INTERRELATIONSHIPS OF SMALLMOUTH BASS (MICROPTERUS DOLOMIEU) AND WALLEYED PIKE (STIZOSTEDION VITREUM) IN FALCON LAKE, MANITOBA

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By

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walleye preyed on their own species as well as on smallmouth bass.

Both smallmouth bass and walleye appeared to fare well in Falcon Lake. The interrelationships of the two populations studied suggested they were compatible but it was speculated that the current relationship would change because of a predicted increase in the smallmouth bass population.

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INTRODUCTION

The welfare of two species of organisms occupying a common habitat is dependent upon several factors. Part of their interaction may be described as competitive because of the common usage of a resource or resources and of other factors such as predation. In an established community a balance has usually been attained so that the mechanisms and expressions of a competitive relationship are not readily apparent. Generally, all species in such a community seem to fare well. However, when an exogenous species enters into the complex and fares well, it is expected that it does so at the expense of the established residents. The situation in Falcon Lake, Manitoba, provides an opportunity to observe the interactions between a native and an alien species of fish; or, between the long time resident, the walleye (Stizostedion vitreum v. Mitchill) and an introduced species, the smallmouth bass (Micropterus dolomieu Lacepede).

The walleye occur naturally and have been the mainstay of the sports fishery in Falcon Lake for many years. Smallmouth bass on the other hand are exogenous to the lake. They were first introduced as sixty-four adults in 1946. The smallmouth bass found a receptive habitat and have increased to a population approaching that of the walleyed pike in recent years. There are undoubtedly many aspects of interaction between the species, among which may be competition between them for environmental resources, predation by the walleye on the bass, and predation by the bass on the walleye. The purpose of the study reported herein was to assess what constitutes the interrelationships of these fishes.

A program of study was set up extending over three seasons, 1957 to 1959. The primary objectives of the study were to determine the nature of the habitat and its suitability for each species; how each species fared in this environment, and, how the species were interrelated through their habits.

This work was conducted under the auspicies of the Fisheries Branch of the Manitoba Government, and included, among other things a creel census on Falcon Lake through the summers 1957 to 1959. The general plan and the field supervision were the responsibility of the author. All compilations, summaries and conclusions are his.

METHODS AND EQUIPMENT

GENERAL

The field approach was designed to provide an assessment of the environment as well as information on the feeding habits, distribution habits, growth and population characteristics of smallmouth bass and walleye. Standard limnological equipment was used to explore the environment. Depth, type of bottom and the temperature and chemical nature of the water were determined. Biological sampling included the taking of plankton, dredging for bottom fauna and the capturing of fishes. Some direct observations on smallmouth bass and walleye were made by the writer equipped with a scuba[1].

Three sampling stations were selected and maintained over the study period. Each station was chosen on the basis that when the three were combined they would be representative of the entire lake. Intermittent tests were made at other locations to check on the reliability of these stations. Their locations are shown in Figure 1, Station I, near Toniata Beach, provided a sampling depth of up to 65 feet (20 m.). Station II, in a remote bay at the east end of the lake, had a depth of 40 feet (12 m.). Station III at the west end of the lake had a depth of 25 feet (8 m.).

Data and samples from this field work were analysed in the laboratories of the Fisheries Branch and the University of Manitoba.

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[1] scuba - - self contained underwater breathing apparatus.

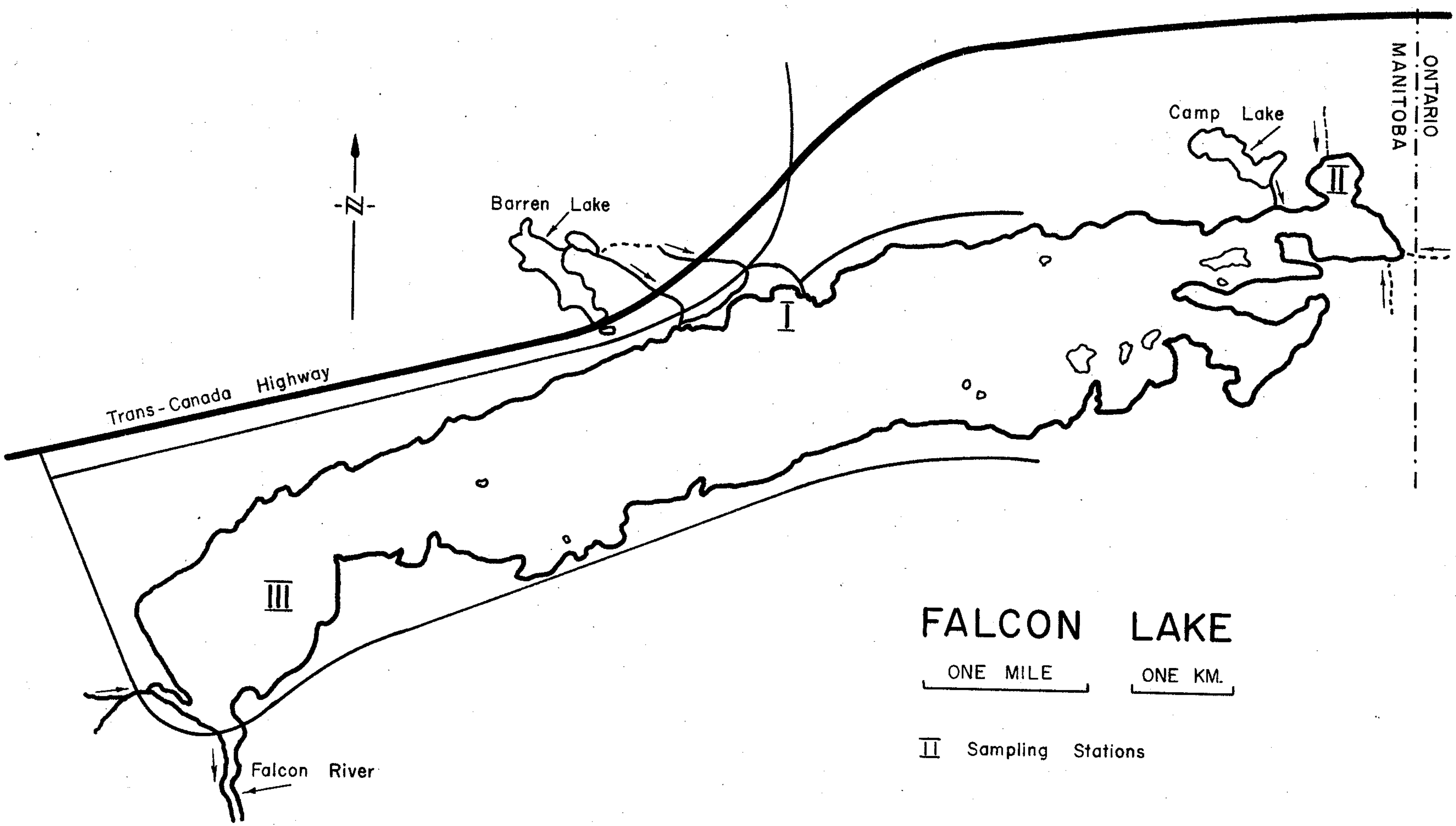

FIGURE I. Map of Falcon Lake showing general features and the locations of the sampling stations.

PHYSICAL FEATURES

The depth features of the lake were tested with 200 plumb soundings. These were later verified with an electronic sounder[2] which also gave information on the type of bottom. A scuba equipped observer also made notes on the bottom characteristics. A contour map was prepared from the depth observations.

Surface water temperatures were taken daily at Station I and periodically at Stations II and III. Additionally, temperatures at 20 (6m.), 40 (12 m.) and 60 feet (18 m.) were measured at one week intervals. A thermometer in a brass case equipped with valves to permit the trapping of water at a required depth was used. The water temperature profile was determined at two to three week intervals by use of a bathythermograph.

The clarity of the water was measured weekly at various locations with a Secchi disc.

WATER CHEMISTRY

Analyses were made to test for dissolved oxygen and hydrogen-ion concentrations. Surface samples were taken from each of the three stations and at 20-foot (12 m.) depth intervals. These were collected with a Foerst water sampler. During 1959 sampling was done at regular 10 day intervals. The unmodified Winkler system was used for dissolved oxygen determinations. The pH was measured with a LaMotte colour comparator.

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[2] electronic sounder -- Bendix depth recorder, Model DR-11.

PLANKTON

Plankton samples were collected at two week intervals from the denoted stations. Both vertical and horizontal hauls were made. A No.20 bolting silk plankton net was used to collect forty-eight samples. These were preserved in 5 per cent formalin.

In the laboratory all samples were examined microscopically and organisms were identified taxonomically to genera. The relative abundance of each was also recorded.

BOTTOM FAUNA

Throughout the study periods of 1958 and 1959, a total of 131 dredge samples were taken. These were collected with a six-inch (15.2 by 15.2 cms.) Ekman dredge at various locations and from different types of bottom.

Areas, recognized by uniformity in depth and substatum were selected and dredging was at random within each. Inshore dredgings were taken at closer intervals both in space and in time.

To recover bottom organisms from the dredgings a screen, 30 grids to the inch, was employed. The organisms were removed at once from the residue, thus, taking advantage of movements as an aid in locating them. Preservation was in vials of 80 per cent alcohol. In the laboratory the organisms were identified, enumerated and measured. Wet weights were determined by use of a balance sensitive to one milligram. The volume of organisms was determined by water displacement in a cylinder graduated to 0.1 cubic centimeters. When some of the organisms were exceptionally small, displacements were measured for ten at a time and the average value per organism was calculated.

The distribution and abundance of the bottom organisms were noted. The results were interpreted in terms of the number and kinds of bottom organisms per square foot (.09 sq.m.) of each type of bottom.

FISH SAMPLING AND TREATMENT

Fish were taken by gill nets, pound nets, seines, spot poisoning and provide information on the distribution and habits of the species. In the spring of each year pound nets were used to capture spawn-run walleyed pike and northern pike. Some were tagged and released while others were retained for food studies and other analyses. Seines and spot poisoning were used to collect small walleye, smallmouth bass and other fishes. When poisoned not all fish came to the surface. Those which didn't were picked up by scuba equipped personnel. Field personnel also caught fish by angling and some fishermen donated their catches for examination.

Most gill nets were set at the time of and in habitat associated with smallmouth bass spawning. Sets were also made through the summers at other locations in the lake. The mesh size of these nets ranged from 3-inch (7.6 cm.) to 5.1/2-inch (13.9 cm.). Catches were analysed with respect to walleye and smallmouth bass and were interpreted in terms of the numbers of each species caught per 50 yards (45.7 m.) of net.

All fish were measured and weighed. Scale samples were taken and ages were estimated later in the laboratory. The stomachs of most smallmouth bass and walleye were removed, assigned a reference number and preserved in 10 per cent formalin. In the laboratory the food items were washed from the stomachs, identified and counted. The number and frequency of occurrence of the food items were noted.

THE FALCON LAKE HABITAT

LOCATION AND DEVELOPMENT

Falcon Lake, in the southeastern corner of the Province of Manitoba has its eastern end almost coincident with the Manitoba-Ontario border. It is accessible by P.T.H. No.4 and by the Trans Canada Highway, 90 miles east from Winnipeg. The lake and its surrounding territory are within the boundary of the Whiteshell Forest Reserve.

Within the past four years Provincial Government agencies have developed this area into one of the more attractive tourist sites in the country. Close to 700 summer cottages are now located at Falcon lake and many more at neighbouring lakes. Boat liveries and general businesses operate from three points on the lake. With the available facilities and the improvements, this area offers great recreational potential. In the past, angling pressure on the lake has been moderate but it is increasing markedly each year. Fishery management has been directed mainly to promote walleye through eyed-egg plantings and rough fish removal.

MORPHOMETRY AND PHYSICAL FEATURES

The location of the lake across the southern perimeter of the Canadian Shield is responsible for the rugged contours of the north and east shorelines. The ancient granitic gneisses and schists of the Pre Cambrian outcrop boldly and dip gradually to the south where they are overlain with sedimentary deposits. Chromite and gold have been located in formations along the north and east margins of the lake but, there is little mining interest in these deposits.

The lake, roughly elongate-rectangular in shape, is seven and one half miles (12 km.) long by one mile (1.6 km.) wide, and encloses an area of 4,400 acres (1,780 ha.). The depth features of the lake are shown in Figure 2. The basin is steep from the north shore and reaches its maximum descent about one-third of the way across the lake. From here the ascent is gradual to the south shore. The maximum depth discerned was seventy-eight feet (23.7 m.) and the mean depth was calculated to be thirty-four feet (10.3 m.).

Six characteristic types of bottom were noted, even though some of the distinctions were subtle. In areas associated with outcroppings, bedrock, boulder and rubble bottoms were distinguished. Sand and coarse gravel appeared in localized areas. The bottom of the entire west end and scattered patches along the south ascent were silt or mud. A clay band, probably an exposed sedimentary stratum, was detected at a depth of thirty feet (9 m.) in the south ascent. Three types, sand and gravel, rubble, and silt accounted for almost all of the bottom area-wise.

There are nine islands scattered throughout and the few shoal areas present are in relation to these islands.

The water itself is moderately clear, generally giving a Secchi disc reading of from twelve to fourteen feet (3.6 to 4.2 m.). Mean monthly turbidity readings are given in the appendix, Table AI.

Inflow to the lake comes from the north through creeks from Barren

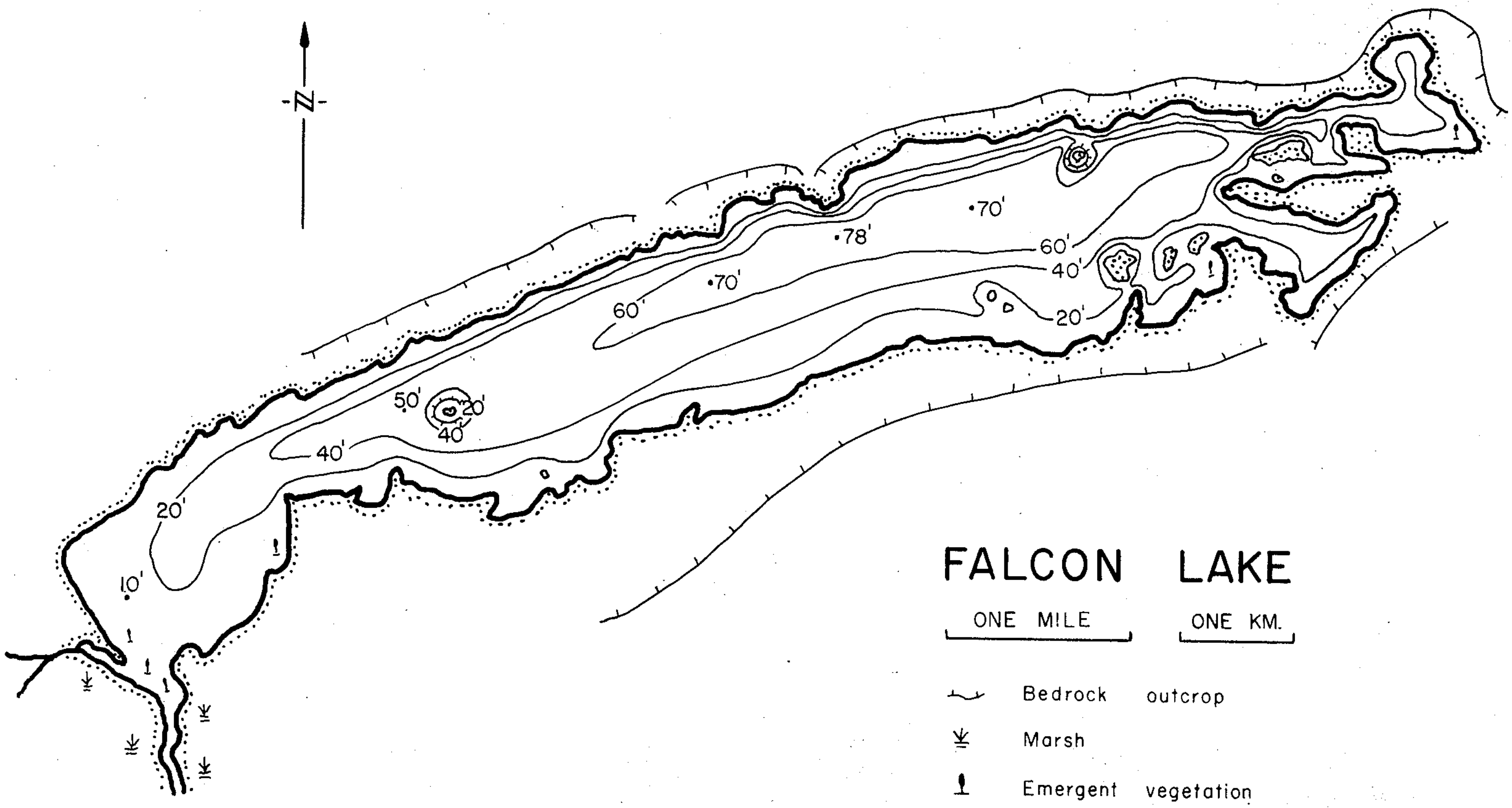

FIGURE 2. Map of Falcon Lake showing depth contours in feet; one foot = 0·3 meters.

and Camp Lakes (Figure 1) and run off from the rocky Precambrian area. Intermittent streams drain the eastern runoff. A relatively large influent stream which drains a muskeg enters at the southwest corner of the lake. A few springs, especially in the eastern part of the lake also make a contribution. The streams are short and small, but two, the one of the west end and the one from Barren Lake, accommodate spawn-runs of walleyed pike, northern pike and suckers. The lake drains through one outlet, the Falcon River. This effluent stream leaves from the southwest corner of the lake and meanders sixteen miles (25 km.) to Indian Bay which is part of the Lake of the Wood's system, six miles (10 km.) due south from Falcon Lake. Walleye are known to run to and from Indian Bay by way of this river. A control is maintained at the origin of the river thereby keeping the lake level constant.

The forest cover of the Falcon Lake area is typical northern coniferous as is found in much of the Canadian Shield, dominated by white and black spruce. South and west from the lake is a low swampy region of muskeg with tamarack and black spruce vegetation. Intermittently are found mixed woods with well developed stands of poplar and some birch.

TEMPERATURE AND CHEMICAL CONDITIONS.

The maximum water temperatures recorded in each year were: 26°C on July 29, 1957; 28°C on August 2, 1958; and 27°C on August 11, 1959. On the basis of monthly mean temperatures (see Table I) it is demonstrated that the course of heating and cooling was essentially the same in each year. All temperature readings obtained are given in Tables AII and AV inclusive of the Appendix.

TABLE I

MONTHLY MEAN WATER SURFACE TEMPERATURES CALCULATED FROM DAILY TESTS MADE AT STATION I, MAY-SEPTEMBER, FALCON LAKE, 1957 - 1959 EXPRESSED AS DEGREES CENTIGRADE

Year	May	June	July	August	September
1957	8.9	15	22.2	23.4	17.8
1958	10.0	15.5	21.7	22.8	16.1
1959	7.8	14.5	22.2	22.8	17.8

The ice cover usually forms on Falcon Lake about mid-November and break up occurs in late April or early May. This leaves an open water period of about six and one-half months. Surface temperatures rise from about 5°C in early May to 27°C in late July and early August. The lake shows summer thermal stratification and the process is illustrated through selected temperature curves in Figure 3.

The lowest oxygen level measured for a surface sample was 6.5 ppm. (68% saturation) on June 29, 1959, and the highest was 10.0 ppm. (114% saturation) on July 18, 1959. From the deep water a low of 2.5 ppm. (28% saturation) was observed for a sample from seventy feet (21 m.) on August 28, 1959. Oxygen depletion apparently occurs below the thermocline but tests showed that the concentration was rarely below 5 ppm.

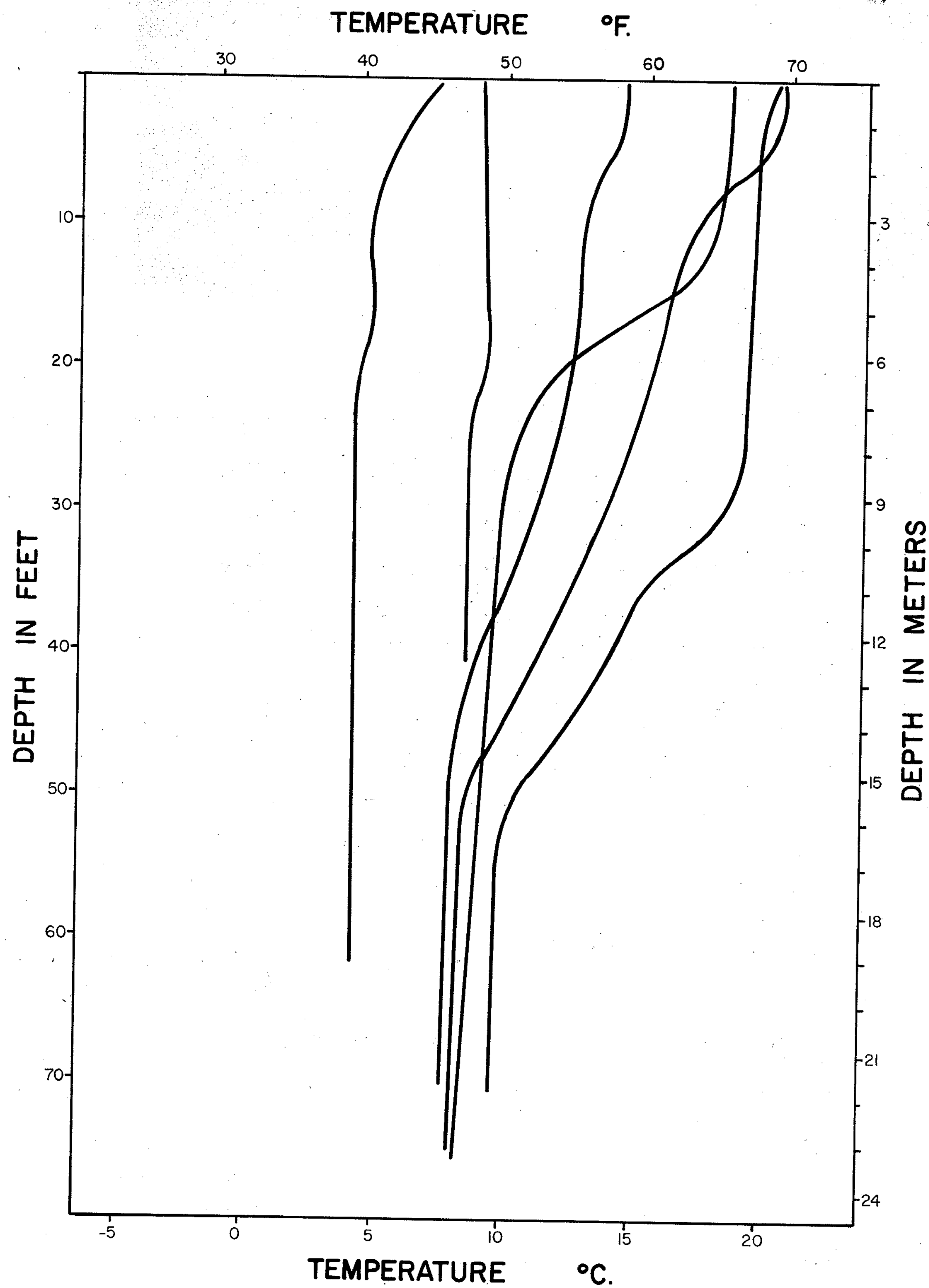

FIGURE 3. Selected water temperature curves to show the seasonal changes at Station 1, Falcon Lake, 1959.

The oxygen concentrations at each depth zone and for each summer month are summarized in Table II. The results of all tests are given in the Appendix, Table AVI.

TABLE II

MEAN DISSOLVED OXYGEN AVERAGED FOR ALL STATIONS; AT THE SURFACE, AT 20 FEET (6 M.), AT 40 FEET (12 M.) AND AT 60 FEET (18 M.), GIVEN MONTHLY, FALCON LAKE, 1959 - EXPRESSED AS PARTS PER MILLION.

Month	Surface	20 feet (6 m.)	40 feet (12 m.)	60 feet (18 m.)
May	7.8	7.4		
June	9.4	9.7	9.6	8.3
July	9.6	8.4	7.3	6.2
August	8.5	9.6	7.1	5.2

In 1959, pH tests were made consistently at five to seven day intervals at each of three stations and at 20-foot (12 m.) depth intervals. There was little or no variation between stations on the same day. For the most part, the water of Falcon Lake was found to be alkaline with pH varying from 7.3 to 8.1 (see Appendix Tables AVII and AVIII). In mid-August of 1957 and late August of 1959, slightly acid readings (pH 6.8) were obtained in forty and sixty feet (12 and 18 m.) of water. A summary of the pH values is given in Table III.

TABLE III

MEAN MONTHLY HYDROGEN-ION CONCENTRATIONS AT THE SURFACE, AT 20 FEET (6 M.), AT 40 FEET (12 M.) AND AT 60 FEET (18 M.), FALCON LAKE, 1959 - EXPRESSED AS pH.

Month	Surface	20 feet (6 m.)	40 feet (12 m.)	60 feet (12 m.)
May	8.2	8.0	7.9	7.9
June	7.4	7.6	7.4	7.3
July	7.7	7.5	7.9	7.4
August	7.8	7.8	7.2	7.0
September	7.7	7.9		

PLANKTON

The taxonomic groups of plankton discerned were Chlorophyceae, Myxophyceae, Bacillarophyceae, Protozoa, Rotatoria, Copepoda and Cladocera. The genera collected in each group and their relative abundance in each month is given in the Appendix, Table AIX.

The blue-green algae and the diatoms were the predominant phytoplankton and the copepods the predominant zooplankton. Seasonal pulses in the abundance of some plankters were observed. Peaks in the abundance of *Aphanizomenon* were noted in June and August. *Stephanodiscus*, *Asterionella* and *Fragilaria* also were discerned to peak but each at different times. All plankters identified appeared more or less stable in their relative abundance.

BOTTOM FAUNA

The predominant bottom organisms were insect larvae, amphipods (mostly Pontoporeia) and gastropods. These constituted more than 85 per cent of the numbers of the total sample population. The occurrence and kinds of bottom organisms are summarized in Table IV. The organisms listed as miscellaneous include dipterous larvae, other than chironomids, planaria, stonefly nymphs, odonata nymphs and ostracods.

TABLE IV

SUMMARY OF THE BOTTOM ORGANISMS COLLECTED IN 131 DREDGINGS IN FALCON LAKE, 1958 AND 1959.

Organism	Total number collected	Average number per square (09 sq.m.) foot of sample	Percentage of sample
Chironomid larvae	308	10	20.2
Ephemeroptera	260	8	19.9
Gastropoda	237	7	18.2
Amphipoda	154	6.3	11.8
Trichoptera	77	2.2	5.9
Sphaeriidae	67	2	5.5
Oligochaeta	46	1.5	3.5
Hirudinea	26	0.8	2.0
Nematoda	4	0.05	0.3
Miscellaneous	15	0.2	1.0
All organisms	1,194	38	

Throughout the four-month study periods the ten major groups of bottom organisms were represented in all bottom samples. The average number fell from 38.4 organisms per square foot (.09 sq.m.) in the 0-20 foot (0-6 m.) depth range to 30.9 at 20-40 feet (6-12 m.), then markedly to 11.1 in the profundal bottom. The number of chironomid larvae decreased as sample depth increased but they were still the most numerous representatives in all samples. Other insect larvae appeared more often in the 20-40 foot (6-12 m.) samples, but their numbers dropped off markedly in deeper dredgings. Nematodes became consistently more abundant in deeper water. All other organisms became fewer as sample depth increased. The depth distribution of the bottom fauna sampled is summarized in Table V. The Ephemeroptera, Hexagenia sp., were most abundant on rubble bottoms, less abundant on silt and least abundant on sand and gravel; Ephemera sp., were only found on silt and rubble bottoms. Chironomids were found most often on silt and rarely on other types of bottom. Trichoptera and Amphipoda were found more frequently in silt bottoms. On the other hand, Gastropods appeared more consistently on rubble and least frequently on silt. The Oligochaeta, sphaerids and Hirudinea were frequently in association with silt, less in sand and least on sand and gravel. The nematodes and all other organisms were taken only from sand and gravel substrata. The number and kind of bottom organisms collected from each type of bottom is given in the Appendix, Table AXI.

On the whole, seasonal changes in the composition and distribution of the bottom fauna were not too marked. All organisms were found at all times over the four month sampling periods, and, as indicated in Table V, were found at all depths. Seasonal trends were discerned for some groups. The chironomids appeared most numerous in June but were generally small; they became fewer by August but larger in size.

TABLE V

AVERAGE NUMBER OF THE VARIOUS GROUPS OF BOTTOM ORGANISMS PER SQUARE FOOT (09 SQ. M.) OF BOTTOM AT EACH DEPTH ZONE IN FALCON LAKE.

Organism	Depth Zone		
	0 - 20 feet (0 - 6 m.)	20 - 40 feet (6 - 12 m.)	40 - 60 feet (12 - 18 m.)
Chironomids	11.2	8.8	3.2
Ephemeroptera	6.2	8.4	1.6
Gastropoda	8.9	4.8	1.5
Amphipoda	3.6	4.8	2.0
Trichoptera	1.1	1.9	0.4
Sphaeriidae	2.7	1.4	1.2
Hirudinea	1.6	0.2	0.2
Nematoda	0.2	0.3	0.4
Oligochaeta	1.5	0.3	0.6
Miscellaneous	1.4	0.03	0.01
All organisms	38.4	30.9	11.1

Ephemeroptera were more or less consistent in numbers but increased in size over the study period. Amphipods became more numerous towards the end of the sampling season. Oligochaetes appeared to reach a peak in July and then rapidly diminish in numbers to the end of August. All other organisms appeared more or less consistent in their seasonal distribution (Appendix Tables AXIII to AXVI inclusive).

Other benthic organisms, largely because of their mobility, were able to avoid the traps, and, consequently were not accounted for in the samples. The Amphipod, Hyalella sp., was observed quite frequently in littoral zones, especially in association with vegetation. Many of them became tangled in the threads of the minnow seine and it is believed they are quite abundant. The crayfish, Cambarus virilis, was observed to be present but was not thought to be plentiful. It did, however, appear quite frequently as a food item in the stomach samples from fish.

FISHES OF FALCON LAKE

Twenty-four species of fish have been found and identified from Falcon Lake to date. These are listed below. The first twelve are large, the remaining twelve are small species rarely over four inches (10 cm.) in length and are commonly referred to as 'minnows'. The smallmouth bass is an exogenous species. Plantings of brown trout, lake trout and largemouth bass made intermittently in past years apparently have failed as none of these species have ever been reported caught. The rainbow trout is included in this list but only two have officially been recorded as caught in this lake; these probably came from neighboring Camp Lake via a connecting stream. Dr. J. A. McLeod (1943) reported catching eleven mooneye in nets while making a preliminary biological study of the lake. Since this time, however, the existence of this species has not been re-confirmed. Seine hauls were made intermittently and on occasion small portions of the lake were poisoned in order to collect young-of-the-year walleyed pike and bass. In the process many of the fish were collected and identified. One species, the ninespine stickleback, was encountered only in the stomach contents of walleyed pike and bass.

Mooneye	*Hiodon tergisus* LeSueur
Rainbow trout	*Salmo irideus* Gibbons
Black-fin tullibee	*Leucichthys-nigripinnis* (Gill)
Common whitefish	*Coregonus clupeaformis* (Mitchill)
White sucker	*Catostomus commersonii* (Lacepede)
Brown bullhead	*Ictalurus nebulosus* (LeSueur)
Northern pike	*Esox lucius* Linnaeus
Walleyed pike	*Stizostedion vitreum* (Mitchill)
Yellow perch	*Perca flavescens* (Mitchill)
Rock bass	*Ambloplites rupestris* (Rafinesque)
Smallmouth black bass	*Micropterus dolomieu* (Lacepede)
Burbot	*Lota lota maculosa* (LeSueur)
Fathead minnow	*Pimephales promelas* (Rafinesque)
Spot-tail minnow	*Notropis hudonius* (Clinton)

Lake shiner ------------------ _Notropis_ _atherinoides_ Rafinesque

Mimic shiner ------------------ _Notropis_ _volucellus_ (Cope)

Hornyhead chub ---------------- _Hybopsis_ _biguttatis_ (Kirtland)

Trout perch ------------------ _Percopsis_ _omiscomaycus_ (Walbaum)

Log perch -------------------- _Percina_ _caprodes_ _zebra_ (Aggasiz)

Iowa darter ------------------ _Etheostoma_ _exile_ (Girard)

Johnny darter ---------------- _Etheostoma_ _nigrum_ Rafinesque

Millers thumb ---------------- _Cottus_ _bairdii_ Girard

Brook stickleback ------------ _Eucalia_ _inconstans_ (Kirtland)

Ninespine stickleback--------- _Pungitius_ _pungitius_ (Linnaeus)

SUMMARY AND ANALYSIS OF THE HABITAT

The depth of the lake, water temperatures, the fairly high thermocline and the extensive areas of inorganic bottom all give support that Falcon Lake is oligitrophic. The overall abundance of plankton is believed to be only moderate and this coupled with the lack of desmids substantiates such a classification. The predominant plankter representative like _Asterionella_, _Fragilaria_, _Pediastrum_, and others, however, hold with an eutrophic classification (Welch. 1952). The fish food organisms are well distributed and appear to be abundant throughout. Bottom organisms occur below the thermocline so oxygen depletion in these depths is a rarity. These latter features also hold with an eutrophic classification.

It was concluded that Falcon is an oligotrophic lake but succeeds into an eutrophic classification. In any event, it was believed that the lake was moderately fertile and had favorable conditions - of water chemistry, feed and spawning substratum - to support good populations of both smallmouth bass and walleyed pike as well as other fishes.

SMALLMOUTH BASS ECOLOGY

GENERAL

Smallmouth bass occur naturally in fresh waters of North America from Texas to eastern Canada. Its occurrence in Manitoba is due to artificial introduction (Hinks, 1943). The population in Falcon Lake is the progeny of sixty-four adults planted in 1946. The species apparently found a ready niche in this environment, for a population estimate[1] made of the 1959 stock places their adult numbers between 6,000 and 10,000. Data from the creel census have shown that the average annual catch by the anglers in the three years (1957 - 1959) has been 610 fish. Previously the smallmouth bass was not considered a preferred species by most anglers and this accounts for its low harvest and gives one of the reasons for its prolific advances.

The nature of the niche that the smallmouth bass occupies in this environment is in a way the basis of this study. If this niche can be delineated and compared with that occupied by walleyed pike then a means of assessing their interrelationship can be established.

DISTRIBUTION AND MOVEMENT

Knowledge of the distribution and movement of smallmouth bass in

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[1] Population estimates of three game species, walleyed pike, northern pike and smallmouth bass were made as part of a tagging and creel census program. These data are unpublished, but are on file with the Fisheries Branch.

Falcon Lake was provided by anglers observations, netting, and tagging data. The species, for the most part, appeared to be spotty in distribution. Falcon Lake lacks the extensive gravel and rock shoals characteristic of ideal smallmouth bass waters. The predominant bass habitat lies in the northeastern portion of the lake where these substrates are present and attract the species through much of the season. The major features of smallmouth bass distribution are shown in Figure 4. Each of the areas denoted as A, B and C, represents a major region of smallmouth bass concentration. Spawning concentrations outside these areas are minor.

The original stock of sixty-four adults was planted in Area A. As the population increased this limited select area became taxed and new territory was sought. Their direction of encroachment was westward, and to a lesser extent to regions along the south shore. In each year subsequent from 1957, progressively more bass were observed to inhabit these areas. The established areas along the north shore likewise attracted more bass in each subsequent year. In 1959 smallmouth bass and their nests were observed in places along the north shore far westward from the nearest places seen in previous years. These are indicated in Figure 4. as the extreme westward ones opposite Area C.

Continued gill netting from May through mid-September in 1959 and June through August in 1958 has provided some information on bass movement and distribution. In two years a total of 85 sets were made at depths from 5 to 65 feet (1.5 to 20 m.) in which 162 bass were caught.

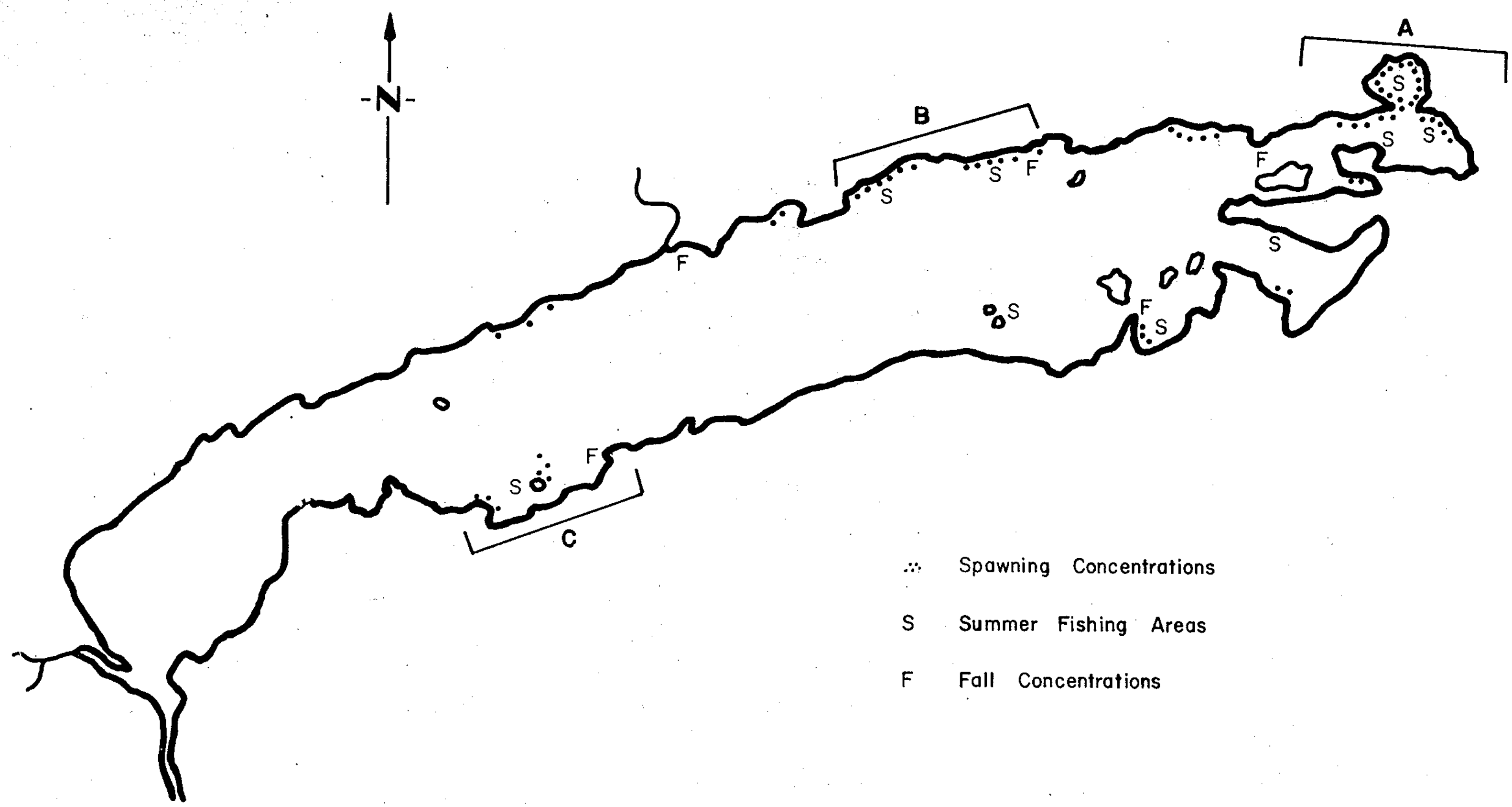

FIGURE 4. - Map of Falcon Lake showing known areas of spawning, summer fishing and fall concentrations for Smallmouth Bass.

These nets were 3 to 5.1/2 (7.6 to 4 cm.) inch stretched mesh so that generally only bass over 9 to 10 inches (23 to 25 cm.) in length were caught.

The sets were divided into those made in each depth range, 0 to 20 feet (0 - 6 m.), 20 to 40 feet (6 - 12 m.), and 40 to 60 feet (12 - 18 m.) and were made in each month at each depth range. Results of the analysis are presented in Table VI. September data are few based only on six net sets. An additional integration of the sets is made in Table VIII. In this latter table, results of sets made in Areas A, B, C and R (R is any random area other than where bass spawning concentrations were observed), in each depth range and in each month are compared.

TABLE VI.

AVERAGE NUMBER OF SMALLMOUTH BASS CAUGHT PER 50 YARDS (45.7 m.) OF NET SET IN EACH DEPTH RANGE AND IN EACH MONTH. FALCON LAKE, 1958 AND 1959. THE NUMBER OF SETS IS IN PARENTHESIS.

Depth range	May	June	July	August	September	Average per set for each depth
0-20 feet (0-6 m.)	5.6 (15)	2.6 (12)	1.3 (9)	1.0 (9)	3.0 (2)	2.7 (47)
20-40 feet (6-12 m.)	0.5 (2)	0.8 (4)	0.5 (9)	1.4 (5)	1.0 (2)	0.8 (22)
40-60 feet (12-18 m.)	0 (2)	0 (3)	0.4 (5)	1.0 (4)	0.5 (2)	0.4 (16)
Average per set for month	2.0 (19)	1.4 (19)	0.7 (23)	1.1 (18)	1.5 (6)	

In the spring most of the adult population seemed to run along the eastern north shore. Netting was begun in mid-May and these early sets yielded bass quite readily in shallow water (Table VI), close to the spawning areas (Table VII). By early June the bass appeared to be more or less concentrated around the spawning areas along both the north and south shores where they remained until late July . Netting and angling during May and June yielded few bass at places other than those around the spawning grounds (Table VII).

From mid-July on, the bass departed from these spawning aggregations and became scattered. With notable exceptions, late July, August and September have not produced satisfactory bass angling. The yield from nets was likewise meagre. Of the bass gilled, more were taken in waters five to thirty feet (1.5 to 9 m.) deep, that margined precipitous shelves than in other parts of the lake. The more consistent areas where bass were found at this time are indicated in Figure 4 as "fall concentrations". The September catch, as delineated in the tables, suggests a tendency for the bass to return to the shallows in the fall. During rough fish removal in November of each year, the occasional bass was captured in the extensive shallows of the west end of the lake where none had been observed during the summer.

The depth at which fish were captured was estimated by their linear position in the nets as related to the known profile of the bottom. The average seasonal catch per 50 yards (45.7 m.) of net diminished from 2.7 in the upper 20 feet (6 m.) to 0.4 below 40 feet (12 m.). Of the sixteen bass indicated in Table VI that were captured in the 40 to 60 foot

(12 to 18 m.) range, only two were taken at depths greater than 45 feet (13 m.). It appears that Falcon Lake bass will frequent waters up to 45 feet (13 m.) and occasionally descend to deeper waters. A depth of 40 feet (12 m.) corresponds with the approximate lower limits of the epilimnion (Figure 3) during late summer. It may be that bass are reluctant to penetrate the thermocline or regions below it.

TABLE VII.

AVERAGE NUMBER OF SMALLMOUTH BASS CAUGHT PER 50 YARDS (45.7 m.) OF NET IN EACH DEPTH RANGE, MONTH AND DENOTED AREAS A, B, AND C, AND R WHICH INDICATES A RANDOM SET, FALCON LAKE, 1958 AND 1959. THE NUMBER OF SETS IS IN PARENTHESIS

Depth range	May	June	July	August	September	Area
0 to 20 feet (0 to 6 m.)	5 (4)	2.5 (3)	3 (2)	0 (1)	-	A
	9 (5)	6 (3)	2 (2)	1.5 (2)	4 (1)	B
	2.3 (3)	2 (3)	1 (2)	1.6 (3)	-	C
	0.7 (3)	1 (3)	0 (3)	0.3 (3)	2 (1)	R
20 to 40 feet (6 to 12 m.)	-	-	0 (1)	2 (1)	-	A
	0 (1)	1 (2)	1.5 (2)	-	0 (1)	B
	-	-	0.3 (3)	2 (2)	-	C
	1 (1)	0.5 (2)	0.3 (3)	0.5 (2)	2 (1)	R

Table VII cont'd.

TABLE VII CONTINUED

Depth range	May	June	July	August	September	Area
	-	-	1 (1)	-	-	A
	0 (1)	0 (1)	1 (1)	0.5 (2)	0 (1)	B
40 to 60 feet (12 to 18 m.)	-	-	-	-	-	C
	0 (1)	0 (2)	0.6 (3)	1.5 (2)	1 (1)	R

During the spawning season in 1959 a total of 234 bass were tagged[2] in late May and early June. They had been captured in gill nets which were fished at two hour intervals and by angling. All bass tagged were caught in Areas A and B (Figure 4). By mid-September, 19 or 8 per cent of these tagged fish were recaptured by anglers. Seventeen of these recaptures were made by the end of July and in the vicinity in which they had been released. The two others were caught during August and again in the vicinity in which they had been released. Only one recapture was made at any distance from the tagging site - this fish was caught in early July, along the north shore about two miles (3.2 km.) west from where it was tagged.

Many workers (Tester 1931, Bauer 1955, Henderson and Foster 1956 among others) have observed that water temperature is one of the major influences affecting the distribution and movements of bass. Water temperatures at both ends of the net were taken for 62 gill net sets

[2] ibid., Footnote 1, p.16.

in 1959. The number of fish caught in water temperature range 4.4°C to 21.2°C, at intervals of 2.8°C, summarized as follows:

Degrees C.	4.4-7.2	7.2-10.0	10.0-12.8	12.8-15.6	15.6-18.4	18.4-21.2
Average number of bass per net	1	9	2	2	3	1

This evidence does not suggest that the bass selected or moved into water of any particular temperature range. However, it is evident that this supposedly warm water species tolerated, and was active in, water at a temperature of 7.2°C.

No investigations were made during the winter months. Webster (1954), Townsend (1916), and others, have all noted that bass for the most part enter a semi-dormant state when the water becomes cold, and this is perhaps the case in Falcon Lake.

SPAWNING

From observations made in the past three seasons it was noted that Falcon Lake smallmouth bass generally aggregate into inshore runs in late May. Most of the species concentrated in Areas A and B (Figure 4). Other scattered points of minor concentrations are also illustrated in the figure. The bass generally remained in these areas until mid-July. Regions of summer concentrations are also shown in Figure 4; some of these are places where no active spawning was observed but where bass were most frequently caught in July and August.

According to the observations in this study, activity associated with spawning may start when water temperatures are just below 10°C. In Table VI it is shown that bass were readily caught in May and in Table VII that they were in the shallow areas associated with their spawning activity. The water temperatures at this time generally ranged from 7.2 to 12.8°C (Appendix Tables AII to AV). Tester (1931), and Henderson and Foster (1956), hold that adults will not move into likely spawning areas until water temperatures reach 12 to 16°C. The actual spawning season in Falcon Lake runs from mid-June to early July when temperatures range from 14 to 21°C. The spawning peak was reached in late June when water temperatures were around 18°C.

Nests were usually located along rocky shores which were free from vegetation and in the lee of the shore so as to receive protection from prevailing winds and wave action. Most nests were observed in depths of water from four to six feet (1.2 to 18 m.). Observers equipped with scuba gear, encountered the occasional nest in depths up to twelve feet (3.6 m.). Fry generally hatched in fourteen to twenty days and by another ten or twelve days had scattered from the nests. From the time that the nests were made and for as long as fry stayed in the vicinity guardian males patrolled the area fending off interlopers. This vigilance may have been peculiar to males only, but, spent females were frequently taken in nets or by angling in the spawning areas as late as mid-July.

HABITS AND HABITAT OF YOUNG

By late July most young bass lost their identity with the parent nest site. Fingerlings, taken by seines and spot poisoning, were most frequently found in the general spawning areas until mid or late August. In late August of 1959 several bass fingerlings were seined from the extreme west end of the lake. The closest observed nests were at least 1.1/2 miles (2.4 km.) away. Whether these fish had migrated from the observed nesting sites or had been hatched in unobserved nests in the vicinity is not known. Additional data on the young-of-the-year, yearlings, and two-year-old fish are lacking. Webster (1954), noted that at these stages of development smallmouth bass range in bouldery bottoms within lower littoral depths.

FOOD HABITS

The study of the feeding habits of smallmouth bass in Falcon Lake was based on the examination of their stomach contents. The stomachs of eight young and twenty-three fingerlings, collected with seines and by poisoning, and of 234 adults caught in nets and by angling were examined.

The analysis of food of the smallmouth bass was made on the basis of the number of food items found in their stomachs, and on the number of stomachs containing each type of food. In order to evaluate the relationship of smallmouth bass to other fishes in the lake, numbers and frequency of occurrence of the food items provided a more meaningful interpretation than volumes or weights of the items.

Of the 234 adult stomachs examined, 178 or 76 per cent contained food. Those considered empty were entirely free of food remnants or had detritus digested beyond recognition. Table VIII summarizes the items taken as food. In frequency of occurrence 68 per cent of the 178 stomachs contained crayfish, 49 per cent contained fish and 41 per cent contained insects. These results agreed in general with those of Dymond (1931), Tester (1932), Webster (1954) and others, in that crayfish are the major food items when available and that fishes and insects are close seconds.

Over half the items regarded as fish were digested beyond recognition, but, of the identifiable species, yellow perch were the most frequent. Small tullibees and sticklebacks were also identified but did not appear often. Most items classified as insects were identifiable with a good deal of assurance. Nymphs of the mayfly, Hexagenia sp., were more frequently found in bass stomachs than any other insect component.

There were indications that the results obtained from stomach analyses of bass captured in gill nets were not comparable with those caught by angling. With either method of capture bass were observed to regurgitate their stomach contents when in the throes of the struggle to escape. This occurred more frequently with bass caught by angling. Hooked bass would often surface and spew out contained food. These observations are documented in Table IX which relates the number of stomachs containing food to the method of capture. Sixteen per cent of the bass captured by nets and twenty nine per cent caught by angling were empty. With regards to the frequency of occurrence of food items

TABLE VIII

SUMMARY OF FOOD ITEMS ANALYZED FROM 178 SMALLMOUTH BASS STOMACHS, FALCON LAKE, 1959.

Food item	Number of stomachs containing item	Number of items	Frequency of occurrence (per cent)
Pisces (all species)	88	100	49
Leuchichthys	3	3	1.3
Perca	29	37	16
Pungitius p.	4	5	2
Unidentified	51	55	28
Eggs	1	-	-
Crustacea			
Crayfish	120	201	68
Insecta			
Diptera (all species)	73	165	41
Chironomids	4	13	2
Ephemerida			
Hexagenia	37	89	21
Hemiptera	2	2	1
Hymenoptera			
Formicidae	7	8	4
Coleoptera	2	2	1
Unidentified	12	-	7

compared with the method of capture, these observations hold true for fish and crayfish components. However, insect items were more frequently found in stomachs of bass caught by hook and line. This in part may be due to conditioning whereby these bass took artificial lures that simulated insect forms or it may be implicit in the netting method. The gill nets were generally finished at short intervals but some were left overnight (eight to ten hours) in which case some digestion occurred before bass were removed for examination. The more delicate organisms may have been mutilated beyond recognition hence were not considered in the tally.

TABLE IX.

VARIATION IN THE QUANTITY OF FOOD IN THE STOMACHS OF 234 BASS CAUGHT IN GILL NETS AND BY ANGLING - PERCENTAGE OF TOTAL IN PARENTHESIS.

Item	Gill nets	Angling
Total number of stomachs	93	141
Number of empty stomachs	15 (16)	41 (29)
Number containing food	78 (84)	100 (71)
Number containing fish	52 (56)	36 (35)
Number containing crayfish	69 (74)	51 (37)
Number containing insects	24 (26)	49 (36)

Crayfish, small fish and Hexagenia essentially accounted for the bulk of the food utilized by Falcon Lake smallmouth bass during the study period. Distinct seasonal trends were observed in the degree to which bass selected these items. This is illustrated in Tavle X.

TABLE X

DIET OF SMALLMOUTH BASS FROM FALCON LAKE IN EACH OF THE SUMMER MONTHS MAY TO SEPTEMBER. FOOD ITEMS ARE EXPRESSED AS FREQUENCY OF OCCURRENCE

Food item	May	June	July	August	September
Pisces (all species)	42	30	85	87	70
Leucichthys	5	-	-	1	-
Perca	21	9	22	29	35
Pungitius	-	3	1	-	-
Unidentified	16	18	63	58	35
Crustacea					
Crayfish	71	59	89	64	70
Insecta	17	45	76	-	-
Diptera (all species)	-	9	11	-	-
Ephemerida					
Hexagenia	16	14	63	-	-
Hemiptera	-	2	-	-	-
Hymenoptera					
Formicidae	-	8	-	-	-
Coleoptera	-	2	-	-	-
Unidentified	1	10	2	-	-
Number of stomachs with food	38	90	28	14	8

In May, June and early July the diet was varied and bass selected those items which were most available to them. In the shallows at this time, they fed readily on aquatic insects and to a lesser degree on terrestrial insects which fell into the water. The intensity of insect feeding was greatest in July. The August and September analysis, keeping in mind the few stomachs examined, showed that no insects were included in the diets. Distribution information suggests that bass are in deep water during the later summer where insect items are not available. During these later months fish items were taken with considerable more frequency. The consumption of crayfish however, remained essentially the same throughout the five months. Bass do not appear to be rigidly selective in their feeding habits but tend to eat those organisms which are available to them by virtue of their distribution.

FOOD OF YOUNG BASS

Eight yearling smallmouth bass were collected in 1959, all of which were taken in July. One was caught by angling and the others in seines or were poisoned. Of the eight stomachs examined two were empty. One stomach contained crayfish only. Three stomachs had unidentifiable remains of small fish and two of these also contained *Hexagenia* nymphs. One stomach contained *Hexagenia* alone and one contained several "flying-ants" along with an unidentifiable insect larva. Although these data are fragmentary, it appears that young bass, to the same degree, take very much the same items as the adults.

Twenty-three young-of-the-year smallmouth bass were captured in seines and by poisoning. These were collected in early August and preserved in 10 per cent formalin. An incision was made through the flesh into the body cavity before each was preserved in order to check post mortem digestion. When examined most of the contents were digested beyond recognition. A few Cladocera and insect larvae were able to be distinguished. In one stomach, remains of a small fish were detected but the species could not be identified.

AGE COMPOSITION

The age composition of bass caught by anglers and by nets in the years 1957 to 1959 is presented in Table XI. Most of the young were taken by netting. Limited data are available for 1957 and 1958, but no notable changes in age composition of the catch was discerned over the years.

In the sample population of 236 smallmouth bass the age classes ranged from II to XI years. The best represented age group was V, and the next most numerous (disregarding the incomplete information on the 1957 catch) was VI. Bass of the years IV, V and VI generally accounted for 70 per cent or more of a sample. These data compare with those of smallmouth bass in South Bay, Lake Huron. Fraser (1954) states that the range in age of captured specimens was from II to XII years and that groups III, IV, V, and VI dominated the population. Webster (1954), on the other hand, in an especially designed quantitative study of the smallmouth bass population in Cayuga Lake, found ages II and II to be by far the strongest representatives and with ages IV and V following second.

TABLE XI

THE PERCENTAGE AGE COMPOSITION OF SMALLMOUTH BASS CAUGHT IN NETS AND BY ANGLING IN FALCON LAKE IN THE YEARS 1957 TO 1959.

	Year of capture		
Age	1957	1958	1959
II	-	-	1.2
III	-	1	4.8
IV	20	18	18
V	64	38	31
VI	8	21	21
VII	4	18	12
VIII	2	1	6
IX	2	1	4.2
X	-	1	6
XI	-	-	0.6
Number examined	53	86	236

RATE OF GROWTH

In Table XII are presented the numbers of fish for which age determinations were made and the length and weight attained by these fish at each age. The bracketed values in the table are not representative owing to the selectivity of the nets at these ages.

TABLE XII

RATE OF GROWTH OF SMALLMOUTH BASS 1957 TO 1959, INCLUSIVE. THE BRACKETED VALUES REPRESENT THE CATCH BUT NOT THE POPULATION.

Age	Number of fish	Average fork length inches	cm.	Average weight pounds	gms
II	4	(9.8)	24.9	(0.6)	284
III	19	(10.8)	27.5	(0.8)	369
IV	67	12.6	32	1.2	539
V	139	13.8	35	1.9	879
VI	72	14.7	37.4	2.3	1049
VII	46	15.2	38.6	2.8	1276
VIII	16	15.8	40.2	3.3	1503
IX	12	16.6	42.2	3.7	1673
X	2	17.3	44	4.2	1899
XI	2	18.3	46.5	4.7	2126

The growth is apparently satisfactory considering an active growing season of about four months and the comparatively cool waters encountered during the summer throughout much of the lake. The date presented on the growth of bass are intended to give a descriptive picture of this phase of their life history. As most fish were taken in the early part of the summer the mean lengths do not represent size at the end of the growing season.

The length-weight relationship for smallmouth bass from Falcon Lake has been derived from measurements of 371 individuals taken in gill nets and by angling. The average weights for representative fork lengths are given in Table XIII. The range in variation of weight for fish of the same length was rather large, often 30 per cent heavier or lighter than the averages indicated in the table. There was no significant difference in the length-weight relations of the two sexes except in the spawning period when females were heavier than males of the same length.

TABLE XIII

AVERAGE WEIGHTS FOR REPRESENTATIVE FORK LENGTHS OF 371 SMALLMOUTH BASS, FALCON LAKE, 1958 AND 1959.

Fork length		Average weight		Fork length		Average weight	
Inches	cm	Pounds	gms.	Inches	cm.	Pounds	gms.
10	254	0.6	284	15	381	2.0	907
11	280	0.8	369	16	407	2.5	1191
12	305	1.1	510	17	433	3.0	1361
13	330	1.3	595	18	457	3.6	1645
14	356	1.7	766				

WALLEYE ECOLOGY

GENERAL

Walleye occurring in Falcon Lake naturally are the main constituent of the angling fishery there and have been exploited by anglers from commercial lodges, private cottages and tourist camps. In the past few years, with the development of the area as a major tourist centre, the demands on the walleye as a sports fish have greatly increased. Management has been directed largely in the interest of this species. In almost each of sixteen consecutive years eyed-walleye-eggs have been planted. In each fall of the past four years rough fish (whitefish and suckers) have been removed to allay some of the competitive pressures. In 1957 a creel census was initiated to assess the status of this fishery and during its course walleye were subject to considerable study. In the spring of each year, 1957 to 1959, a number of walleye were tagged, and the tag-return information gave the basis for estimating that the number of adult walleye generally ranged around 10,000 fish. As a result of the creel census, the extent of the smallmouth bass population was disclosed, and, holding with current opinions on these species interrelationships, a new management problem for walleye was portended.

DISTRIBUTION AND MOVEMENT

According to most workers (Hinks 1943, Rawson 1957, Neimuth et al. 1959, among others) walleye are not too rigid in habitat requirements and fare equally well in almost any environment. Specificity of the substrate is only demanded during spawning. The generality of their habitat requirement is summarized by Neimuth et al (loc. cit) - "Walleyes live near or on the lake bottom. They have nocturnal habits and largely depend upon unwary, often resting fish for food. They appear to have no restricted home range, and apparently drift around in their environment responding to food supplies. They seem to travel in loose aggregations in open water. Their habits are such that they never evidently become abundant in weedy waters."

The only obvious migration in Falcon Lake is the spring spawning run which has been observed primarily in the influent streams at the west end of the lake and to a lesser degree in the creek leading from Barren Lake (Figure 1). The distribution of walleye during the early summer is characterized by the gradual return of the spawning runs and concentration inshore. This is subtly followed by wide scattering into deeper waters in July where they appear to stay until late September. The same gill net sets made in 1958 and 1959 and from which generalizations on bass habits were made, provided information about walleye and their movements. In the 85 sets 238 walleye were taken.

The features of walleye distribution are analysed in Tables XIV and XV. Collection localities were from each of the bass areas (Figure 4) and other variously scattered points (indicated in Table XV as R). The species unquestionably occurs elsewhere, in fact, it is probably widely distributed throughout the lake. Collection was essentially restricted to bass areas so that the relationship between species could be tested.

TABLE XIV

AVERAGE NUMBER OF WALLEYE CAUGHT PER 50 (45.7 m.) YARD OF NET IN EACH DEPTH RANGE AND MONTH, FALCON LAKE, 1958 AND 1959 THE NUMBER OF SETS ARE IN PARENTHESIS

Depth range	May	June	July	August	September	Total
0-20 feet 0-6 m.	3.5 (15)	3.0 (12)	2.5 (9)	1.6 (9)	2.0 (2)	2.7 (47)
20-40 feet 6-12 m.	8 (2)	3.5 (4)	3.0 (9)	2.4 (5)	4.5 (2)	3.5 (22)
40-60 feet 12-18 m.	0 (2)	1 (3)	3.9 (5)	4.0 (4)	1.5 (2)	2.5 (16)
Monthly average	3.5 (19)	2.8 (19)	3.0 (23)	2.4 (18)	2.8 (6)	

The bathymetric range of walleye extended from the shallowest to the deepest water in the lake. Averaged over the season, fish were more frequently caught in the mid-depth range, that of 20 to 40 feet (6 to 12 m.), when the rate of catch was 3.5 walleye per 50 yard (45.7 m.) of net. Throughout the season marked changes in distribution were observed. During May walleye were most frequently found in the shallows down to the 40 feet (12 m.) depth range, but never any deeper. The species appeared to be widely distributed and was taken from all areas except bass area "A" (Figure 4). This reluctance of the walleye to associate with this remote bass area was not only peculiar to May but prevailed over the seasons. Throughout June the distribution of the species was somewhat similar in that the fish were widely scattered, but, they began to show an acceptance for water 40 to 60 feet (12 to 18 m.) deep.

TABLE XV

AVERAGE NUMBER OF WALLEYE CAUGHT IN EACH RANGE OF DEPTH AND MONTH WITH RESPECT TO AREAS A, B, C AND R (FIGURE 4), FALCON LAKE, 1958 AND 1959; THE NUMBER OF SETS IS IN PARENTHESIS

Depth range	May	June	July	August	September	Area
0 to 20 feet (0 to 6 m.)	1.3 (4)	0.7 (3)	2.5 (2)	2.0 (1)	-	A
	3.4 (5)	3.3 (3)	3.0 (2)	2.5 (2)	4 (1)	B
	3.6 (3)	2.3 (3)	2.5 (2)	1.0 (3)	-	C
	6.0 (3)	1.5 (4)	1.7 (3)	1.7 (3)	-	R
20 to 40 feet (6 to 12 m.)	-	-	0 (1)	3.0 (1)	-	A
	4 (1)	1 (2)	2.5 (2)	-	0 (1)	B
	-	-	2 (3)	2.5 (2)	-	C
	12 (1)	6 (2)	3 (3)	2 (2)	2 (1)	R
40 to 60 feet (12 to 18 m.)	-	-	2 (1)	-	-	A
	0 (1)	0 (1)	7 (1)	4 (2)	0 (1)	B
	-	-	-	-	-	C
	0 (1)	1 (3)	6.5 (2)	4 (2)	1 (1)	R

During July and August nets set in deeper water caught more walleye than those in shallow water. The fish still ranged widely save for a continuing reluctance to inhabit Area 'A'. In September sets, fish were caught more frequently in mid-depth zones but a tendency for these fish to inhabit shallower water became apparent.

These observations based on net catches were substantiated by angling experiences. Anglers' creel census data showed that walleye were more frequently caught in the same areas and depths in which they were taken in nets. That walleye move into shallow water in the fall is further supported by the observation that many of this species were caught in pound and trap nets set inshore at this time especially to capture whitefish.

In the spring of each successive year since 1957 a number of walleye, captured in the spawn run at the west end of Falcon Lake, were tagged and released. Throughout each season returns of these tags from anglers and from netting gave information on the movements of the walleye. All tags returned save for six were taken from within Falcon Lake, but from such diversified locations and at such times that no systematic pattern to their movements could be interpreted. The six other recaptures were made either in the Falcon River or in Shoal Lake. These substantiated the suggestions prevalent among local observers that once through spawning many walleye migrated down the Falcon River.

SPAWNING

In each year, spawning runs of walleye were first observed in the creek at the west end of Falcon Lake during late April. At this time the channel was free of ice. The initiation of spawning movements is probably dictated by water temperature, which at this time was observed to be between 4.5 and 7.0^{o} Centigrade. These observations were consistent in the three consecutive years. This was the only part in the lake in which spawning concentrations were observed 'en masse'. Other runs of minor consequence were noted to occur in the creek running from Barren Lake (Figure 1) and netting results suggested some spawning may occur along appropriate shallows in the lake. The walleye remained in association with their respective spawning areas for about two weeks. By the last week in May identity with these areas was lost and their distribution became scattered as outlined in the preceding discourse.

HABITS AND HABITAT OF THE YOUNG

No observations were able to be made on the newly hatched of each year. In late May and early June sampling for these fry was tried in spawning areas but none was captured or observed. Neimuth et al. (1959) state that the rate at which walleye eggs hatch is dependent on temperature. Based on their observations walleye eggs should hatch in about twenty to twenty-six days after spawning at the temperatures that prevailed.

The behaviour pattern of young walleye in Falcon Lake remains a mystery to this study. In late summer, however, several young-of-the-year were taken in a sample from bass area A.

FOOD HABITS

Stomach contents were examined from 384 walleye taken from various localities in the lake. Samples used for food studies comprised all individuals taken in nets and a few taken by angling. Almost all of these were large or adult fish. Nine fingerlings were taken by spot poisoning and the stomachs of these were likewise examined. The fish and contents of their stomachs were treated in a similar manner as outlined for the smallmouth bass.

Of the 384 walleye included in this facet of the study, 94 or 25 per cent contained no food in their stomachs. The frequency of occurrence and number of food items as they appeared in the 290 stomachs with food is analysed in Table XVI. Insect items were conspicuous in the majority of stomachs; 94 per cent of the stomachs with food contained at least one insect representative. Among the insects, Ephemerid nymphs were by far the most favoured choice of walleye. Fish items, comprising mostly perch and small suckers, appeared next to insects in abundance. Crustaceans, as food items, appeared least often and only two groups were identified, crayfish and copepods. These observations do not totally agree with that of other workers. Hinks (1943) states that walleye, a piscivore, feeds essentially on other fishes and consumption of other items is only of minor consequence. Rawson (1953), on the other hand, regards insects as a common food item for walleye.

As was the case with smallmouth bass, walleye taken by angling did not show comparable stomach content analysis with those taken in nets.

TABLE XVI

SUMMARY OF FOOD ITEMS ANALYSED FROM 290 WALLEYE STOMACHS
FALCON LAKE, 1959

Food item	Number of stomachs containing item	Number of items	Frequency of occurrence (per cent)
Pisces	170	303	58
Catostomus	11	12	4
Cyprinidae	6	6	2
Perca	47	129	16
Stizostedion	10	16	4
Micropterus	6	8	2.7
Cottus sp.	1	1	0.4
Pungitius	2	3	0.7
Unidentified	87	128	30
Crustacea	37	70	13
Crayfish	9	15	3
Copepods	28	55	9
Insecta	277	5,353	94
Diptera	30	58	10
Ephemerids	223	5,250	76
Others and Unidentified remains	23	45	8

The observations comparing the method of capture of fish and the frequency with which food items occur in their stomachs are shown in Table XVII.

TABLE XVII

VARIATION IN THE QUANTITY OF FOOD IN THE STOMACHS OF 384 WALLEYE CAUGHT IN NETS AND BY ANGLING — PERCENTAGE OF TOTAL IN PARENTHESIS.

Item	Gill nets	Angling
Total number of stomachs	223	161
Number of empty stomachs	39 (13)	55 (35)
Number containing food	184 (87)	106 (65)
Number containing fish	103 (46)	67 (41)
Number containing crayfish	5 (2)	4 (2)
Number containing insects	197 (88)	80 (50)

With either mode of handling, however, walleye were not observed to regurgitate their stomach contents, as was the case with bass. Almost three times as many angled-walleye-stomachs were empty as those caught in nets. Likewise, those stomachs containing food had fewer of each item when taken from angled fish. Weighed with the consideration that net caught walleye were held eight to ten hours before examination of stomach content, thus allowing time for delicate and smaller items to decompose and not be recognized, these observations may reflect the habits of the species. Angled caught fish may have taken a lure or bait because they were more hungry.

There appeared to be distinct seasonal trends in the feeding habits of the walleye. Throughout the five month study period, fish and ephemerids appeared more frequently than any of the other food items. Hexagenia, however, was eaten most frequently in May and June, times at which the choice of fish was least. There appears to be a relationship between the consumption of Hexagenia and fish items. These insects were taken more often when fish were taken least and vice versa. Dredge samples, however, demonstrated that the nymphs more or less were consistent in numbers over the study period. The availability of fish as food items may have changed throughout this time. Young-of-the-year of many fish species should have entered the fishery as potential food items in the latter part of the summer. This feeding picture may also reflect the distribution habits of the walleye. The features of the feeding habits of the walleye in each month of the summer season are delineated in Table XVIII.

AGE COMPOSITION

Scales were collected for age studies from 765 walleye in 1957, 1958 and 1959, at Falcon Lake. To secure fish samples representative of the fish population and of the catch, fish were taken in gill nets and from anglers' creels. More of the young in the sample were taken by netting. The age composition of the walleye taken is shown in Table XIX.

In this sample of 765 walleye the age classes ranged from II to XIII years. The 1957 sample was small and consisted mainly of fish

TABLE XVIII

DIET OF WALLEYE FROM FALCON LAKE IN EACH OF THE SUMMER MONTHS, MAY TO SEPTEMBER. FOOD ITEMS ARE EXPRESSED AS FREQUENCY OF OCCURRENCE

Food item	May	June	July	August	September
Pisces	44	52	75	57	77
Catostomus	1	4	4	3	15
Cyprinidae	0	4	3	3	0
Perca	16	8	19	15	15
Stizostedion	0	3	7	8	0
Micropterus	1	0	5	5	0
Cottus sp.	1	0	0	0	0
Pungitius	2	0	0	0	0
Unidentified	23	33	37	23	47
Crustacea	22	10	9	3	0
Crayfish	2	4	4	3	0
Copepods	20	6	5	0	0
Insecta	100	100	64	78	57
Diptera	3	13	13	7	10
Ephemerida	100	82	43	71	47
Others and Unidentified	12	6	8	0	0
Number of stomachs with food	92	85	56	38	19

TABLE XIX

THE PERCENTAGE AGE COMPOSITION OF WALLEYE CAUGHT IN NETS AND BY ANGLING IN FALCON LAKE IN THE YEARS 1957 TO 1959.

Age	Year of capture 1957	1958	1959
II	-	-	0.5
III	2	-	4.6
IV	2	3.7	36.4
V	6	17.5	31.0
VI	11	15.5	12.5
VII	22	19.5	9.3
VIII	13	13	3.4
IX	15	13	2
X	13	17.5	0.8
XI	10	-	0.3
XII	6	-	-
XIII	-	-	0.3
Number of fish in sample	55	304	406

taken in nets. This sample in congruous with those taken in other years and its paucity may deter from its being representative. The 1958 and 1959 samples were of more satisfactory numbers and each sample was collected in the same manner. Disregarding the incomplete data from 1957, the best represented group was that of age V. Walleye of the years IV, V, VI and VII accounted for 84 per cent of the 1959 sample but only 46 per cent of 1958 sample. In the earlier year the majority of the sample was included in the age range of V to IX years. There is a definite difference in the age composition between the samples of the two years and this is believed to be a reflection of some event in the fishery.

Most walleye samples in studies made in other fisheries have about 75 per cent of their members included in the age groups IV to VI. This is documented by such workers as Rawson (1953), Slasteneko (1956), Niemuth, et al. (1959), among others. These observations agree favorably with the 1959 sample taken from Falcon Lake.

RATE OF GROWTH

The average fork lengths and weights for each age in the samples taken in each of the three years, 1957, 1958 and 1959 are shown in Table XX. The values tabulated for the ages II and III are not likely representative because of the selectivity of nets at this age.

There is little consistency in growth rates of samples between years. Even if the 1957 sample is ignored because of its small representation, the two more appropriate samples of 1958 and 1959 still do not harmonize. The only consistent suggestion of these data is that the growth rate of walleye has increased in each successive sample. That is, the 1959 population exhibited a better rate of growth than the 1958 sample which in turn was better than the 1957 sample. By way of example, IV year old fish in the 1959 sample average 16.6

TABLE XX

RATE OF GROWTH OF WALLEYE AS DETERMINED FROM SAMPLES TAKEN FROM FALCON LAKE IN 1957, 1958 AND 1959; SEXES COMBINED

	Number of fish			Average fork length in inches, cm. in parenthesis			Average weight in pounds, gms. in parenthesis		
Age	57	58	59	57	58	59	57	58	59
II	-	-	2	-	-	13.2 (33.3)	-	-	0.9 (425)
III	1	-	18	12 (30.5)	-	13.9 (35.3)	0.8 (369)	-	1.0 (454)
IV	1	22	150	12.4 (31.5)	15.1 (38.4)	16.6 (42.2)	0.9 (425)	1.4 (652)	1.6 (737)
V	3	54	130	12.9 (32.8)	16.6 (42.2)	18.1 (46.0)	1.0 (454)	1.6 (737)	2.1 (964)
VI	6	46	50	13.8 (35.1)	17.4 (44.2)	19.0 (48.3)	1.1 (510)	1.8 (822)	2.7 (1219)
VII	14	60	35	15.6 (39.6)	18.5 (47.0)	21.3 (54.1)	1.5 (680)	2.1 (964)	3.8 (1729)
VIII	7	39	14	15.4 (39.1)	19.6 (49.8)	23.1 (58.7)	1.4 (709)	2.5 (1134)	4.7 (2126)
IX	8	39	7	16.9 (42.9)	20.0 (50.8)	22.6 (57.4)	1.8 (822)	2.7 (1219)	4.8 (2183)
X	7	24	3	18.4 (46.8)	20.8 (52.9)	19.9 (50.6)	2.2 (992)	3.1 (1418)	3.4 (1559)
XI	5	-	1	19.2 (48.8)	-	22.9 (58.2)	2.4 (1106)	-	4.7 (2126)
XII	3	-	-	21.4 (54.4)	-	-	3.8 (1729)	-	-
XIII	-	-	1	-	-	27.6 (70.1)	-	-	8.8 (7625)

inches (42.2 cm.) in fork length, in 1958, 15.1 inches (38.4 cm.) and in 1957, 12.4 inches (31.5 cm.). This same difference prevails for each age group and to almost the same degree.

The growth rate of Falcon Lake walleye when compared with that displayed by walleye in other waters, suggests it is better or at least comparable for any of the three year-samples. Eschmyer (1950) reports that Lake Erie IV year olds average 13.6 inches (34.6 cm.) total length, Lake Manitoba walleye are 13.0 inches (33 cm.) and an average for the Prairie Provinces is 13.2 inches (33.6 cm.). From Table XXII, in Falcon Lake IV year old walleye are 12.4, 15.1 and 16.6 inches (31.5, 38.4 and 42.2 cm.) fork length for the years 1957, 1958 and 1959 respectively. These lengths converted to total lengths (see Appendix Figure A2) are 12.8, 15.5 and 17.2 inches (32.5, 39.4 and 43.7 cm.). Falcon Lake walleye, especially in 1958 and 1959, exhibit even better growth than the species in more temperate climates. Neimuth et al. (1959) document that the Minnesota average for IV year olds in 15.1 inches (38.4 cm.) total length.

The growth of Falcon Lake walleye is apparently better than satisfactory considering the short growing season. Most fish were taken before mid-summer and the cited lengths do not represent size at the end of the growing season.

The length-weight relationship of a species may serve as an indicator of the robustness or well-being for that species. This aspect is shown for Falcon Lake walleye in Table XXI, as derived from 406 measurements made in 1959. Average weights are given for representative fork lengths. The range in variation in weight for fish of the same length is quite large, often 50 per cent heavier or lighter than the averages indicated. By way of example, 18 inch (45.7 cm.) fish averaged 2.1 pounds (965 gms.), but, the weights for all fish of this length ranged from 1.4 to 3.9 pounds (652 to 1786 gms.).

TABLE XXI

AVERAGE WEIGHTS FOR REPRESENTATIVE FORK LENGTHS OF 406 WALLEYE, FALCON LAKE, 1959

Fork length		Average weight		Fork length		Average weight	
inches	cm.	pounds	gms.	inches	cm.	pounds	gms.
10	25.4	0.6	284	17	43.2	1.8	822
11	28.0	0.7	313	18	45.7	2.1	964
12	30.5	0.8	369	19	48.3	2.3	1049
13	33.0	1.0	454	20	50.8	2.8	1276
14	35.6	1.1	510	21	53.4	3.2	1446
15	38.1	1.3	595	22	55.9	3.8	1729
16	40.7	1.5	680	23	58.4	4.4	2013

These observations on the length-weight relations of the 1959 sample further substantiate the suggestion that the growth of Falcon Lake walleye is as good as or better than average for this isotherm. This aspect interpreted for walleye from Three Mile Lake, Ontario (Slasteneko, 1956) and from Lac La Ronge, Saskatchewan (Rawson, 1953) suggests that Falcon Lake walleye are a little more robust.

SPECIES INTERRELATIONS

GENERAL DISCUSSION

It is not uncommon to visualize that animal populations living in the same habitat compete with each other for survival. Every activity of each animal in some way or another becomes interrelated with those of all other members of the community. If one species dominates a resource or exerts an antagonistic influence, another in the community may be forced into decline. A competative relationship is then made apparent by the end result.

With fishes one can detect some of the aspects by which two populations are interrelated. They may use resources, like certain food items, or space, in common, or, they may prey upon one another. With fishes, however, it is difficult to detect what the expression is as a result of the interrelationships of two species. The mechanisms for competition apparently may be in effect but the expressions subdued. It may be as Larkin (1956) points out, "adaptability and flexibility are characteristically the habits of fishes". A population in competition may merely bend to the pressures of a dominator, rather than follow a recognizable course like emigration or extinction.

In the Falcon Lake situation one might expect to find the mechanisms of competition in play. Undisturbed over the years the fishery was left to seek its own balance. Smallmouth bass were introduced and they found a habitat in which to advance until they became one of the most numerously represented species in the lake. It follows, that to accomodate their advance the bass either found a vacant niche or encroached on pre-existing species.

The observations in this study were meant to test some of the interactions between smallmouth bass and walleye in Falcon Lake. Since there was no previous picture and since the current observations were over such a short span of time this work does not propose a conclusion that through their associations the species are or are not in competition. Rather, it is the purpose to explore some of the aspects by which the species are interrelated. Three aspects, some of those by which competition may be qualified, were investigated; these were, (1) space interrelations, (2) food interrelations, and (3) predatory interrelations.

Observations on the distribution habits of the species over the course of each season were interpreted to determine their space interrelationship. The space factor phenomenon with fish is difficult to define. This undoubtedly a density dependent factor which finds its basis in territorial behaviour where social dominance and aggression have an influence. Overlap in space requirements would especially culminate as a mechanism of competition when one species exercised its demands for space so as to exert an influence on another during its spawning time.

The food interrelationship was resolved through the analysis of the stomach contents of each species. With this aspect, the use of a tangible resource was being measured and it follows that an interaction may readily be qualified. If the two species live on the same range of food, and especially if there is a limited supply of the items, then competition is imperative. At the same time, however, the species may have common food preferences but an inferior species may be able to live on a less choice food and adapt itself favorably. Then again, they may demand exactly the same food, but, variation in the physical environment may alter their feeding efficiency. Regardless, the basis of the food interaction of bass and walleye will depend on to what degree they eat food items in common. The degree or state of this interaction was determined by the relative amount of each food item taken by the species.

One of the more obvious mechanisms of an interaction is the degree to which the species prey upon one another. Through the course of studying the food relationships of the species a resolution was also made of their predatory interactions.

SPACE INTERRELATIONS

In the early spring of each year the walleye moved in toward their spawning grounds and frequented the shallows. Later as the temperatures warmed they tended to move into deeper water. By late May the species was netted most often in waters 20 to 40 feet (6 to 12 m) deep (Table XIV). From this time on the net catches indicated that the walleye had either moved into deeper water or had stayed at the bottom of the mid-range. The catches also showed that the walleye were fairly well scattered throughout the lake. There were, however, select feeding grounds where the walleye congregated intermittently up until mid-summer.

During the smallmouth bass spawning and nesting season, territories were established and maintained by the bass. By the time this came about the walleye had moved into deeper water. By mid-July the bass left the nesting areas and exhibited a trend to scattering into deeper water. For the most part, however, they did not descend below 35 feet (11 m.) and they did not range much beyond the areas they had maintained earlier.

There appears to be little overlap in the distribution of walleye and smallmouth bass. When one inhibits an area or depth range, the other, preceding this choice, has voluntarily moved out. There is a suggestion of conflict in June when some walleye still inhabit the shallows where bass are nesting. At times, these common grounds were kept under surveilance by scuba equipped observers. A few walleye were seen in the proximity of the nests, but, no bass were seen to exhibit aggressiveness to keep the walleye away. Another possible realm of interaction was on the selected feeding grounds which the walleye visited intermittently from June to late July. Throughout this time an occasional bass was caught in the areas.

Apart from these instances the species remained distinct in their distribution habits. There were few situations observed when large numbers of one species were found in association with the other. For that matter, neither were there smaller numbers of one persistently in association with the other.

The distinctness of their distribution habits also applied throughout the spawning times of the species. Neither incited any appreciable degree of interaction with respect to the spawning expression of one or the other. The walleye spawned in the early spring and were usually finished with this activity before the bass became active. The walleye spawned in the creek at the next end of the lake, in the effluent from Barren Lake and to a lesser extent in appropriate shallows around the lake. Even at the height of their activity the bass showed no interest in these locations. Bass were never observed in association with spawning walleye both in respect to time and place, and it was assumed there was no interaction between the species in this regard.

The bass spawned in June and maintained vigilance over their nests until mid-July. At this time the walleye showed a trend to move to deeper water away from the shallow bass spawning areas. During the early part of the bass spawning a few walleye were detected in the vicinity of the nesting areas. It is conceivable that the presence of the walleye may have incited some anxiety amongst the bass but, apart from this there was no other interference.

FOOD INTERRELATIONS

From observations on their feeding habits, grounds were established for aggressive interaction between the species. Three groups of food items, insects, small fishes and crayfish composed almost the entirety of their diets. Walleye fed almost totally on insect nymphs and small fishes, whereas, bass fed on insects, small fishes and crayfish. Figure 5 summarizes and compares the feeding habits of the species with respect to these items through the course of a summer.

The mainstay of the bass diet was crayfish. This item was taken more often than any other and to almost the same degree throughout a study period. Walleye rarely ate crayfish at any time so there was little interspecific competion for this item.

Almost all walleye stomachs contained ephemerid nymphs. This item appeared to be the most consistent food of the species. Bass fed on a variety of insects, from terrestrial to aquatic forms, but, took more ephemerid nymphs than any other. The bass, however, did not feed on the ephemerids as consistently as the walleye did whereas walleye fed on them avidly throughout the summer, bass took them to a comparable degree only in July. Prior to and after this time the bass' interest in this item dropped off markedly.

Both bass and walleye fed to almost the same degree and consistency on small fishes. The walleye ate a larger variety of fishes than did the smallmouth bass, but, both species took more yellow perch than any other fish item.

Since the bass and walleye select food items in common they are involved in interactions. These interactions could be realized as a mechanism of competition if the food items were present in a limited supply. Bottom fauna studies and other observations, however, suggested that the food supply was more than adequate. Each species

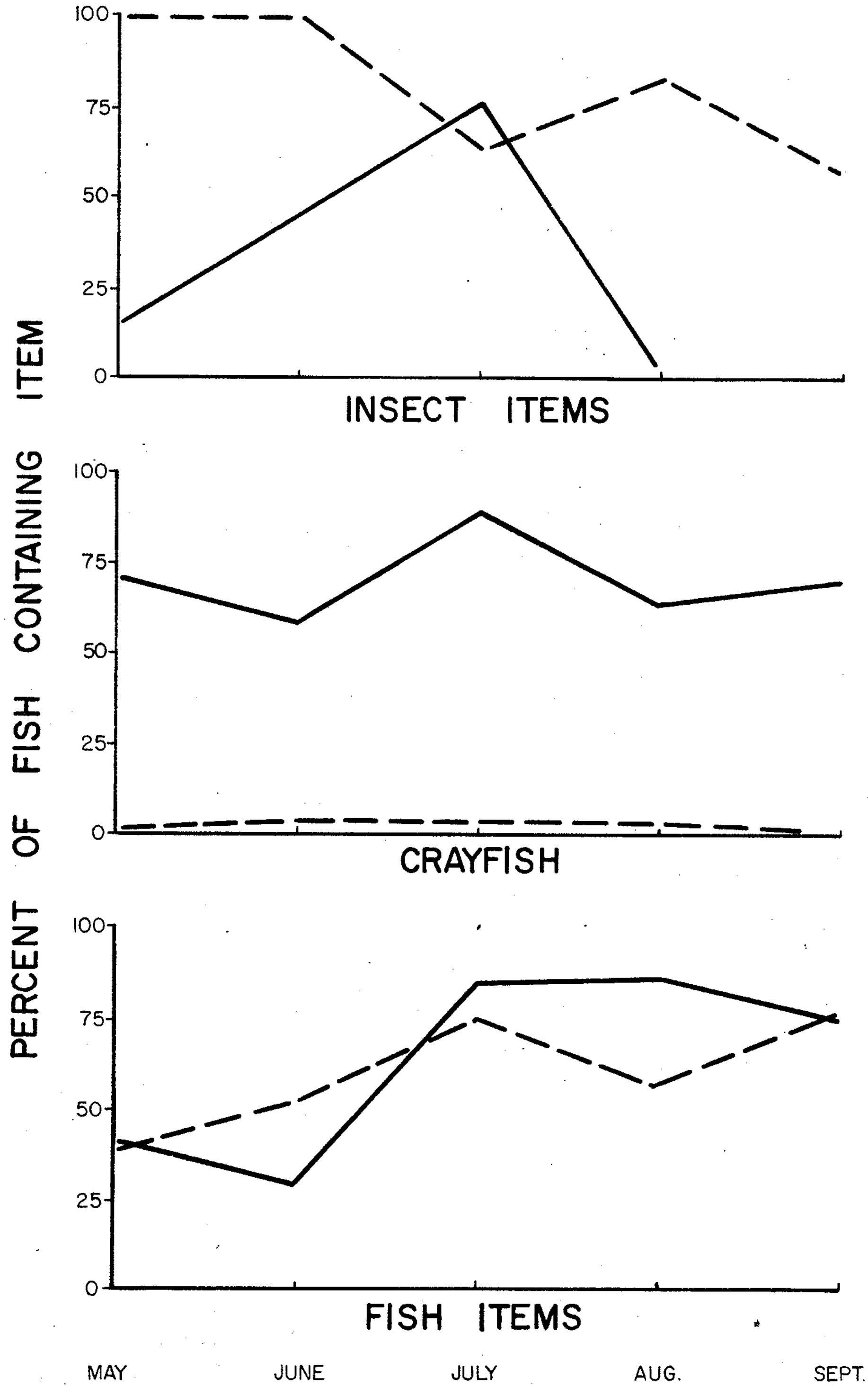

FIGURE 5. Choice of the three major food items, in each month, made by smallmouth bass and walleye, Falcon Lake, 1959. The solid line represents the choice of bass and the broken line that of walleye.

exhibited a satisfactory rate of growth and hence must have received the necessary nourishment. Furthermore, the overlap in feeding habits is of short duration. Each species may feed comparably on small fishes, but, during the winter the bass likely feed less or hardly at all (Webster 1954). In July the interaction may be more intense when the bass's choice of insects rivals that of the walleye. Their contentious relationship seems to be a seasonable one and for the better part of the year their feeding habits are distinct enough to keep the species on a compatible basis.

PREDATORY INTERRELATIONS

From their feeding habits it was demonstrated that the species are involved in a predatory relationship. Three per cent of the walleye examined had taken smallmouth bass as part of their diet. Although this event occurs to only a small degree, grounds are still established for an aggresive interaction between the species. At the same time, however, four per cent of the walleye had eaten other walleye thereby exhibiting intraspecific aggression. The smallmouth bass on the other hand neither ate their own kind nor walleye.

CONCLUSIONS

The Falcon Lake habitat provides a favorable environment for both walleye and smallmouth bass. Each species seems to fare well in this lake; their population numbers are substantial and their rate of growth is good.

Many workers regard the species complex of smallmouth bass and walleye as an incompatible one, (Lachner 1950, Webster 1954, Henderson and Foster 1956, Neimuth et al., 1959, among others) because the competitive interactions between them are too intense. From the studies at Falcon Lake, however, it was demonstrated that there was no extensive antagonistic interaction between the species on three aspects of their relationships. Their space interrelationships were not such that one incited an aggressive interaction with the other. From their feeding habits it was shown that there is a basis for a competitive relationship. This, however, was a short term or seasonal interaction. The walleye preyed on young smallmouth bass and thereby set up a basis for a competitive relationship. This occurred to such a small degree, however, that adverse effects on the prey population were unlikely.

Further observations suggested that the smallmouth bass population may increase beyond its current size. If this event is fulfilled then the observed compatible relationship between smallmouth bass and walleye may no longer exist. More space and more food will be demanded. Intraspecific pressures may force the bass to vie more intensely with the walleye for these resources. Then again, the question arises - how will the walleye respond to this encroachment? Apart from there being more bass available as food items, under increased pressure the walleye may respond with less resiliance (if it can be said they have so responded to date) and resist the expansion.

In regarding future events, the interplay of other fish species must also be taken into consideration. Other fishes in the lake are also involved in relationships with both walleye and smallmouth bass. Prior to the introduction of the bass there was probably a balance in the community with which the walleye harmonized. Apparently, as well, there was a vacant niche into which the bass could fit without adversely reflecting on the walleye. To what degree this niche is filled, or to what size the bass population can expand before the aspects of interaction culminate as mehanisms of competition and adversely reflect on the walleye is open to conjecture and relegated to further research.

SUMMARY

(1) The habitat, habits and interrelationships of two fish species, smallmouth bass and walleye, were studies in Falcon Lake through the summers 1957 to 1959.

(2) Falcon, a 4,400 acre (1,780 ha.) lake in the perimeter of the Canadian Shield, is located in southeastern Manitoba. On the basis of physical, chemical and biological observations it was judged to be an oligotrophic lake succeeding into an eutrophic classification. It was regarded as being moderately fertile and had satisfactory features to support walleye and smallmouth bass.

(3) The smallmouth bass population, estimated to be upwards to 10,000 in adult numbers, originated as sixty-four adults planted in 1946. The species adapted well to Falcon Lake. These fish exhibited a good rate of growth, generally reaching a weight of two pounds (907 gms.) in their fifth year of life, which is apparently satisfactory in this isotherm (Fraser 1954, Webster 1954).

(4) Most of the bass were associated with localized habitat, spawning and ranging in proximity to these areas. New nesting areas were observed in each subsequent year. Bass did not actively appear on the scene until late May and they followed a characteristic distribution pattern through to the end of the season. Once through spawning and associated activity, by mid-July, they ranged further from the nesting areas but showed a reluctance to pene-

trate the thermocline or go below it.

(5) The stomach contents of 234 smallmouth bass were examined over the seasons to determine their feeding habits. Fifty-six or 24 per cent of these stomachs contained no food. Of the fish with food 68 per cent had selected at least one crayfish as part of their diet. These crustaceans were the most frequent item taken. Fish items were eaten second most and insect items least often. The bass apparently fed most avidly in July when at least 75 per cent of their diet consisted of each of the three group items. Bass were consistent in the taking of crayfish but probably took insects and small fishes because they were more avai0 lable to them at the time.

(6) Estimates of the adult walleye population made in each of the three years indicated that it had remained the same, generally ranging upwards from 10,000. Samples taken from each of the years 1957, 1958 and 1959 do not show similar age structure or comparable growth rates. In 1957 four-year old fish averaged 12.9 inches (33 cm.) in total length, in 1958 members of this same age group were 15.5 inches (39 cm.) and in 1959 they were 17.2 (44 cm.). Eschmeyer (1950) quotes the Prairie Provinces average for IV year walleye as 13.2 inches (34 cm.); Neimuth et al. (1959) cite the Minnesota average to be 15.1 inches (38 cm.).

(7) Apart from spawning in select areas in late April and early May, and holding an association with these areas for a short time following spawning, the walleye ranged widely in the lake. Their bathy-

metric distribution was distinct. By June they tended to move to deep water and they stayed there until September when once again they ranged into the shallows. At the height of the summer they generally stayed in water over forty feet (12 m.) deep.

(8) A feeding habit analysis was made through the investigation of 384 walleye stomachs. Ninety-four or 25 per cent were empty. Of the stomachs containing food, 94 per cent contained at least one insect item, the most common by far being ephemerid nymphs. Over the seasons insect items were taken most often in May and June. Fish items were found in 58 per cent of the stomachs. Yellow perch were taken more often than any other small fish. Four per cent of the fish had eaten other walleye and almost three per cent had eaten smallmouth bass. The selection of crayfish as food was almost negligible at any time. The walleye diet was influenced by the distribution and behaviour of the food organisms and that of the fish itself.

(9) By virtue of their coexistence smallmouth bass and walleye are involved in interrelationships. Through a study on their habits three aspects of relationships wer resolved. These were:

(a) space interrelations,

(b) food interrelations, and

(c) predatory interrelations.

These are mechanisms by which competition may be defined.

(10) The distribution habits of the two were distinct; they did not

overlap save for a few cursory instances. There was no interference of one with the other in achieving space requirements. Neither disturbed the spawning activities of the other.

(11) Both walleye and bass select some food items in common. On this basis they can be regarded as being in competition, but other observations suggest the food supply is not limited. Through the summers they fed to almost the same degree and with the same consistency on fish items. During July the bass fed on ephemerid nymphs almost as much as walleye did.

(12) Walley preyed on smallmouth bass to a small degree.

(13) Both smallmouth bass and walleye fare well in Falcon Lake from studies on three aspects of their interrelationships it was concluded the species live together compatibly. It was speculated that the smallmouth bass population may increase, in which case, the relationships between the species may also change.

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APPENDIX

TABLE AI. MEAN MONTHLY TURBIDITY READINGS, FALCON LAKE, 1957-1959. THE NUMBER OF TESTS IS IN PARENTHESIS.

	1957 (7)			1958 (15)			1959 (61)		
	feet		meters	feet		meters	feet		meters
May	12	(1)	3.7	12	(2)	3.7	11.5	(6)	3.5
June	14	(2)	4.4	105	(5)	3.2	15	(19)	4.6
July	14	(2)	4.4	14	(3)	4.4	17	(18)	5.1
August	17	(1)	5.2	16	(3)	4.9	15	(13)	4.6
September	15	(1)	4.6	15	(2)	4.6	15	(5)	4.6

TABLE AII. SURFACE WATER TEMPERATURE AT STATION I, FALCON LAKE, 1957. EXPRESSED AS DEGREES CENTIGRADE

Day of Month	May	June	July	August	September
1		12.2	17.8	25.0	20.6
2		12.2	16.7	23.9	20.0
3		12.2	18.4	23.9	21.7
4		15.6	17.8	22.8	16.1
5		15.6	18.4	22.8	
6		15.6	18.4	23.4	
7		16.7	18.4	23.4	
8		15.6	20.0	22.2	
9		15.6	18.9	23.4	
10		14.5	20.0	23.4	
11		14.5	21.7	23.4	16.1
12		13.4	23.4	23.4	16.1
13		13.4	21.7		
14		14.5	23.4		
15		13.4	23.4		
16		13.9	22.2		
17		13.4	25.0		
18		13.9	25.6		
19		13.4	24.5		
20		14.5	23.4		
21		15.6	23.9		
22		15.0	23.9		
23		16.7	25.0		
24	11.7	17.8	23.9		
25	11.7	16.7	23.9		
26	11.7	15.6	24.5		
27	11.7	16.7	26.1		
28	10.6	17.2	26.1		
29	11.7	18.9	26.7		
30	14.5	16.7	25.6		
31	11.7		25.6		

TABLE AIII. SURFACE WATER TEMPERATURES AT STATION I, FALCON LAKE, 1958. EXPRESSED AS DEGREES CENTIGRADE.

Day of Month	May	June	July	August	September
1		11.7		25.6	21.1
2		10.6		28.4	21.1
3		11.1	18.4	27.2	19.5
4		14.5	18.4	25.6	17.8
5		15.0		26.1	17.8
6		17.2		26.1	17.8
7		15.0		26.1	17.2
8		16.1		26.1	18.4
9		15.0	18.4	27.8	18.4
10		15.0	20.0	26.1	17.8
11		15.0	21.7	27.2	17.8
12		15.0	23.4	26.1	17.8
13		14.5	23.4	25.6	
14	15.0	14.5	21.7	26.1	
15	16.1	15.0	28.0	24.5	
16	18.4	15.0	22.2	25.0	
17	16.7	16.1	28.0	25.6	
18	15.0	16.7	21.7		
19	13.4	18.7	22.8	26.1	
20	12.8	16.1	22.8		
21	13.9	16.7	23.4		
22	15.0	16.7	23.9	20.0	
23	14.5	16.7	25.0	18.4	
24	15.0	17.2	23.9	18.9	
25	15.0	20.6	24.5	16.7	
26	15.0	18.9	25.0	18.4	
27	14.5	16.7	22.8	20.0	
28	15.0		22.8	22.8	
29	17.2		23.4	24.5	
30	17.8		25.0	20.0	
31	15.0		26.7	16.7	

TABLE AIV. SURFACE WATER TEMPERATURES AT STATION I, FALCON LAKE, 1959. EXPRESSED AS DEGREES FARENHEIT.

Day of Month	May	June	July	August	September
1		10.6	20.0	26.7	23.4
2		10.6	20.6	26.1	23.4
3		13.4	21.7	23.9	21.1
4		13.4	17.8	24.5	20.0
5	4.5	17.8	20.6	25.6	20.0
6	4.5	18.4	20.6	25.6	20.0
7	5.0	18.9	20.6	25.0	20.0
8	5.6	17.8	20.6	23.4	21.1
9	7.2	20.0	17.8	26.1	18.9
10	7.2	18.9	19.5	25.6	20.0
11	6.1	15.0	21.7	27.3	19.5
12	5.6	16.1	20.6	26.1	18.9
13	5.6	16.7	21.1	26.7	18.4
14	6.1	16.7	22.2	27.3	16.7
15	5.6	17.2	21.1	25.6	
16	10.0	17.8	19.5	26.1	
17	10.0	17.8	19.5	26.7	
18	9.9	18.4	21.7	23.9	
19	7.2	16.7	21.7	27.3	
20	7.2	17.2	21.1	23.9	
21	7.2	18.4	20.6	17.2	
22	8.4	18.4	21.7	21.1	
23	8.4	17.8	23.4	19.5	
24	11.7	18.9	25.6	28.0	
25	10.0	20.0	26.7	20.6	
26	9.5	20.6	25.0	22.8	
27	10.0	19.5	26.1	21.1	
28	10.6	18.4	24.5	21.7	
29	10.0	18.4	21.7	19.5	
30	10.0	18.9	20.0	20.6	
31	11.1		21.1	22.2	

TABLE AV. SURFACE WATER TEMPERATURES TAKEN PERIODICALLY AT STATION II AND II AND AT RANDOM STATIONS R, FALCON LAKE, 1958. EXPRESSED AS DEGREES CENTIGRADE

Day of	May			June			July			August			September		
Month	II	III	R	II	III	R	II	III	R	II	III	R	II	III	R
3				18.4	19					25			19	18.4	
4				15	15										
9					15		19	19							
11											21				
12							22.2	22.2							
13															
16				14.5	14.5										
19		9.3													
20															
24				17.8	17.8										
25							24.5	23.9							
28										23.4					
31	16.7	17.2													

TABLE AVI. DISSOLVED OXYGEN READINGS AT EACH STATION AND DEPTH THROUGHOUT THE SUMMER, 1959, FALCON LAKE: EXPRESSED AS P.P.M. 'S' DENOTES A SURFACE SAMPLE.

	Month and Depth of Sample													
Day of	May		June				July				August			
Month feet	S	20	S	20	40	60	S	20	40	60	S	20	40	60
meters		6		6	12	18		6	12	18		6	12	18
Station I:														
1			9.5											
3							9.8	8.6						
5			9.1	8.4							9.8	8.7		
10	7.6	7.8												
14			8.8	9.2							8.8	10.4	9.2	
17											8.3	10.0	9.6	
20			10.0	10.4	9.4	9.6	8.5	8.9	9.1	6.8				
21			9.6	10.1	9.8	6.8								
24	8.0													
25			9.2											
28							8.5	8.0	5.9	5.0	9.6	9.5	3.6	2.5
Station II:														
2			9.5											
3											10.0			
10			10.0	11.2										
18							10.5	8.3						
22											8.3	9.4		
24	8.0	7.8												
29			6.5	8.8										
31											8.1			
Station III:														
3			9.1											
10							10.3	10.3						
14	8.0	6.6												
18			9.7											
26							5.0	5.8						
30											7.6			

Day of Month	Feet / Meters	May S	May 20 / 6	May 40 / 12	May 60 / 18	June S	June 20 / 6	June 40 / 12	June 60 / 18	July S	July 20 / 6	July 40 / 12	July 60 / 18	August S	August 20 / 6	August 40 / 12	August 60 / 18	September S	September 20 / 6
1						7.5													
3										7.8				7.6	7.4			7.7	7.9
4						7.5	7.4												
5										7.8	7.8								
9																		7.7	
10		8.2	8.0							7.6	7.5								
13										7.7	7.5	7.8							
14														8.0					
15						7.4	7.6	7.6	7.3										
17														8.0	8.1	8.0			
20										7.6	7.5								
21														7.7					
22						7.7	7.9	7.4											
24		8.3	8.0	7.9	7.9														
26										7.7	7.3								
28														8.3	7.7	6.8	6.8		
29						7.3	7.5	7.3	7.3										

TABLE AVII. HYDROGEN ION CONCENTRATION AT STATION I THROUGHOUT THE SUMMER, FALCON LAKE, 1959 - EXPRESSED AS pH.

TABLE AVIII. HYDROGEN-ION CONCENTRATION AT STATION II AND III THROUGHOUT THE SUMMER, FALCON LAKE, 1959 - EXPRESSED AS pH.

Day of Month	Month and Depth of Sample							
	May		June		July		August	
Feet Meters	S	20 6	S	20 6	S	20 6	S	20 6
Station II:								
1			7.5					
3					7.8			
5							8.1	
6			7.4	7.3				
9					7.7			
10	8.2							
18					7.7			
21							7.7	
24							7.6	7.7
26			7.3	7.7				
28					7.7	7.5		
Station III:								
3					7.8			
7			7.6	7.6			7.9	
9					7.7			
14	7.8							
18					7.8			
21							7.8	
23			7.7	7.9				

TABLE AIX. PLANKTER REPRESENTATIVES AND THEIR RELATIVE ABUNDANCE AS DISCERNED FROM 48 SAMPLES FROM FALCON LAKE, MAY – AUGUST 1959. A–ABUNDANT, C – COMMON, O – OCCASIONAL, R – RARE.

PLANKTER	May	June	July	August
CHLOROPHYCEAE				
Spirogyra	R	R	O	R
Ulothrix	R	O	O	O
Zygnema	R	R	R	R
Dictosphaerium	R	O	O	R
Pediastrium	C	C	C	C
Staurastrum	C	C	C	C
Tetraspora	O	O	O	O
MYXOPHYCEAE				
Nostoc	O	O	O	O
Rivularia	R	R	R	R
Aphanizomenon	C	A	C	A
Anabaena	O	C	C	C
Oscillatoria	O	C	C	A
Microcystis	C	C	C	C
BACCILARIOPHYCEAE				
Stephanodiscus	A	C	C	C
Navicula	C	C	O	O
Tabellaria	C	O	O	O
Asterionella	A	C	O	O
Fragilaria	C	C	C	A
PROTOZOA				
Ceratium	O	O	C	C
Dinobryon	R	R	O	O
Difflugia	R	R	R	R
Volvox	R	R	C	C
ROTATORIA				
Keratella	O	O	C	C
Notholca	C	O	R	R
Asplancha	R	R	R	C
Branchionus	R	O	O	R
Euchlanis	C	C	O	O
COPEPODA				
Diaptomus	C	C	C	C
Cyclops	C	C	C	C
CLADOCERA				
Daphnia	O	C	C	C
Bosmina	C	C	C	C

TABLE AX. THE AREAS OF BOTTOM UNDER EACH DEPTH RANGE OF WATER, THE PERCENTAGE OF THESE AREAS WITH RESPECT TO THE TOTAL AREA OF BOTTOM AND THE NUMBER OF BOTTOM SAMPLES TAKEN FROM EACH DEPTH-AREA, IN FALCON LAKE, 1958 AND 1959.

	Depth Range		
	0 - 20 feet (0 - 6 m.)	20 - 40 feet (6 - 12 m.)	40 - 60 feet (12 - 18 m.)
Area(acres)	1500 (607 ha)	800 (324 ha)	2100 (850 ha)
Percentage of total area	34	18	48
Number of samples	60	55	16

TABLE AXI. NUMBER OF BOTTOM ORGANISMS COLLECTED IN 131 DREDGE SAMPLES FROM EACH OF THREE CLASSES OF SUBSTRATE, FALCON LAKE, 1958-1959.

Organism	Silt	Rubble	Sand and Gravel
Chironomids	147	97	66
Ephemeroptera	85	137	38
Gastropoda	38	120	79
Trichoptera	42	12	23
Sphaeriidae	35	24	8
Oligochaeta	16	17	13
Hirudinea	12	9	5
Nematoda			4
Miscellaneous			15
Total	473	428	293

TABLE AXII. CLASSIFICATION OF BOTTOM TYPE AT EACH SAMPLING STATION FALCON LAKE, 1959.

Depth Range	Station I	Station II	Station III
0 - 20 feet 0 - 6 meters	sand and gravel	rubble and gravel	silt or mud
20 - 40 feet 6 - 12 meters	rubble	rubble	silt or mud
40 - 60 feet 12 - 18 meters	rubble and mud		

TABLE AXIII. NUMBER OF DREDGE SAMPLES TAKEN FROM EACH STATION AND FROM EACH DEPTH RANGE THROUGHOUT THE SUMMERS OF 1958 TO 1959, FALCON LAKE.

Station and depth	May	June	July	August	September
1958:					
Station I					
0 - 20	1	2	1	1	
20 - 40	1	2	4		
40 - 60		1	1		
Station II					
0 - 20	1	2	2		
20 - 40	1	2	2		
Station III					
0 - 20		1	1		
1959:					
Station I					
0 - 20	2	4	4	4	2
20 - 40	2	4	4	4	2
40 - 60	1	4	4	4	2
Station II					
0 - 20	2	4	4	4	2
20 - 40	2	4	4	3	2
Station III					
0 - 20	2	4	4	4	2
20 - 40	2	4	4	2	2

TABLE AXIV. AVERAGE NUMBER OF BOTTOM ORGANISMS PER DREDGE SAMPLE IN EACH MONTH, 1958 AND 1959, FALCON LAKE.

Organism	May 58	May 59	June 58	June 59	July 58	July 59	August 58	August 59	September 58	September 59
Chironomids	2	2	3	4	3	2	2	2		1.5
Ephemeroptera	3	2.8	1.7	1.9	2	2.2	1	2.3		1
Gastropoda	1.5	1.4	1.8	1.9	2	2.1	2	2.1		1.8
Amphipoda	1.5	1.4	1	1	1.4	2.2	1.8	2.3		1.7
Trichoptera	0.6	0.7	0.5	0.5	0.5	0.6	0.2	0.6		0.5
Sphaeriidae	1	8.6	0.4	0.4	0.4	0.4	0.5	0.4		0.3
Oligochaeta		0.2	0.2	0.2	1.0	1.0	0.4	0.3		0.3
Hirudinea			0.2	0.3	0.2	0.2	0.1	0.2		0.1
Nematoda		1		0.1		0.1		0.1		
Miscellaneous		0.01	0.01	0.2	0.1	0.1	0.2			0.05

TABLE AXV. AVERAGE WEIGHT OF SOME BOTTOM ORGANISMS COLLECTED IN DREDGE SAMPLES. FALCON LAKE, 1959 - EXPRESSED AS MILLIGRAMS.

Organism	May	June	July	August	September	Seasonal Average
Chironomids		4.1	5.0	5.9	4.1	
Ephemeroptera	30.1	30.6	31.8	32.7		
Trichoptera						
Amphipoda						

TABLE AXVI. AVERAGE VOLUME OF SOME BOTTOM ORGANISMS COLLECTED IN DREDGE SAMPLES, FALCON LAKE, 1959 - EXPRESSED AS CUBIC CENTIMETERS.

Organism	May	June	July	August	September	Seasonal Average
Chironomids		.006	.005	.006	.005	
Ephemeroptera		.003	.003	.001		.002
Trichoptera			.005			
Amphipoda		.004				

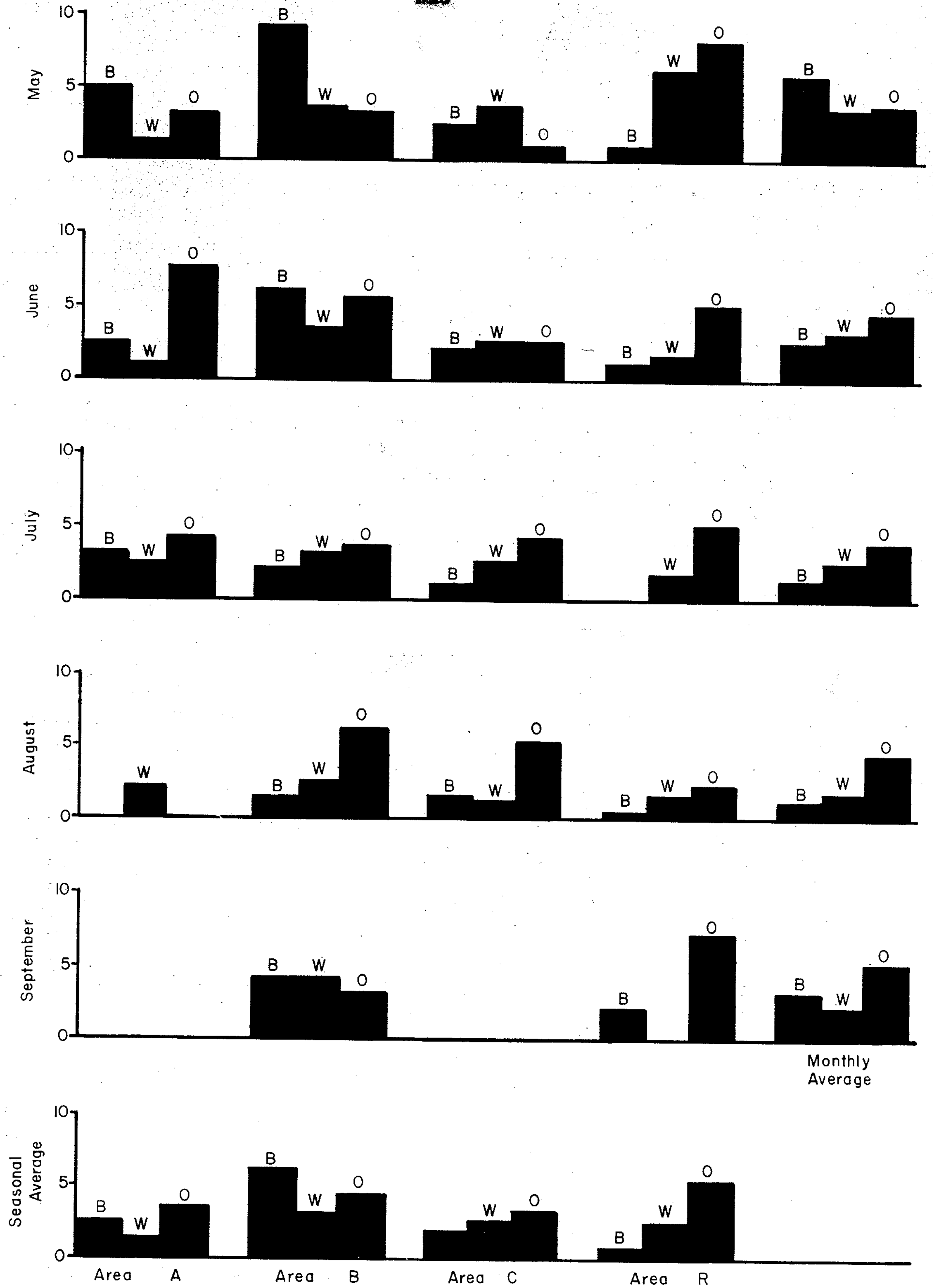

FIGURE A I. - Comparison of the catch composition, expressed as numbers of fish per 50 yards of net, Falcon Lake, 1958 - 1959.

B - Smallmouth Bass, W - Walleye, O - Other species.

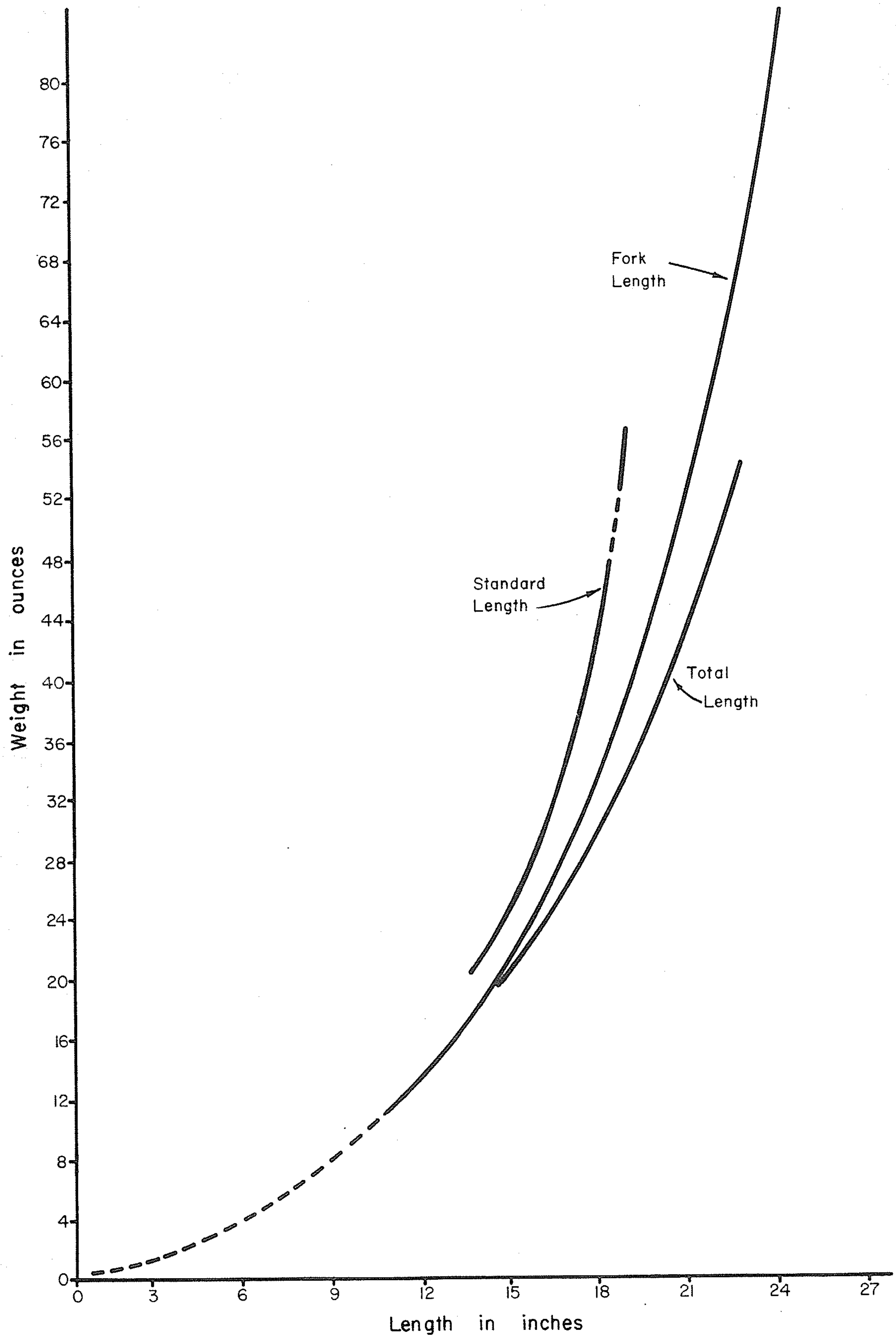

FIGURE A 2. - Length-weight relationship of walleye from Falcon Lake.

TABLE AXVII. NUMBER OF FISH CAUGHT IN 23 NETS OF VARIOUS MESH SIZES, BUT EACH 50 YARDS IN LENGTH, FALCON LAKE, 1958. EACH VERTICAL SET OF THREE NUMBERS READS RESPECTIVELY FROM TOP TO BOTTOM - NUMBER OF FISH, NUMBER OF NETS WITH NO REPRESENTATIVES OF THE SPECIES, AND, NUMBER OF NETS.

Depth range in feet	June	July	August	September	Total
Smallmouth bass:					
0 - 20	16 0 3	7 1 3	5 1 3		28 2 9
20 - 40	0 2 2	0 4 4	1 1 2		1 7 8
40 - 60	0 1 1	1 2 3	2 0 2		3 3 6
Total	16 3 6	8 7 10	8 2 7		32 12 23
Walleye:					
0 - 20	13 0 3	7 0 3	6 0 3		26 0 9
20 - 40	0 2 2	22 0 4	4 0 2		26 2 8
40 - 60	0 1 1	17 0 3	11 0 2		28 1 6
Total	13 3 6	46 0 10	21 0 7		70 3 23

TABLE AXVII - (CONT'D)

Whitefish,suckers,tullibee,perch,burbot:

0 - 20	0 3 3	5 0 3	4 1 3	9 1 9
20 - 40	10 0 2	14 0 4	7 0 2	31 0 8
40 - 60	8 0 1	10 0 3	9 0 2	27 0 6
Total	18 3 6	29 0 10	20 1 7	67 4 23
Rock Bass:				
0 - 20	3 2 3	11 1 3	12 1 3	26 4 9
20 - 40	0 2 2	0 4 4	1 1 2	1 7 8
40 - 60	0 1 1	13 2 3	9 1 2	49 15 23
Total	3 5 6	24 7 10	22 3 7	49 15 23
Northern Pike:				
0 - 20	0 3 3	0 3 3	5 0 3	5 6 9
20 - 40	3 0 2	3 2 4	2 1 2	8 3 8
40 - 60	0 1 1	0 3 3	1 1 2	1 5 6
Total	3 4 6	3 8 10	8 2 7	14 14 23

TABLE AXVIII. NUMBER OF FISH CAUGHT IN 62 NETS OF VARIOUS MESH SIZES, BUT EACH 50 YARDS IN LENGTH, FALCON LAKE, 1959. EACH VERTICAL SET OF THREE NUMBERS READS RESPECTIVELY FROM TOP TO BOTTOM - NUMBER OF FISH, NUMBER OF NETS WITH NONE OF THE SPECIES, AND, NUMBER OF NETS.

Depth range in feet	May	June	July	August	September	Total
Smallmouth bass:						
0 - 20	78 3 15	16 6 9	5 4 6	4 3 6	6 0 2	109 16 38
20 - 40	1 1 2	3 0 2	5 2 5	6 1 3	2 0 2	17 4 14
40 - 60	0 2 2	0 2 2	1 1 2	2 1 2	1 1 2	4 7 10
Total	79 6 19	19 8 13	11 7 13	12 5 11	9 1 6	130 27 62
Walleye:						
0 - 20	51 3 15	23 4 9	16 1 6	9 2 6	4 1 2	103 11 38
20 - 40	16 0 2	14 0 2	5 2 5	8 0 3	9 0 2	52 2 14
40 - 60	0 2 2	3 0 2	2 1 2	5 1 2	3 0 2	13 4 10
Total	67 5 19	40 4 13	23 4 13	22 3 11	16 1 6	168 17 62

TABLE AXVII - (CONT'D)

Whitefish, suckers, tullibee, perch, burbot:

0 - 20	25 4 15	46 0 9	6 4 6	6 3 6	7 0 2	90 11 38
20 - 40	4 0 2	8 0 2	15 2 5	8 1 3	6 0 2	41 3 14
40 - 60	2 1 2	1 1 2	8 0 2	9 0 2	5 1 2	25 3 10
Total	31 5 19	55 1 3	29 6 13	23 4 11	18 1 6	156 17 62
Rock bass:						
0 - 20	0 15 15	1 8 9	16 3 6	9 3 6	1 1 2	27 30 38
20 - 40	0 2 2	3 1 2	1 4 5	2 1 3	0 2 2	6 10 14
40 - 60	0 2 2	0 2 2	0 2 2	0 2 2	0 2 2	0 10 10
Total	0 19 19	4 11 13	17 9 13	11 6 11	1 5 6	33 50 62
Northern Pike:						
0 - 20	28 5 15	14 5 9	2 4 6	2 5 6	2 1 2	48 20 38
20 - 40	8 1 2	2 1 2	2 3 5	2 1 3	1 1 2	15 7 14
40 - 60	1 1 2	2 1 2	1 1 2	1 1 2	0 2 2	5 6 10
Total	37 7 19	18 7 13	5 8 13	5 7 11	3 4 6	68 33 62

TABLE AXIX. THE PERCENTAGES OF MATURE SMALLMOUTH BASS IN AGE GROUPS II TO XI IN FALCON LAKE, 1959.

Age	Mature male	Mature female	Fish Examined
II	50	0	4
III	40	25	16
IV	25	63	40
V	45	55	67
VI	26	74	45
VII	14	86	28
VIII	25	75	14
IX	40	60	10
X	0	0	0
XI	100	0	2

TABLE AXX. THE PERCENTAGE OF MATURE WALLEYE IN AGE GROUPS II TO IX OF A SAMPLE FROM FALCON LAKE, 1959.

Age	Mature Male	Mature Female	Fish Examined
II	50	50	2
III	30	20	13
IV	53	35	54
V	64	33	45
VI	68	31	41
VII	43	57	23
VIII	46	54	24
IX	63	37	8