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Biology of Smallmouth Bass (*Micropterus dolomieu*) in Lake Sammamish, Washington³

Abstract

Smallmouth bass (*Micropterus dolomieu*) grew very rapidly in Lake Sammamish, with mean averages of 10.1 cm (1-year), 18.5 cm (2-year), 26.0 cm (3-year), 31.4 cm (4-year), 35.7 cm (5-year), 38.3 cm (6-year) and 41.4 cm (7-year). Most of the fish were 2- and 3-year-old bass, representing 39 and 24 percent of the total population respectively. Incremental growth was greatest between the ages of 1 and 3 and progressively decreased between the ages of 4 and 7. The growth rate exceeds that observed in most other North American waters. While crayfish (*Pastaculus leniusculus*) and sculpins (*Cottus* sp.) made up a major part of the diet in most months, migratory salmon (*Oncorhynchus* sp.) were the most important prey item in the month of May, at the peak of the salmonid outmigration. Evidence is presented to support the theory that smallmouth bass do not selectively feed on salmon but are random feeders, eating whatever prey item is available. A regression line plot of prey length versus smallmouth bass size showed a positive correlation between prey size and predator size. The preferred habitat of the smallmouth bass was characterized by a hard substrate combined with a dropoff from an overbank and the absence of aquatic vegetation.

Introduction

Because of the growing interest in smallmouth bass (*Micropterus dolomieu*) by anglers in the state of Washington, a study was undertaken to learn more about the life history of this fish in a natural lake in Washington. Research concerning this important game fish in the Northwest has been confined to the Columbia and Snake Rivers and their associated tributaries (Henderson and Foster 1956, Keating 1970, Munther 1970, Montgomery *et al.* 1980).

Lake Sammamish has a thriving stock of smallmouth bass, as evidenced by the growing number of anglers each year on the lake, which is situated in an urban setting 16 km east of Seattle. Significant game fish populations of other species exist in the lake; these include resident trout (*Salmo* sp.) and anadromous salmon (*Oncorhynchus* sp.), most of which originate in the Issaquah Creek Salmon Hatchery at the South end of the lake. The lake is used as a transportation route for the massive outmigration of smolts from the hatchery each spring and the subsequent return of adult salmon to the hatchery

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²The Unit is jointly supported by the Washington State Department of Game, the Washington State Department of Fisheries, the University of Washington, and the U.S. Fish and Wildlife Service.

³Contribution Number 653, School of Fisheries, University of Washington, Seattle, Washington.

each fall (Pflug 1981). Since one of the major concerns in transplanting smallmouth bass into new waters is their potential impact on any resident trout or anadromous salmon populations, Lake Sammamish offers a unique setting for the study of smallmouth bass biology. The objectives of this study were to provide data on the following life history parameters: age and growth; spawning and nesting areas; habitat preference; food and feeding; and impact on existing salmon and trout populations in the lake. This paper describes these various aspects of the life history of smallmouth bass in Lake Sammamish, Washington.

Materials and Methods

For this study, Lake Sammamish was subdivided into 23 littoral sections of various sizes (Fig. 1). Sectional boundaries were established where visual changes occurred in the littoral habitat type, such as a depth profile transition, presence or absence of aquatic vegetation, and littoral substrate changes.

Shoreline habitat assessments, based on identifiable physical elements, were conducted on each section of the lake. Three distinct elements were used to make these sectional assessments: (1) littoral substrate type, (2) littoral depth profile, and (3) aquatic vegetation type and density. Four distinct substrates were identified: (1) silt, (2) sand, (3) gravel (6 to 40-mm diameter), and (4) cobble (40 to 250-mm diameter). Four littoral depth profile types were: (1) shallow flats—small depth change with increasing distance from shoreline; (2) gradual slope—moderate depth change with increasing distance from shoreline; (3) drop-off from overbank—moderate slope yielding to a steep drop-off; and (4) drop-off—steep drop starting directly from the shoreline. Aquatic vegetation densities were classified visually as dense, moderate, spotty, or absent (Goodpasture 1979).

Electrofishing and angling were the two methods used for collection of smallmouth bass in Lake Sammamish since these sampling techniques have been shown to be the most effective for securing large numbers of live bass (Bennett 1970). Electroshocking was conducted nocturnally and angling occurred diurnally between March and September of both 1979 and 1980. Additional samples of smallmouth bass were obtained from organized bass tournaments that were conducted during both sampling seasons.

During the 1979 and 1980 sampling seasons the following information and samples were obtained from each of 734 smallmouth bass: (1) total length in centimeters, (2) weight in grams, (3) a scale sample taken near the base of the pectoral fin, and (4) the stomach contents extracted for identification. Corollary information taken from 695 fish (Table 3) included sections of capture and release, maturity, date, and method of capture.

Scales were soaked and cleaned in a water solution and non-regenerative scales were selected and mounted on strips of clear cellulose acetate with a heated vertical hydraulic press (Campbell and Witt 1953). The plastic slide impressions of the scales were viewed with a microfiche reader at 48 \times magnification. Age determinations were made by interpreting and counting the growth zones (annuli) that appeared on each non-regenerative scale. To determine the length of smallmouth bass at younger ages, the scale radius was measured between the mid-point of the focus and the outer margin, along the primary radii. A back calculation technique was used (June 1979), measuring the distance from the focus to each annulus on the scale to estimate the corresponding

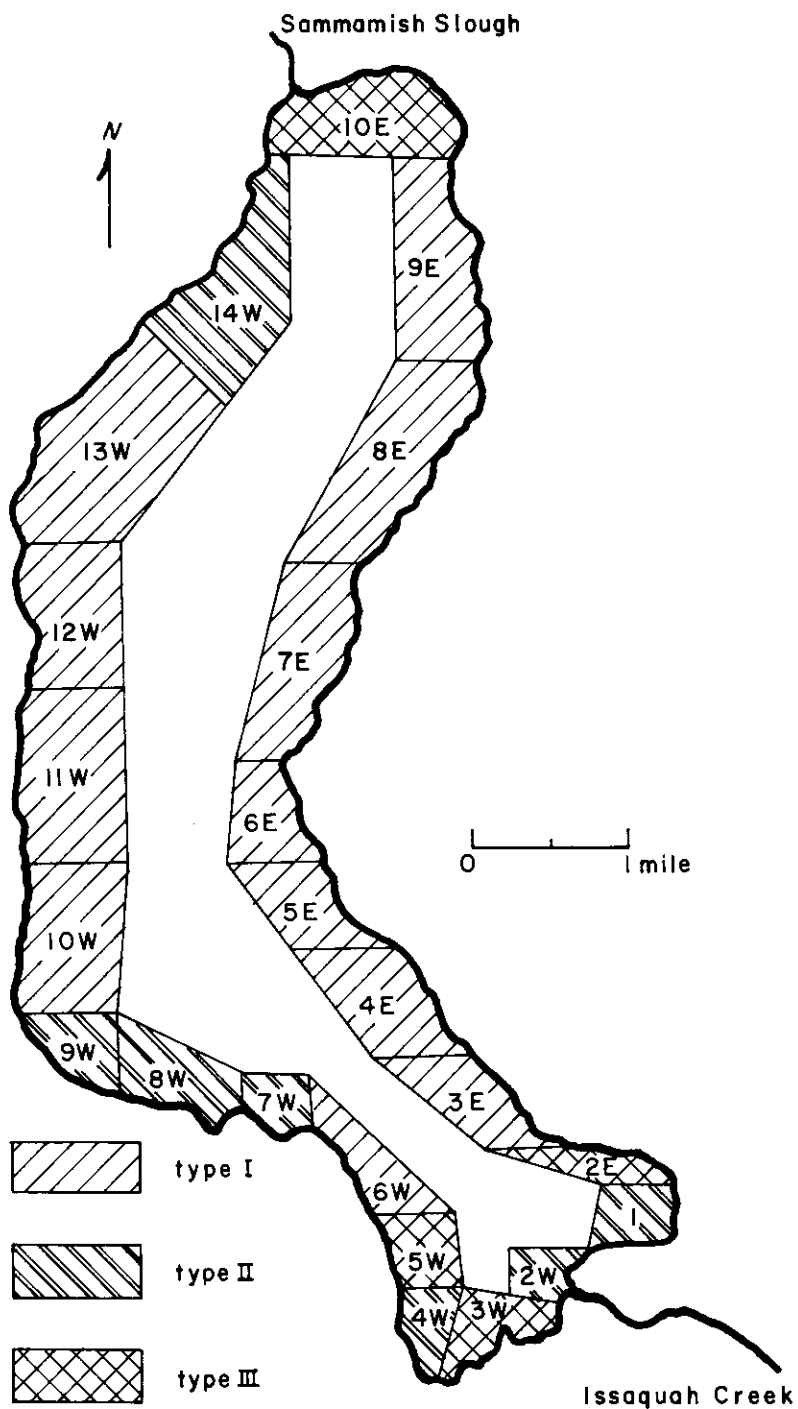


Figure 1. Map of Lake Sammamish (King County, Washington) showing the 23 lake sections used during the study with the location and distribution of the three different shoreline habitat types. (See Table 1 for an explanation of the three habitats.)

body length for that scale measurement. The body-scale relationship in smallmouth bass was linear.

The food and feeding preferences of smallmouth bass were determined through a numerical analysis in which the number of each prey type in each stomach was counted (Windell 1971). These were summed to yield a total for each food type in the entire sample, and a grand total for all items. The totals gave the representative percentage, by number, of each prey type consumed. This method also furnished data that were used to determine the seasonal variation in food types and associated feeding rates. Prey lengths (cm) were used to evaluate food size specificity for smallmouth bass age groups. As an alternative to killing smallmouth bass, a pulsed gastric lavage technique described by Foster (1977) was modified to remove all stomach contents (Pflug 1981).

Spawning surveys were conducted along the lake shoreline periodically between April and July in 1979 and 1980. Bass nest sites were counted by lake section and water depth, substrate type, and cover type were recorded for each nest. Smallmouth bass nests were distinguished visually by identifying the adult species in attendance.

Results

Age and Growth

The majority of the smallmouth bass population was composed of 2- and 3- year-old fish, representing 39 and 24 percent of the total sample, respectively (Fig. 2). Smaller percentages of the population were composed of 1-year-olds (14 percent), 4-year-olds (12 percent) and 5-year-olds (6 percent), while 6- and 7-year-olds combined represented 5 percent.

Total length ranged from 7 cm to 48 cm. The 2-year-olds, 18 to 23 cm long, clearly represented the major year class in 1979, which predictably became a major year class in 1980 as 3-year-old fish. A small year class was represented by the 3-year-old fish in 1979 and 4-year-old fish in 1980. The prominent 4-year-olds of 1979 still composed the largest group older than 3 in 1980.

The back-calculation procedures conducted on all year classes to determine lengths at various ages showed that mean total lengths increased rapidly from the 10.1-cm average for 1-year-olds to average 18.5, 26.0, 31.4, 35.7, 38.3, and 41.4-cm for each successive year class (Fig. 3). The annual growth curve for Lake Sammamish smallmouth bass in 1979-1980 combined reveals the exceptionally good growth of these fish compared to smallmouth bass in other waters of North America (Fig. 3). The length-weight relationship mode $W = aL^b$, with $b = 3.0$, demonstrates that young smallmouth bass gain additional weight but length progression is depressed (Fig. 4).

Food and Feeding Habits

Sculpins (*Cottus* sp.) were the major prey item for age one bass, although juvenile salmon and crayfish (*Pasifastacus leniusculus*) were eaten also (Table 1). Surprisingly, no aquatic insects were observed in the stomachs of yearling bass. Smallmouth bass between ages 2 and 3 fed most on sculpins, while 4- and 5-year-olds most frequently ate crayfish and juvenile salmon. Aquatic insects were most abundant in age 2 fish. Incidental prey items included zooplankton, smallmouth bass fry, sqawfish (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), and brook lamprey (*Lampetra richard-*

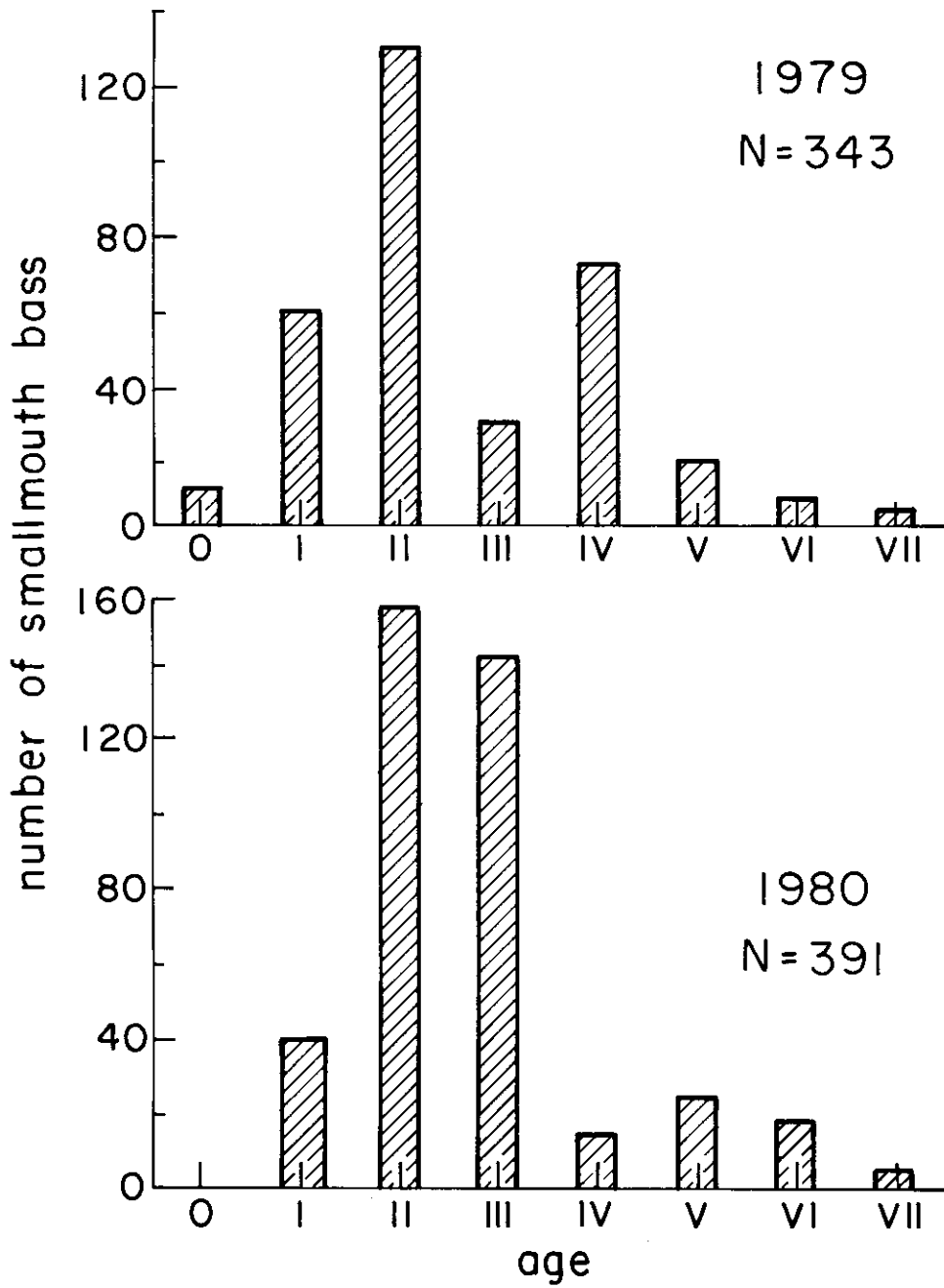


Figure 2. Age group for smallmouth bass captured during the 1979 and 1980 sampling periods.

soni). Partly digested unidentifiable fish made up a large percentage of the prey items in all age groups of smallmouth bass.

Monthly changes in the diet of smallmouth bass for April-July showed a marked

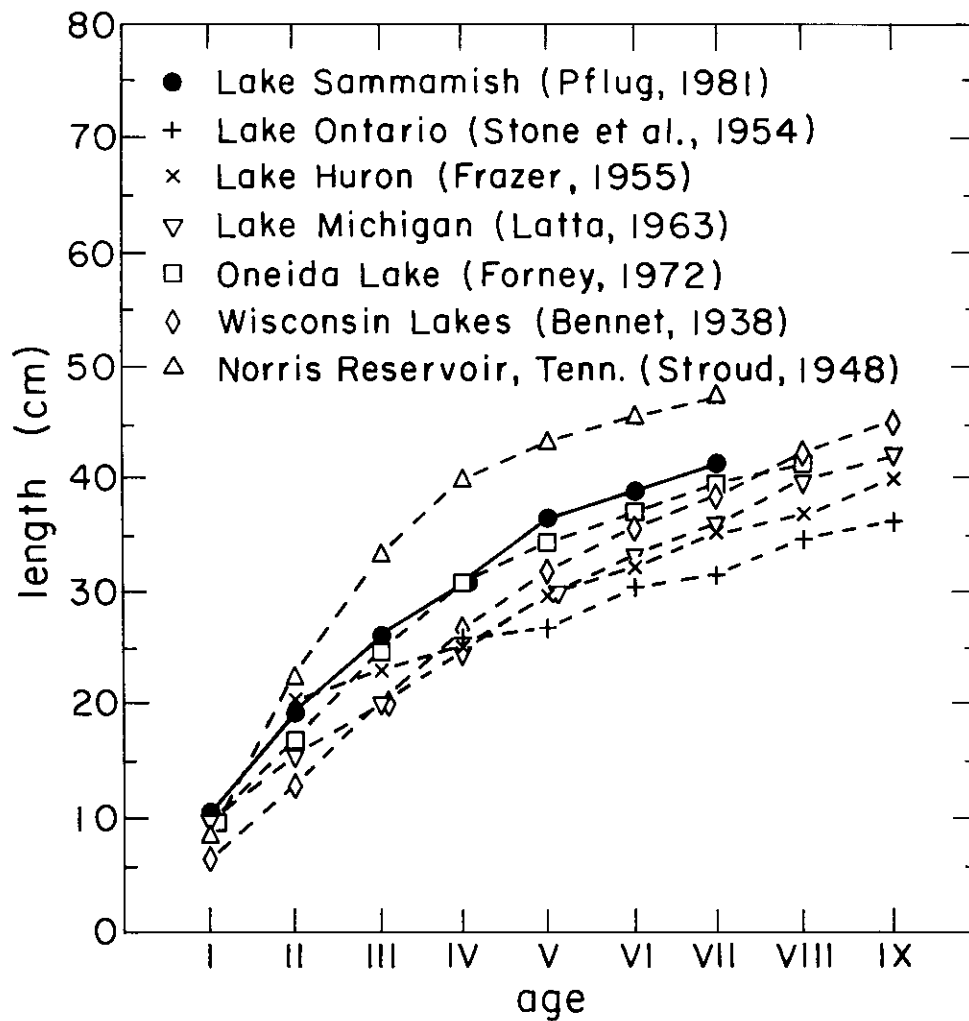


Figure 3. A comparison of growth rates from seven different populations of smallmouth bass in North America.

TABLE 1. Total prey items taken from the stomachs of each smallmouth bass age group during March-August, 1979-80.

Prey Item	Age				
	I	II	III	VI	V
Salmonid	5	42	12	20	10
Sculpin	11	67	50	15	6
Crayfish	2	44	38	24	16
Aquatic insects	0	54	13	2	0
Unidentified fish	5	47	34	16	8
Total No. stomachs examined	30	286	192	72	38
Percent empty stomachs	33%	61%	61%	64%	50%

TABLE 2. Total number of prey items counted in smallmouth bass stomachs for each month, April-July, 1979-80.

Prey items	Month			
	April	May	June	July
Salmonid	7	76	25	8
Sculpin	2	30	24	93
Crayfish	15	36	27	47
Aquatic insects	14	35	38	2
Unidentified fish	7	52	54	26
Total prey items	44	229	168	176
Total number stomachs examined	93	217	205	170
Percent empty stomachs	37%	59%	57%	72%

importance of salmon in May (Table 2). This prominence was a result of the outmigration of young salmon from the Issaquah hatchery at the south end of the lake. Crayfish and sculpins made up the majority of food items observed in July. There was a dramatic increase in feeding that occurred between April and May and continued at a high level through July (Table 2).

Prey size preference was determined by measuring the total length of the recovered prey items to the nearest centimeter. Smallmouth bass selected prey items in relation to their size, with a preference toward progressively larger prey items of all types (Fig. 5). A positive, linear relationship existed between the prey size consumed and the size of the smallmouth bass, which was best described by the linear regression function:

$$Y = 2.596 + 0.793 X$$

where, Y = size of the prey item

X = age group of the smallmouth bass

The correlation coefficient of 0.374 was significant ($P < 0.05$).

Habitat Preference

Three clearly definable shoreline habitat types exist in Lake Sammamish (Fig. 1 and Table 3). Type I habitat made up approximately 65 percent of the shoreline, which was characterized by a hard substrate, combined with a drop-off from an overbank, and the absence of aquatic vegetation. Approximately 25 percent of the littoral area available in the lake was classed as Type II habitat, characterized by sand or gravel substrate, light to dense growths of aquatic vegetation, with a gradual or moderate depth profile that terminated with steep drop-offs. Type III habitat, which made up approximately 10 percent of the littoral area, possessed moderate to dense aquatic vegetation in shallow water over silt and sand substrate, and was located exclusively at the northern and southern ends of the lake.

Smallmouth bass display a definite predilection for shoreline areas devoid of vegetation and composed of gravel and cobble that had a gradual slope with a drop-off (Table 3). The 12 areas classed as Type I produced 599 of our smallmouth bass; the 7 Type II areas yielded 85 smallmouth bass; and the 4 Type III areas produced only 11 smallmouth bass (Table 3).

Typical smallmouth bass spawning areas also were categorized as Type I habitat (Table 3). The preferred spawning substrate consisted of gravel and cobble devoid of

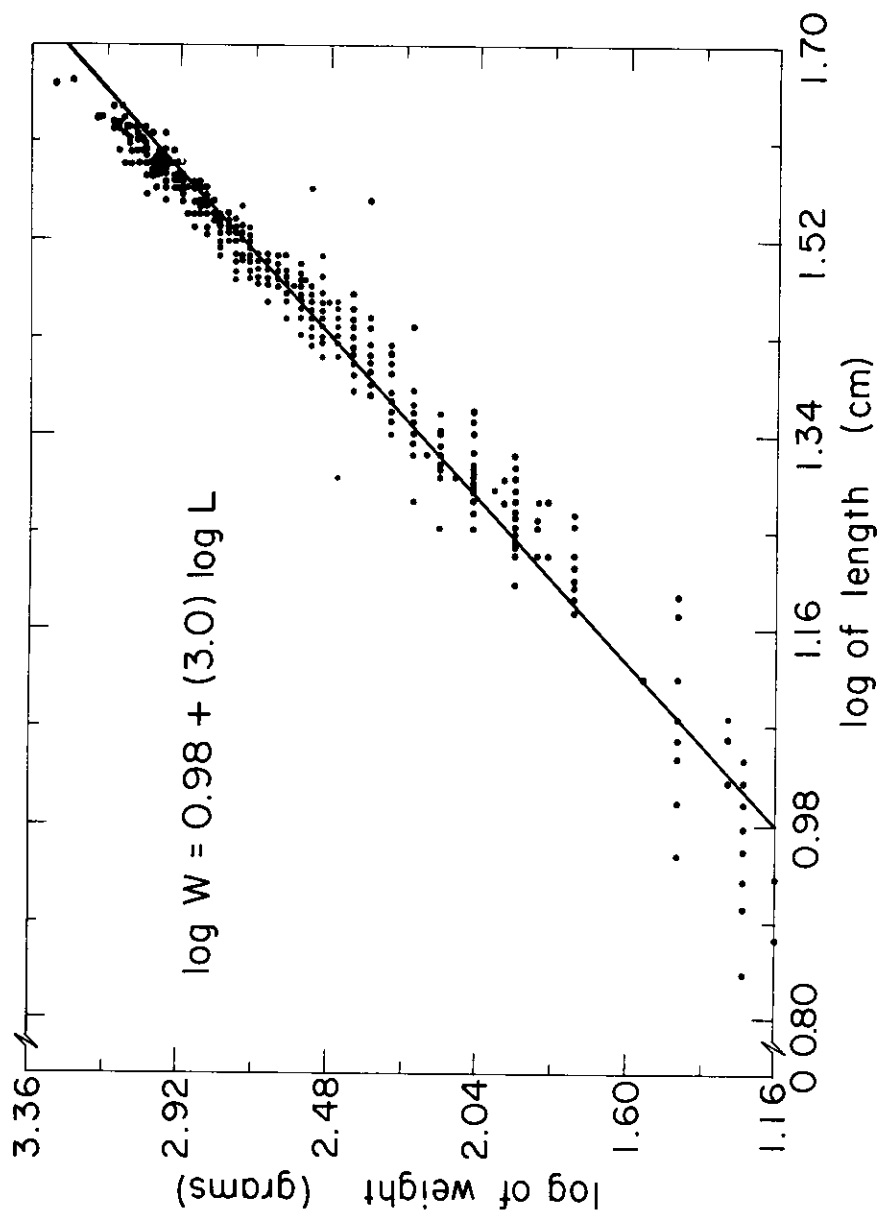


Figure 4. Length-weight relationship for smallmouth bass sampled in 1979-1980.

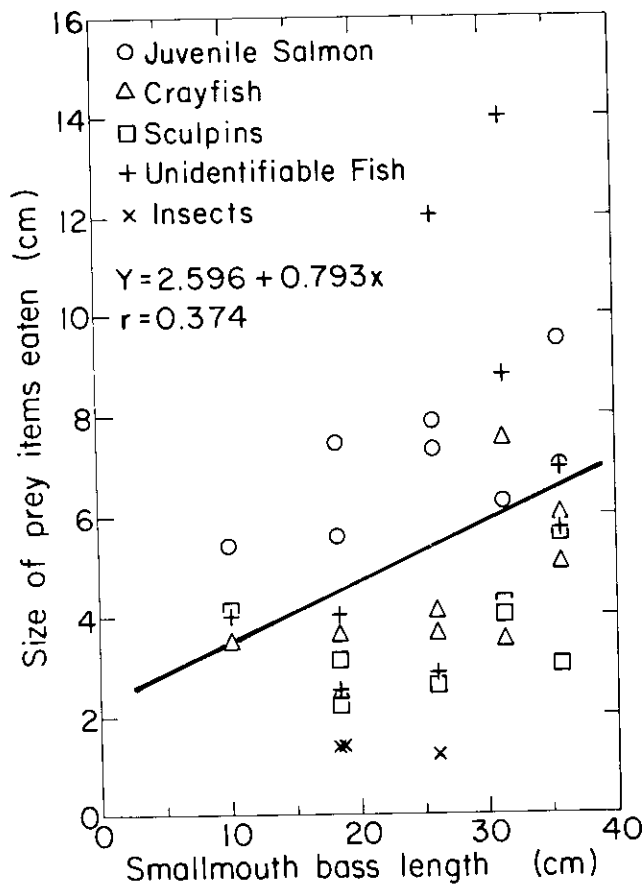


Figure 5. Relationship between the size of various prey items eaten and the size of smallmouth bass. Data points are group means of different food items observed in each age group of smallmouth bass in either 1979 or 1980.

aquatic vegetation. However, nest sites were typically associated with a benthic structure such as an isolated boulder, log, or dockpiling. Nest depths ranged from 1 to 4 meters, but most were in 1.5 to 2.5 meters of water. Counts of nest sites showed that spawning began in early May, peaked late May, and ended in mid-June. May and June surface water temperatures ranged between 13°C and 17°C. The major spawning areas of smallmouth bass were along the eastern shore of the lake from Section 3E northward to Section 9E (Fig. 1), where 125 nest sites were counted during spawning in 1979 and 1980. The western shore from Section 9W northward to Section 14W was a less important spawning area and contained 45 smallmouth bass nests during the two-year study period. Type I habitat accounted for 85 percent of the nests observed (Table 3).

Discussion

Growth rates of smallmouth bass in Lake Sammamish were exceptionally rapid when compared with growth rates reported for this species in other regions of North America (Fig. 3). Faster growth has been observed only by Stroud (1948). The rapid growth

TABLE 3. Habitat and spawning areas of smallmouth bass in Lake Sammamish during 1979 and 1980.

Section	Number of fish sampled	Number of nests counted	Substrate type	Depth profile type ¹	Aquatic vegetation density	Habitat type ²
1	20	7	sand:gravel	2	moderate	II
2E	2	0	gravel:cobble	2	moderate	III
3E	65	14	gravel:cobble	3	absent	I
4E	80	7	gravel	3	absent	I
5E	47	18	gravel:cobble	3	absent	I
6E	90	13	gravel:cobble	3	absent	I
7E	138	24	gravel:cobble	3	absent	I
8E	60	28	gravel:cobble	3	absent	I
9E	88	21	gravel:cobble	3	absent	I
10E	0	0	silt	1	dense	III
2W	20	0	sand	3	light	II
3W	9	0	silt	3	dense	III
4W	3	4	sand:gravel	1	moderate	II
5W	0	0	silt	3	dense	III
6W	8	3	gravel	3	light	I
7W	7	0	sand:gravel	2	moderate	II
8W	12	4	gravel	3	moderate	II
9W	18	7	gravel:cobble	2	light	II
10W	2	8	gravel:cobble	3	absent	I
11W	1	9	gravel:cobble	3	absent	I
12W	16	5	gravel:cobble	4	absent	I
13W	4	7	gravel:cobble	4	absent	I
14W	5	9	sand:gravel	2	moderate	II

¹Depth Profile Types: (1) Shallow flats
 (2) Gradual slope
 (3) Drop-off from overbank
 (4) Drop-off from shoreline

²Habitat Types: (I) Hard substrate, drop-off, lack aquatic vegetation.
 (II) Sand or gravel, gradual depth profile leading to a drop-off, varying aquatic vegetation.
 (III) Silt or sand, shallow depth, dense aquatic vegetation.

in Lake Sammamish is probably attributable to an excellent food supply, abundant suitable habitat, favorable water temperatures, and a presumed lack of competitive and predatory fish species (Pflug 1981). The two most important influences on growth are probably temperature and abundant food (Coble 1975). Lake Sammamish appears to have both at optimal levels.

Studies conducted on the Columbia River have shown that within this geographical area smallmouth bass sometimes attain an age of 12 years (Henderson and Foster 1956). The oldest smallmouth bass captured in Lake Sammamish had just begun its eighth growing season. The exact introduction date of smallmouth bass into the lake is unknown, but smallmouth bass did not begin to appear in angler catches until the early 1970s (Pflug 1981). Johnson and Hale (1977) observed that smallmouth bass do not reach maximum abundance until 9-15 years after introduction into new lakes. Therefore, Lake Sammamish may be 2-5 years away from its maximum potential as a producer of smallmouth bass.

Littoral water temperatures in Lake Sammamish ranged from 13°C to 25°C during the smallmouth growing season (Pflug 1981), indicating that growth occurs over a broad range of temperatures, as observed by other investigators (Coble 1967, Wrenn 1980). Although total annual growth and water temperature are probably related, it

appears that factors other than temperature are important in influencing growth in smallmouth bass, especially in older fish (Coble 1967).

In Lake Sammamish, the major prey of smallmouth bass were juvenile salmon, crayfish, and sculpins, with young smallmouth bass feeding primarily on smaller versions of the same prey types that the adults fed on, rather than different food types. Prey size and smallmouth bass size were positively correlated in Lake Sammamish. In other waters, the diet of smallmouth bass changes from small to large items, but often involves a distinct shift of food type as the fish grow larger. Often there is a progression from zooplankton to insects to small fish, finally culminating in crayfish and larger fish (Coble 1975). Guillory (1979) claimed that this shift in type of prey is due to the size of the prey selection rather than any other factors. However, this does not appear to be the case with smallmouth bass in Lake Sammamish, which showed a size preference in the prey selected at all ages with a distinct prey type preference noted only during the month of May, when migratory juvenile salmon were abundant.

Salmon are not abundant in April and July, because release from the Issaquah hatchery has not taken place yet in April, while in July outmigration from Lake Sammamish is completed. As would be expected, the number of salmon in the stomachs of smallmouth bass was lowest in April and July, and highest in May and June.

Resident trout did not appear in any of the smallmouth bass stomachs (Pflug 1981). Bass in other waters do not appear to selectively feed on trout or salmon (Lachner 1950, Stoeck and McCrimmon 1965, Warner *et al.* 1968). However, it has been shown that an influx of young salmon or trout into a body of water will yield a higher than normal predation rate by smallmouth bass (Warner 1972), largemouth bass (*Micropterus salmoides*) (Stoeck and McCrimmon 1965, Warner 1972), spotted bass (*Micropterus punctulatus*) (Axon 1971), and striped bass (*Morone saxatilis*) (Deppert 1979). Similarly, the influx of a large number of vulnerable salmon smolts into a system like Lake Sammamish should aid in accelerating predation by smallmouth bass and may be a major reason for the excellent growth of Lake Sammamish smallmouth bass.

Smallmouth bass in Lake Sammamish are apparently feeding "generalists" that follow the "numbers maximizer" feeding strategy, which assumes that the predator eats prey items as they are encountered, so that the most numerous prey in the environment should be the most numerous in the stomach (Griffiths 1975). This theory assumes that prey size and abundance are the only factors of importance to predators.

Smallmouth bass were observed spawning during the months of May and June in both 1979 and 1980, when water temperatures ranged from 13°C to 18°C in Lake Sammamish (Pflug 1981). Similar spawning temperatures were reported by Stone *et al.* (1954) from Lake Ontario. Although an occasional smallmouth bass was taken from heavily vegetated Type III habitat, smallmouth spawning nests were never observed in that type of habitat. Lake Sammamish bass utilized gravel and cobble shoreline areas devoid of aquatic vegetation for nest building sites, which usually were situated next to some isolated object such as a rock, piling, or log. This is the same situation that Voegelé (1980) observed with smallmouth bass in Bull Shoals Reservoir. Smallmouth bass spawning nests generally appear to be made in water less than 2 m deep (Watson 1965, Schneberger 1977), but deeper nests have been noted (Forney 1972, Voegelé 1980), which are considered atypical for this species and attributed to heavy wave action occurring during spawning combined with extreme water clarity. Lake Sammamish small-

mouth bass probably spawn at 2 to 4 m depths because of the extremely clear water and severe wave action created by heavy boat traffic on the lake during May and June.

Smallmouth bass in Lake Sammamish exhibited unmistakable habitat preferences for gravel and cobble substrate with access to drop-offs. Habitat of this type appears to be preferred by smallmouth bass in many areas of the United States (Munther 1970, Schneberger 1977, George and Hadley 1979, Hubert and Lackey 1980). This preference for rocky habitat is possibly thought to be due to the preference smallmouth bass have for crayfish in some areas (Munther 1970, Johnson and Hale 1977). We did not detect a distinct preference for crayfish by smallmouth bass in Lake Sammamish. Juvenile salmon frequented the littoral area of the entire lake (Pflug 1981), and sculpins were found on all substrate types without preference for gravel or rock (Richard 1980). Since salmoids, sculpins, and crayfish make up most of the diet of smallmouth bass, it appears that food items are not the major reason for the distinct smallmouth bass preference of gravel and rock in Lake Sammamish. Watson (1965) noted a strong need by smallmouth bass for gravel to spawn, and this may be the determining factor for habitat preference in Lake Sammamish since an abundant food supply exists in the rocky areas also. Smallmouth bass show an extremely strong home area tendency in Lake Sammamish (Pflug and Pauley 1983), and this may be related to the availability of adequate spawning habitat combined with an abundant and accessible food supply.

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Received June 21, 1982

Accepted for publication February 15, 1983