of a 9- to 12-inch slot limit on reducing overall smallmouth bass density by limiting each angler's daily harvest. Anglers could have reduced overall smallmouth bass density, and perhaps improved bass growth, had they been able to harvest more smallmouth bass under the slot. Anglers in a Missouri impoundment, for example, kept 98% of largemouth bass shorter than a protective slot limit imposed without a daily bag limit (Eder 1984).

The Nebish Lake slot limit, like the one in Missouri, did not function as a minimum length limit, with anglers ignoring undersized bass. Quantity was still important in the Nebish Lake fishery and more undersized smallmouth bass would surely have been kept had length limits been discontinued or no daily bag limit been imposed.

Population responses to length and bag limits can be delayed. Protection for age-3 smallmouth bass increased after the 8-inch limit: Angling exploitation averaged 46% less and nests increased 3–5 times (Wiegmann et al. 1992) under the 10-inch limit. Yet production of fall fingerling smallmouth bass increased only under the subsequent slot and bag limits when more age-4 smallmouth bass were protected. The mean annual harvest of smallmouth bass 12.0–14.0 inches long significantly increased only 5 years after the 10-inch minimum limit was imposed. The angling yield (lb/acre) of largemouth bass in two Texas reservoirs took only 4 years to increase, after a slot limit of 14 to 18 inches replaced a 10-inch minimum length limit (Dean et al. 1991).

Anglers accepted stricter bass regulations. Fishing pressure increased ($H = 13.0$, $P < 0.01$) with each successive bass regulation on Nebish Lake and was not found to change significantly ($U = 1.0$, $P = 0.31$) on nearby 71-ha Pallette Lake before (1985–88) and after (1989–92) a 16-inch minimum and 2 bass/angler daily bag limit was imposed on smallmouth bass angling. Although more anglers came to Nebish Lake, we found no significant change ($H = 2.6$, $P = 0.45$) among years of our study periods in mean annual fishing pressure on 119-ha Escanaba Lake.

Successively stricter bass regulations, coupled with increased fishing pressure, meant a larger proportion of the Nebish Lake catch had to be released. Anglers released 14 times as many smallmouth bass under the 10-inch limit and 20 times as many such bass under the slot and bag limits as were harvested during these periods. The release rate of smallmouth bass, likewise, increased while harvest decreased under a 12-inch minimum limit in a Virginia river (Kauffman 1983). Release rates of largemouth bass increased as well under minimum or slot length limits in Kansas lakes (Mosher 1991) and Missouri impoundments (Novinger 1988).

The combined slot and bag limits on Nebish Lake have balanced the size distribution of smallmouth bass harvested: Anglers have kept almost as many smallmouth bass under 9 inches as above 12 inches, leaving most spawning-age smallmouth bass protected. Meanwhile the angling yield of smallmouth bass 12.0–14.0 inches long has increased.

Some harvest effects of bass regulations continued into later study periods: Smallmouth bass and yellow perch both produced strong year classes in 1970 that affected harvest into the 8-inch limit. The increased harvest of smallmouth bass 12.0–14.0 inches long actually began two years before the slot and bag limits.

What if the daily bag limit applied just to smallmouth bass over the slot limit? Removing the daily bag limit for undersized fish could improve gamefish stock (Anderson and Weithman 1978) by reducing food competition. Although fewer fish would then reach sexual maturity, Nebish Lake has a surplus of spawning-age bass: Each spring less than one-third of adult males build nests (Baylis et al. 1991), yet population density stays high. Harvest might increase for smallmouth bass over the slot, because anglers would no longer divide their daily bag among fish under and over the slot. Yet few anglers have taken more than 2 smallmouth bass/angling permit on Nebish Lake, making it unlikely that bass over the slot would be overexploited. Keeping the 9- to 12-inch slot with a daily bag limit just on fish over the slot could, at last, improve fish growth on Nebish Lake!

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We dedicate our report to the memory of Steven L. Serns.

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U.S. Metric Equivalents

1 acre = 0.405 ha or 4.047 g/m^2
1 ft = 30.48 cm or 0.3048 m
1 g = 0.035 oz (avoirdupois)
1 inch = 2.54 cm or 25.4 mm
1 L = 33.81 oz
1 lb = 0.454 kg
1 mile = 1.609 km
1 oz = 28.35 g

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