The Sport Fishery for, and Selected Population Characteristics of, Smallmouth Bass in Pallette Lake, Wisconsin, 1958-1984

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Cover Photo: Entrance sign for the Northern Highlands Fishery Research Area, Vilas County. Pallette Lake is one of five experimental lakes in the research area.

ABSTRACT

A complete record of the smallmouth bass (*Micropterus dolomieui*) sport fishery in Pallette Lake, Wisconsin, for the period 1958-84 was available from a compulsory permit-type creel census. Data from additional years were also available for calculating growth. Data analysis showed that annual angling pressure during 1958-84 averaged 870 hours (4.9 hours/acre), and annual angling harvest of smallmouth bass averaged 234 fish (1.3/acre) weighing 82 lb (0.5 lb/acre). The mean length of smallmouth bass harvested from 1952-85 was 9.0 inches. There was a positive and significant ($P < 0.01$) relationship between angling pressure and both the number and weight of smallmouth bass creeled by anglers in this lake, which had no season, bag, or size limit regulations on this species. Smallmouth bass were the primary target of open-water anglers, who accounted for most of the angling pressure.

Total instantaneous and annual mortality rates for adult smallmouth bass averaged 1.332 and 0.709, respectively. Pope's method of cohort analysis was used to calculate the number of spring yearling (age I) smallmouth bass alive in Pallette Lake for the 1958-79 cohorts. For these cohorts, an estimated average of 23% of the fish alive at age I were harvested between ages I through V by anglers under the liberalized fishing regulations existing during the period.

Growth of smallmouth bass was faster in Pallette Lake than in nearby Nebish Lake, presumably because of lower densities in Pallette Lake. Growth of age II smallmouth bass in Pallette Lake appeared to be positively related to summer water temperatures and unaffected by the number of adult smallmouth bass (age III-V) in the lake.

Management implications from this study include: (1) Managers may need to more closely monitor exploitation even in lakes receiving relatively low use. The Pallette Lake smallmouth bass population was exploited at a relatively high rate despite low annual angling pressure. This low angling pressure may have been so effective, in part, because no size, season, or bag limits were in effect on the lake. (2) the 12.0-inch minimum length limit established in 1989 for smallmouth bass harvested from most northern Wisconsin waters should increase quality in the fish populations as well as in the creel, based on results from our Pallette Lake study. However, this regulation should be evaluated to determine how it affects density and biomass levels in waters of various types, and how these factors affect growth rates.

Key Words: Smallmouth bass, cohort analysis, harvest, exploitation, growth.

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INTRODUCTION

Part of the harvest of 100 "black bass" (all or at least most were smallmouth bass) taken from Pallette Lake by a guide and his client on 9 July 1896.

A stringer of smallmouth bass harvested during 1987.

The Pallette Lake sport fishery has been monitored through a compulsory permit-type creel census since 1946 with complete records from 1958 to date. This long-term data base presented an opportunity to profile the sport fishery for smallmouth bass (*Micropterus dolomieui*), the principal game fish in the lake, and to estimate population size. Information contained in this previously unpublished data set should contribute to better understanding and more effective management of smallmouth bass in Wisconsin lakes.

The primary objective of our study was to summarize the 1958-84 data on the smallmouth bass sport fishery and to determine the strength of each cohort as measured in the spring yearling stage (hereafter termed age I). We also determined growth of smallmouth bass and analyzed factors that might be related to it. Our analysis of information on population size of age I smallmouth bass in Pallette Lake utilized both the angling catch-per-effort (CPE) for a cohort, over a given range of ages, and the estimated number of each age I cohort as calculated by the method of Pope (1972). CPE was defined as harvest per hour registered in the compulsory permit-type creel census.

STUDY AREA

Pallette Lake is a 176-acre infertile, clear-water, seepage lake with a total alkalinity of 6 ppm, Secchi disc transparency of approximately 16 ft during the summer months, and a maximum depth of 60 ft. It is located in the Northern Highland State Forest in north central Wisconsin at latitude 46° 04' and longitude 89° 35'. The entire shoreline is forested and state owned.

Pallette Lake is one of five lakes in the Northern Highland Fishery Research Area (Fig. 1). All anglers are required by law to obtain a permit at the Escanaba Lake contact station before fishing. When done angling for the day, they are required to return each permit and allow station personnel to collect data on harvested fish. Fishing was allowed from 4 a.m. to midnight during the earlier years of the study and from 4 a.m. to 10 p.m. in more recent years. No season, size, or bag limits restricted harvest of smallmouth bass during the entire period of study. Smallmouth bass were the primary target of open-water anglers who accounted for most of the angling pressure.

From 1958 through 1968, access to Pallette Lake was facilitated by a 0.3-mile road to the only boat landing. Beginning in 1969 this access road was closed, limiting access to walk-in (wading or shoreline fishing) or boat portage (approximately 600 ft) from Escanaba Lake. The access road was closed by State Forest personnel after the area surrounding Pallette Lake was designated a Scenic Area.

METHODS

Data Collection

Each smallmouth bass brought to the checking station was measured to the nearest 0.1 inch (total length) and weighed to the nearest 0.01 lb. The number of hours (to the nearest 0.5) fished by each angler was recorded along with the type of gear and bait used. Scales from each smallmouth bass were collected and later examined using a microfiche reader. A small percentage of fish were not aged because permits and fish were returned to the checking station after hours or because all sampled scales from a creeled fish were regenerated. Fish that were not aged were apportioned into age groups based on the percentage of fish their size comprising various age groups in the total sample aged.

The angling harvest of smallmouth bass by age group was determined each year for the period 1958-84. Since very few smallmouth bass over age V were harvested, we were able to determine the number of bass belonging to the 1958-79 cohorts that were harvested by anglers over the cohort life span. In addition, we determined the summed catch-(actually harvest)-per-effort (CPE) for each cohort using the number harvested per angling hour each year (Hayman et al. 1980).

Cohort Analysis

The estimated number of smallmouth bass present in the lake at age I for each of the 1958-79 cohorts was calculated by the cohort analysis method of Pope (1972), using the formula:

$$N_t = N_{t+1}e^M + C_t e^{M/2}$$

where N_t is the number of fish in a cohort alive at age t, M is instantaneous rate of natural mortality, and C_t is harvest at age t.

To estimate M, we first determined a mean instantaneous total fishing mortality (Z) for the smallmouth bass population in Pallette Lake using a catch curve analysis (Ricker 1975) of angling CPE values for each cohort from 1958-79, by age group over the life of the cohort. Ages included in the least squares regression analysis of age vs. $\log_e$ of the CPE were usually II-V, although II-IV, III-V, and III-VI were used for some cohorts. The individual Z values for each year class were summed and averaged to provide the mean Z value. The estimate of instantaneous rate of fishing mortality (*F*) was calculated using the formula (Ricker 1975):

$$Z/A = F/u$$

where A is total annual mortality and u is exploitation rate.

A was determined from the catch curve analysis while the value of u (0.400) was determined for age III-V smallmouth bass in nearby Nebish Lake during the period 1972-76 when there were no size, season, or bag limits on the harvest of smallmouth bass (Serns 1984). Finally, the value of M was derived by subtracting F from Z (Ricker 1975).

Estimates of the strength of each 1963-79 cohort from cohort analysis were regressed against cohort analysis estimates of stock at ages III-V for the previous year. This was performed to determine whether a stock-recruitment relationship was discernible.

Calculation of Growth

The growth of smallmouth bass, 1958-84, was determined by calculating the mean length at age for fish caught by anglers between ice-out and 30 June each year. We assumed that little growth occurred during that period and, therefore, mean lengths at age would indicate completed years of growth. Mean annual growth increments were determined for fish of the various age groups and through regression analysis were compared with summer (June-August) water temperatures for 1958-79 and smallmouth bass numbers for 1963-79. Water temperatures used in these analyses were shoreline surface temperatures from nearby Escanaba Lake since no data were available for Pallette Lake. These data are only indicative of trends that affected both lakes similarly. Actual temperatures in Pallette Lake were probably lower than in Escanaba Lake.

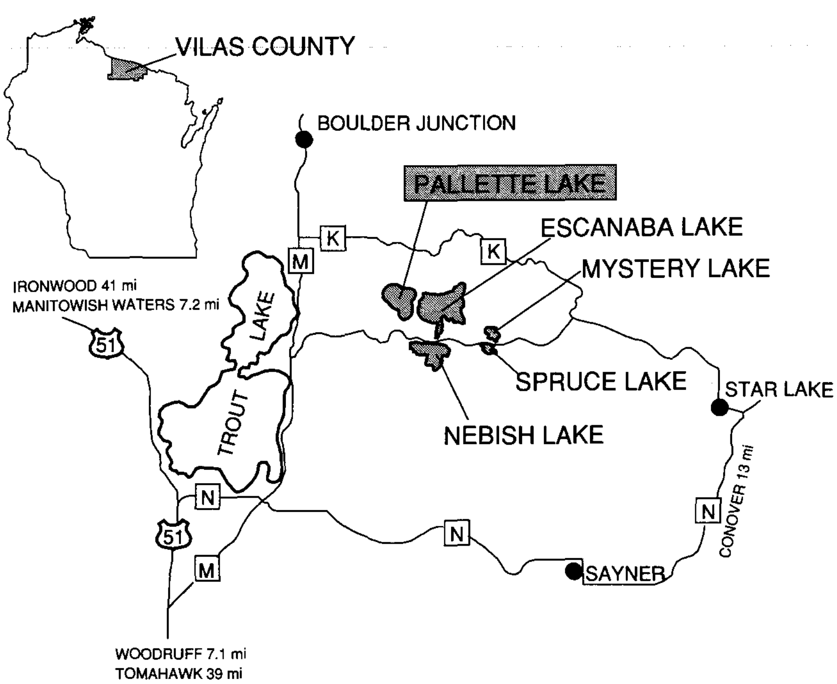

FIGURE 1. *Location of Pallette Lake and the other 4 lakes in the Northern Highland Fishery Research Area, Vilas County.*

RESULTS

Angling Pressure, Harvest, and Population Size

Total angling effort (hours) and harvest (no. and lb) of smallmouth bass, 1958-84, are presented in Table 1. Angling effort averaged 870 hours/year (4.9 hours/acre), while the annual angling harvest of smallmouth bass averaged 234 fish (1.3/acre) and 82 lb (0.5 lb/acre), respectively. Angling effort was significantly correlated ($P < 0.01$) with both the number ($r = 0.610$) and weight ($r = 0.700$) of smallmouth bass creeled by anglers. Angling effort and harvest were similar before and after road access to Pallette Lake was closed (1958-68 vs. 1969-84).

Numbers of age I-V smallmouth bass harvested by anglers over the life spans of the 1958-79 cohorts are presented in Table 2. The 1975 cohort supported the largest harvest (508) and the 1968 cohort the smallest (27). Total CPE over the life span of each of the cohorts ranged from a high of 0.715 for the 1976 cohort to 0.053 for the 1968 cohort while mean CPE per cohort varied from 0.143 for the 1976 cohort to 0.011 for the 1968 cohort (Table 2).

Z and A averaged 1.332 and 0.709, respectively, for the 1958-79 year classes (Table 3). From these data, F was estimated at 0.751 and M was estimated at 0.581. Pope's (1972) method of cohort analysis was applied to the angling CPE for each cohort (Table 2) using these values for F and M, resulting in estimates of number of age I smallmouth bass for each cohort (Table 4). These results indicate that at age I the 1968 cohort was the poorest (179) over the time series, while the 1963 cohort was the largest (2,161).

Cohort analysis estimates of spring population size of ages III-V fish for the

Table 1. *Angling pressure and harvest of smallmouth bass in Pallette Lake, 1958-84.*

	Total Effort		Harvest of Smallmouth Bass					
Year	Angler Hours	Hours/acre	No.	No./100 hours	No./acre	Lb	Lb/100 hours	Lb/acre
1958	692	4	238	34	1.4	81	11.7	0.5
1959	915*	5	241	28	1.4	87	10.1	0.5
1960	1,561	9	265	17	1.5	59	3.8	0.3
1961	680	4	344	51	2.0	96	14.1	0.5
1962	648	4	182	28	1.0	55	8.5	0.3
1963	689	4	369	54	2.1	103	14.9	0.6
1964	472	3	200	42	1.1	62	13.1	0.4
1965	295	2	92	31	0.5	25	8.5	0.1
1966	497	3	242	49	1.4	68	13.7	0.4
1967	1,507	9	189	13	1.1	69	4.6	0.4
1968	1,313	7	215	16	1.2	96	7.3	0.5
1969	845	5	157	19	0.9	85	10.1	0.5
1970	1,224	7	153	13	0.9	81	6.6	0.5
1971	486	3	35	7	0.2	26	5.3	0.1
1972	571	3	59	10	0.3	33	5.8	0.2
1973	358	2	198	55	1.1	43	12.0	0.2
1974	425	2	190	45	1.1	65	15.3	0.4
1975	474	3	138	29	0.8	70	14.8	0.4
1976	846	5	255	30	1.4	130	15.4	0.7
1977	1,533	9	463	30	2.6	128	8.3	0.7
1978	869	5	179	21	1.0	49	5.6	0.3
1979	439	2	287	65	1.6	83	18.9	0.5
1980	844	5	245	29	1.4	89	10.5	0.5
1981	897	5	256	29	1.5	94	10.5	0.5
1982	1,008	6	279	28	1.6	111	11.0	0.6
1983	865	5	320	48	1.8	117	17.6	0.7
1984	2,530	14	528	21	3.0	207	8.2	1.2
Means								
1958-84	870	5	234	31	1.3	82	10.6	0.5
1958-68	843	5	234	33	1.3	73	10.0	0.4
1969-84**	888	5	234	30	1.3	88	11.0	0.5

* Calculated from the relationship of fishing pressure (x) vs. smallmouth angling harvest (y) for the period 1958-84 (1959 excluded). Actual fishing pressure in 1959 (4,923 hours) was unusually high resulting from an introduction of catchable-size rainbow trout that year.

** Access road closed in 1969; only walk-in or portage access was possible from 1969 through 1984.

Table 2. *Total catch at ages I-V of Pallette Lake smallmouth bass belonging to the 1958-79 year classes and angler catch-per-effort (CPE).*

Year Class	No. Caught at Age I	II	III	IV	V	I-V	Summed Age I-V CPE	Mean CPE per Cohort
1958	16	177	86	9	1	289	0.273	0.054
1959	16	246	89	39	1	391	0.568	0.114
1960	5	77	30	3	1	116	0.179	0.036
1961	7	255	76	6	1	345	0.564	0.113
1962	44	107	59	12	3	225	0.517	0.103
1963	10	23	213	91	26	363	0.608	0.122
1964	0	11	32	13	4	60	0.058	0.012
1965	1	39	35	13	2	90	0.072	0.014
1966	21	134	125	44	7	331	0.314	0.063
1967	2	12	100	11	13	138	0.144	0.029
1968	0	2	15	8	2	27	0.053	0.011
1969	0	2	30	16	9	57	0.123	0.025
1970	0	6	85	67	27	185	0.463	0.093
1971	0	93	101	53	20	267	0.634	0.127
1972	0	13	29	16	3	61	0.113	0.023
1973	0	24	133	21	0	178	0.222	0.044
1974	0	61	36	0	3	100	0.102	0.020
1975	23	376	101	8	0	508	0.406	0.081
1976	24	74	227	79	3	407	0.715	0.143
1977	3	38	54	8	1	104	0.164	0.033
1978	2	96	46	9	1	154	0.180	0.036
1979	14	196	122	12	1	345	0.371	0.074

Monitoring of harvest by anglers fishing Pallette Lake has occurred since 1946. Here 2 anglers submit their catch for inspection by clerks at Escanaba Station.

Table 3. *Catch curve estimates of total mortality for smallmouth bass belonging to the 1958-79 year classes in Pallette Lake as determined from angling catch-per-effort data over the life of each cohort.*

Year Class	Z*	A**	r[a]	Ages Included
1958	-1.165	0.688	-0.999	II-V
1959	-1.682	0.814	-0.945	II-V
1960	-1.312	0.730	-0.990	II-V
1961	-1.785	0.832	-0.981	II-V
1962	-1.518	0.781	-0.954	II-V
1963	-1.508	0.790	-0.994	III-VI
1964	-0.779	0.542	-0.982	III-VI
1965	-0.941	0.609	-0.909	II-V
1966	-1.184	0.693	-0.999	III-V
1967	-0.759	0.532	-0.878	III-V
1968	-0.613	0.457	-0.991	III-V
1969	-0.481	0.381	-0.995	III-V
1970	-1.527	0.784	-0.913	III-VI
1971	-1.336	0.738	-0.912	II-VI
1972	-1.717	0.821	-0.984	III-V
1973	—[b]	—[b]	—	—
1974	-1.029	0.643	-0.717	II-V
1975	-1.343	0.738	-0.972	II-IV
1976	-2.443	0.913	-0.977	III-V
1977	-1.535	0.785	-0.943	II-V
1978	-1.410	0.756	-0.985	II-V
1979	-1.908	0.852	-0.958	II-V
Mean	-1.332	0.709		

* Instantaneous rate of total mortality.
** Total annual mortality rate.
[a] Correlation coefficient.
[b] No estimate possible. The total harvest for this cohort was comprised of 2 ages, so no linear regression analysis of mortality rates was performed.

period 1963-79 (Table 5) were regressed against the population size at age I of the cohort produced that year (Table 4). No relationship (r = 0.117, df = 15, P > 0.05) was detected between the abundance of smallmouth bass ages III-V and the size of the cohort they produced. The average cohort analysis estimate of population size of age groups II-V and III-V from 1963-79 was 820 (4.7/acre) and 305 (1.7/acre), respectively (Table 5).

Comparing the estimated number of smallmouth bass present at age I (Table 4) with the number harvested between ages I through V (Table 2) yielded estimates of the percentage of smallmouth bass alive at age I that were harvested between ages I and V. These values averaged 23%, and varied from a low of 12.2% for the 1969 cohort to a high of 34.5% for the 1975 cohort (Table 6).

Growth

The mean lengths at age for 1,752 age II-VII smallmouth bass harvested from Pallette Lake, 1952-85, are presented in Table 7. Annual means ranged from 5.5 (age II) to 18.6 (age VII) inches. When these data for all years were pooled, mean lengths for ages II-VII were 7.0, 9.1, 11.4, 13.9, 15.9, and 18.1 inches, respectively. Mean length of the total sample was 9.0 inches. Mean annual growth increments for smallmouth bass of various ages collected from 1952-85 are presented in Table 8. The largest increment (4.9 inches) occurred in 1960 for age III fish. Each age group showed a wide range of growth increments with the broadest (4.4 inches) occurring at age III. The grand mean annual growth increments over the entire period were 2.2, 2.6, 2.9, and 2.3 inches, at ages II-V, respectively.

Simple regression analysis of the growth of smallmouth bass in Pallette Lake (Table 8) versus the estimated number of smallmouth bass of the various ages (Table 5) revealed no significant relationship (Table 9). There was a significant (P < 0.05) positive relationship between the growth of age II smallmouth bass and the mean summer water temperature, but no such relationship was documented for age III smallmouth bass.

Multiple regression analysis of summer water temperatures and abundance of smallmouth bass of various ages vs. mean annual growth increments yielded positive coefficients of correlation (r) in all 6 cases. However, none of these were significant at P < 0.05 (Table 9).

Table 4. *Number of smallmouth bass at age I determined from cohort analysis of summed angler catch-per-effort (CPE) for age I-V bass, 1958-79.*

Year Class	Cohort Analysis* No. at Age I	Summed Age I-V CPE
1958	905	0.273
1959	1,312	0.568
1960	367	0.179
1961	1,014	0.564
1962	787	0.517
1963	2,161	0.608
1964	449	0.058
1965	393	0.072
1966	1,391	0.314
1967	808	0.144
1968	179	0.053
1969	466	0.123
1970	1,346	0.463
1971	1,420	0.634
1972	351	0.113
1973	915	0.222
1974	374	0.102
1975	1,471	0.406
1976	1,857	0.715
1977	444	0.204
1978	522	0.180
1979	1,125	0.372

* Instantaneous rates of natural (M) and fishing (F) mortality used were 0.581 and 0.751, respectively.

Table 5. *Cohort analysis estimates of smallmouth bass ages II-V present each spring in Pallette Lake from 1963-79.*

	Estimated No. Smallmouth at Various Ages in Spring					
Year	II	III	IV	V	II-V	III-V
1963	562	55	56	2	675	113
1964	407	124	8	2	541	134
1965	1,201	148	12	2	1,363	162
1966	251	655	39	2	947	696
1967	219	132	207	13	571	352
1968	762	93	50	48	953	191
1969	451	326	26	18	821	370
1970	100	243	89	5	437	337
1971	261	55	61	17	394	133
1972	753	144	19	26	942	189
1973	794	417	58	5	1,274	480
1974	196	375	170	21	762	566
1975	512	100	134	45	791	279
1976	209	268	34	35	546	337
1977	806	71	51	7	935	129
1978	1,021	170	13	0	1,204	183
1979	246	515	19	7	787	541
Mean ± SD	515 ± 325	229 ± 175	62 ± 58	15 ± 15	820 ± 283	305 ± 178

Table 6. *Estimated number of smallmouth bass at age I and number and percent of year class present at age I harvested from age I-V.*

Year Class	No. at Age I*	No. Harvested from Age I-V**	Percent of Year Class Present at Age I Harvested from Age I-V
1958	905	289	31.9
1959	1,312	391	29.8
1960	367	116	31.6
1961	1,014	345	34.0
1962	787	225	28.6
1963	2,161	363	16.8
1964	449	60	13.4
1965	393	90	22.9
1966	1,391	331	23.8
1967	808	138	17.1
1968	179	27	15.1
1969	466	57	12.2
1970	1,346	185	13.7
1971	1,420	267	18.8
1972	351	61	17.4
1973	915	178	19.5
1974	374	100	26.7
1975	1,471	508	34.5
1976	1,857	407	21.9
1977	444	104	23.4
1978	522	154	29.5
1979	1,125	345	30.7
Mean $\pm$ SD	912 $\pm$ 542	216 $\pm$ 138	23.3 $\pm$ 7.2

* From Table 4.
** From Table 2.

DISCUSSION

Angling pressure on Pallette Lake, 1958-84, averaged only 870 hours/year (4.9 hours/acre/year). During 1958-66, angling pressure on nearby Nebish Lake, another lake in the Northern Highland Fishery Research Area, was over 5 times greater than on Pallette Lake. However, the harvest of smallmouth bass/100 angling hours was about 3 times greater from Pallette Lake than from Nebish Lake for the same period (Christenson et al. 1982). Therefore, even though the mean annual harvest of smallmouth bass from Nebish Lake was higher than from Pallette Lake, the angling quality as measured by the number and weight of smallmouth bass creeled/100 hours of angling was considerably better in Pallette Lake. Comparisons of the fishery in the 2 lakes after 1966 were not made because Nebish Lake was chemically treated in late fall 1966 and stocked with only 2 species, resulting in a much different fishery (Christenson et al. 1982).

Angling quality, as measured by the average length of harvested smallmouth bass, was not great, however. The mean length of harvested Pallette Lake smallmouth bass from 1952-85 was only 9.0 inches. This was slightly greater than the 8.2-inch mean from Nebish Lake (Serns 1984) during the years (1972-76) when regulations governing harvest were identical to those at Pallette Lake. Anglers were apparently willing to accept low quality smallmouth bass in both waters when given the opportunity. This is presumably part of the reason that there was a correlation between angling pressure and smallmouth bass harvest. Another reason was an artifact of the liberal regulations; anglers could, and often did, keep what they caught. Thus, if the smallmouth bass were biting, anglers kept fishing, and angling pressure increased until fish no longer were being caught.

There was little difference in angling pressure or smallmouth bass harvest for Pallette Lake during the period of road access to the lake (1958-68) and the period of walk-in access (1969-84). Angling pressure was low even when the access road was open, presumably because the road was narrow and the boat landing and parking areas were poorly developed; parking was limited by space to a maximum of only 3 vehicles with trailers. However, the lake is part of a canoe trail for the Boy Scouts of America, who begin trips from their National Canoe Base on nearby White Sand Lake, and they fished the lake at the same rate before and after access road closure. Also, since this lake has always been a popular lake to fish by wading or from the shoreline, anglers fishing in this manner continued to fish the lake after access road closure. Therefore, access road closure caused no major change in the angling clientele or angling pressure.

Angling pressures in Pallette Lake during 1987 and 1988 were nearly identical to the long-term mean, but minimum exploitation rates determined from tag returns for these years indicate that anglers harvested at least 44% and

Table 7. *Mean lengths-at-age for smallmouth bass (sexes combined) caught by anglers between ice-out and 30 June 1952-85. Sample sizes are in parentheses.*

Year Caught*	Mean Total Length (inches) at Various Ages					
	II	III	IV	V	VI	VII
1952		10.5 (6)	13.0 (1)	13.0 (16)		
1953	5.5 (108)	10.1 (53)	12.5 (38)	14.1 (6)	15.2 (12)	
1954	5.7 (4)	7.7 (31)	13.9 (7)	15.0 (1)	16.4 (1)	
1955	6.3 (21)	8.5 (9)	10.8 (4)			17.5 (1)
1956	7.0 (16)	8.9 (10)				18.6 (2)
1957	6.7 (6)	8.9 (10)				
1958	7.0 (1)	8.2 (14)	11.6 (4)			
1959	6.7 (4)	8.6 (18)	11.1 (4)			
1960	6.5 (18)	9.3 (12)	11.9 (4)	14.3 (1)	17.3 (1)	
1961	7.1 (8)	8.4 (21)	14.2 (1)			
1962	6.8 (10)	9.4 (21)	12.8 (4)			
1963	7.1 (17)	9.7 (11)	11.1 (12)	14.0 (1)		
1964	7.0 (6)	9.5 (26)	10.8 (1)			
1965		7.8 (9)	12.2 (3)			
1966		7.5 (21)	9.4 (4)			
1967	6.9 (1)	8.0 (8)	9.5 (29)			
1968	7.7 (3)	10.3 (2)	12.4 (2)	13.3 (1)		
1969	8.0 (1)	9.8 (1)	10.8 (1)			
1970	5.8 (1)	9.0 (43)	12.6 (35)	14.3 (2)	15.2 (2)	
1971				14.9 (1)		
1972		8.7 (3)	11.6 (2)	13.2 (8)		
1973		9.3 (2)	9.2 (1)			
1974			9.8 (3)	12.1 (2)		
1975			8.3 (1)		15.6 (1)	
1976	6.6 (3)	8.5 (12)	10.1 (2)			
1977	7.8 (116)	10.1 (16)	11.7 (17)	13.9 (3)	15.3 (2)	
1978	7.1 (15)	9.3 (60)				
1979		8.1 (77)	11.6 (4)			
1980	6.8 (5)	8.5 (10)	10.3 (35)			
1981	7.5 (13)	10.0 (16)	11.5 (3)			
1982	8.1 (2)	10.2 (26)	13.0 (2)	14.8 (1)		
1983	7.0 (6)	9.4 (31)	11.0 (2)		16.1 (1)	
1984	7.3 (24)	9.5 (246)	12.0 (13)	14.1 (1)		
1985	8.3 (154)	10.5 (41)	12.0 (11)			
Mean length	7.0 (563)	9.1 (866)	11.4 (252)	13.9 (48)	15.9 (20)	18.1 (3)
Standard deviation	0.7	0.9	1.4	0.8	0.8	0.8
Range of annual means	5.5-8.3	7.5-10.5	8.3-14.2	12.1-15.0	15.2-17.3	17.5-18.6

* All fish caught between ice-out and 30 June.

Table 8. *Mean annual growth increments for smallmouth bass (sexes combined) and mean summer water temperatures in Pallette Lake, 1952-84.*

Growing Season	Mean Annual Growth Increment (inches) at Various Ages					Mean Summer Water Temperature (F)
	II	III	IV	V	VI	
1952		2.0	1.1	2.2		
1953	2.2	3.8	2.5	2.3		
1954	2.8	3.1			1.1	
1955	2.6	3.3	3.1			
1956	1.9					
1957	1.5	2.7				
1958	1.6	2.9				67.7
1959	2.6	3.3	3.2			70.5
1960	1.9	4.9				68.1
1961	2.3	4.4				69.5
1962	2.9	1.7	1.2			68.5
1963	2.4	1.1				70.0
1964	0.8	2.7				68.4
1965		1.6				67.7
1966		2.0				69.2
1967	3.4	4.4	3.8			68.6
1968	2.1	0.5				68.3
1969	1.0	2.8	3.5			68.6
1970			2.3			71.2
1971						69.4
1972		0.5				68.6
1973		0.5	2.9			70.1
1974				3.5		68.5
1975						69.9
1976	3.7	3.2	3.8			70.8
1977	1.5					68.5
1978	1.0	2.3				68.6
1979		2.2				69.2
1980	3.2	3.0				
1981	2.7	3.0	3.3			
1982	1.3	0.8		1.3		
1983	2.5	2.6	3.1			
1984	3.2	2.5				
Grand mean*	2.2	2.5	2.8	2.3		
SD	0.8	1.3	0.9	0.9		
Range of mean annual increments	0.8-3.7	0.5-4.9	1.1-3.8	1.3-3.5		

* Only positive values were used to calculate the grand mean annual growth increment.

Table 9. *Linear correlation coefficients (r) for relationships between smallmouth bass (SMB) mean annual growth increments and smallmouth bass abundance and summer water temperatures.*

Variables Analyzed	Correlation Coefficient Using Mean Annual Growth Increment For: Age II-III	Age III-IV
Simple regression analysis of mean annual growth increments vs:		
No. SMB in population[b]		
Age II	-0.594	-0.575
Age III	0.009	-0.040
Age II-V	-0.519	-0.569
Age III-V	0.441	0.166
Summer water temperature[b]	0.561*	-0.011
Multiple regression analysis[a] of mean annual growth increment vs:		
Summer water temperature + no. age II-V SMB	0.695	0.598
Summer water temperature + no. age II SMB	0.733	0.643
Summer water temperature + no. age III SMB	0.662	0.042

* Significant at $P < 0.05$.
[a] Data for 1963-79.
[b] Data for 1958-79.

56% of the smallmouth bass ≥ 8.0 inches (M. Hoff, Wis. Dep. Nat. Resour., unpubl. data). These data indicate that the average angling mortality rate of only 23% estimated by cohort analysis may be an underestimate. The estimated total mortality rate of 71% for 1958-79, also leads us to believe that the actual average angling mortality rate for all cohorts combined was higher than the average of 23% estimated using cohort analysis.

Estimates of Pallette Lake smallmouth bass population sizes by age and cohort using cohort analysis may be subject to some error because of the use of the Nebish Lake smallmouth bass exploitation rate (0.400) in the calculations. Based on the 1987 and 1988 data for Pallette Lake, and our professional opinions, the true exploitation rate for smallmouth bass during the study was not markedly different from 0.400 and very likely fell within the range of 0.300-0.500. If that was the case, the true population size of a year class of smallmouth bass at any age in Pallette Lake would be within 14% of our estimates (Pope 1972).

There was no apparent relationship between the number of smallmouth bass age III and older in Pallette Lake during spring and the number of age I individuals the following spring. Similar findings have been reported for smallmouth bass in other waters (Christie 1957, Fry and Watt 1957, Serns 1982*a*). However, the lack of a stock-recruitment relationship for a given set of data may not be adequate proof that an underlying relationship is nonexistent. The analysis is confounded by the possible masking of any positive relationship between stock and recruits by the overriding impacts of other environmental and biological variables influencing year-class strength (Beddington and May 1977, Serns 1982*b*). It has, however, been well demonstrated that at some threshold level of spawner density, despite the influence of other factors, there is a direct relationship between spawners and year-class strength (Beddington and May 1977, Skud 1982). Hoff (in review) has demonstrated a significant positive relationship between number of successful smallmouth bass nests and CPE of fall young-of-year in low density populations. Therefore, the stock in the stock-recruitment relationship for smallmouth bass may well be the number of successful nests, instead of the total number of adults or the total number of a particular age category.

The mean total lengths at ages II-VI were higher in Pallette Lake than in Nebish Lake during 6 years of concurrent study (1972-77) (Serns 1984). The slower growth of smallmouth bass in Nebish Lake was probably the result of more intense intraspecific competition for food in Nebish Lake where population density was much higher. Densities of age III-V smallmouth bass in Nebish Lake, determined by mark-recapture population estimates, averaged 13.5/acre (Serns 1984) while the estimated number of age III-V smallmouth bass in Pallette Lake, as determined by cohort analysis, averaged only 1.7/acre. Thus, population density in Pallette Lake was apparently not large enough for intraspecific competition to negatively affect growth. We suspect that densities in Pallette Lake approaching those found in Nebish Lake would have caused compensatory decreases in growth rates since both lakes have similar water quality characteristics. Compensatory decreases in growth rates, condition, mean weight, and asymptotic length of Pallette Lake cisco (*Coregonus artedii*) did apparently occur, resulting from population increases when seining harvest decreased after access road closure (Hoff and Serns 1983). However, smallmouth bass were found in low densities throughout the study, while cisco in Pallette Lake were found in high densities based on CPE by fall seining.

Smallmouth bass densities may be influenced by fisheries management activities such as regulations on angling harvest. Recently (January 1989), a 12.0-inch minimum length limit was established for smallmouth bass harvested from most northern Wisconsin waters (not Pallette Lake). This regulation was established after substantial modeling efforts to determine how various size limits affect growth rates. However, the model did not account for the thresholds of densities or standing stocks that negatively affect growth in waters of various types. Therefore, we recommend evaluation of this new length limit to determine how it affects density and biomass levels in waters of various types and how these factors affect growth rates.

MANAGEMENT IMPLICATIONS

(1) Despite low angling pressure documented annually on Pallette Lake, the smallmouth bass population has been exploited at a relatively high rate (approximately 23% from cohort analysis, but empirical data on tag returns for this population indicate rates more than double this amount during 1987-88). This low angling pressure may have been so effective, in part, because no size, season, or bag limits were in effect.

(2) The mean length of smallmouth bass harvested from Pallette Lake, 1952-85, was only 9.0 inches. This indicates that most anglers accepted smallmouth bass below the 12.0-inch minimum length limit established in January 1989 for most northern Wisconsin lakes. Therefore, the effect of this new limit on sport harvest should be to increase quality in populations as well as in the creel. However, the degree of these increases may depend on population sizes of smallmouth bass and other biological variables, as well as chemical and physical lake variables.

(3) The growth of age II smallmouth bass in Pallette Lake was influenced positively by summer water temperatures. However, no relationship between adult smallmouth bass densities and growth rates was documented at the relatively low densities (average of 1.7/acre) noted throughout the study. Therefore, lakes such as Pallette Lake will benefit at least initially by the new 12.0-inch minimum length limit. However, evaluation of the effects of this regulation on northern waters is recommended.

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