THE ECOLOGY OF THE SMALLMOUTH BASS AT WAUGOSHANCE POINT, LAKE MICHIGAN

WILLIAM CARL LATTA

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ABSTRACT

THE ECOLOGY OF THE SMALLMOUTH BASS, *MICROPTERUS D. DOLOMIEUI* LACÉPÈDE, AT WAUGOSHANCE POINT, LAKE MICHIGAN

By William Carl Latta

This is a study of reproduction, growth, movement, mortality rates and numerical abundance of the smallmouth bass at Waugoshance Point, Lake Michigan, 1953 through 1955. Basic data are provided for comparison with other smallmouth bass populations in Michigan's Great Lakes for the formulation of a management plan.

Male bass matured at a total length of about 10 inches, females at about 12.5 inches. During the spring of 1955, water temperatures, falling from the sixties to the fifties (°F.) after nesting had begun, caused male bass to desert many nests. The eggs were removed by some predator. Temperature fluctuations were indirectly responsible for most nest failures. Although common shiners (*Notropis cornutus*) spawned in bass nests, they were not detrimental. Carp (*Cyprinus carpio*) destroyed bass nests in a limited area only, where much silt and detritus overlaid the gravel. Fishermen were not harmful to nests. Discounting temperature-related loss of nests in 1955, there was still a nest mortality of 46 percent. Likewise, in 1954, a year in which temperatures during spawning time were stable, there was a 45 percent loss. Predation seemed to be the most likely cause of this loss of nests.

Age of the smallmouth bass was determined from the scales. Validity of the annulus was verified by recoveries of tagged fish. The annulus

1955, the same procedures indicated populations of 4,920 and 4,184 bass, respectively. Total mortality rate for 1954, using mark and recapture of fish in two successive years, was 0.58. During 1954, from an estimate of fish available to be caught and an estimated harvest, a fishing mortality rate of 0.22 was calculated. Natural mortality was 0.36. The anglers harvested an estimated 1,996 bass during the fishing season.

Karl F. Lagler
from W C Latta
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was formed each year in the period from mid-June through the third week in July. The body-scale relationship was established; growth for previous years of life was calculated. Fish from Waugoshance were growing faster than those from the Lake Ontario-St. Lawrence River region, equal to those from Cayuga Lake, New York, and slower than the bass from inland waters of Wisconsin. The numbers of fish in the 1947 and 1949 year-classes were exceptionally large. The length-weight relationship of the bass was found to be $\log W = -5.39796 + 3.35611 \log L$. Coefficients of condition (K) were higher than K values from the inland waters of Michigan and Wisconsin.

A tag was fastened on the left side of the upper jaw of each of 1,058 bass in 1953, 1,819 in 1954, and 264 in 1955. Loss of tags was estimated on the basis of recoveries of 1953 fin-clipped fish without tags. Neither the jaw tag nor clipped fin caused excessive mortality. Analyses of tag returns from nets and anglers showed little movement of bass either to, or away from, Waugoshance Point. Among the 1954 tagged bass, with an increase in size, there was an increase in distance traveled and an increase in the number of times a fish was captured in a net. In early 1954, fin-clipping and tagging were alternated in marking a group of bass captured in the nets. Anglers caught tagged bass as readily as fin-clipped ones. Tagged bass showed the same pattern of movement as fin-clipped bass.

Estimates of the numerical abundance of bass 10 inches or longer were made, using the mark-and-recapture (Petersen) method. The size of the population in the spring of 1954, estimated with trap-net recoveries, was 6,007 bass; using angler returns the estimate was 5,264 bass. In

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By

William Carl Latta

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Doctoral Committee:

Professor Karl F. Lagler, Chairman
Professor David C. Chandler
Doctor Gerald P. Cooper, Research Associate
Professor Kenneth C. McMurry
Assistant Professor Frederick E. Smith

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Dr. Karl F. Lagler, Chairman of the Department of Fisheries of the School of Natural Resources, as chairman of my doctoral committee, provided invaluable quidance throughout the study.

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INTRODUCTION

The smallmouth bass, Micropterus d. dolomieui Lacépède, is a member of the sunfish family, Centrarchidae. This family, which includes such fishes as the largemouth bass (Micropterus salmoides), rock bass (Ambloplites rupestris), and the bluegill (Lepomis macrochirus), undoubtedly contributes more fish to the creel of the angler than any other group of freshwater fishes. The smallmouth bass, one of the better-known members of the family, is noted for its angling qualities. As early as 1881 this bass was being lauded as "the gamest fish that swims" (Henshall, 1881).

In the past, the smallmouth bass was distributed "from Quebec to northern Minnesota and south to eastern Oklahoma and the Tennessee River drainage" (Hubbs and Bailey, 1938). These authors stated, further, that the species, in all probability, did not live originally in the Atlantic coastal rivers. The Hudson valley was invaded by the smallmouth bass when the Erie Canal opened in 1825 and it was soon introduced widely throughout the New England and Middle Atlantic states. It has since been distributed in waters all over North America and the world.

For many years, sport fishermen have known of areas of smallmouth bass fishing in the Great Lakes, but it was only in 1947 that they discovered the bass population of Waugoshance Point, Lake Michigan. Waugoshance Point is part of a wilderness area appropriately proclaimed Wilderness State Park by the state of Michigan. The area of the Point was, for practical purposes, without a road in 1946, and only a few of the native sport and commercial fishermen knew of the large concentration of bass. The road was improved in 1947 and the rush of anglers started. Tales claim that everyone caught a legal limit of five bass, and that the fish ranged in weight from 1 to 6 pounds. The aspects of wading the shore waters of the Great Lakes, like surf fishermen in the ocean, and of catching many bass, apparently captured the imagination of both sportsmen and outdoor writers. There was, and still is, much publicity about wading for smallmouth bass in the waters of the Great Lakes. Bass fishing today at Waugoshance Point does not compare with the fishing tales from the recent past.

The interest shown by the anglers for bass fishing in the Great Lakes prompted the Michigan Department of Conservation, through the Institute for Fisheries Research, to sponsor this study of the ecology of the smallmouth bass of Waugoshance Point. The investigation was concerned with reproduction, growth, movement, mortality rates and numerical abundance. With some of the basic information available for comparison with future data from other smallmouth bass populations in Michigan's Great Lakes, it is hoped that a management plan can be formulated for the best use of the smallmouth bass resource.

The study area was restricted to Waugoshance and neighboring areas in northern Lake Michigan (Figure 1). Waugoshance Point is located at the northern tip of the lower peninsula of Michigan; it extends westward for about 3 miles into Lake Michigan, and for most of its length it is less than a half mile wide. Just beyond the end of the Point, a series of islands extends further westward for approximately 2 1/2 miles. The first few islands are low, sandy and sparsely wooded, and are grouped together on most maps as a single island, Temperance. Following these is the largest island--over a mile long and heavily wooded--called Crane or Waugoshance. This is the extent of land until the Beaver Islands are reached, some 20 miles further west in Lake Michigan. Hog Island (Figure 1) is one of the

Figure 1. Waugoshance Point and neighboring areas in northern Lake Michigan, including Hog Island, one of the Beaver Islands. The trap net locations, other than those at Waugoshance Point, are shown.

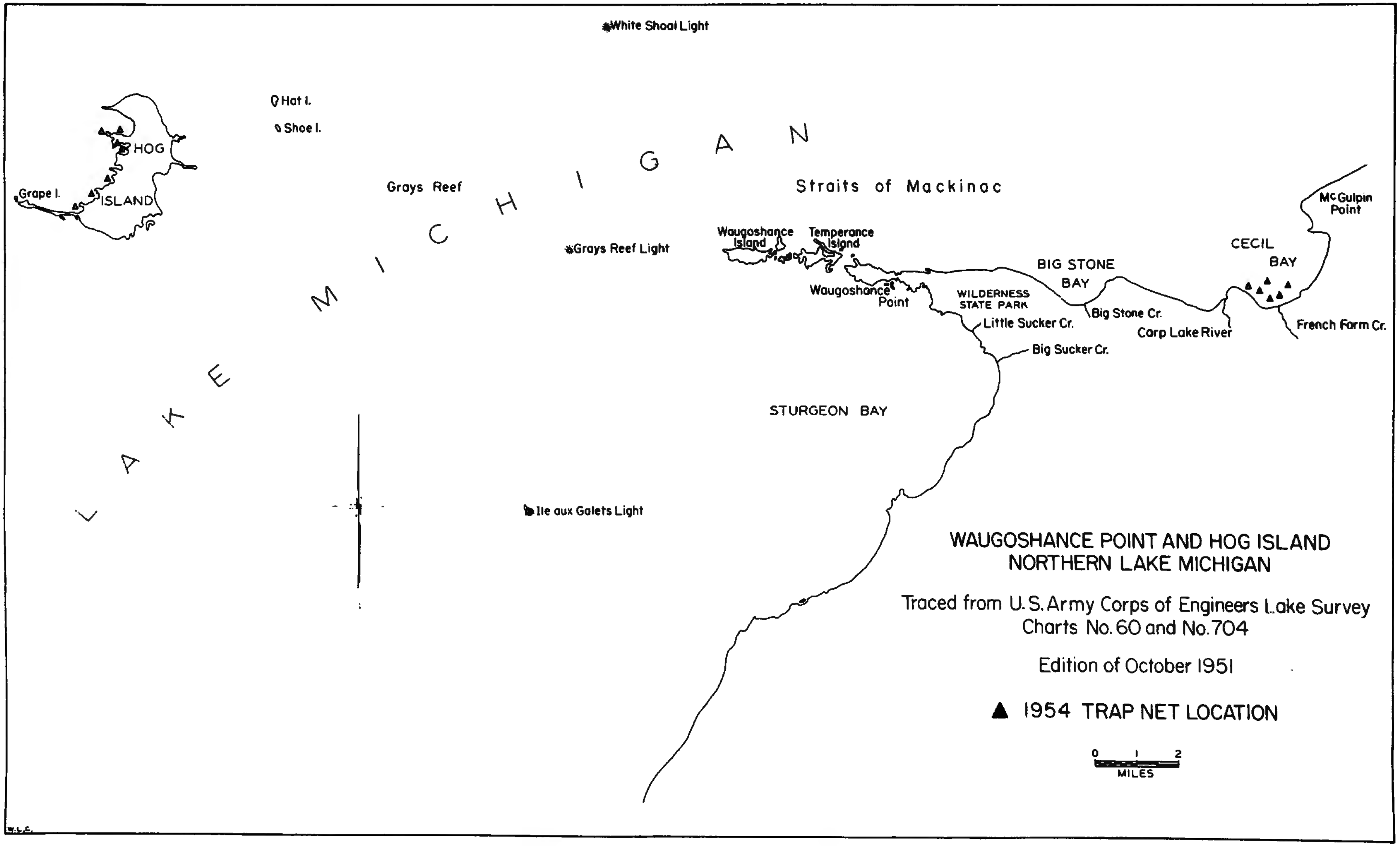
White Shoal Light
Hat I.
Shoe I.
HOG
ISLAND
Grape I.
Grays Reef
LAKE MICHIGAN
Straits of Mackinac
Grays Reef Light
Waugoshance Island
Temperance Island
Waugoshance Point
WILDERNESS STATE PARK
BIG STONE BAY
Big Stone Cr.
Little Sucker Cr.
Big Sucker Cr.
Carp Lake River
CECIL BAY
McGulpin Point
French Farm Cr.
STURGEON BAY
Ile aux Galets Light
WAUGOSHANCE POINT AND HOG ISLAND
NORTHERN LAKE MICHIGAN
Traced from U.S. Army Corps of Engineers Lake Survey
Charts No. 60 and No. 704
Edition of October 1951
1954 TRAP NET LOCATION
0 1 2
MILES

Fig. 1

Beaver Islands. Waugoshance Point lies between Sturgeon Bay to the south and the Straits of Mackinac to the north. Four miles eastward along the north shore is Big Stone Bay and 6 miles further, Cecil Bay. Both were involved in the study.

Most of the north shore of Waugoshance Point is wave-swept beach. In contrast, the south shore is very irregular and well protected from wave action by a series of rocky shoals, which lie as far as a mile off shore. The entire area was heavily glaciated. The Bois Blanc formation from the Lower or Middle Devonian, composed of interbedded chert and dolomite, and limestone, underlies the glacial and recent deposits (Ehlers, 1945). The bottom materials are sand, gravel and rubble, with silt, marl and detritus overlying these in the backwaters.

The water is clear, with the bottom easily visible at 15 feet. Water temperatures of the shallows follow closely the air temperatures, but the temperatures of the open water of the lake seldom exceed 70° F. during the summer.

In the protected bays, the aquatic plants _Scirpus_ spp. and _Phragmites communis_ are the most common.

Fishes commonly associated with smallmouth bass in trap nets were the rock bass, yellow perch (_Perca flavescens_), brown bullhead (_Ictalurus nebulosus_), common sucker (_Catostomus commersoni_) and northern pike (_Esox lucius_). The rock bass was the most abundant of these.

The bass were captured with trap nets of the same design, but of smaller dimensions, than those used by commercial fishermen on the Great Lakes. The leads were 150 feet by 3 feet and the single pot 5 feet by 8 feet by 3 feet. Cooper and Latta (1954) described the net in detail. These nets were excellent for fishing in the rocky, shallow waters of Waugoshance Point. The Department of Corrections at Southern Michigan State Prison, through the Corrections Conservation Camp Program, provided inmate help for trap netting and other field work.

The field work fell into three categories: (1) capture of fish; (2) census of anglers and their catch; and (3) direct observation of the spawning behavior of bass. The spawning observations were made during the spring of 1954 and 1955. The census effort was interspersed among other activities during the 3 years. Most of the bass were captured with trap nets, but some were also taken with seine, rod, and fish toxicant. In 1953, the netting at Waugoshance Point started on July 7 and continued until September 2, for a total of 222 trap-net lifts. The usual procedure was to lift each net every day, but there were occasions when this was impossible. The greatest length of time between lifts was 6 days; this occurred once in 1954. The netting in 1954 (397 trap-net lifts) extended from May 27 to October 14, with a few short interruptions. In 1954, trap nets were set at Cecil Bay (34 trap-net lifts) and Hog Island (21 trap-net lifts), neighboring localities of Waugoshance Point. In 1955, there were only 61 trap-net lifts during a short netting period between May 17 and June 3. Figure 1 shows trap-net sites at the neighboring localities, and Figure 2 shows all of the sites at Waugoshance Point.

Almost every bass captured was tagged, a sample of scales was taken, and the total length was measured to the nearest 0.1 inch. Selected fish were also measured for standard length; some were weighed in ounces or grams, and the sex of some of the fish was determined. Anglers, interviewed during the creel census, provided many of the fish examined. Methods will be treated in more detail in each section.

Figure 2. Waugoshance Point and adjacent islands, in northern Lake Michigan, with the trap net locations for 1953, 1954 and 1955.

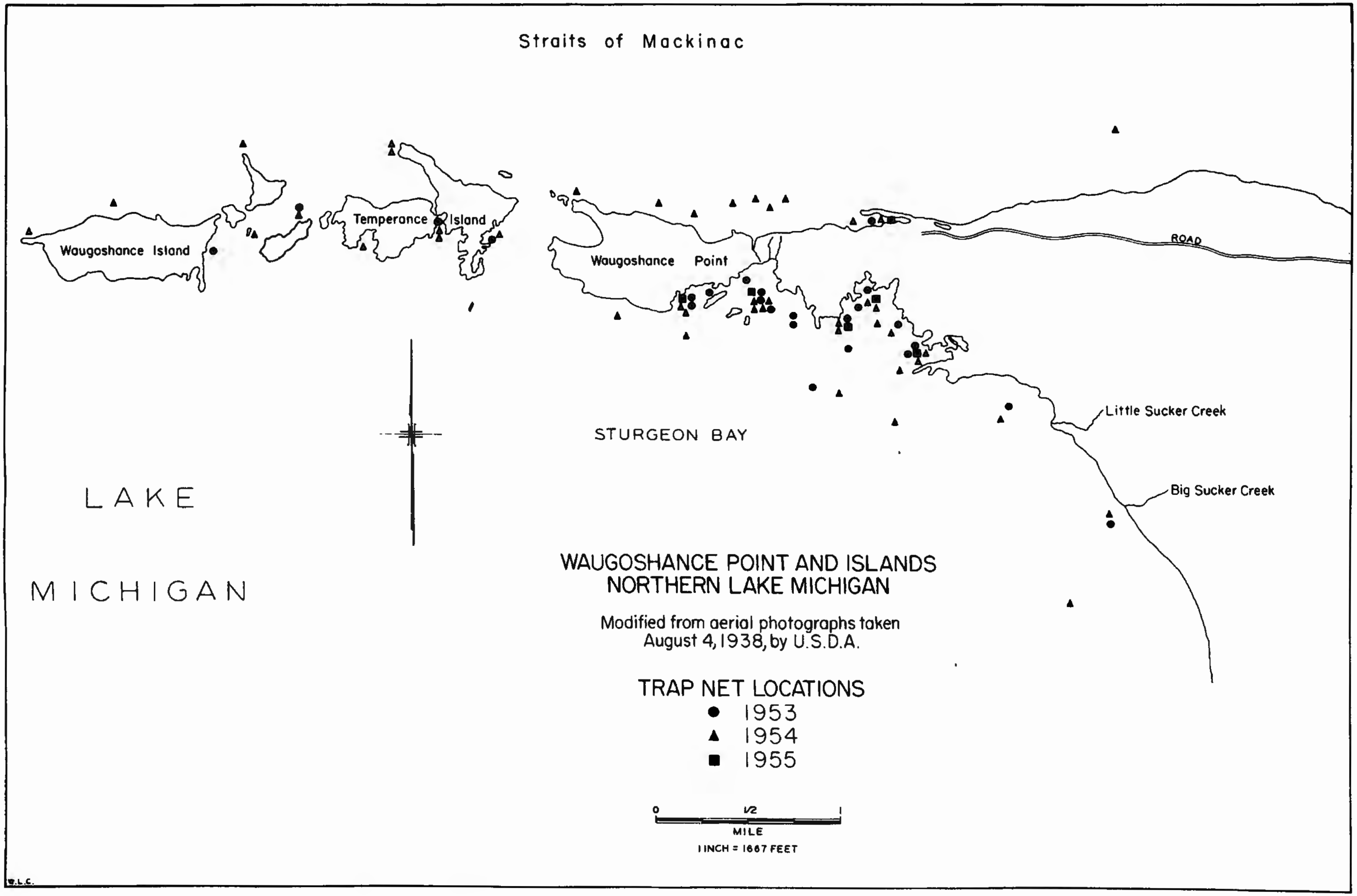
Straits of Mackinac
Waugoshance Island
Temperance Island
Waugoshance Point
ROAD
Little Sucker Creek
Big Sucker Creek
STURGEON BAY
LAKE
MICHIGAN
WAUGOSHANCE POINT AND ISLANDS
NORTHERN LAKE MICHIGAN
Modified from aerial photographs taken
August 4, 1938, by U.S.D.A.
TRAP NET LOCATIONS
● 1953
▲ 1954
■ 1955
0 1/2 1
MILE
1 INCH = 1667 FEET
W.L.C.

Fig. 2

REPRODUCTION

Age and Size at Maturity

At Waugoshance Point, all of the male bass were sexually mature at the age of 5 years (average total length 10.9 inches) and all females at 7 years (average total length 14.2 inches) (Table 1). Mature were 84 percent of all males in age-group IV (average total length 9.9 inches) and 65 percent of the females in age-group VI (average total length 12.5 inches). Some of the fastest-growing male bass reached maturity at 3 years (10.2 inches) and the fastest-growing females at 4 years (12.8 inches).

A safe generalization would be that the males attained maturity at about 10 inches, whereas females did not do so until about 12.5 inches.

Two year-classes, the 1947 and 1949, were dominant. The 1949 year-class was represented by 26 of the 31 male bass in age-group IV and, likewise, by 95 of the 100 specimens in age-group V of the male category (Table 1). This was also true for the female category in age-groups IV and V, but age-group VI was represented almost equally by the 1949 year-class (30 individuals) and the 1947 year-class (28 individuals). In age-group VII, 12 of 14 specimens were from the 1947 year-class. There was evidence that the fish of most of the year-classes grew very slowly in 1950 and 1951. This meant that the average empirical lengths listed were slightly less than might be expected in comparison with growth for previous years. Otherwise it is felt that the sampling methods were not overly biased and that the total lengths are typical of the Waugoshance population.

Table 1.--Age and size of the smallmouth bass at maturity, Waugoshance Point, Lake Michigan, 1953-1955

Age-group	Stage of maturity	Number	Average total length, in inches	Standard deviation
Males				
III	Immature	7	8.8	0.66
	Mature	2	10.2	0.00
IV	Immature	5	9.2	0.62
	Mature	26	9.9	0.79
V	Immature	...	...	...
	Mature	100	10.9	0.93
Females				
IV	Immature	18	9.4	1.16
	Mature	2	12.8	0.71
V	Immature	60	10.8	0.77
	Mature	14	12.7	0.74
VI	Immature	22	11.5	0.85
	Mature	41	12.5	1.04
VII	Immature	...	...	...
	Mature	14	14.2	1.46

In the Lake Ontario-St. Lawrence River region, male smallmouth bass reached maturity at the end of the fourth year of life, and nearly all were mature by the time they were 6 years old (Stone, Pasko and Roecker, 1954). On the basis of the average total lengths for all localities of this region, these bass were 10.3 inches in their fourth year and all were mature by 11.9 inches. The females began to reach maturity at the end of the fifth year (10.9 inches) but did not all mature until about 8 or 9 years of age (between 13.7 and 14.4 inches).

Fraser (1955), working on the smallmouth bass in South Bay, Lake Huron, found in the anglers' catch that 50 percent of the males in age-group III were mature. All had reached maturity by their sixth year. Using average fork lengths for each age-group, as cited in Table III of Fraser's paper, the fish in age-group III were 9.2 inches and in age-group VI, 12.8 inches. Approximately half of the females reached maturity at age IV (10.4 inches) and all were mature at age VI (12.8 inches). Again, these average lengths for the age-groups do not indicate that it is the fastest-growing individuals that reach maturity first.

In Cayuga Lake, a large oligotrophic lake in New York, the males of the smallmouth bass reached maturity at ages III and IV, and the females, at ages IV and V (Webster, 1954). All males older than II+ (the + indicates the fish were taken at the end of the third growing season) were adults. The mature individuals in the II+ group averaged 9.2 inches total length. About 13 percent of the females were mature at III+ (11.8 inches), 62 percent at IV+ (12.4 inches) and nearly all at V+.

Sex Ratio

As might be expected, the proportion of males and females of the smallmouth bass varied among samples. The sex ratio during the census of the anglers' catch was 109 males to 120 females (Table 2). A Chi-square test (0.53) did not indicate a significant departure from a 1:1 ratio of males to females. The fish ranged from 9.4 to 17.3 inches total length.

Sex was determined for 157 bass taken in trap nets during the 3 years; 143 of them were captured in 1954. These fish ranged in size from 6.5 inches to 18.6 inches. The ratio in the total catch of 89 males to 68 females reflects the early maturity of the males in comparison to the females. The males of the dominant 1949 year-class entered the spawning group in large numbers in 1954. Apparently the immature females come into the spawning area later than the earlier maturing males of the year-class. Netting during the early part of the season showed a ratio of 47 males to 18 females (Table 3). The ratio of mature males to mature females approached 4 to 1 (45 to 12). In the nets, after the spawning movement to the shallows was finished, the ratio was again 1:1 as the figures 36 to 42 indicated (Chi-square 0.46).

Data on sex ratio of bass from the anglers' catch, from the trap nets (excluding the early season netting of 1954) and from 29 other specimens (for the most part sublegal bass collected by angling) were combined by age-groups (Table 4). Age-groups IV and V seemed to have a preponderance of males; age-group VI had many more females; age-group VII had twice as many males as females, but the other age-groups showed

Table 2.--Sex ratio of smallmouth bass taken by anglers, Waugoshance Point, Lake Michigan, 1953-1955

Year	Number of specimens			
	Male		Female	
	Mature	Immature	Mature	Immature
1953	29	2	25	15
1954	54	1	7	37
1955	22	1	19	17
	105	4	51	69
Total	109		120	

Table 3.--Sex ratio of smallmouth bass in trap-net catches, for pre-spawning and post-spawning periods, Waugoshance Point, Lake Michigan, 1954

Period	Number of specimens			
	Male		Female	
	Mature	Immature	Mature	Immature
May 27 - June 14	45	2	12	6
Total	47		18	
June 16 - October 7	29	7	14	28
Total	36		42	

Table 4.--Sex ratio of smallmouth bass for each age-group, from all collections, excluding the fish taken during the 1954 spawning movement, Waugoshance Point, Lake Michigan

Age-group	Number of specimens	
	Male	Female
I	1	...
II	13	10
III	6	6
IV	32	19
V	79	67
VI	21	63
VII	12	6
VIII	2	3
IX	1	1
X	1	1
XI	...	2
Total	168	178

no apparent differences for the few individuals involved. The totals were a 1:1 ratio (Chi-square 0.29). There seemed to be no predictable relationship between age-group and sex ratio. The variations can probably be attributed to sampling errors.

Doan (1940) also had a 1:1 ratio for all age-groups of the smallmouth bass collected in western Lake Erie in 1938. In the Lake Ontario-St. Lawrence River region, Stone, Pasko and Roecker (1954) found, in trap-net samples taken during the spawning runs, a tendency for the earlier-maturing males to be predominant among the younger fish, and the females among the older fish. The ratio was about 1:1 for fish of intermediate age. There was a significant departure from a 1:1 ratio, in the direction of the females, in age-groups IV and V of the angler-caught bass from Cayuga Lake, but no trend in this direction among the older age-groups. Neither did the younger age-groups deviate from the 1:1 ratio (Webster, 1954). Fraser (1955), in examining the anglers' catch over a period of 6 years (1,495 bass), found 49.2 percent males in South Bay, Lake Huron.

Time of Spawning

In 1954 and 1955, nesting activities began when the water temperatures, in degrees Fahrenheit, rose from the fifties to the sixties; Rawson (1945) and Langlois (1932) also found this temperature relationship. Figures 3 and 4 are graphs of the daily mean water temperatures, as recorded from maximum-minimum thermometers, each year during the spawning season at Waugoshance Point. The thermometer was placed on a stake, located on the spawning grounds, in 4 feet of water; the thermometer was midway between the bottom and the surface.

Figure 3. Daily mean water temperatures (°F.), as recorded from a maximum-minimum thermometer, during the 1954 spawning season.

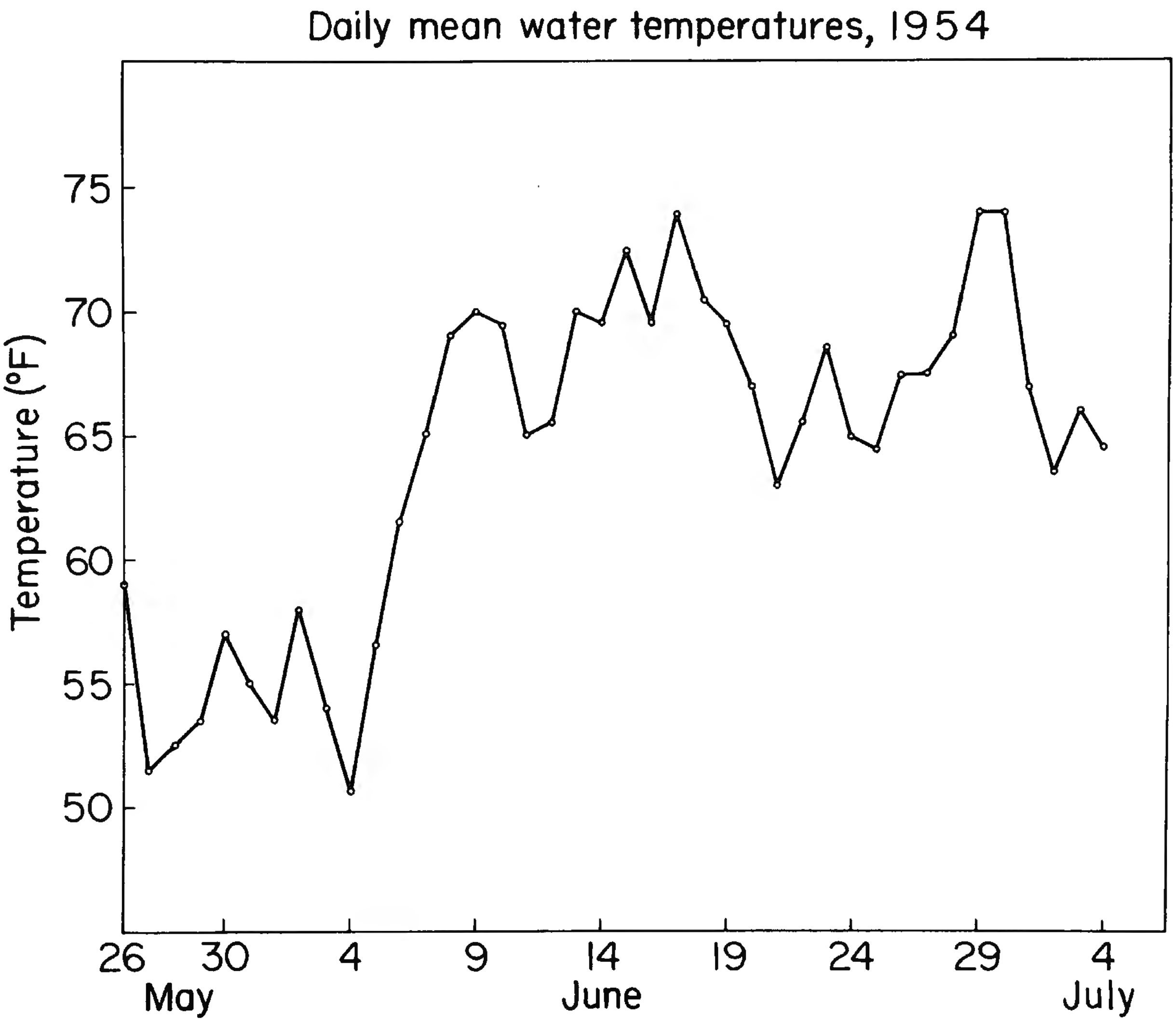
Daily mean water temperatures, 1954
Temperature (°F)
75
70
65
60
55
50
26
30
4
9
14
19
24
29
4
May
June
July

Fig. 3

Figure 4. Daily mean water temperatures (°F.), as recorded from a maximum-minimum thermometer, during the 1955 spawning season.

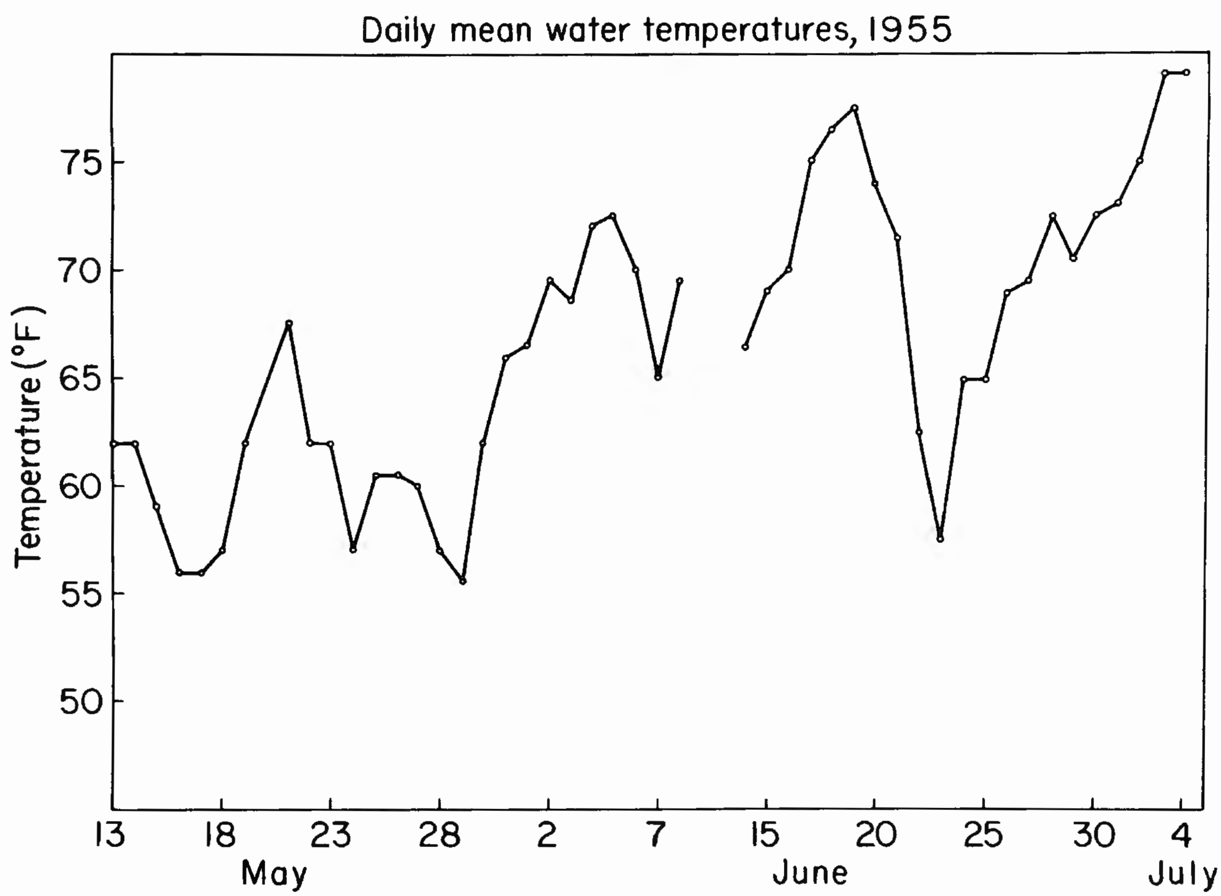
Daily mean water temperatures, 1955
Temperature (°F)
75
70
65
60
55
50
13
18
23
28
2
7
15
20
25
30
4
May
June
July

Fig. 4

In 1954, nesting started intensively on June 7, at a mean water temperature of 65° F. (Figure 3). On June 4 the mean temperature was only 50° and previously all were below 60°, but they started to rise on the 5th of June and reached a high of 70° on the 9th. They continued to remain well above 60° throughout the spawning season.

In 1955, an early spring with varying temperatures was the cause of at least two waves of spawning failure. Nests were found first on May 13, when the mean water temperature was at 62° F. (The maximum-minimum thermometers were installed too late to record the initial rise). There was then a drop in the temperature to 56°, another rise, this time to 68°, and another drop to 56°, before the final rise to the low seventies and the continuation of mean temperatures mostly above 65° (Figure 4). While the temperatures were in the fifties, many nests were deserted by the guardian males, with the resultant loss of the eggs to predators, until the start of the successful spawning on June 1, which coincided with the last rise in temperature. There will be a more detailed discussion of the effect of temperature on nesting in the section dealing with factors influencing nesting success.

Description of Nests

The typical nest of the smallmouth bass at Waugoshance Point was built on gravel and rubble, in a protected bay, at a water depth of 2 feet and with an excavation diameter of 1 1/2 feet. Dead aquatic plants, their stems and/or roots, or small boulders often provided the only protection to the nest. In the shallows there was a scarcity of large stones or logs to provide nest shelter on one or more sides, such as described by Reighard (1905), Tester (1930) and Cleary (1956).

The average depth of water measured at 17 nests was 25 inches, with a range of 15 to 44 inches. The average diameter, from measurements of 15 nests, was 19 inches; the range 12 to 24 inches. Although the predominant nesting materials were gravel and rubble, the exception was a combination of sand and the rootlets of aquatic plants.

Bensley (1915) described nests in Georgian Bay, Lake Huron, as 15 to 20 inches in diameter, the bottoms of rocks or pebbles, but more often of the short stems of the aquatic plant Eriocaulon. Lydell (1926), an early smallmouth-bass culturist, got the best results with nest sites in about 2 feet of water. Tester (1930) found nests in Lake Nipissing in 3 to 4 feet of water. Greeley and Bishop (1932) found nests in Morristown Bay, St. Lawrence River, on "areas of sticks cleared of muck and duckweed." One nest of this type was 20 inches in diameter and at a depth of 18 inches. Also, a nest cleared on bare rock was found, in addition to the usual nest of gravel. Breder (1936) reported smallmouth bass nesting in depths greater than 12 feet. Doan (1940), in Mitchell's Bay, Lake St. Clair, found the smallmouth bass nesting on sand. There were no other bottom materials available and apparently very little cover to provide protection for the nests. Doan stated, "Living reeds served to outline and define the nest boundaries, but did not give substantial protection from wave action or enemies." The nests were in 2 to 3 feet of water; had an average diameter of 18 inches and a central depth of 3 1/2 inches. In contrast, he observed nests at Georgian Bay to be at an average depth of only 18 inches and to have a diameter of 14 inches, a depth of 1 3/4 inches, with a bottom of gravel. Surber (1943), working on smallmouth bass in rivers, located nests in 2 to 3 feet of water. The average depth decreased as the season progressed, e.g., a drop from 27.5 inches to 18.5 inches in the South Branch of the Potomac River. He also found a few nests on bed rock. Latta (1954) found nests built on the rootlets of aquatic plants on the St. Clair Flats, northwest of Mitchell's Bay, Lake St. Clair. Stone, Pasko and Roecker (1954) described the nests in Miller Bay, St. Lawrence River, as being 1 1/2 to 2 1/2 feet in diameter, on a gravel bottom, at depths ranging from 1 1/2 to 3 feet. Cleary (1956) observed nests in Iowa streams that were usually constructed over rubble, but nests over bedrock were not uncommon. Most were in water less than 30 inches deep, in places where the current was at a minimum. Overhead cover and obstructions in the form of stumps, logs, stones or cuts in the banks were sought. Nests were usually on the downstream side of these obstructions.

Apparently the over-all preferred nesting site is in about 2 feet of water, with some adjacent cover, and a bottom of gravel. But a variety of other sites are used. In contradiction to the apparent preference, at Waugoshance Point, ideal nesting sites which superficially had all of the desired requirements were left vacant, while nests were built on rootlets or fanned down through a silty bottom to gravel. It was not the desire for cover that prompted these nests, for this is at a minimum at Waugoshance Point, and the nests built on poor bottom materials were not characterized by having cover. The nesting sites were usually, however, in the most protected waters, the back parts of the shallow, almost enclosed, bays. The tentative explanation is that the bass seek the quieter, perhaps warmer, waters first and use the best sites there, even if some are second-rate.

Spawning

The complete spawning act, or portions of it, has been described many times, with Reighard (1905) publishing the first, most detailed, description. Breder (1936) adequately summarized the literature on the subject. I have watched the complete spawning act once, and the only variation I found from the literature was the length of time between emissions of the sex products. The time varied from 5 to 15 minutes as compared to the 30 seconds of Reighard's description and the "at least 3 minutes" given by James (1930).

The number of eggs deposited may vary from about 2,000 to 10,000 according to Surber (1935). This may result from one, or more than one, female spawning in the nest. At Waugoshance Point, the eggs were collected from two nests and counted. The procedure was to carefully move by hand into an adjacent pail, all large rocks and clumps of rootlets, while watching with a water telescope. Then the remaining gravel and sand were shoveled into the container. Very few of the partially adhesive eggs were lost. The eggs were separated from bottom materials by using a fine mesh sieve, followed by several washings in a saturated calcium chloride solution. Newly made nests were selected to eliminate any possible loss from predation. The first nest (June 11, 1954) was 20 inches in diameter, in 15 inches of water, and contained 5,281 eggs. The second nest (June 15, 1954) was 18 inches in diameter, in 21 inches of water, and contained 9,593 eggs. The average for the two was 7,437.

In 1954, the black fry of three nests were collected. A screen was placed around the nest just before the fry rose. This is a common hatchery method of collecting bass fry from ponds. After the fry rose, they were dipped out, preserved and counted. The counts were 1,355, 1,989 and 2,819, for an average of 2,054.

The number of nests used for the egg counts and the fry counts was too small for reliable averages. However, using the figures available, an average nest at Waugoshance produced 2,054 fry from a complement of 7,437 eggs, which means an approximate 72 percent loss up to the black fry stage.

In comparison with my figure of 2,054 fry per nest, Langlois (1932) had a hatchery figure of 3,062, from 66 nests, with a range of 92 to 11,329. Surber's (1943) counts, taken from nests in the wild, provide a more realistic comparison. From the South Branch of the Potomac River, the average count of fry per nest was 2,159, from the Cacapon River, 2,210 and from the Shenandoah River, 1,998.

Factors Influencing the Success of Spawning

Many nests of the smallmouth at Waugoshance were marked with numbered stakes driven into the bottom about 10 feet from the nests. Stakes were not used when natural markers such as logs or distinctive boulders were present. In 1954, 37 nests were marked, 6 of these on the north side of Waugoshance Point; and in 1955, 62 were marked, with 14 on the north side. These nests were visited at intervals ranging from once every day to once in 5 days. The checks were made with a boat or by wading, using a water telescope and binoculars. Care was taken not to disturb the fish or nest any more than was necessary in approaching the site. I believe the annoyance was not detrimental to nesting.

In 1954, from 20 nests with eggs, 9 produced no black fry, a loss of nests to the black fry stage of 45 percent. In 1955, in the spawning after May 30, no black fry were produced in 13 of 28 nests, a 46 percent loss. These percentages can be compared with the estimate-of-loss figures of Webster (1954), which for 3 years were 20, 30, and 20 percent. He emphasized, though, that these are minimal, "since many nests without males were overlooked up to the black-fry state." His counts were biased by the inclusion of successful nests only. Stone, Pasko and Roecker (1954) reported only 7 of 16 nests produced fry (a 66 percent loss).

Minnows

On several occasions in 1954, common shiners (Notropis cornutus) were observed over the nest with the male smallmouth bass. Also, in 1954, minnow fry were collected along with bass fry from a screen placed around a nest (but not one of those where common shiners had been observed). These two incidents were not connected until the 1955 spawning season was underway. In 1955, common shiners were common over the bass nests. A total of 15 nests were seen with common shiners, the male bass, and a deposit of bass eggs present. Although they were not observed spawning, it appeared that the shiners were spawning congregations. The male shiners were in breeding colors, with tubercles, at this time, and three individuals captured were ripe (two females and one male). On one occasion a boiling of the water over a known bass nest proved to be a large group of shiners and a few bluntnose minnows (Pimephales notatus). There were no bass eggs in this nest, but the bluntnose minnows appeared to be picking (feeding?) something out of the gravel of the nest. On another occasion, bluntnose minnows were seen picking bass eggs out of a nest.

An examination of the contents of two bass nests, one collected in 1954 and another in 1955, revealed minnow eggs in addition to the bass eggs. The eggs of the common shiner are about three-fifths the size of the bass eggs (1.5 mm., Raney, 1940; as compared to 2.5 mm., Reighard, 1905). Additional confirmation was provided by again collecting minnow fry with the bass fry from an enclosed nest. Earlier a congregation of minnows had been seen over this nest. The minnow fry were left in the enclosure of screen to obtain as much growth as possible (about 16 mm. at time of preserving) to facilitate identification. Identification of the common shiner was verified by R. M. Bailey, Curator of Fishes, University of Michigan Museums, Ann Arbor, Michigan. There is no doubt that this species spawns successfully with the smallmouth bass at Waugoshance Point.

The water temperatures at which the common shiner spawns, 60° to 65° F. according to Raney (1940), are similar to those used by the smallmouth. In the area on the south shore of Waugoshance Point, where the common shiners were first seen over bass nests, there were two cleaned areas of gravel about the size of bass nests, but with little or no depression, in water of one foot or less in depth, that were probably minnow nests. Shiners were seen at one of these nests.

The common shiner's utilization of nests of other minnows for spawning has been often reported, but no mention was found of this species' use of centrarchid nests (Raney, 1940: Pfeiffer, 1955). This ubiquitous cyprinid apparently will spawn over any clean gravel that is available. Carr (1942), studying the largemouth bass in a small lake in Florida, found the chub sucker (Erimyzon s. sucetta) spawning successfully in the bass nests.

The question arises as to whether the presence of a spawning aggregation of minnows is detrimental to bass nesting. In 1954, only one nest was observed with large numbers of minnows; the male bass and a complement of bass eggs were present. This nest was a failure. The minnows, male bass and eggs disappeared.

In 1955, of the 15 bass nests recorded with minnows, 6 were in the period before May 30. None of these were successful, i.e., produced black fry, but this was part of the early nesting which was adversely affected by subsequent low temperatures. Of the 9 remaining bass nests with minnows observed after May 30, 3 were successful. This proportion of 3 successful to 6 unsuccessful was compared with the other nests observed during this period using a Chi-square test of independence. The total number of nests observed with the adult bass and eggs present was 28. Subtracting the 9 nests recorded as having minnows present leaves 19. Of this, 12 were successful and 7 were not, as compared to the minnow figures of 3 and 6. The Chi-square (adjusted) was 1.15 which suggests that the hypothesis of independence be accepted, i.e., there is no relationship between success of nests and the presence or absence of minnows.

Carp

The carp (Cyprinus carpio) apparently spawns at about the same time as the smallmouth bass at Waugoshance Point. Although only chance observations of spawning carp were made, it was noted that they started to spawn about June 8, 1954 and were out of the shallows by June 13. This coincided with bass spawning in that year. Likewise, in 1955, the carp were in the shallows from June 3 to June 8, which was approximately the same time as the main spawning effort of the bass. In 1954, there seemed to be no destruction of bass nests by the carp. In one incident, the guarding male bass drove off a lone approaching carp. In 1955, in a cove with a bottom consisting of a large accumulation of silt and detritus over gravel, carp apparently caused the abandonment of several bass nests. Carp were first seen in the cove on June 3. On the 5th, the water was very turbid and the carp were still present. On the 6th, the water was so turbid that I could not see the nests, which were at a depth of about 2 feet. Three nests, of several in this area, had been marked. None, marked or unmarked, was successful. There was as much carp activity in other areas where bass nests were present, but the usual bottom of sand and gravel produced only little turbidity. It is probable that a combination of physical activity of carp and the resultant turbidity caused the failure of these bass nests.

Fishermen

When the fishing season opened in 1954 (June 19), there were nests with eggs or fry in all stages of development, but in 1955 (June 18), all of the functional nests had black fry. Of nests with eggs to the black fry stage, there was no difference in loss in the 2 years, even though in 1954 the season opened while many of the nests contained eggs. There was no evidence in either season that the fishermen were detrimental to nesting. Conceivably they could destroy nests by tramping through them or catching the male or disturbing him enough so that he would desert, leaving the nest exposed to predation.

In 1954 and 1955, I attempted to evaluate the ease or difficulty with which smallmouth males could be caught while they were guarding nests. Upon fishing the waters over 12 nests where there were known to be bass or where the male was often seen, fish were caught at 6 of these areas and there was a strike or rise at 2 others. This seems to indicate that there is a definite advantage to the angler to fish the nest sites or areas where nests are present.

Temperature

Temperature was the most significant cause of nest desertion. A sufficient drop in the temperature caused the male bass to desert the nest, and if eggs were present they were taken almost immediately by some predator. As previously stated, a rise in water temperature from the fifties to the sixties triggered spawning, and any subsequent drop to the fifties led to desertion. In 1954, there was no sudden drop in the water temperature after spawning began (Figure 3).

In 1955, the early spring was characterized by fluctuations in the water temperature. Nests were found on May 13, the first day in the field. On this day and the next, 9 nests were marked; 5 of these had a complement of eggs. Figure 4 shows that the water temperature started to drop on May 15. It reached on May 16 an actual low of 50° F. (mean temperature 56° F.). Four of the nests were checked on the 15th; these were progressing satisfactorily. On the 17th, all of the nests were deserted, with neither eggs nor males present.

The water temperature started to rise again, and on the 19th through the 24th of May, 16 nests were marked. These were in various stages of development, from cleaned gravel to nests filled with eggs. After a drop in temperature to 51° F. on the 24th, some of these nests were deserted. The mean temperature then climbed not much above 60° F. although the actual temperature on the 25th reached a high of 68° F. There were four nests being built and two nests with eggs were recorded from the 25th through the 28th, but the temperatures were hardly sufficient to encourage spawning. On the 29th there was again a low water temperature of 51° F. with the resultant desertion of all nests. Finally the temperature started to climb; nest-building activities were observed on the 31st, and the peak of spawning occurred during the nest 3 days. During the period of May 13 through May 29, a total of 15 nests with eggs were deserted and destroyed. A large number of the 31 nest sites recorded were utilized again during the successful spawning period. (Rock bass also used some of the old nests of smallmouth bass). In both years, barring interruption, the egg-laying period lasted from 7 to 10 days, with the peak at the beginning.

Nest desertion can only be attributed to temperature drop. It has been shown that the common shiner probably did not influence the nesting adversely; carp had not yet started to move into the shallows; it was too early in the year for the fishermen to disturb the nest (although the bass season had not yet opened, there were a few people fishing for northern pike); the eggs were not attacked by fungus to any large degree; and turbidity was very low in these waters, which leaves temperature as the only observed and most probable cause of nest desertion. Various authors have observed or commented upon this relationship of temperature to desertion (Reighard, 1905; Meehan, 1911; Surber, 1935; Rawson, 1945; Webster, 1954).

Fluctuating water temperature does not adversely affect the development of bass eggs. Tester (1930) held that a rise in temperature to 73.5° F. killed eggs in a nest he was watching. Many others have connected low temperatures with loss of eggs (Meehan, 1911; Beeman, 1924; Rawson, 1945). Webster (1948), by bringing smallmouth bass eggs into the laboratory and varying the temperature within a range of 50° to 77° F., has shown that neither high nor low temperatures cause mortality in the eggs. Jurgens and Brown (1954) subjected the eggs of the largemouth bass to temperatures as low as 33° F. without loss of the eggs.

The temperature which causes the male to desert is somewhere in the low fifties, depending probably upon previous water temperatures, rate of drop, stage of nest development, and guarding instinct of the male.

Discussion

Although temperature plays an important part in the success or failure of a nest, there still is substantial unaccounted for mortality. In 1954 at Waugoshance Point, mortality of nests was 45 percent, and as temperature fluctuations were not involved this year, the spawning activities of common shiners, or the turbidity and disturbances caused by carp or man must be considered as possible causes. But it has been shown previously that all of these probably did slight or negligible harm. In 1955, the mortality for the period after temperature fluctuations was 46 percent, again only partially attributable to these factors. Also to be accounted for is an approximate 70 percent loss of eggs from nests that were successful enough to produce black fry. Fungus infections, siltation, infertile eggs, and, to a large extent, predation (judging from the rapidity with which the eggs disappeared from deserted nests), could all contribute to this loss from individual nests. Predation might also account for the high percentage of loss of whole nests.

Nests with guardian males became as silty as nests that had been deserted. The presence or absence of the fanning male seemed to make no difference in the amount of silt accumulating on the nest. Reighard (1905) and Webster (1954) both observed this same thing. Webster, after finding nests developing successfully without males, proposed "that the principal value of the guarding male is protective rather than physiological, and that the cause of excessive egg mortality must be elsewhere than in lack of parental care or in temperature fluctuations." Both Reighard and Webster, after being unable to attribute egg losses to anything in the external environment, suggested the study of the viability of the sex products under different environmental conditions and from individual fish.

Because of the apparent low degree of fungus infection in the nests, which would be expected to be high in the dead tissue provided by unfertilized eggs, and because of the swiftness with which the eggs disappeared from nests, predation is thought to be of more importance than unviable sex products as a factor in egg loss at Waugoshance Point.

Surber (1943) pointed out that the second spawning produces less fry per nest (about one-half less) than the original spawning, and also fewer nests are built. Unfortunately, I was not able to collect black fry at Waugoshance Point in 1955, but there appeared to be no difference in the number of fry per nest. Comparing the two successful spawning seasons, and excluding those nests that were built and deserted during the temperature changes, there were more nests built in 1955 than in 1954, undoubtedly caused by the coming to maturity of the large 1949 year-class. In 1954, all of the males of the 1949 year-class, but only 19 percent of the females, were mature. By 1955, about 65 percent of the females were mature, which probably accounts for the larger number of nests. The only other year-class present with any sizable number of mature fish was that of 1947, and the number in this year-class had declined considerable by 1955.

Behavior of Adults and Fry

Generally, the male was seen in the vicinity of the fry for a week to 10 days after they appeared black in the bottom of the nest. In situations where the screens were placed around the nests, the male would usually be there, circling outside. The fry gradually spread out in the water over the nest, becoming more and more dispersed, and seeking cover in the adjacent emergent aquatic plants. The color of the fry changed from black to brownish-green. Gradually they assumed the typical fingerling coloration (described very well in Hubbs and Bailey, 1938). In 1954 they reached this stage by July 13 or 14 and in 1955 by July 5 or 6--in both years from 30 to 35 days after eggs were observed in the nests.

The numbers of fry decreased noticeably over nests; in at least four instances the whole aggregation disappeared between observations made within 3 days. It is suggested that this complete disappearance is the result of predation, because it happened before normal dispersion and no individuals could be found in the vicinity. The gradual decline is undoubtedly a combination of predation and dispersion. Probably the male provides valuable protection that lessens as the aggregation spreads, and early removal of the male results in greater losses.

AGE AND GROWTH

Scale Method

The age of the smallmouth bass was determined by counting the annuli, or year marks, on the scales. The annulus of this species is similar in appearance to that of other sunfishes. It consists of the usual interrupted ridges or circuli, followed by a complete circulus which is laid down as growth resumes in the spring. The "cutting over" created by this pattern of growth is most apparent in the posterior field of the scale.

There is no doubt about the validity of the annulus as a mark formed each year on smallmouth bass scales. At Waugoshance Point, scales taken on recapture of fish, previously tagged and scale-sampled, confirmed the validity for the species. Year marks appeared as expected (Table 5) for fish in several age-groups. The time involved was too short to allow recoveries of fish with more than one annulus formed after tagging.

The time formation of the annulus was delimited as from early June to late July, based on scales taken from fish examined in the creel census and from fish captured in the nets. In 1953, the earliest collections were made the last few days of June; at this time, 50 percent (16 of 32) of the bass had an annulus on the scale margin. Thereafter an increasingly large proportion of the individuals in the daily collections had new annuli present, until on July 21 and in subsequent collections, scales of all smallmouth bass had formed the annulus of the year.

In 1954, the time of annulus formation was essentially the same as in 1953. The annulus was first preceived on scale samples collected

Table 5.--Validation of scale annuli in the smallmouth bass, Waugoshance Point, Lake Michigan. The table gives the number of tagged smallmouth bass forming the expected annulus between captures, 1953-1955

Annulus number	Years of capture			
	1953-1954	1954-1954	1954-1955	1953-1955
3	1	...	...	...
4	...	...	...	...
5	22	6	20	2
6	2	1	3	1
7	16	1	2	7
8	2	...	1	...
9	...	1	...	...
10	...	...	...	...
11	1	...	...	...
12	1	...	...	...

June 13 (1 of 220); at the end of June, about 50 percent of the bass in the collections had formed a year-mark, and by July 23 all of the individuals had the annulus present.

In 1955, scale collections were less extensive than in previous years. Only the creel census provided samples (June 18 through July 4). One-third (10 of 30) of the fish had formed an annulus on June 18, but by early July about three-fourths (38 of 50) had formed the mark.

In all years, fish in the younger age-groups formed an annulus earlier than those in the older age-groups.

Body-Scale Relationship

Most of the scales used in the calculation of the growth of the smallmouth bass were taken from fish captured in the trap nets. Additional sources of scales were fish checked during the creel census, those captured in a seine (mostly young-of-the-year), a few caught personally by angling, and, finally, a lesser number collected with a fish toxicant. In the field, fingerlings alone were preserved in formalin for later scale sampling. A few scales were removed from the left side of the body of all fish, at a spot just below the lateral line, at the tip of the pectoral fin. Everhart (1950) found no evidence that the use of a few scales from the pectoral region, a key scale (a scale from the same position on each fish), or scales from the area of the fish where they first form (the caudal peduncle), made any more precise the calculated growth of the smallmouth bass. Everhart also concluded that the measurement of the anterior radius of the scale was preferable to other scale dimensions for calculating growth from scale dimensions.

Impressions in plastic were made of scales of all bass larger than fingerling size (Smith, 1954). The impressions were magnified 51.3 times with a microprojector for age assessment and measurement. Annuli were counted, and their positions along the anterior radius of the scale were marked on heavy strips of paper. The length of the anterior radius was measured in millimeters. In the field, bass were measured to the nearest 0.1 inch in total length; these measurements were converted to millimeters for growth calculations. The measurements of anterior radius of scales were grouped in 10-millimeter intervals, and the means were calculated for these and for the corresponding total length measurements (Whitney and Carlander, 1956). The 1953 and 1955 scale collections were used and, in addition, the extremes of the groups were bolstered with the 1954 samples (Table 6). The means were plotted, with the scale measurements on the x-axis and the total lengths on the y-axis; and a regression line was calculated by the least squares method: $y = 65.1 + 1.2x$ (Figure 5). A straight line described the data very well.

Scales of the preserved small bass were mounted temporarily in water on slides and magnified 51.3 diameters. Total body lengths and scale measurements, in millimeters, were made and a regression line ($y = 14.3 + 2.0x$) was calculated for the grouped data (Table 7, Figure 5). No allowance was made for possible shrinkage caused by the preservatives, with the result that the intercept of 14.3 might be slightly different if based on fresh material. Scales taken from marked fish were excluded from body-scale and growth calculations, because a tag or a clipped fin might have an unnatural effect on growth.

Table 6.--Mean length of anterior radius of scales (x51.3), for 10-millimeter groups, and the corresponding mean total lengths of the smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955

Length groups in millimeters, anterior scale radius	Number of fish			Mean anterior radius of scales, in millimeters (x51.3)	Mean total length of bass, in millimeters
	1953	1954	1955		
70 - 79	2	1	1	76	150
80 - 89	8	7	3	85	167
90 - 99	15	22	6	95	177
100 - 109	13	33	1	105	192
110 - 119	48	53	2	115	203
120 - 129	78	...	6	125	216
130 - 139	129	...	4	134	228
140 - 149	145	...	14	144	237
150 - 159	116	...	29	154	246
160 - 169	78	...	32	165	259
170 - 179	74	...	28	174	275
180 - 189	58	...	40	184	290
190 - 199	44	...	51	194	304
200 - 209	54	...	49	204	312
210 - 219	54	...	39	214	320
220 - 229	41	...	20	224	332
230 - 239	26	27	20	234	342
240 - 249	16	23	6	244	361
250 - 259	13	8	5	254	368
260 - 269	8	10	2	265	379
270 - 279	4	6	3	273	395
280 - 289	10	4	...	284	417
290 - 299	2	2	2	297	421
300 - 309	3	2	1	306	440
310 - 319	2	2	1	316	445
320 - 329	3	...	...	324	449
330 - 339	...	...	...	...	...
340 - 349	1	...	...	348	470
350 - 359	1	...	...	350	488

Figure 5. Relationship between length of smallmouth bass and anterior radius of the scale (x51.3), Waugoshance Point, Lake Michigan. Line AB and the quantities designated by a and b illustrate how the direct proportion calculations of growth were adjusted to the actual body-scale growth line.

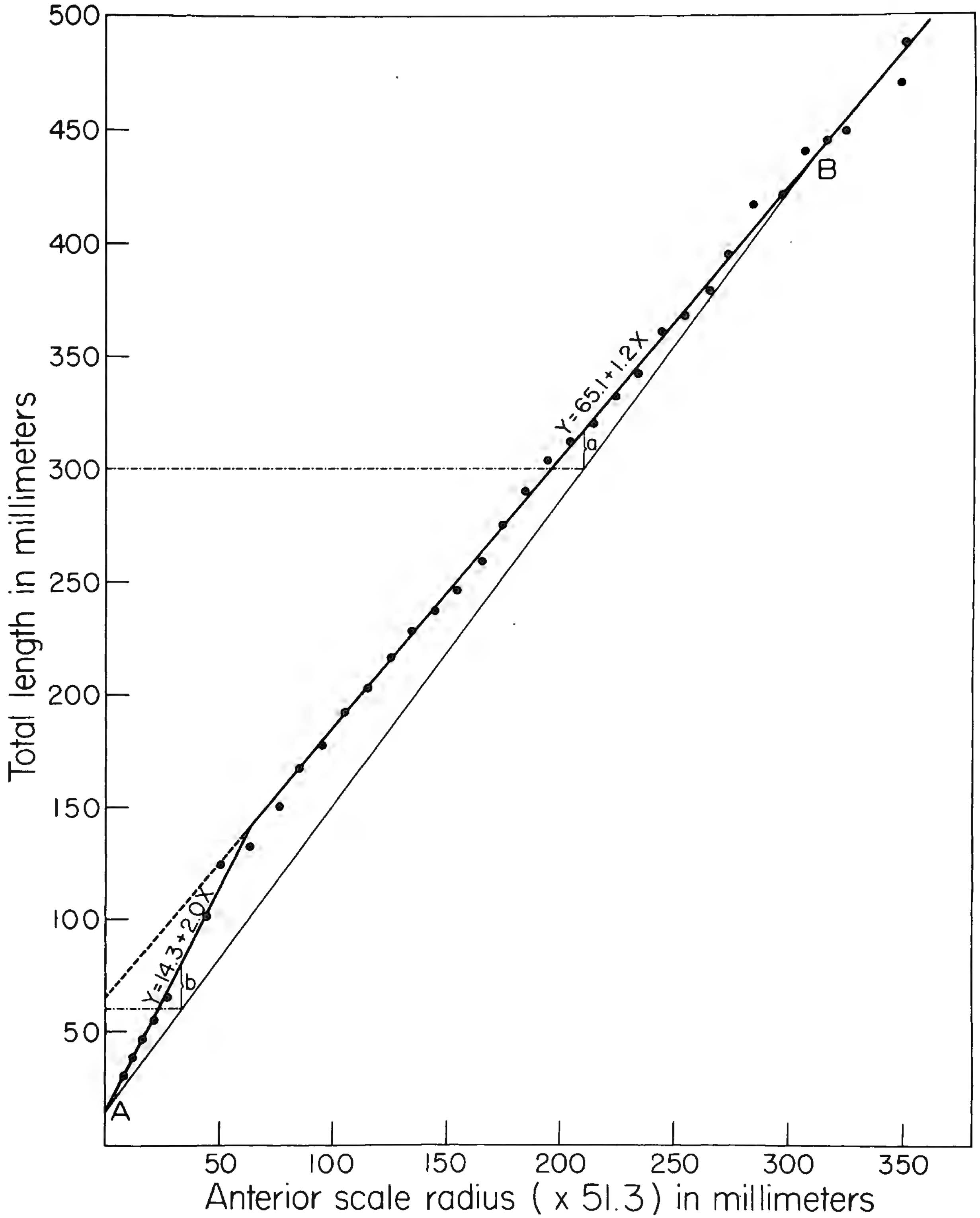
500
450
400
350
300
250
200
150
100
50
Total length in millimeters
Y=65.1+1.2X
Y=14.3+2.0X
a
b
A
B
50
100
150
200
250
300
350
Anterior scale radius (x 51.3) in millimeters

Fig. 5

Table 7.--Mean length of anterior radius of scales (x51.3), for 5-millimeter groups, and the corresponding mean total lengths of preserved fingerling smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955

Length groups in millimeters, anterior scale radius	Number of fish	Mean anterior radius of scales, in millimeters (x51.3)	Mean total length of bass, in millimeters
5 - 9	19	8	30
10 - 14	29	12	38
15 - 19	26	16	46
20 - 24	8	21	55
25 - 29	4	27	65
40 - 44	3	44	101
50 - 54	2	50	124
60 - 64	2	63	132

It appears that the body-scale relationship for the smallmouth bass is characterized by two straight lines joined with an obvious inflection at a body length of about 140 millimeters (Everhart, 1950). The intercept of 14.3 millimeters was used as a correction factor in the back-calculations of growth. Everhart (1949) found by empirical methods that scales started to form at an average fork length of about 20 millimeters. The writer had two specimens, 17 millimeters total length, without scales. The next largest specimen in the collections, 25 millimeters, had scales formed. Because there were only three fish available to determine the size at time of scale formation, the use of the intercept value as calculated seemed better.

Calculated Growth

The growth for previous years of life of the smallmouth bass was calculated from scale measurements relative to body length. The correction factor, 14.3 millimeters, was used in the formula for direct proportion calculations of growth,

$$L' = C + \frac{S'}{S} (L - C)$$

where,

L' = length of fish when annulus x was formed,

L = length of fish at the time the scale sample was taken,

S' = length of scale radius to annulus x,

S = length of total scale radius,

and C = correction factor.

Calculations of fish lengths were facilitated by use of a nomograph (alignment chart) in conjunction with the paper strips, upon which were marked the positions of the annuli on the scale (Carlander and Smith, 1944).

The average total length in millimeters at the end of each year of life was calculated for each age-group. These averages were then corrected by adding the difference between the body-scale line and the straight lines of the direct-proportion calculations. For example, in a given age-group X, the average empirical length might be 436 millimeters. Growth calculations on a direct proportion basis would follow the straight line, AB, from the intercept, 14.3 millimeters, to a point, 436 millimeters, on the body-scale line (Figure 5). At the end of the fifth year of life, the average calculated length for bass in age-group X might be 300 millimeters. The 16 millimeters difference (a, in Figure 5) between the two lines, at the point where 300 millimeters falls on line AB, would be added to the 300 millimeters body length to adjust the direct proportion calculation to the more correct body-scale growth line. In the same way, at the end of the first year of life, at an average calculated length of 60 millimeters, the difference would be 20 millimeters (b, in Figure 5) and the corrected length would be 80 millimeters. The position of line AB usually changes with each age-group, depending upon where B (average empirical length) falls on the body-scale line.

A correction was made for each year of life of each age-group; the age-groups were arranged by year-class and year of capture (Table 8).

An alternative method of calculating the growth for the previous years of life would have been to use the intercept value 65.1 millimeters in the direct-proportion formula and to correct only those calculated lengths that fall below the inflection (about 140 millimeters body length) in the body-scale line.

Table 8.--Average calculated total lengths, in millimeters, for each year of life, for each age-group, arranged by year of capture and year-class, for the smallmouth bass of Waugoshance Point, Lake Michigan, 1953-1955

Year-class	Year of capture	Age-group	Number of fish	Total length at capture	Year of life											
					1	2	3	4	5	6	7	8	9	10	11	12
1941	1953	XII	1	470	92	162	195	246	300	350	387	407	426	442	450	463
1942	1953	XI	6	462	96	160	214	258	310	355	388	413	428	444	456	...
	1954	XII	1	432	78	143	192	228	266	316	342	375	391	402	419	432
1943	1953	X	4	457	104	170	225	266	321	361	398	418	432	448	...	...
	1954	XI	2	460	105	170	215	271	328	377	406	419	435	448	458	...
1944	1953	IX	2	421	88	154	199	228	290	336	373	397	412	...	...	...
	1954	X	3	457	124	178	238	290	339	385	403	425	439	451	...	...
1945	1953	VIII	4	391	80	151	203	260	306	330	360	382	...	...	...	...
	1954	IX	3	409	82	145	190	239	300	329	358	386	407	...	...	...
	1955	X	1	432	74	130	187	242	298	328	353	383	410	432	...	...
1946	1953	VII	13	363	90	161	208	260	292	320	352	...	...	...	...	...
	1954	VIII	5	404	98	168	222	278	311	344	376	404	...	...	...	...
	1955	IX	1	434	140	182	228	276	308	346	388	413	434	...	...	...
1947	1953	VI	250	325	102	157	205	235	266	307	...	...	...	...	...	...
	1954	VII	85	358	102	157	206	235	266	309	352	...	...	...	...	...
	1955	VIII	12	371	100	152	199	226	255	299	341	370	...	...	...	...
1948	1953	V	61	290	100	162	193	223	269	...	...	...	...	...	...	...
	1954	VI	27	328	100	160	187	216	262	312	...	...	...	...	...	...
	1955	VII	9	351	98	163	192	220	264	313	349	...	...	...	...	...
1949	1953	IV	643	241	114	149	173	215	...	...	...	...	...	...	...	...
	1955	VI	242	307	114	146	170	210	262	307	...	...	...	...	...	...
1950	1953	III	6	224	90	150	196	...	...	...	...	...	...	...	...	...
	1954	IV	13	249	76	143	184	233	...	...	...	...	...	...	...	...
	1955	V	2	290	94	145	185	238	290	...	...	...	...	...	...	...
1951	1953	II	35	198	90	163	...	...	...	...	...	...	...	...	...	...
	1954	III	102	241	94	163	215	...	...	...	...	...	...	...	...	...
	1955	IV	33	267	94	161	215	264	...	...	...	...	...	...	...	...
1952	1953	I	21	168	114	...	...	...	...	...	...	...	...	...	...	...
	1954	II	218	208	112	176	...	...	...	...	...	...	...	...	...	...
	1955	III	68	244	120	186	239	...	...	...	...	...	...	...	...	...
1953	1954	I	8	165	110	...	...	...	...	...	...	...	...	...	...	...
	1955	II	11	170	112	165	...	...	...	...	...	...	...	...	...	...
Average of calculated lengths, in millimeters					108	157	188	222	267	310	357	395	425	443	452	448
Growth increment, in millimeters					108	49	31	34	45	43	47	38	30	18	9	...
Average of calculated lengths, in inches					4.3	6.2	7.4	8.7	10.5	12.2	14.1	15.6	16.7	17.4	17.8	17.6
Growth increment, in inches					4.3	1.9	1.2	1.3	1.8	1.7	1.9	1.5	1.1	0.7	0.4	...
Number of fish					1892	1863	1599	1423	734	671	152	45	24	18	10	2

The number of fish in the 1949 year-class was so much larger than the number in any other year-class that it unduly influenced the over-all result. It was obvious from the space between annuli on the scales of most of the bass that the amount of growth in 1950 and 1951 was less than might be expected. The periods of poor growth were the second and third years of life for the 1949 year-class; this slow growth, in conjunction with the large numbers involved, was reflected in the small increments for the second and third years in the average of the calculated growth for all year-classes. Furthermore, the next largest year-class, that of 1947, had poor growth in the fourth and fifth years of life, and this, to a lesser extent, also lowered the corresponding growth increments. None of the fish in the 1949 year-class, collected in 1954, were used in the growth calculations, because the numbers in the collections for the other 2 years (1953 and 1955) were more than sufficient; otherwise all of the 1954 scale collection was included. The 1953 and 1955 collections, that were used in establishing the body-scale relationship, plus 14 additional fish collected in 1955, provided the remainder of the scales for the growth calculations.

In addition to the influence of dominant year-classes on average growth figures, net selection of the faster-growing individuals of the younger age-groups undoubtedly played a part. Particularly noticeable was the relatively larger calculated growth for age-groups of the 1952 and 1953 year-classes than for earlier year-classes.

The calculated total lengths for each year of life were compiled by year-class and the corresponding growth increments were found (Table 9). Inspection of the increments shows the decidedly smaller growth for the calendar years 1950 and 1951 for most of the year-classes

Table 9.--Average calculated total lengths and increments of growth (in parentheses), in millimeters, for each year of life, of each year-class of smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955

Year-class	Number of fish	Year of life 1	2	3	4	5	6	7	8	9	10	11	12
1941	1	92 (92)	162 (70)	195 (33)	246 (51)	300 (54)	350 (50)	387 (37)	407 (20)	426 (19)	442 (16)	450 (8)	463 (13)
1942	7	93 (93)	158 (65)	211 (53)	254 (43)	304 (50)	349 (45)	381 (32)	408 (27)	423 (15)	438 (15)	451 (13)	432 ...
1943	6	104 (104)	170 (66)	222 (52)	268 (46)	323 (55)	366 (43)	401 (35)	418 (17)	433 (15)	448 (15)	458 (10)	... ...
1944	5	110 (110)	168 (58)	222 (54)	265 (43)	319 (54)	365 (46)	391 (26)	414 (23)	428 (14)	451 (23)	... ...	... ...
1945	8	80 (80)	146 (66)	196 (50)	250 (54)	303 (53)	329 (26)	358 (29)	384 (26)	408 (24)	432 (24)	... ...	... ...
1946	19	95 (95)	164 (69)	213 (49)	266 (53)	298 (32)	328 (30)	360 (32)	406 (46)	434 (28)	... ...	... ...	... ...
1947	347	102 (102)	157 (55)	205 (48)	235 (30)	266 (31)	307 (41)	351 (44)	370 (19)	... ...	... ...	... ...	... ...
1948	97	100 (100)	162 (62)	191 (29)	221 (30)	267 (46)	312 (45)	349 (37)	... ...	... ...	... ...	... ...	... ...
1949	885	114 (114)	148 (34)	172 (24)	214 (42)	262 (48)	307 (45)	... ...	... ...	... ...	... ...	... ...	... ...
1950	21	82 (82)	145 (63)	188 (43)	234 (46)	290 (56)	... ...	... ...	... ...	... ...	... ...	... ...	... ...
1951	170	93 (93)	163 (70)	215 (52)	264 (49)	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
1952	307	114 (114)	178 (64)	239 (61)	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
1953	19	111 (111)	165 (54)	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...

(see underlined figures in Table 9). In the older year-classes, the annual increment is either too small to effectively show this slow growth, or they were less affected by whatever factors caused the decrease. A plotting of the growth increments for each year of life by calendar years readily illustrates the poor growth for the years 1950 and 1951 (Figure 6).

In December, 1949, the water level of Lake Michigan was at the lowest point since 1938 (578.25 feet of elevation above mean tide at New York).[1] It started to rise and continued upward until August, 1952, when the level reached 582.7 feet, the highest point since 1887. In addition to the rising water level of the lake, the precipitation and temperatures for the years 1950 and 1951 were far from normal. The annual summaries of climatological data for these years present a picture of cold, wet growing seasons.[2] The year 1950, in Michigan, ranked second in amount of rainfall since 1888, and temperatures averaged about 1° F. below normal. The growing season for the smallmouth bass is essentially from late June through August. July, 1950, was recorded as the fourth coolest and sixth wettest July since records began in 1887. It was the fifth coldest August in Michigan since 1887. The year 1951 was the wettest of record and temperatures also averaged a little below normal.

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[1] The lake level figures were taken from a hydrograph of the monthly mean levels of the Great Lakes, published by U. S. Lake Survey, Army Corps of Engineers, 1953.

[2] Climatological Data, Michigan, Annual Summary, 1950, Vol. LXV, No. 13, pp. 258-268, and 1951, Vol. LXVI, No. 13, pp. 240-249, published 1951 and 1952, respectively, by the Weather Bureau, U. S. Dept. Commerce, Kansas City, Mo.

Figure 6. Growth increments of the smallmouth bass, in millimeters, for each year of life, plotted by calendar years.

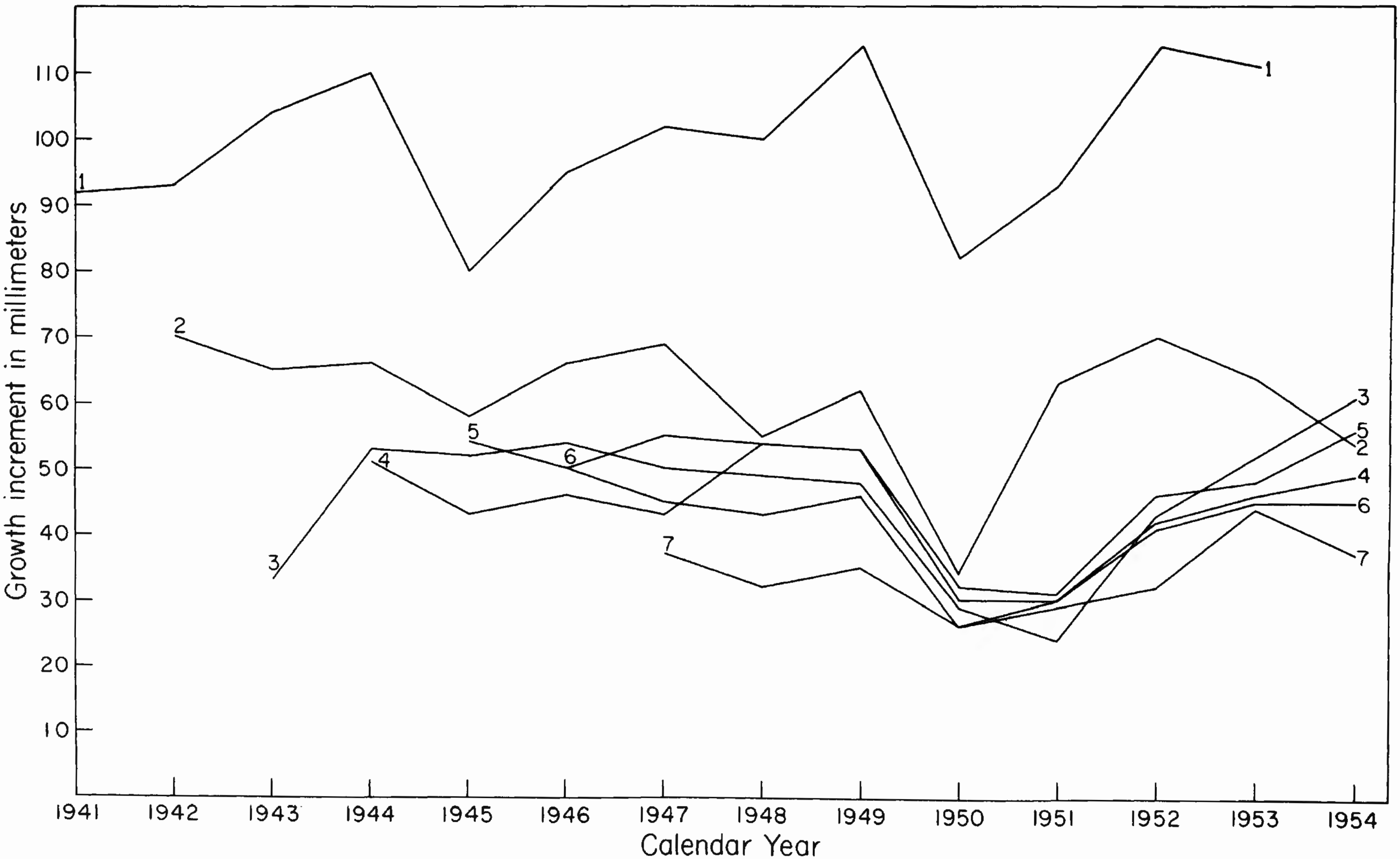
Growth increment in millimeters
110
100
90
80
70
60
50
40
30
20
10
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
Calendar Year
1
2
3
4
5
6
7

Fig. 6

The weather station nearest Waugoshance Point is at Mackinaw City Light House, about 15 miles east of the Point. The average monthly temperatures, total precipitation, and departures from the normal for the months of July and August, 1950 and 1951, at Mackinaw City, probably provide the best summary available of the weather conditions affecting Waugoshance Point (Table 10). These data from the local station, for the 2 months of the year, illustrate emphatically the low temperatures for July and August, 1951 and 1952, and the much greater-than-normal precipitation for July, 1951 only.

What the exact relationship is between growth of the smallmouth bass and such environmental factors as water level fluctuations, precipitation and temperature, remains to be determined in the future.

Most investigators have found the same or very similar growth rates for the male and female smallmouth bass (Bennett, 1938; Beckman, 1949; Westman and Westman, 1949; Webster, 1954; Stone, Pasko and Roecker, 1954). The comparison of the average empirical total lengths, for the sexes, of the smallmouth bass collected at Waugoshance Point during the 3 years (Table 11) agrees with the finding of these authors. There appears to be no difference in the growth rate, at least for the limited sample for which the sex of the fish was determined. Most of these fish were examined during the creel census.

Comparison of Growth Rates

During the course of the tagging program, in 1954, scale samples were taken from fish netted at Hog Island and Cecil Bay, localities near Waugoshance Point. No body-scale relationship was established for the fish in these collections. The intercept value of the Waugoshance

Table 10.--Average monthly temperature (°F.), total precipitation (inches), and departures from the normal for the months of July and August, 1950 and 1951, Mackinaw City Light House, Mackinaw City Michigan

Year	July		August	
	Temperature	Departure	Temperature	Departure
1950	63.9	-2.6	59.8	-5.1
1951	65.2	-1.3	62.7	-2.4
	Precipitation	Departure	Precipitation	Departure
1950	2.06	-0.48	3.56	0.73
1951	6.98	4.48	1.73	-1.10

Table 11.--Comparison of the average empirical total lengths in inches, for the sexes, of smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955

(N = number of fish)

Age-group	Male		Females	
	Length	N	Length	N
II	7.2	12	7.7	10
III	9.2	8	9.4	6
IV	9.8	33	9.7	20
V	10.9	100	11.2	71
VI	11.8	19	12.1	57
VII	13.6	8	14.2	14

Point data was used as the correction factor, and the growth calculated as described previously. The growth rates for the bass from the three localities were the same (Table 12). The tag returns (see Movement) indicated a small exchange of fish between Cecil Bay and Waugoshance Point, but very little movement between Hog Island and Waugoshance Point.

The growth of the smallmouth bass of Waugoshance Point, Lake Michigan, was compared with the growth of the smallmouth bass in some other waters within the Great Lakes region (Table 13). Only those references were used that provided calculated growth rates or empirical averages directly comparable to the Waugoshance data. Many other growth studies have been made of the smallmouth bass (Carlander, 1950 and 1953), but for the Great Lakes (other than Stone, Pasko and Roecker, 1954, listed in Table 13) there have been only Doan, 1940, and Fraser, 1955. The growth rate for the first few years of life of the Waugoshance Point population is slower than the growth rate for the earlier years of the other populations listed in Table 13 (undoubtedly reflecting the poor growth for 1950 and 1951 of the Waugoshance bass). Later years show a growth rate greater than the rate for the Lake Ontario-St. Lawrence River bass, equal to the Cayuga Lake fish, and less than the rate for the bass from the inland waters of Wisconsin.

Conversion Factors

The total-length measurement, in inches, was used throughout the study, but 413 bass were also measured to standard length to

Table 12.--Average of calculated lengths in inches, for each year of life, for the smallmouth bass from three localities in northern Lake Michigan

(N = number of fish)

Year of life	Locality					
	Waugoshance Point		Cecil Bay		Hog Island	
	Length	N	Length	N	Length	N
1	4.3	1,892	4.1	214	4.1	157
2	6.2	1,863	6.1	214	5.9	157
3	7.4	1,599	7.4	164	7.4	155
4	8.7	1,423	8.7	111	8.7	139
5	10.5	734	10.6	107	10.5	139
6	12.2	671	13.5	10	12.4	72
7	14.1	152	15.0	8	14.0	65
8	15.6	45	16.3	3	15.6	20
9	16.7	24	16.7	2	16.2	15
10	17.4	18	16.8	1	17.0	13
11	17.8	10	17.1	1	17.6	10
12	17.6	2	...	...	18.5	1

Table 13.--Growth of the smallmouth bass of Waugoshance Point, Lake Michigan, compared with the growth in other waters (all measurements total lengths in inches)

(N = number of fish)

Year of life	Waugoshance Point, Lake Michigan (Present study)[1]		Lake Ontario-St. Lawrence River, N.Y. (Stone, Pasko and Roecker, 1954)[2]		Cayuga Lake, New York (Webster, 1954)[3]		Wisconsin waters (Bennett, 1938)[4]	
	Length	N	Length	N	Length	N	Length	N
1	4.3	1,892	...	...	...	...	2.4	...
2	6.2	1,863	...	...	6.4	291	5.3	...
3	7.4	1,599	...	...	8.4	795	8.2	...
4	8.7	1,423	10.3	49	10.3	1,022	10.6	...
5	10.5	734	10.9	152	12.1	479	12.5	...
6	12.2	671	11.9	321	13.7	220	14.1	...
7	14.1	152	12.5	257	14.7	103	15.3	...
8	15.6	45	13.7	308	15.6	64	16.7	...
9	16.7	24	14.4	296	16.7	34	17.6	...
10	17.4	18	15.4	102	17.0	7	18.3	...
11	17.8	10	14.5	183	18.0	10	18.9	...
12	17.6	2	15.1	178	...	...	...	...
13	...	...	16.2	22	...	...	...	...
14	...	...	16.9	3	...	...	...	...
Total	...	1,892	...	1,871	...	3,025	...	1,322

[1] Direct proportion calculations, with correction factor, adjusted to body-scale line.

[2] Empirical lengths just prior to annulus formation.

[3] Empirical lengths at end of growing season.

[4] Direct proportion calculations without correction factor.

provide factors for conversion (Table 14). There seems to be a slight increase in the relative size of the tail as the bass increase in length. Bennett's (1938) ratios of standard to total length did not indicate any change in the size of the tail with an increase in body length of the bass. Beckman (1948), commenting on a table of conversion factors for several species said, "Examination of the factors will show that as the fish increases in length the tail becomes relatively shorter ... and is probably a characteristic of most species." This is true for all of the species in his table except the smallmouth bass for which the data suggest that the larger bass have the relatively longer tails.

Length-Weight Relationship and Condition

The length-weight relationship for Waugoshance smallmouth bass was calculated from data collected during the summer months of 1953, 1954, and 1955; about half of the fish that were weighed and measured were caught in trap nets, and the rest were taken by anglers. The formula used was $W = cL^n$, where

W = weight in grams

L = standard length in millimeters

and c and n are constants (Beckman, 1948). The resulting equation, using the grouped lengths and corresponding weights from 537 bass, was $\log W = -5.39796 + 3.35611 \log L$ (Table 15). The empirical data for each length interval were plotted, including six intervals that were represented by only one or two fish (Figure 7). These intervals with few fish were not included in the calculations of c and n. The curve was constructed using the equation. Most of the disagreement between the empirical and calculated weights was in the upper intervals where there were few specimens.

Table 14.--Conversion factors, total length in inches to standard length in inches, for the smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955

Total length interval, in inches	Number of fish	Conversion factors, total length to standard length
6.0 - 6.9	1	0.806
7.0 - 7.9	24	0.821
8.0 - 8.9	75	0.816
9.0 - 9.9	87	0.814
10.0 - 10.9	42	0.810
11.0 - 11.9	41	0.809
12.0 - 12.9	64	0.807
13.0 - 13.9	37	0.808
14.0 - 14.9	18	0.804
15.0 - 15.9	7	0.804
16.0 - 16.9	8	0.803
17.0 - 17.9	3	0.803
18.0 - 18.9	5	0.823
19.0 - 19.9	1	0.807

Table 15.--Length-weight relationship and coefficients of condition (K) for the smallmouth bass of Waugoshance Point, Lake Michigan, 1953-1955

Total length interval, in inches	Number of fish	Total length, in inches	Standard length, in millimeters	Empirical weight, in ounces	Empirical weight, in grams	Calculated weight, in grams	K
5.5 - 5.9	1	5.7	117	1.4	40	...	...
6.0 - 6.4	1	6.3	130	1.9	53	...	...
6.5 - 6.9	7	6.7	137	2.3	65	59	2.53
7.0 - 7.4	3	7.2	150	2.8	79	80	2.34
7.5 - 7.9	12	7.7	160	3.2	92	100	2.25
8.0 - 8.4	22	8.2	170	4.3	123	122	2.50
8.5 - 8.9	22	8.7	180	5.4	154	148	2.64
9.0 - 9.4	25	9.2	190	6.3	180	178	2.62
9.5 - 9.9	42	9.7	201	7.5	213	215	2.62
10.0 - 10.4	63	10.2	211	8.6	244	253	2.60
10.5 - 10.9	68	10.7	221	10.1	285	295	2.64
11.0 - 11.4	64	11.2	231	11.5	327	342	2.65
11.5 - 11.9	43	11.7	241	13.9	394	395	2.81
12.0 - 12.4	46	12.2	249	15.7	444	440	2.88
12.5 - 12.9	38	12.7	259	18.2	516	503	2.97
13.0 - 13.4	22	13.1	269	20.2	572	571	2.94
13.5 - 13.9	14	13.7	282	23.1	654	669	2.92
14.0 - 14.4	11	14.2	290	26.3	747	735	3.06
14.5 - 14.9	11	14.6	297	28.9	820	796	3.13
15.0 - 15.4	4	15.1	307	31.3	886	890	3.06
15.5 - 15.9	4	15.8	323	35.2	999	1055	2.96
16.0 - 16.4	6	16.2	330	42.0	1191	1134	3.31
16.5 - 16.9	2	16.5	335	42.5	1204	...	...
17.0 - 17.4	4	17.1	348	49.7	1410	1342	3.35
17.5 - 17.9	1	17.9	366	68.0	1928	...	...
18.0 - 18.4	6	18.2	381	63.4	1796	1836	3.25
18.5 - 18.9	1	18.6	388	73.0	2070	...	...
19.0 - 19.4	1	19.2	394	72.0	2041	...	...

Figure 7. Calculated length-weight relationship for the smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955. The points represent the empirical data for each length interval.

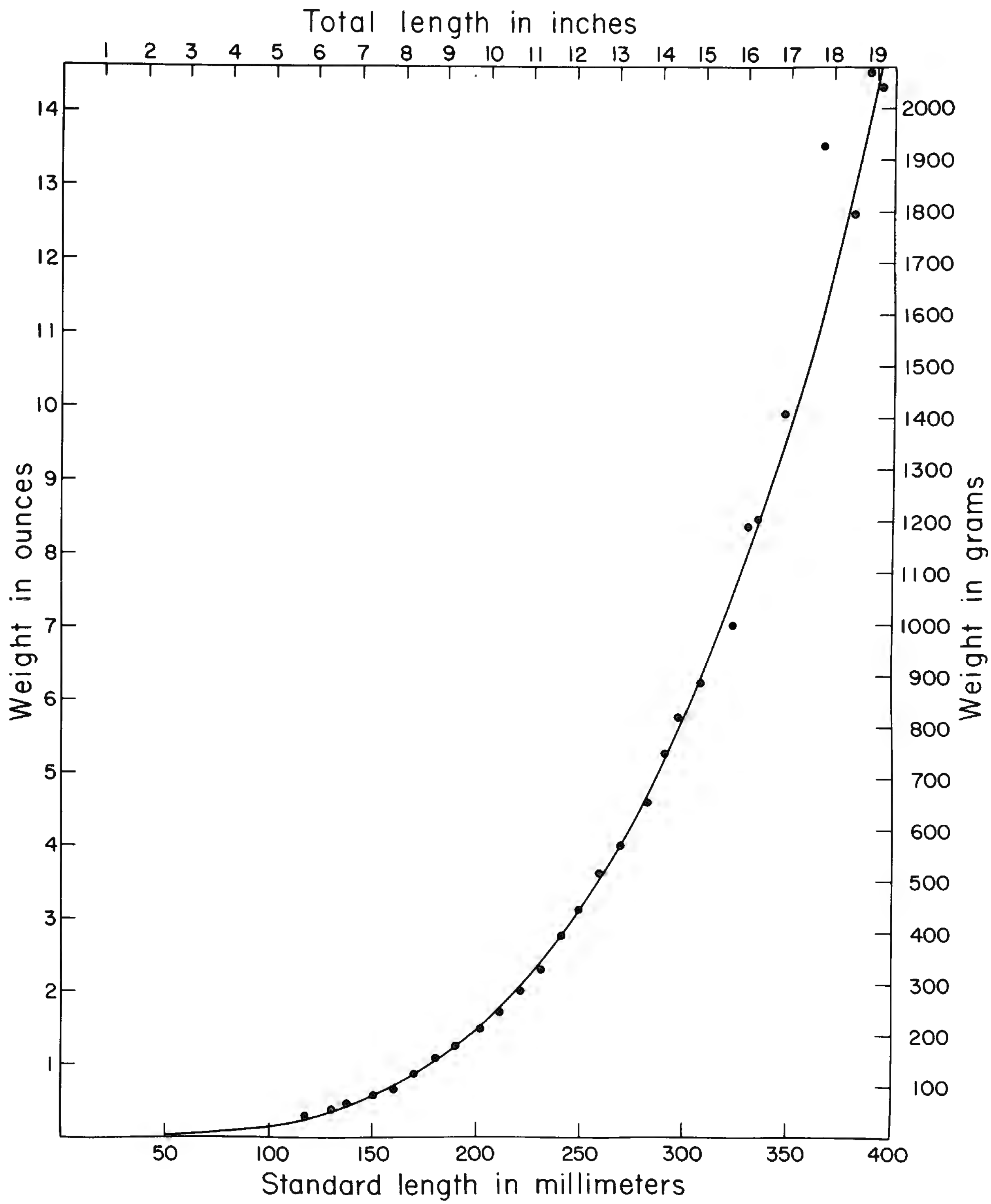
Total length in inches
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Weight in ounces
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Weight in grams
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
50
100
150
200
250
300
350
400
Standard length in millimeters

Fig. 7

Figure 7. Calculated length-weight relationship for the smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955. The points represent the empirical data for each length interval.

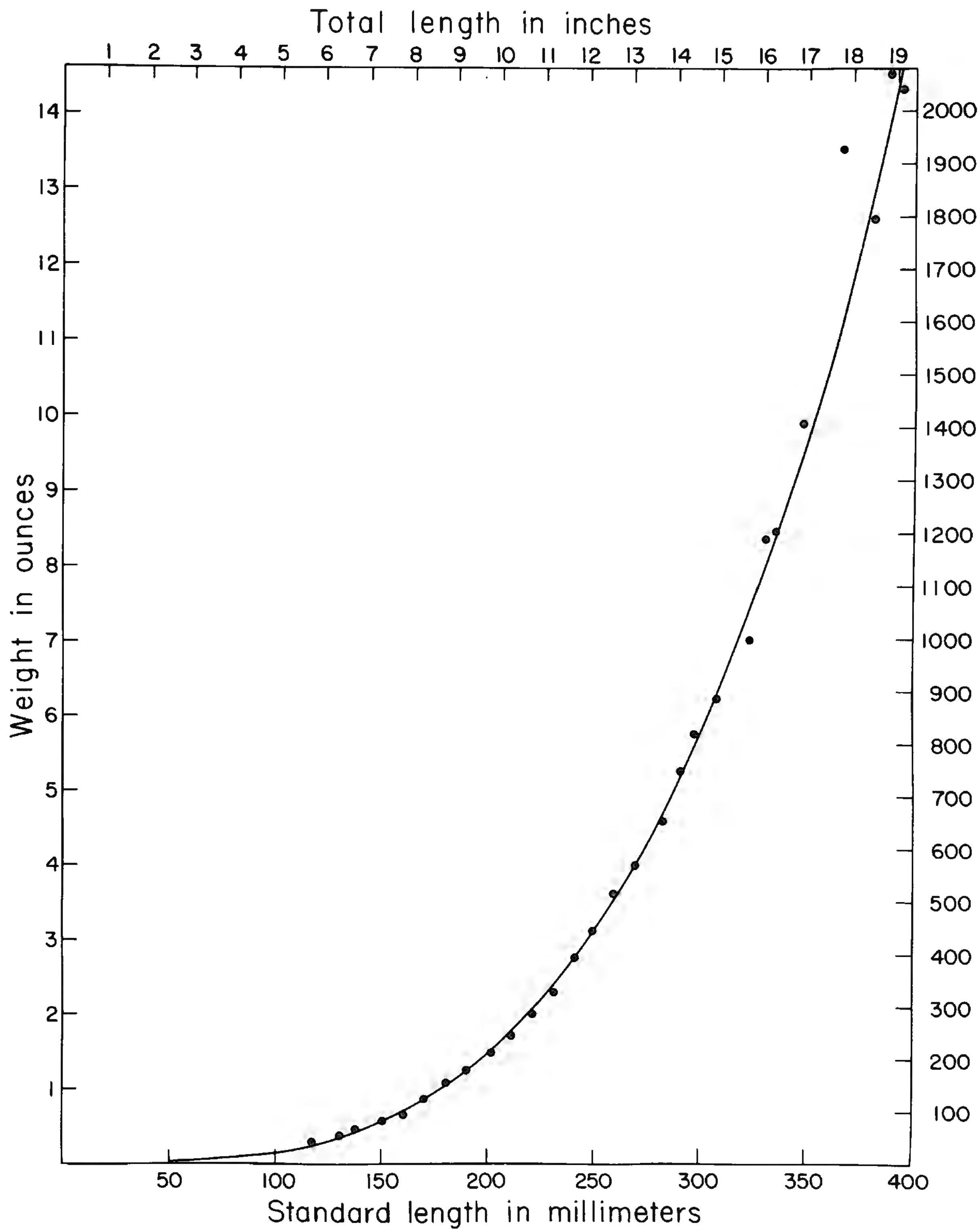
Total length in inches
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Weight in ounces
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Weight in grams
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
50
100
150
200
250
300
350
400
Standard length in millimeters

Fig. 7

The coefficients of condition, K, were also determined, using the formula $K = \frac{W \times 10^5}{L^3}$. W and L were defined previously. The coefficients of condition for the smallmouth bass of Waugoshance Point were considerably higher than comparable K values for the bass from the inland waters of Michigan (Beckman, 1948) and Wisconsin (Bennett, 1938).

Webster (1954) does not give K values for Cayuga Lake smallmouth bass, but he does list some average weights by total lengths, which are very similar to those for Waugoshance Point bass.

MOVEMENT

Loss of Tags

The fish were marked with a Monel metal, strap tag, size No. 3, fastened around the left maxillary bones. Relatively few tags were lost by the fish. The strap tag does not unfasten easily; rather, it cuts its way through the tissues and falls off while still locked. Loose fitting tags caused the most irritation around the maxillaries. Cutting proceeded posteriorly, parallel to the maxillary bones, through the softer tissues, rather than through the bones. The scar or wound was always apparent where a tag was lost.

In order to appraise tag loss, fish tagged in 1953 were also fin-clipped. Part of a different fin was cut off for each of three research areas of Waugoshance Point. Most of the fish had the soft part of the dorsal fin removed and it was only this group that provided sufficient returns to estimate the amount of tag loss. Judging from trap-net recoveries (there were not enough angler returns), there was no loss of tags during the 2 months of the 1953 study season.

In 1954, during the spawning period, another group of bass was marked by clipping the soft-dorsal, but not by tagging. Fish that had been clipped and tagged in 1953 and had lost their tags after the 1953 study season were readily distinguishable from those marked in 1954. Early in the season the fresh clip was easily recognizable as such, but later in the year, and in 1955, each fish with a soft-dorsal clip was examined for scar tissue around the maxillaries to see whether or not it belonged to the 1953 group.

In all 3 years, many of the bass were caught in the nets more than once. This was easy to determine for a tagged fish, but not for a fin-clipped fish that had lost its tag; therefore, in figuring the percentage of loss, every recapture was counted. It was assumed that a bass that had lost its tag would respond in the same manner to the nets as a bass carrying a tag. It is known, from recognizing a few individual fish that had lost their tags, that some were recaptured repeatedly.

In 1954, the estimated loss of tags was 6.1 percent (231 recoveries of which 14 had lost tags) and the 1955 estimate was 14.7 percent (75 recoveries with 11 lost tags). The netting in 1955 extended only through June 3, and undoubtedly the tag loss would have been higher if the netting period had been prolonged.

Mortality of Tagged Fish

During the course of field work, a record was kept of all tagged fish found dead. Of the 1,058 bass tagged in 1953, 4 were found dead in that year, 1 in 1954, and 1 in 1955, for a known loss during the three seasons of 6 (0.6 percent). The known mortality for the 1,819 bass tagged in 1954 was 12 the first year and 1 in 1955 (0.7 percent for 2 years). The 1955 tally of 3 dead bass out of 264 tagged gave the high of 1.1 percent. The total lengths of these recoveries, taken at the time of tagging, ranged from 8.4 inches to 14.3 inches. There was no indication that any particular size group within this range was adversely affected by the tag. Eschmeyer (1942), for the smallmouth bass among other species, and Ricker (1942), for the bluegill, both concluded that a strap tag attached to the jaw caused little mortality.

It does not appear that the handling of the bass, i.e., netting, taking a scale sample, tagging and, in 1953, clipping a fin, was the source of any excessive mortality. Ricker (1949) too, found that removing fins from adult centrarchids (two species) did not increase the mortality during one growing season.

Analysis of Tag Returns from Nets and Anglers

For the study of bass movement, the waters around Waugoshance Point were designated by sections (Figure 1) as follows: (1) Sturgeon--that part of Sturgeon Bay southeast of Little Sucker Creek; (2) Island--the waters around the islands at the tip of Waugoshance Point; (3) South--that part of Sturgeon Bay directly south of the Point; and (4) North--the waters directly north of the Point. Localities outside the Waugoshance Point area were identified with their proper names, Cecil (Bay) and Hog (Island).

Eleven of 1,058 smallmouth bass tagged in 1953 were transferred from the south side where they were captured initially to the north side for release. Bass, when moved away from their "homes," travel extensively in trying to return (Larimore, 1952). The returns from these 11 bass showed an interesting pattern; of the five recoveries, four were from the home section and one from the island section, the section adjoining "home."

All other bass (1,047) were released, after marking, where they were captured. Recaptures of these fish, by nets and anglers, numbered 186 in 1953, 264 in 1954, and 71 in 1955. Many were recaught more than once, in the same year and in different years, e.g., in the returns for three years of the fish tagged in 1953, there were 89 bass taken twice, 52 three times, 14 four times, 6 five times, and 4 six times. Eighty-four fish were caught in two different years and six in three different years. The returns for fish tagged in 1954 and 1955, for the year in which they were tagged, and succeeding years, were similar. One bass of the 1954 tagging was recaptured nine times and one of the 1955 tagging, eight times.

Marked bass, released at capture site, did not, as shown from the net returns (Table 16), move considerable distances. The procedure of releasing the tagged fish at the net resulted in many of the bass being recaptured in the same net within a few days. Nets were left in the same position for an average of 9.7 days (91 stations, range 1-38 days). For an analysis of movement, only fish which had been at liberty for at least 30 days were considered (Table 16). The listing of only the farthest movement, at the latest date recovered, was done to overcome the difficulty of recording several moves of the individual through different sections. The purpose of Table 16 is to show the extreme distances moved; it illustrates the locally circumscribed nature of the population in the entire study area. For example, if a tagged bass was released on the south side in early 1954, recaptured in the island section in late 1954, and then recaptured for the third

Table 16.--Number of smallmouth bass returns from trap nets, after 30 days of liberty, recorded for the farthest distance from the point of release, at the latest date captured

Release			Recapture							
Year	Locality	Number	Year	Locality					
				South	North	Island	Sturgeon	Cecil	Hog
1953	South	784	1953	9	...	1	1	...	...
	North	111		...	...	...	...	1	...
	Island	123		...	...	...	...	1	...
	Sturgeon	29		...	...	...	...	...	...
	South	...	1954	71	4	14	9	...	...
	North	...		6	1	1	...	...	...
	Island	...		8	3	7	...	1	...
	Sturgeon	...		1	...	...	1	...	...
	South	...	1955	33	...	...	...	...	...
	North	...		1	...	...	...	...	...
	Island	...		4	...	...	...	...	...
	Sturgeon	...		...	...	...	...	...	...
1954	South	748	1954	22	10	13	16	3	...
	North	102		1	2	2	1	...	...
	Island	412		...	4	19	3	...	...
	Sturgeon	172		1	...	...	...	...	...
	Cecil	223		1	...	1	2	...	...
	Hog	162		...	...	...	...	...	...
	South	...	1955	49	...	...	...	...	...
	North	...		9	...	...	...	...	...
	Island	...		8	...	...	...	...	...
	Sturgeon	...		18	...	...	...	...	...
	Cecil	...		11	...	...	...	...	...
	Hog	...		...	...	...	...	...	...

time back on the south side in 1955, this fish was recorded as having moved to the island section in 1954, the farthest distance from the place of release. If it had been recaptured again in the island section instead of the south section in 1955, the farthest distance would still be the island category but the latest date would have been 1955.

In all 3 years the netting effort was more intensive on the south side than elsewhere because of the larger concentration there of both bass and anglers. The returns from 1953 best illustrate the amount of movement in the population. The sample of bass tagged that year at Waugoshance Point was reasonably large. In 1954, the netting effort was spread to sample possible areas to which the bass might move, such as Cecil Bay and Hog Island. The netting period was relatively short in 1953, which explains the lack of returns for that year. The two individuals captured from Cecil Bay were taken in a commercial fisherman's gill net late in the fall. However, in 1954, the trap nets at Cecil Bay recovered only one of the 1953 tagged fish and none were captured at Hog Island. The 1955 netting effort was all in the south section and the returns show only that many of the 1953 tagged fish were still present.

In 1953, the trap netting was exploratory, spreading from the north side to the south, then to the islands, back to the south section and briefly to Sturgeon Bay. The goal was to locate the best fishing grounds and to tag bass for future recoveries. In 1954, the system started with the south section (before the fishing season opened) went to Hog Island in early July, came back to Cecil Bay in mid-July, the north section in late July, and then, individually, the island section, the south section and Sturgeon Bay during August. In early September, nets were distributed simultaneously through Sturgeon Bay, the south, island and north sections. Late in the fall of 1954 there was occasional netting in each of the last three areas. In general, five or six trap nets were used at each locale, with the exception of the short period in early September, 1954, when twelve nets were spaced widely over the area of the Point.

In 1954, recoveries of fish tagged in that year showed free movement among all water areas of Waugoshance Point and Sturgeon Bay. Also, three of the fish tagged on the south side moved as far away as Cecil Bay, and four of the fish tagged at Cecil Bay returned to Waugoshance Point. In 1955, 11 of the bass from Cecil Bay were taken in the nets on the south side. As far as the recaptures in nets are concerned (there were also some angler recoveries), none of the fish tagged at Waugoshance in 1953 were found at Hog Island in 1954, and likewise, none of the 162 bass tagged at Hog Island in 1954 moved to Waugoshance in 1954 or 1955. From the recaptures in nets alone, it appears that the bass population is concentrated at Waugoshance Point and the part of Sturgeon Bay studied, with some minor alongshore movement, both into, and out of, the area.

An analysis of the returns from anglers (Table 17), considering the waters around Waugoshance Point as a whole, showed almost the same pattern of movement as the returns from nets. Voluntary returns were secured for Hog Island, Cecil Bay, and other localities. Returns for Waugoshance Point were obtained by creel census. The fishing pressure was the heaviest at Waugoshance and considerably lighter at the other two places. The returns from anglers, as from nets, showed the same movement for bass between Waugoshance and Cecil Bay. In addition, the angler returns showed movement between Hog Island and

Table 17.--Number of smallmouth bass tagged and number of returns from anglers for each locality

Release			Recapture				
Year	Locality	Number tagged	Year	Locality			
				Waugo-shance	Hog Island	Cecil Bay	Other
1953	Waugo-shance	1047	1953	35	...	1	1
			1954	102	2	...	...
			1955	26	...	...	...
1954	Waugo-shance	1434	1954	61	...	...	2
			1955	84	2	...	3
	Hog Island	162	1954	...	10	...	...
			1955	1	5	...	...
	Cecil Bay	223	1954	...	...	...	1
			1955	10	...	1	1
1955	Waugo-shance	264	1955	47	...	...	1

Waugoshance. Two of the bass tagged in 1953 were caught at Hog Island in 1954 and two of the fish tagged in 1954 were caught there in 1955. Only one of the fish tagged at Hog Island was recovered at Waugoshance Point. On the basis of the returns from anglers and the recaptures in nets, there appears to be less movement of bass between Hog Island and Waugoshance than there is between Cecil Bay and Waugoshance.

Any tagged bass recovered outside of the localities mentioned were placed in the "other area" category; for the 3 years only nine such fish were reported by anglers. Some of the distances (minimum measurements, following the shore line) that they moved were less than the distances between sections, e.g., from Sturgeon Bay to the islands is about 5 miles, from the north section to Cecil Bay is only 10 miles, whereas the least distance traveled for a fish in the "other area" category was 4 miles, from the north section to Big Stone Bay (Table 18). The farthest distance was 92 miles, from the south section to Ford Island in Grand Traverse Bay, Lake Michigan. Three "other area" bass moved the relatively short distances of 4, 6 and 8 miles, whereas the other six traveled more than 20 miles. The relatively few individuals found more than 20 miles away (the six above plus the five either to or from Hog Island) emphasize the modesty of movement for this species. Also, the returns from both the anglers and the nets attested to the integrity of the Waugoshance population, which is an important consideration in any attempt to estimate the numerical abundance of a species.

Until recently there have been few studies of the movement of the smallmouth bass. Snyder (1932), working in Lake Ontario, marked 150 bass with aluminum tags attached to the gill cover. Anglers reported

Table 18.--Distances traveled by smallmouth bass captured outside of the areas netted

Release		Recapture		
Year	Locality	Year	Locality	Distance[1] (miles)
1953	North	1953	Big Stone Bay, L. Michigan	4
1954	Cecil	1954	Cheboygan River, L. Huron	22
1954	South	1954	Duncan Bay, L. Huron	37
1954	South	1954	Duncan Bay, L. Huron	37
1954	Sturgeon	1955	Cross Village, L. Michigan	8
1954	Island	1955	Big Stone Bay, L. Michigan	6
1954	South	1955	Bay View, L. Michigan	36
1954	Cecil	1955	L. Charlevoix, L. Michigan	69
1955	South	1955	Ford Island, Grand Traverse Bay, L. Michigan	92

[1] Distance is the minimum number of miles from point of release to place of recapture following the shoreline.

19 of these, none of which were more than 3 miles from where they were originally taken in the nets of the commercial fishermen, and where they were released after tagging. The tags had nearly worn through the gill cover of fish caught the second season, and probably all, or nearly all, were thought to have lost their tags in that year.

Doan (1942), working in Lake Erie, tagged 117 smallmouth bass in a 3-year period, using a strap tag attached to the gill cover. There were nine returns, three within the first week at a distance of 9 miles from the point of release, five between 2 and 4 weeks at a distance of 12 miles, and one returned between 2 and 6 months, 2 miles from the release point.

Cuerrier (1943) tagged 970 smallmouth bass on spawning grounds in the Chateauguay River, Quebec (a tributary of the St. Lawrence River). The majority of recaptures were by anglers in Lac Saint-Louis, within 5 miles of the point of release. The farthest a bass was taken from the tagging area was 30 miles. It was shown that this population was distinct from others nearby in the St. Lawrence system. Also, there was some indication that this population returned each year to the Chateauguay River to spawn.

An extensive study of the movement of the smallmouth bass was made by Stone, Pasko and Roecker (1954) in the Lake Ontario-St. Lawrence River region. From 1944 through 1950, 4,408 smallmouth bass were tagged using a strap tag attached to either the dorsal fin, maxillary or mandible. Angling recoveries were 2.0 percent, 9.1 percent and 21.5 percent, respectively, for the three positions of attachment; from 1946 on, the tag was attached only to the lower jaw (2,853 fish, 612 recoveries). Most of the bass traveled less than 5 miles from the point of release. It was concluded from movement and growth data that there were six distinct populations in the ten localities netted.

Fraser (1955) tagged 3,331 smallmouth bass in South Bay, Lake Huron. Eighty-five percent of the recaptures were taken within 2 miles of the point of release. Only 5 percent of all recaptures were over 5 miles from the point of release, based on trap-net returns. Most angling recaptures were near the point of original release. The larger bass tended to range farther than the smaller ones.

Webster (1954), working on the smallmouth bass in Cayuga Lake, a large (66 square miles), oligotrophic, glacial lake in central New York, found two discrete populations--one, a localized group centering around a spawning ground in a tributary, and the other, around a wintering ground in the lake. The returns from the stream population were mostly taken within 2 miles of the release point (from 1944 through 1952, 827 bass were tagged and 113 recovered). In contrast to this local population, the bass tagged in the lake (3,115 tagged, 236 recoveries) apparently migrated to the northern end, about 30 miles distant, only to return the next fall to the wintering area.

Larimore (1952) demonstrated in Jordan Creek, east-central Illinois, the tendency of the smallmouth bass to remain in the same pool in which they were tagged, and the ability of those transferred to other parts of the stream to return to the pool from which they had been removed.

Schumacher and Eschmeyer (1942) found that the smallmouth bass in Norris Reservoir, Tennessee, traveled much less than did the largemouth bass and spotted bass. It was computed that 90 percent of the smallmouth were within 2 miles of the point of liberation on the 15th day after release, within 3 miles on the 40th day, and within 3.3 miles at the end of the fishing season.

Movement with Relation to Size

The question may now be raised for the Waugoshance region: what is the relationship among size of fish, distance traveled, and the number of times captured? The 1954 trap-net data were best to use in answering this question because returns were more numerous than in the other 2 years and netting effort was better distributed. For convenience, the length data on fish were grouped in one-inch intervals, except that the extremes were combined in an attempt to provide the most substantial sample possible, i.e., the 6.0- to 8.9-inch fish were included in a single group, as were the 14.0- to 16.9-inch fish. Then, for each group, the following were computed: (1) the mean minimum number of miles traveled per day; (2) the mean minimum number of miles traveled between captures; and (3) the mean number of times a fish was captured (Table 19). For the most part, with an increase in size of the fish, there was an increase in distance traveled, and correspondingly, an increase in the number of times an individual was captured. The outstanding disagreements were in the extreme groups. In the smallest size group, distances traveled per day and between captures were much larger than might be expected. A possible explanation of this is sampling error; it is known that the trap nets captured the larger, faster-growing individuals in this size group and that these fish were probably more active than the smaller ones. Fish in the largest size group also disagree in the mean number of times a fish was captured; this probably can be attributed to the small size of the sample. Discounting the 6.0- to 8.9-inch fish, there is a positive correlation between the distance traveled between captures and number of times a fish is captured ($r = 0.55$) and there is excellent correlation ($r = 0.87$) if

Table 19.--Relationship of size, movement and number of times a fish was captured

Length intervals in inches	Number of fish	Mean number of times a fish was captured	Mean minimum number of miles traveled per day	Mean minimum number of miles traveled between captures
6.0 - 8.9	32	1.09	0.048	0.521
9.0 - 9.9	58	1.19	0.017	0.181
10.0 - 10.9	127	1.43	0.022	0.315
11.0 - 11.9	124	1.40	0.044	0.582
12.0 - 12.9	59	1.46	0.045	0.679
13.0 - 13.9	30	1.53	0.042	0.954
14.0 - 16.9	19	1.37	0.047	1.067

the 14.0- to 16.9-inch group is not used. Watt (1956) has given an illustration of how important it is to correct for differences in movement of fish, in each age-group, in population estimates based on net recaptures.

Catchability of Tagged Fish

Fin-clipping and tagging were alternated in marking the bass captured during the course of the 1954 pre-season netting in the south section. The average total length of the 236 fin-clipped bass was 11.1 inches (range 6.5-18.6) and of the 234 tagged bass, 11.0 inches (range 8.2-16.2). Apparently the two groups were random with regard to size. The catchability of the marked fish was measured by tabulating the number of recoveries of each (tagged or fin-clipped) in the creel census.

In Michigan, 10 inches is the minimum legal length for capture of smallmouth bass. In this early 1954 lot of marked fish, 27 of those tagged and 30 of those fin-clipped were less than 10 inches long. The smallmouth at this size in early spring, at Waugoshance Point, will grow almost 2 inches in a year. At least half of this growth would be expected during the sampling time (no returns for August and September). Therefore, all fish 9.0 inches and longer were assumed to become available to the anglers by the end of July. When the total figures of 236 and 234 were adjusted for undersize fish and known mortality, there were 219 tagged bass and 221 fin-clipped bass available; of these, 15 tagged fish and 20 fin-clipped fish were recovered. The test of independence was made with the hypothesis that the two attributes--how marked and number of recoveries--were not related. The hypothesis was accepted (X^2 = 0.37, P falling between 0.50 and 0.70); there was no difference in the catchability of tagged versus fin-clipped bass. Ricker (1949) found that fin-clipped adult bluegills were caught by fishermen as readily as unmarked adults. If we assume this to be true for the bass, then there is probably no difference, in response to angling, between a tagged and an unmarked bass.

Distribution of Fin-Clipped Versus Tagged Bass

With regard to amount of movement, some information on the influence of a tag on the upper jaw of a smallmouth bass as compared to none on a fin-clipped fish, was garnered from the distributional pattern of recaptures of tagged fish and fin-clipped fish (Table 20). In this experiment, the recoveries by nets, during the 1954 season, of both 10-inch, and shorter, tagged and fin-clipped fish, were recorded for the five localities providing returns. Each time an individual was taken in a net it was recorded, i.e., the first, second, third, etc., recapture was listed. This was done because it was not possible objectively to tell individual fin-clipped fish apart. It was assumed that a fin-clipped fish would be recaptured as often as a tagged fish. A Chi-square analysis of the distribution showed that there was no relationship between the mark used and the number found in different localities (X^2 = 3.72, d.f. = 4, P falling between 0.30 and 0.50). The returns were in about the same ratio for all localities except the north and Cecil Bay (Table 20). Apparently the movement of the smallmouth bass was not influenced more by one kind of mark than the other.

The net returns for tagged fish were consistently about one-third greater than those for the fin-clipped fish, although almost equal numbers of tagged (234) and fin-clipped (236) bass were released, known

Table 20.--Comparison of the distribution, in different localities, of recoveries of two differently marked groups of bass

Mark	Locality					Total
	South	North	Island	Sturgeon	Cecil	
Soft dorsal	87	7	7	12	2	115
Tag	130	3	11	18	2	164

mortality was about the same for each, and the anglers' catch was not significantly different for the two groups. A possible explanation of this is that fin-clipped fish escaped notice more readily than tagged ones, in the processing of large numbers of fish in nets. It would be easy to overlook a clipped fin, especially if there was regeneration to any extent, as is likely late in the season. Although I tried to see every fish, I did not quite succeed and had to rely in part on my field helpers. Another possibility is that the tagged fish were more susceptible to trap netting than the fin-clipped fish.

If a third of the fin-clipped fish were overlooked, the loss-of-tag data (see section on loss of tags) should be adjusted accordingly, which would increase the tag loss, for 1954, to about 9 percent and, for 1955, to about 22 percent.

The fish in the creel census were examined much more closely than were those taken in the nets; the bulk of the catch was made during the early part of the fishing season before the fin would be regenerated very much, so there is much less likelihood of any error in the comparison of the returns of the marked fish to the anglers.

NUMERICAL ABUNDANCE

Population Statistics

Ricker (1948) listed six requirements that must hold true in a mark-recapture estimate of a fish population. Each of these will be considered in relation to the estimates of the size of the smallmouth bass population (Table 21) made in 1953, 1954 and 1955 at Waugoshance Point. These requirements are:

(1) "That the marked fish suffer the same natural mortality as the unmarked;"

Table 21.--Estimates of the size of the population of smallmouth bass at Waugoshance Point, Lake Michigan

Period of tagging	Period of sampling	Method of sampling	Size of population	Confidence limits	
Aug. 18-Sept. 2, 1953	May 30-June 14, 1954	Nets	6,007	4,290	10,011
May 30-June 14, 1954	June 19-June 30, 1954	Anglers	5,264	3,668	9,317
Aug. 13-Aug. 30, 1954	May 19-May 26, 1955	Nets	4,920	4,018	6,346
May 19-May 26, 1955	June 18-June 30, 1955	Anglers	4,184	2,891	7,571

The known mortality of bass tagged during the 3 years was minimal. Ricker (1942) concluded that trapping, handling, removing fins and tagging resulted in very little or no mortality for the bluegill and other sunfishes in Shoe Lake, Indiana. Eschmeyer (1942) decided that a strap tag attached to the upper jaw of some of the common species of fish (including the smallmouth bass) present in Norris Reservoir, did not appreciably increase mortality. On this evidence, it seems a safe assumption that mortality was proportional for the tagged and the untagged bass.

(2) "that the marked fish do not lose their mark;"

Occasionally, the tagged bass did lose the tag, but an estimate of the percentage loss was computed and applied where necessary to properly adjust the estimates of numerical abundance.

(3) "that the marked fish are as vulnerable to the fishing being carried on as are the unmarked ones;"

This was demonstrated in the angler returns of smallmouth bass, but there was doubt with regard to returns from the nets. However, the actual estimates of the size of the population, comparing the angler returns with the net returns, are close enough to suggest that there is no difference in the vulnerability of tagged, as compared to untagged, fish. The difference found in the proportion of tagged to fin-clipped bass caught in the nets can probably be attributed to regenerated fins overlooked in the catch.

Another consideration is that the larger fish move farther than the smaller fish and therefore are more vulnerable to capture. This proved true at Waugoshance Point but, because the estimates were concerned primarily with legal size fish, and the mean number of times a fish was captured scarcely increased with size in this group, no adjustment was made for this factor in the population estimates.

> (4) "that the marked fish become randomly mixed with the unmarked; or that the distribution of fishing effort is proportional to the number of fish present in different parts of the body of water;"

The tagged bass distributed themselves throughout the sections of Waugoshance Point in the same proportion as the fin-clipped bass. Further, the tag returns from both nets and anglers indicated freedom of movement throughout the area of the Point. The angling effort was, in all probability, nearly proportional to the numbers of fish present in each section, but the netting effort was concentrated, for two of the three estimates, in the south section.

> (5) "that all marks are recognized and reported on recovery;"

A jaw tag is easily recognized. I saw all fish used in the estimates based upon angler returns, and was present at all netting activity.

> (6) "that there is only a negligible amount of recruitment to the catchable population during the time the recoveries are being made."

In situations where it was necessary, an adjustment for recruitment was made from known growth. As for fish moving into the Waugoshance Point area, the movement study demonstrated the integrity of the population, i.e., movement into, and out of, the area was very small. The fact that tagged fish and fin-clipped fish distributed themselves similarly indicated that the proportion of tagged individuals remained constant even with some movement out of the area.

The Petersen type of estimate of the size of the population, where the proportion of individuals is assumed constant, is the most applicable to the situation at Waugoshance Point. Unlike the Schnabel method, this type of estimate is not appreciably affected by changes in the population size, if the causes of these changes work equally upon tagged and untagged fish (Ricker, 1948; DeLury, 1951). DeLury's notations were used, where

$\hat{N}$ = an estimate of the number of individuals in the population,

X = number of tagged individuals in the population,

n = number of individuals in the sample,

x = number of tagged individuals in the sample.

Thus the equation used for the estimate of the size of the population was

$$\hat{N} = \frac{X \Sigma n}{\Sigma x} .$$

The approximate 95 percent confidence limits were calculated with

$$\frac{nX}{x + 2\sqrt{x\left(1 - \frac{x}{n}\right)}} < N < \frac{nX}{x - 2\sqrt{x\left(1 - \frac{x}{n}\right)}}$$

In 1954, from May 30 through June 14, 320 legal-size bass taken from nets set in the south section were tagged and released. From the creel census returns for June 19 (the opening day of the fishing season) through June 30, 329 bass were counted, of which 20 were tagged during the preseason netting. The estimated population was 5,264 legal-size bass, with confidence limits of 3,668 to 9,317. Relative to the factors discussed above, there should be little bias in this estimate of the population. Natural mortality, and any mortality caused by tagging, should have been at a minimum during the month involved. In 1953, there was no loss of tags in two months, so none would be expected during this first month among bass tagged in early

June, 1954. It has been shown previously that tagged bass were as catchable as untagged bass; the anglers fished most of the waters of Waugoshance Point fairly well. There was no doubt that all of the tagged fish in the sample were seen. Growth did not begin in this population until late June or early July; therefore recruitment can be discounted. It would seem then, that this is a good estimate of the size of the population available to the fisherman at the opening of the season.

Verification of the estimate was provided by the preseason net returns of a group of bass tagged in late 1953 (August 18 through September 2). In this situation, there was a problem of recruitment. It was desirable to know how many of these fish would be in the legal-size population available to the anglers in 1954. The only fish involved belonged to the dominant 1949 year-class. From known calculated growth, this year-class averaged 10.3 inches at the time of the annulus formation in 1954. The average empirical length for those members of this year-class tagged in late 1953 was 9.8 inches, which is an average of about 0.5 inch of growth between time of tagging and time of possible recapture. The assumption was made that the jaw tag did not appreciably retard growth in such a large-mouthed fish as a smallmouth bass. Allowing for the recruitment, there were 136 bass 9.5 inches or longer available to be recaptured during the 1954 preseason netting. The sample consisted of 1,060 fish, of which 24 were tagged, for an estimate of 6,007 (confidence limits 4,290 to 10,011).

The basic assumptions considered here were that: natural mortality for the tagged and untagged individuals was proportional; that any movement out of the area was proportional; because smallmouth bass remain practically dormant during the winter months (Webster, 1954), any mortality or movement would be negligible; tag loss would be negligible; and finally, there was a sufficient time between dates of release and recapture to permit even spread of the tagged fish through the population. Therefore, the sample would be random, even though the nets were not moved extensively throughout the south section.

The estimate of 6,007 bass of the foregoing compares favorably with the estimate of 5,264 based upon returns from anglers. Any small error in growth calculations would vary the number of bass in the total estimate, because this large year-class was in the process of entering the fishery, e.g., if 0.3 inch of growth is considered necessary for recruitment, instead of 0.5 inch, 122 tagged fish would be available for sampling, and the estimate is thus lowered to 5,388 bass. There were insufficient returns in the anglers' catch, of those fish tagged in 1953, to estimate the size of the population in this way.

The same procedure was followed in 1955 as in 1954. During the preseason netting (May 19 to May 26), 238 legal-size bass were tagged, and the sample was taken during the census (334 bass, of which 19 were recoveries). The number of bass was estimated to be 4,184, with confidence limits from 2,891 to 7,571. Again, a test was provided by an estimate based upon the returns from fish tagged August 13 through August 30, 1954. There were 368 tagged fish available, of which 73 were recorded in a sample of 976. This was an estimated population of 4,920 (confidence limits 4,018 to 6,346), which agreed very well with the figure 4,184, based upon angler returns. Recruitment was again based upon growth of 0.5 inch from late August, 1954, to the time of annulus formation in 1955. In this interval, there was no large year-class entering the fishery. The 1950 year-class was very small, and only a few of the faster-growing individuals of the 1951 and 1952 year-classes entered the catch in 1955. The rate of growth for 1954 for these three year-classes was very close to that of the 1949 year-class, so that the assumption of 0.5 inch of growth is probably safe. There were not enough returns from the anglers' catch of 1954 marked fish to estimate the population size.

Although anglers fished practically all of the waters of Waugoshance Point, they concentrated in the south section, and the estimates based upon net returns were likewise concentrated in this area. The question arises as to whether or not these are estimates of the bass in the south section only. In the case of the net-estimates, the tagged fish had sufficient opportunity to become mixed with the whole population. As for the angler-estimates, the tagged fish had little time to become distributed, but the anglers did sample over a wider area than did the nets. In 1954, at stations starting in the north section on July 23, and moving systematically to the island section, to the south section, and finally, on August 30, finishing in Sturgeon Bay, a large number of bass were tagged. Then a sample was taken from all sections simultaneously, using twelve trap nets distributed at regular intervals throughout the sections. The sample of 478 legal bass, of which 69 were recoveries, was taken September 3 through September 9 (with the exclusion of September 6). There were 513 tagged bass available. Thus, the estimate was 3,554 (confidence limits 2,905 to 4,575). It was assumed that natural mortality and, likewise, fishing mortality, would be proportional in the tagged and untagged fish, also, that any movement out of the area would be proportional. No allowance was made for recruitment, which, if significant, would increase the size of the estimate. Tag loss over so short a period would be negligible. Still, this estimate was considerably smaller than the 1954 net-estimate of 4,920. The source of bias was probably in the sampling; of the twelve nets, five were in the same position as when the available fish were tagged. Thus, there was perhaps too little time between release and sampling to permit a thorough mixing of the population. However, if there was a much larger population of smallmouth bass than the previous estimates (which were concentrated in the south section) showed, it is probable that this estimate (which considered all of the waters of the Point) would indicate the larger size, even with the bias involved.

Mortality Rates

Ricker (1945) described two methods of estimating survival, or its complement, mortality, in a fish population. The first, the "indirect" method, is based upon a comparison of the numbers in successive age groups in a random sample. This is dependent upon equal recruitment of each year-class. Dominance of year-classes of the population at Waugoshance Point prevents the use of this method.

The second, the "direct" method, is based upon the mark and recapture of groups of fish in two successive years. If

x = the fish marked at the start of the fishing season in year one,

y = the fish marked at the start of the fishing season in year two,

c = the returns of x during year two,

d = the returns of y during year two,

then the survival rate (s) will equal

$$\frac{cy}{dx} .$$

The mortality rate (a) will be the complement of this, or

$$a = 1 - s.$$

Only the year-class of 1949 and earlier ones were used in computing mortality so that recruitment bias would be eliminated from the estimate. Of the foregoing year-classes, 308 fish were tagged in 1954, from May 30 through June 14, before the fishing season opened. In 1955, from May 17 to May 26, 190 fish of these classes were tagged. The returns consisted of 19 of those marked in 1954, and 21 of those similarly treated in 1955. These returns were from a census of the anglers carried on from opening day, June 18, through June 30, 1955. The 1955 fish were at liberty for such a short time that there was relatively little, if any, loss of tags, but the 1954 fish were at large for a year. The estimated tag loss figure of 9.0 percent was applied to adjust the number of 1954 fish available (0.91 x 308 = 280). No allowance was made for migration of tagged fish out of the area. The survival rate (s) becomes 0.42 and the mortality rate (a), the complement, 0.58, for the period from June, 1954 to June, 1955. Net returns from 1955 were not used in estimating the survival rate, because the recently tagged fish were recaptured in a larger proportion than their presence in the population.

It was not possible, in the population estimates, to compute the number of bass below the legal size because (1) the fishermen obviously could not provide a sample of the sublegal fish, and (2) the preseason netting, made just prior to, and during spawning, sampled predominantly fish 10 inches in length and longer. But the netting in late 1953 did provide a ratio of legal to sublegal fish which can be used to estimate the number of fish available to the anglers during the 1954 season, and to provide an estimate of those of legal size surviving to 1955. The growth calculations of the 1949 year-class, during the 1954 season (almost the only year-class involved), showed that all fish 8.2 inches and longer would reach the legal size of 10 inches by early 1955. Previous computations have shown that there were 6,007 bass 9.5 inches or longer present in late 1953. This was on the basis of 136 tagged fish of this size. The same sample included 72 bass in the range 8.2 inches through 9.4 inches. Applying the ratio, 136:208, the population of bass 8.2 inches or longer was 9,187. If it is assumed that this will change little from late 1953 to early 1954, a survival rate of 0.42 yields an estimate of 3,859 legal fish left by early 1955. This agrees very well with the previous estimates for the period.

During the 1954 season, the anglers harvested 1,996 bass (see below) of the 9,187 available, for a fishing mortality rate (μ) of 0.22. The natural mortality rate (v) is the difference between total mortality and fishing mortality ($v = a-\mu$) or 0.36. Undoubtedly, some of the natural mortality can be attributed to injurious hooking of fish below the legal size; also in this category are the few fish that migrated out of the area of Waugoshance Point.

Harvest

A single road leads to the fishing grounds of Waugoshance Point. It ends in two closely adjacent parking lots. This situation simplified the taking of the creel census. Hourly counts of the number of fishermen's cars, the average number of fishermen per car, and the catch of bass per hour per angler were taken; with these figures and the over-all time involved, the number of bass caught for the season was estimated.

Cars in the parking lots each hour, from 8 a.m. until 9 p.m., were counted at every opportunity. The area is sufficiently confined so that any picnickers or sightseers could be identified and not counted. There was very little fishing before 8 a.m. and practically none after 9 p.m. The following is an illustration of the number of counts taken, and the number of cars present. It was made during the month of July, 1954.

	a.m.					p.m.	
Hour	8	9	10	11	12	1	2
Cars	21	17	26	38	29	29	34
Counts	10	6	7	11	7	5	8
Cars/Counts	2.10	2.83	3.71	3.45	4.14	5.80	4.25

	p.m.						
Hour	3	4	5	6	7	8	9
Cars	47	65	19	12	9	15	3
Counts	7	9	3	3	3	8	3
Cars/Counts	6.71	7.22	6.33	4.00	3.00	1.88	1.00

In conjunction with angler estimates, many individual fishermen were contacted at the end of their fishing trip. Catches were recorded, along with duration of fishing effort, and some miscellaneous information on bait used, kind of fishing (i.e., boat, wading, trolling, etc.), and home locale. During July, contact was made with 60 fishing parties composed of 137 anglers (2.28 anglers per car). The catch per hour per angler for these individuals was 0.25 bass. Using these data for the 31 days of July, the total catch was estimated at 997 bass. The same procedure was followed throughout the four periods into which the fishing season was divided--June 19 (opening day), June 20 through 30, July, and August plus the first 6 days of September. After the Labor Day holidays, sport fishing was practically nil.

The estimated total catch for 1954 was 1,996 bass. The estimated catch and the catch per hour per angler, for each period, demonstrates the superiority of early fishing (Table 22). Fishing pressure dropped off as the season progressed, and, consequently, so did the number of fish caught. The bass were more concentrated in the shallows during the time of spawning and then gradually became more widely dispersed. Tag returns indicated that they were still within the area of Waugoshance Point, but that the wading anglers (82.5 percent of the anglers waded, in 1954) did not find them as readily as in the early part of the season. Creel censuses conducted in 1953 and 1955, although not for the entire season each year, demonstrated this same pattern of greater fishing success early in the season.

The census also provided data on the year-class composition of the catch (Figure 8, Table 23). In 1953, the 1947 year-class was supporting 50.7 percent of the fishing, with another 36.6 percent being contributed by the 1949 year-class, just entering the fishery. In 1954, the fish of the 1949 year-class provided most of the fishing (88.1 percent), but by 1955, although this year-class was still predominant (71.1 percent), some of the later year-classes were coming into the fishery. In each year, the mean total length of the fish caught was within the 11.0- to 11.9-inch size group, and the mean weight was between 3/4 pound and 1 pound.

Discussion

The fishing mortality rate for the smallmouth at Waugoshance Point was 0.22 (22 percent). Although such a rate does not seem high,

Table 22.--Catch per hour per angler and the estimated catch of the smallmouth bass for four fishing periods of 1954, at Waugoshance Point, Lake Michigan

Period	Catch per hour per angler	Standard error	Standard deviation	Number of anglers contacted	Estimated catch
June 19	1.11	0.20	0.86	25	213
June 20-30	0.54	0.04	0.44	109	677
July 1-31	0.25	0.03	0.37	137	997
Aug. 1-Sept. 6	0.12	0.04	0.27	50	109
Total					1996

Figure 8. Percentage of each year-class in the catch of smallmouth bass, Waugoshance Point, Lake Michigan, 1953-1955, as determined from the creel census. The mean total length and mean weight of the smallmouth bass caught each year are listed.

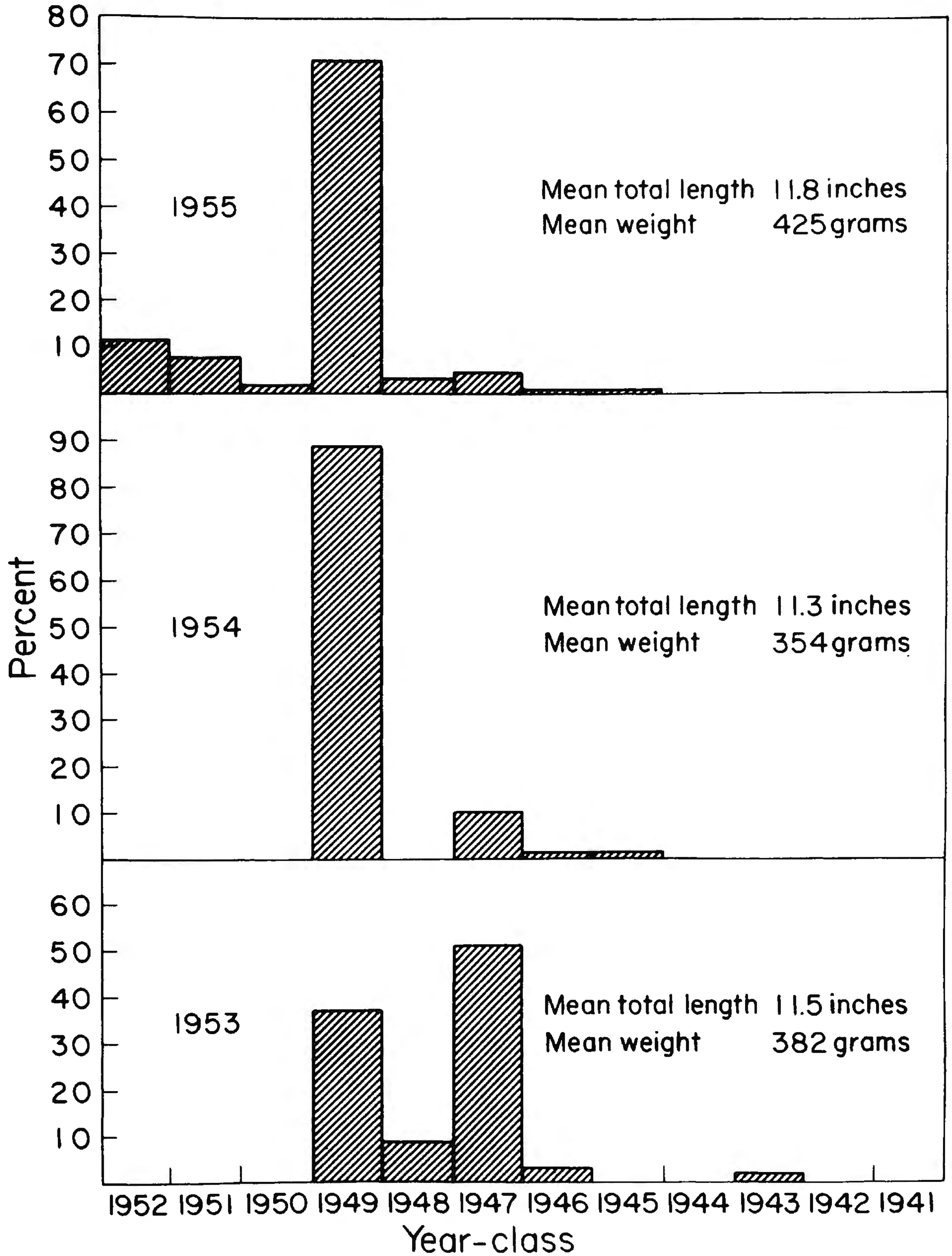
80
70
60
50
40
30
20
10
1955
Mean total length 11.8 inches
Mean weight 425 grams
90
80
70
60
50
40
30
20
10
1954
Mean total length 11.3 inches
Mean weight 354 grams
60
50
40
30
20
10
1953
Mean total length 11.5 inches
Mean weight 382 grams
Percent
1952 1951 1950 1949 1948 1947 1946 1945 1944 1943 1942 1941
Year-class

Fig. 8

Table 23.--Percentage of the catch, by age-group, in the smallmouth bass fishery, for three years at Waugoshance Point, Lake Michigan

(N = number of fish)

Age-group	1953		1954		1955	
	%	N	%	N	%	N
III	...	...	...	...	11.1	15
IV	36.6	26	...	...	7.4	10
V	8.5	6	88.1	89	1.4	2
VI	50.7	36	...	...	71.1	96
VII	2.8	2	9.9	10	3.0	4
VIII	...	...	1.0	1	4.4	6
IX	...	...	1.0	1	0.7	1
X	1.4	1	...	...	0.7	1

when added to a natural mortality of 0.36, the total indicates a substantial reduction each year in the number of bass available to the anglers. Assuming that these rates are fairly consistent from year to year, a depletion of this amount upon a fishery with variable recruitment will undoubtedly lead to poor fishing in some years.

The fishing mortality in the Waugoshance area falls within the range of mortality calculated for other areas. Eschmeyer (1942) gave a rate of exploitation of 14.9 percent, based upon tag returns from a part of Norris Reservoir. Stone, Pasko and Roecker (1954) obtained an 11.1 percent return of bass, tagged on the lower jaw, for the first season after tagging. They believed that "at least 50 percent of the tagged fish caught were reported and probably the return was much higher in some localities." This would mean an approximate rate of exploitation, for the bass of the Lake Ontario-St. Lawrence River region, of 22 percent. Fraser (1955) estimated, from returns of marked fish, a 50 to 65 percent fishing mortality, for the 4 to 5 years following marking, in South Bay, Lake Huron. Maximum rates of exploitation calculated from the virtual population (defined as the complete contribution of a year-class to the fishery), by Fraser, were about 60 percent for those bass of age-groups VI, VII, and VIII; for younger age-groups it became progressively lower, falling to only 10 percent for those fish in age-group III, just entering the fishery.

MANAGEMENT PROPOSALS

On the basis of the information available from the study of the smallmouth bass at Waugoshance Point, Lake Michigan, certain recommendations can be made for the better use of the resource. Whether these would apply to other populations of smallmouth bass in the Great Lakes or the inland waters of Michigan will have to be determined in the future.

In the over-all study, three conditions were paramount--the slow growth of the bass, the dominance of particular year-classes and the relatively low rate of exploitation (as part of a high total mortality rate). The question arises concerning what might be done to change or modify these conditions to increase the harvest.

Most of the bass of Waugoshance Point did not reach the legal size of 10 inches until their fifth year of life. The coefficients of condition were high in comparison with known K values of bass from other bodies of water, suggesting that enough food was available. The bass were not so numerous that the possibility of too little space for each fish should be considered responsible for the slow growth rate. Low temperatures and the short growing season seem the most likely reasons for poor growth of the smallmouth bass, and nothing can be done to improve or modify these conditions.

Numerical strength of the various year-classes is obviously an important factor in the quality of the fishing from year to year. Cause of the fluctuations in the size of the year-class has yet to be determined. The breeding stock is probably always sufficient. Several investigations, including the present study, have shown the large loss of nests and eggs, but none has indicated the magnitude of the loss from fry to early adult.

It was apparent at Waugoshance Point that temperature plays a decided role in the success or failure of nests to produce black fry, but how important this is to the total numbers of fish that become available to the angler is unknown. Even after low temperatures had taken a toll, there was a 45 percent loss of nests that could be attributed to no readily apparent factor. Future studies should determine where the greatest loss lies--in the egg to black fry stage or from the black fry to yearling stage. Then it might be possible to bolster the stock or correct detrimental conditions so that year-classes would be of near equal abundance to enter the fishery. Such things as stocking of fry in years of poor production or protection of the nests and fry from disturbances might be tried, and undoubtedly there are other possibilities that would be recognized in an intensive study of fluctuating year-class strength.

There was no evidence from the Waugoshance study that fishermen were harmful to nesting. In 1954, when the fishing season opened, there were nests with eggs or fry in all stages of development. In 1955, on the opening day, all of the active nests had black fry. There was no difference in the percentage of loss of nests to the black fry stage in the 2 years, even though, in 1954, the season opened while many of the nests contained eggs. If bass nests are not harmed by the anglers, there is no reason to maintain the closed season. However, there was some circumstantial evidence against the fishermen.

The only apparent function of the guarding male is protection. The bass nests were in shallow water where they were easily accessible. The male bass was readily caught from the nesting areas. Predation was an important factor in the disappearance of eggs from deserted nests and black fry from over nests. Because of these facts and the possible disturbance or destruction caused by anglers unknowingly tramping through nesting grounds, it would seem advisable to wait until further studies have been made before the closed season is discarded. It is not known as yet whether the nesting stage is more vulnerable to loss that the fingerling stage, but in this event, it might be advantageous to open the season later than the usual third Saturday in June, thus giving nests as much protection as possible.

The principal argument in favor of keeping the present legal limit of five bass for each angler per day is the psychological value involved in reaching a goal. In 1954, only 10 percent of fishermen interviewed attained the goal of five bass. Removing the limit would add very little to the total harvest and would serve to spread the catch very little. It would be desirable to increase the rate of exploitation, but removing the creel limit would increase it only slightly. If retention of the limit of five bass for its psychological value is not a valid basis for regulation, then there is little point under present angling intensity in retaining the present creel limit on bass in the Waugoshance area.

The size limit of 10 inches, for those fish that an angler can keep, should be removed. At the present time, this provides no protection for the bass. In theory, it should permit the bass to spawn at least once before being exposed to the fishery. At Waugoshance Point, the male bass reached maturity at about 10 inches and the female not until 12 1/2 inches. Although there was no quantitative data, the anglers complained about the large numbers of small fish under 10 inches that they captured and harmed in releasing. It is not surprising that many small fish were caught when one considers that the smaller bass moved less than the large ones, and thus stayed in the shallows where they were more available to the wading fishermen.

In addition, 89 percent of the anglers used worms as bait. Shetter and Allison (1955) have shown how deleterious this type of fishing can be for a trout population. There is no reason to believe that using worms as bait does not add considerably to the loss of bass at Waugoshance. These fish should be added to the harvest which would help to increase the rate of exploitation.

To briefly summarize: (1) the legal size limit of 10 inches should be removed; (2) the limit of five bass per day for each angler should be retained only as a psychological goal; and (3) the opening date of the fishing season, at least until further evaluation is made, should remain the third Staurday in June. More study and experimentation is needed on the problem of year-class dominance. It must be remembered that these changes are based entirely on the Waugoshance study for the years 1953 through 1955. Before state-wide regulations are adopted, verification is needed from other bass populations in the Great Lakes waters and the inland lakes and streams of Michigan.

SUMMARY

A study of the ecology of the smallmouth bass was made at Waugoshance Point, Lake Michigan, 1953 through 1955. The investigation was concerned with reproduction, growth, movement, mortality rates and numerical abundance.

1. Some of the fastest-growing male bass reached maturity at 3 years (10.2 inches) and the fastest-growing females at 4 years (12.8 inches). All of the males in age-group V were mature (average total length 10.9 inches). All of the females in age-group VII were mature (average total length 14.2 inches).

2. The sex ratio of the bass examined during the census of the anglers' catch was approximately 1:1 (109 males to 120 females). The net catches, after the spawning season was over, also indicated a 1:1 ratio of males to females. The combined data by age-groups seemed to vary from a 1:1 ratio, but with no pattern. Total figures were in a 1:1 ratio of males to females.

3. Nesting activities of the smallmouth bass, in 1954 and 1955, began when temperatures rose from the fifties to the sixties, in degrees Fahrenheit. In 1954, nesting started June 7; in 1955 nesting began in mid-May, but low temperatures caused the failure of at least two spawning waves before the successful nesting began on June 1.

4. The typical bass nest at Waugoshance Point was built on gravel and rubble, in protected bays, and at a depth of about 2 feet; nest diameter was about 1 1/2 feet. Dead aquatic plants, their stems and/or roots, or small boulders, provided the only protection for the nest. Some nests were built on a combination of sand and the rootlets of aquatic plants.

5. The number of eggs collected from two nests in June, 1954, averaged 7,437 eggs per nest. The black fry collected from three nests, in 1954, averaged 2,054 fry per nest, an approximate 72 percent loss of eggs to the black fry stage in an average bass nest. The number of nests collected for egg counts and fry counts was too small for a reliable estimate of loss of eggs.

6. In 1954, from 20 nests with eggs, 9 produced no black fry, a loss of 45 percent. In 1955, in the spawning after May 30, no black fry were produced in 13 of 28 nests for a 46 percent loss.

7. Although common shiners spawned in the bass nests, they were not detrimental to the nesting. Carp destroyed bass nests in a limited area where there was much silt and detritus overlying the gravel. There was no evidence that fishermen were harmful to nests. Water temperatures falling from the sixties (°F.) to the fifties caused the male bass to desert many nests during the early spring of 1955. The eggs were almost immediately removed by some predator. Temperature fluctuations were indirectly responsible for most nest failures.

8. Discounting temperature-related loss of nests in 1955, there was still a nest mortality of 46 percent. Likewise, in 1954, a year in which water temperatures during spawning time were stable, there was a 45 percent loss. These losses could not be entirely attributed to any of the observed influences such as the presence of minnows, carp and fishermen. Predation seemed to be the most likely cause of nest loss.

9. The male bass guarded the fry for 7 to 10 days. The black fry gradually changed to a brownish-green color and then to the typical fingerling coloration; at the same time they slowly spread out over the nest site, distributing themselves throughout the emergent aquatic plants. In both 1954 and 1955, the period of dispersion was 30 to 35 days after eggs were observed in the nest. Predators apparently removed whole aggregations of black fry.

10. The age of the smallmouth bass was determined by counting the annuli, or year marks, on the scales. The validity of the annulus as a mark formed each year on the scales of the bass was verified by the recoveries of tagged fish. The annulus was formed in the period from mid-June through the third week in July during each of the 3 years.

11. The body-scale relationship was characterized by two straight lines meeting in an obvious inflection at a body length of about 140 millimeters. The intercept of 14.3 millimeters for the lower line was used as the correction factor in the back-calculations of growth.

12. Growth for the previous years of life of the smallmouth bass was calculated in a direct proportion with measurements of the positions of year marks on the scale relative to the body length. The average total length at the end of each year of life was adjusted to the body-scale line for each age-group; the age-groups were arranged by year-class and year of capture.

13. The numbers of fish in the 1947 and 1949 year-classes were exceptionally large.

14. Growth increments of the bass for the years 1950 and 1951 were much below normal. Such environmental factors as rising water levels, heavy precipitation and low temperatures, alone or in combination, were probably responsible for this slow growth.

15. There appeared to be no difference in growth rates of male and female smallmouth bass.

16. Growth of bass from Waugoshance Point was equal to growth of bass from Hog Island and Cecil Bay, two areas in the same region as the Point. The growth was compared with that of the smallmouth bass in some other waters within the Great Lakes region. Fish from Waugoshance were growing faster than those from the Lake Ontario-St. Lawrence River region, equal to the Cayuga Lake, New York, bass and slower than the bass from the inland waters of Wisconsin.

17. Factors for the conversion of total length to standard length were calculated. There was a slight increase in the relative size of the tail as the bass increased in length.

18. The length-weight relationship of the bass was described by the equation log W = -5.39796 + 3.35611 log L. The coefficients of condition (K) were considerably higher than comparable K values for bass from the inland waters of Michigan and Wisconsin. Average weights were similar to those for the bass from Cayuga Lake, New York.

19. Bass were tagged with a Monel metal strap tag, size No. 3, fastened around the maxillary bones of the upper jaw on the left side. In 1953, each fish tagged was also fin-clipped. The estimated loss of tags, based on recoveries of 1954 fin-clipped fish without tags, was nil in 1953, 6.0 percent in 1954 and 14.1 percent in 1955.

20. The number of tagged bass found dead during the study was 0.6 percent for those fish tagged in 1953, 0.7 percent for those tagged in 1954, and 1.1 percent for the 1955 fish. There was no indication that attaching a jaw tag or clipping a fin caused any excessive mortality in the bass.

21. The number of bass tagged was 1,058 in 1953, 1,819 in 1954, and 264 in 1955. An analysis of the tag recoveries from nets and anglers showed little movement of the bass either to, or away from Waugoshance Point. The recoveries illustrated the integrity of the Waugoshance bass population.

22. There was good agreement for the 1954 tagged bass that with an increase in size there was an increase in distance traveled and, correspondingly, an increase in the number of times a fish was captured in a net.

23. Fin-clipping and tagging were alternated in marking a group of bass captured during the course of the 1954 pre-fishing season

netting. There was no significant difference in the angler recoveries of bass with these marks during the fishing season. Apparently the tagged bass were caught as readily as the fin-clipped ones.

24. The tagged bass showed the same pattern of movement as fin-clipped bass. About one-third of the fin-clipped fish captured in the nets were overlooked, probably due to the regeneration of the clipped fin. Loss-of-tag data were adjusted accordingly, increasing the tag loss for 1954 to 9 percent and, for 1955, to 22 percent.

25. Estimates of the numerical abundance of bass 10 inches or longer were made, using the mark and recapture (Petersen) method. The size of the population in the spring of 1954 at Waugoshance Point, estimated on the basis of trap net recoveries, was 6,007 bass; using angler returns the population was estimated at 5,264 bass. In 1955, the same procedure indicated a population of 4,920 bass, based on net recoreries, and 4,184 bass, estimated from angler returns.

26. The total mortality rate for 1954, using mark and recapture of groups of fish in two successive years, was 0.58. From a population estimate of fish available to be caught during 1954, and an estimated harvest for the year, a fishing mortality rate of 0.22 was calculated. Natural mortality (0.36) was the difference between the total mortality and the fishing mortality.

27. Anglers harvested 1,996 bass during the 1954 fishing season. This was estimated on the basis of the catch of bass per hour per angler, counts of the number of fishermen's cars per hour, average number of fishermen per car and the over-all time involved. The quality of fishing was best during the early part of the season when the spawning concentration of bass was still in shallow water.

28. In 1953, the 1947-year-class fish supported 50.7 percent of the fishing, with the 1949 year-class contributing 36.6 percent. The following year the fish of the 1949 year-class made up 88.1 percent of the bass caught, but by 1955, although this year-class still predominated (71.1 percent), some of the younger year-classes were appearing in the fishery.

29. Proposed management regulations for the smallmouth bass at Waugoshance Point, Lake Michigan were: (1) remove the legal minimum size limit of 10 inches; (2) only as a psychological goal retain the limit of five bass per angler per day; and (3) until more evidence is gathered, open the fishing season on the usual day, the third Saturday in June.

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