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Relation of Temperature and Population Density to First-Year Recruitment and Growth of Smallmouth Bass in a Wisconsin Lake

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Abstract

The effect of air and water temperature and biological variables on the number and first-year growth of age-0 smallmouth bass *Micropterus dolomieui* in Nebish Lake, Wisconsin, during 1974–1981 was investigated. The number of young-of-the-year smallmouth bass present in fall was positively correlated with water and air temperatures during June and during the period June–August combined. Numbers of age-0 fish in fall were not significantly affected by number of adults or number of age-0 smallmouth bass in the previous year(s). First-year growth of smallmouth bass was independent of the density of the age-0 cohort but was positively related to water and air temperatures during August.

The ability to predict the relative strength of a natural year class of a species in a particular lake, or more importantly, within a certain region, would be very valuable to managers of fishery resources. Numerous authors have reported positive correlations between various air-temperature indices and year-class strength of smallmouth bass *Micropterus dolomieui* (Christie 1957; Fry and Watt 1957; Forney 1972; Clady 1975; Hurley 1975). From these studies, it was unclear whether temperatures during the first summer of life influenced the number of young-of-the-year smallmouth bass produced or air temperature during the first summer influenced the accumulation of energy reserves that determined survival during the first winter of life (Shuter et al. 1980).

The present study differs from those mentioned above because it addresses the influence of both air and water temperatures during the summer months on the natural population level of age-0 smallmouth bass in fall and smallmouth bass growth during the first summer of life. I also examine the relationship between adult population size and the number of age-0 fish in fall and the influence of the size of previous year classes on subsequent year-class strength.

Study Area

This study was conducted on Nebish Lake, a 38-hectare seepage lake with a maximum depth of 15 m located in north-central Wisconsin at latitude 46°04′ and longitude 89°35′. The lake is infertile and clear with total alkalinities of 15–19 mg/liter and secchi disc readings during the open-water months of approximately 5 m. The lake is located in the Northern Highland State Forest, and its shoreline is entirely forested.

Prior to fall 1966, the sportfish community of Nebish Lake comprised several warmwater species, most of which had been introduced (Kempinger and Christenson 1978). It was thought that originally the lake contained only three species: smallmouth bass, rock bass *Ambloplites rupestris,* and yellow perch *Perca flavescens* (Hile and Juday 1941). In October 1966, Nebish Lake was chemically treated with 1.0 mg/liter emulsifiable rotenone; subsequent test netting and electrofishing surveys indicated that all fishes had been eliminated. In spring 1967, 38 adult smallmouth bass and 33 adult yellow perch were stocked to reestablish these two species in the lake. Also in the spring of 1967, 4,500 age-0+ brown trout *Salmo trutta* and 4,500 young-of-the-year rainbow trout *Salmo gairdneri* were introduced to provide fishing for a few years until the smallmouth bass and yellow perch populations became reestablished.

Methods

Mark–recapture (Schnabel) population estimates of age-0 smallmouth bass in the fall (usually mid-September–early October) were made each year, 1974–1981, with boat-mounted electrofishing equipment. A sample of age-0 smallmouth bass was measured (total length) on the

TABLE 1.—*Nebish Lake data for age-0 and adult smallmouth bass, and air and water temperatures, 1974–1981.*

Year	Age-0 smallmouth bass: Abundance estimate	Age-0 smallmouth bass: 95% confidence interval	Age-0 smallmouth bass: Mean total length (±SD) in fall (mm)	Mean water temperature (C): Jun	Mean water temperature (C): Jul	Mean water temperature (C): Aug	Mean water temperature (C): Jun–Aug
1974	1,174	705–14,493	68.7 ± 10.4	18.0	24.3	22.5	21.6
1975	5,718	3,185–17,241	76.2 ± 6.6	19.9	24.8	23.6	22.8
1976	7,764	5,405–11,236	81.3 ± 8.6	21.9	24.4	23.4	23.2
1977	3,410	2,212–6,667	71.1 ± 7.6	20.9	24.5	20.9	22.1
1978	2,168	1,560–4,655	71.1 ± 7.6	19.1	22.0	22.1	21.1
1979	4,183	3,202–5,627	71.1 ± 7.6	18.5	24.0	22.1	21.5
1980	3,006	2,882–3,366	81.3 ± 5.0	19.9	23.8	22.5	22.1
1981	4,952	4,454–5,510	78.7 ± 7.6	20.2	24.7	23.4	22.8

Year	Mean air temperature (C), Minimum daily: Jun	Jul	Aug	Jun–Aug	Mean air temperature (C), Maximum daily: Jun	Jul	Aug	Jun–Aug	Adult (≥age III) smallmouth bass: Abundance estimate	Adult (≥age III) smallmouth bass: 95% confidence interval
1974	9.2	15.5	12.3	12.3	21.6	26.8	22.4	23.6	1,045	571–3,261
1975	12.3	15.5	13.3	13.7	23.1	27.0	24.6	24.9	420	242–1,279
1976	12.3	14.2	12.8	13.1	26.4	27.5	25.7	26.5	1,060	784–1,570
1977	10.9	15.1	10.7	12.2	21.4	25.9	20.7	22.7	1,668	1,098–2,612
1978	10.8	13.2	13.8	12.6	21.4	22.1	23.7	22.4	1,084	563–1,682
1979	9.7	14.3	12.7	12.2	22.3	25.4	22.1	23.3	1,401	1,108–1,744
1980	10.2	14.6	14.3	13.0	20.8	25.0	24.8	23.5	2,308	1,640–2,848
1981	12.7	15.3	15.6	14.5	23.6	25.9	24.8	24.8	683	543–801

first night of electrofishing to determine mean length as an indicator of first-summer growth.

Water temperatures (on the bottom in approximately 1 m of water) during the months of June, July, and August of 1974–1981 were measured with a Taylor Model 76J recording thermograph. The noon (1200 hours) temperature was selected as an indicator of daily water temperature, and mean values were determined for each month. Minimum and maximum daily air temperatures were recorded with a Taylor Model 5458 maximum–minimum self-registering thermometer at the nearby (within 400 m) Northern Highland Fishery Research Station located on the shore of Escanaba Lake.

The number of adult smallmouth bass (age III and older) was estimated by the mark–recapture Petersen Method. Fish were captured each year with fyke nets in mid–late May prior to spawning and marked with numbered FD-67 Floy dart tags. A scale sample was removed from each captured fish to determine age. Because of a compulsory creel census system, all fish caught and kept by anglers fishing Nebish Lake were returned to the research station located on nearby Escanaba Lake. These fish then were examined for tags, and a scale sample was removed for aging. In this manner, estimates of adult smallmouth bass abundance were obtained by age group.

Results

Mean water temperatures during the months of June–August combined for the years 1974–1981 were highly correlated ($r = 0.849$; $P < 0.01$) with mean maximum daily air temperatures at nearby Escanaba Lake (Table 1). There was also a positive ($r = 0.643$), although not significant ($P > 0.05$), relationship between water temperatures and minimum daily air temperatures for the same months and years.

Abundance estimates of age-0 smallmouth bass in fall ranged from 1,174 to 7,764 during the period 1974–1981 (Table 1). Significant positive correlations were found between the number of age-0 smallmouth bass in fall and water temperatures in June and during the period June–August combined for the 8-year study period (Table 2). There also were significant positive relationships of age-0 smallmouth bass numbers in fall with mean minimum and mean maximum daily air temperatures in June, and with mean maximum daily air temperatures in June–August (Table 2).

TABLE 2.—*Linear correlation coefficients for relationships between fall age-0 smallmouth bass numbers or total lengths and various water and air temperatures and fish population variables in Nebish Lake, 1974–1981. Centered subheadings are dependent variables. Coefficients with asterisks are significant at* P < *0.05* or* P < *0.01** with 6 degrees of freedom.*

Independent variable	*r*
Density of age-0 smallmouth bass	
Mean water temperature	
June–August	0.847**
June	0.745*
August	0.584
July	0.474
Mean minimum air temperature	
June	0.775*
June–August	0.507
August	0.126
July	0.029
Mean maximum air temperature	
June	0.890**
June–August	0.852**
August	0.568
July	0.536
Adult smallmouth bass (≥age III) numbers in preceding spring	−0.354
Age-0 smallmouth bass numbers in previous fall	−0.029
Mean age-0 smallmouth bass numbers in two previous falls	−0.453
Length of age-0 smallmouth bass	
Mean water temperature	
August	0.799*
June–August	0.596
June	0.386
July	0.136
Mean minimum air temperature	
August	0.724*
June–August	0.679
June	0.503
July	−0.076
Mean maximum air temperature	
August	0.949**
June–August	0.703
June	0.525
July	0.201
Age-0 smallmouth bass numbers in fall	0.580

The coefficient of determination ($r^2 = 0.74$) indicated that 74% of the variability in the number of age-0 smallmouth bass in the fall during the years 1974–1981 could be explained by summer water temperatures. Spearman's rank correlation of abundance with mean June–August water temperatures during 1974–1981 also was positive and significant ($r_s = 0.810$; df = 6; $P < 0.05$).

There was a negative, although not significant, relationship ($r = -0.354$; df = 6; $P > 0.05$) between the number of adult (age III and older) smallmouth bass in spring and the number of age-0 smallmouth bass in fall. The number of age-0 smallmouth bass present in any year was not significantly influenced by the number of age-0 smallmouth bass in either the previous year or two previous years (Table 2).

The mean water temperature and mean maximum daily air temperature during August were significantly correlated with the first-summer growth of smallmouth bass in Nebish Lake (Table 2). Homing and Pearson (1973) reported that the lower threshold for growth of juvenile smallmouth bass was between 10 and 15 C. Temperatures in Nebish Lake in mid-September 1974–1981 were usually 15 C or below, indicating that growth for the calendar year was nearly complete. Air and water temperatures during June and July or during the June–August period were not significantly related to the mean length of age-0 fish in fall. There was no significant ($P > 0.05$) relationship between numbers of age-0 fish and their mean lengths in fall (Table 2). A multiple-regression analysis of the combined influence of August water temperatures (X_1) and age-0 numbers (X_2) on age-0 length in fall (Y) yielded an R of 0.669, which was not significant at $P = 0.05$.

Discussion

This study indicates that the number of age-0 smallmouth bass present in the fall in Nebish Lake is significantly influenced by water temperatures during the first summer of their life. The June–August temperatures were most highly correlated with numbers of young-of-the-year in fall, but the temperatures during June alone also were related significantly to year-class strength. June temperatures may be important in determining year-class strength because smallmouth bass in Nebish Lake spawn in late May and early June, and egg incubation, hatching, and early fry development take place during June. Forney (1972) reported a significant positive relationship between June air temperatures and year-class strength of smallmouth bass in Oneida Lake, New York, but found no significant relationship between year-class strength and temperatures in months adjacent to June. He theorized that temperatures in June may be important in determining the availability of suitable food at a time when the fry become independent of their yolk sac as a source of nutrition. Clady (1975) also felt that warm weather during the early part of the summer (June–July) was important in producing dominant year-classes of smallmouth bass in a Michigan lake.

Other authors have reported significant positive correlations between summer air temperatures and year-class strength of smallmouth bass as represented by adults. Their work, summarized by Shuter et al. (1980), indicates that in smallmouth bass populations near the northern edge of the species' range, temperatures during the first summer of life influence recruitment of a year class to the adult stock. However, these authors did not know whether temperatures during the first summer influenced survival during that period or contributed to increased survival through the first winter of life. Clady (1975), in his study of smallmouth bass year-class strength in a northern Michigan lake, showed that year-class strength was positively correlated with air temperatures when the 1959–1966 cohort abundances were determined later in life, but not when year classes were measured at the end of the first summer during 1967–1969. Those findings made it appear that weather was important in determining survival subsequent to September of the first growing season. However, additional analyses indicated that overall below-average temperatures during 1967–1969 led to limited variability in year-class strength, and the absence of a predominant year class prevented meaningful comparisons. The present study shows that water temperatures during the first summer do positively influence year-class strength during the first summer.

In the present study there was no correlation between the size of the adult stock and the number of age-0 smallmouth bass produced. Other authors who have examined this relationship have reported similar results (Christie 1957; Watt 1959; Forney 1972). There was also no apparent effect of previous year classes on a current year class in Nebish Lake; that is, there was no indication of a large class suppressing a subsequent year class.

The first-summer growth of smallmouth bass in Nebish Lake was positively correlated with water temperatures during August but was not significantly affected by temperatures in June or July or the June–August period. Peek (1965) and Rowan (1962) reported that the rate of growth of young-of-the-year smallmouth bass depends upon both temperature and diet. They also reported that the growth rate of age-0 smallmouth bass is maximal between 25 and 29 C. In Nebish Lake, the growth of age-0 smallmouth bass may be limited by a shortage of suitable food during June and July. Young-of-the-year yellow perch may be competitors with smallmouth bass during their larval and postlarval stages and are probably too large to be potential prey later because of their earlier hatching time (May). Mean lengths of young-of-the-year yellow perch and smallmouth bass collected in seine hauls in Nebish Lake in July 1981 were similar. Also, the lack of other fish species (particularly cyprinids) may limit growth during the early to mid-summer months. By August, young smallmouth bass may be large enough to consume young-of-the-year crayfish *Orconectes propinquus* in adequate numbers so that temperature is a factor influencing growth. Authors working in lakes with several species found that growth of smallmouth bass during their first year of life was positively related to summer temperatures (MacLeod 1967; Forney 1972).

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References

CHRISTIE, W. J. 1957. The bass fishery of Lake Opeongo. Master's thesis. University of Toronto, Toronto, Canada.

CLADY, M. D. 1975. Early survival and recruitment of smallmouth bass in northern Michigan. Journal of Wildlife Management 39:194–200.

FORNEY, J. L. 1972. Biology and management of smallmouth bass in Oneida Lake, New York. New York Fish and Game Journal 19:132–154.

FRY, F. E. J., AND K. E. F. WATT. 1957. Yields of year classes of the smallmouth bass hatched in the decade of 1940 in Manitoulin Island waters. Transactions of the American Fisheries Society 85:135–143.

HILE, R., AND C. JUDAY. 1941. Bathymetric distribution of fish in lakes of the northeastern highlands, Wisconsin. Transactions of the Wisconsin Academy of Science, Arts and Letters 33:147–187.

HOMING, W. B., II, AND R. E. PEARSON. 1973. Growth temperature requirements and lower lethal temperatures for juvenile smallmouth bass (*Micropterus dolomieui*). Journal of the Fisheries Research Board of Canada 30:1226–1230.

HURLEY, G. V. 1975. The reproductive success and early growth of smallmouth bass, *Micropterus dolomieui,* Lacepède, at Baie du Dore, Lake Huron, Ontario. Master's thesis. University of Toronto, Toronto, Canada.

KEMPINGER, J. J., AND L. M. CHRISTENSON. 1978. Population estimates and standing crops of fish in Nebish Lake. Wisconsin Department of Natural Resources, Research Report 96, Madison, Wisconsin, USA.

MACLEOD, J. C. 1967. Factors affecting year class strength of smallmouth bass in the forest districts of Ontario. Ontario Department of Lands and Forests, Research Information Paper 20, Toronto, Canada.

PEEK, F. W. 1965. Growth studies of laboratory and wild population samples of smallmouth bass (*Micropterus dolomieui* Lacepède) with applications to mass marking of fish. Master's thesis. University of Arkansas, Little Rock, Arkansas, USA.

ROWAN, M. I. 1962. Effect of temperature on the growth of young-of-the-year smallmouth black bass. Master's thesis. University of Toronto, Toronto, Canada.

SHUTER, B. J., J. A. MACLEAN, F. E. J. FRY, AND H. A. REGIER. 1980. Stochastic simulation of temperature effects on first-year survival of smallmouth bass. Transactions of the American Fisheries Society 109:1–33.

WATT, K. E. F. 1959. Studies on population productivity, II. Factors governing productivity in a population of smallmouth bass. Ecological Monographs 29:367–392.