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FOOD OF THE SMALL-MOUTHED BLACK BASS (*MICROPTERUS DOLOMIEU*) IN SOME ONTARIO WATERS

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Abstract

The food of the small-mouthed black bass in Georgian Bay, Lake Nipissing, Perch Lake, and other waters, was determined by examining stomach contents. The percentage by volume and the percentage frequency of occurrence of an organism are both considered in presenting the results. As bass fry increase in length, several changes in diet similar to those found by investigators in other localities, take place. These changes are apparently correlated with the ability of growing fish to take organisms of increasing size. In Georgian Bay and Lake Nipissing, the two larger bodies of water, the food of the larger bass consists of about seventy-five per cent. crayfish, chiefly *Cambarus propinquus*, and about twenty-five per cent. fish, mostly *Perca flavescens*. In Perch Lake, the smallest body of water, fish and crayfish are also the most important items but, in addition, a large percentage of insects and other organisms enter into the diet of the smaller fish. While several species of predaceous fish commonly associated with the bass are found to eat similar food, competition does not appear to be seriously detrimental to the latter as the present food supply seems adequate to support all species.

Introduction

As the small-mouthed black bass (*Micropterus dolomieu* Lacépède) is one of the most important game fishes of Ontario, a study of its food becomes of both scientific and popular interest. This paper is based on an examination of stomachs of 540 bass of all sizes obtained during the summers of the years 1928 to 1931 from various localities in Ontario. The study was extended to include the food of fish commonly associated with the black bass to assist in the estimation of the importance of these species as competitors of the bass for food.

I wish to thank Professor W. J. K. Harkness of the Department of Biology, University of Toronto, for his help

and supervision of this investigation. I am indebted also to several other members of the staff of this Department and members of the Ontario Fisheries Research Laboratory who assisted in the identification of certain insects and who collected material for me.

Thanks are given to the fishing clubs and hotels of Georgian Bay and Lake Nipissing and to all sportsmen who assisted in the collection of material.

SUMMARY OF LITERATURE ON THE FOOD OF SMALL-MOUTHED BLACK BASS

Apart from the work of Clemens and others (1923 and 1924), there has been no scientific literature published on the food of the small-mouthed black bass in Ontario. Adams and Hankinson (1928) have given in tabular form the results of the more important food studies on the bass up to 1927. The following summary of the findings of the various investigators, based partly on the tables of Adams and Hankinson, is presented in order that the results of this present investigation may be compared with the results obtained in other regions.

Fry and Fingerlings

Forbes (1880) investigated the food of seven specimens of small bass in Illinois and found that they had eaten entomostracans—five per cent., chironomids—four per cent., odonate nymphs—eleven per cent., and *Corixa*—fifty-one per cent.

Lydell (1904) reports that as bass fry grow older they eat large quantities of corixids.

Pearse (1918) examined the stomachs of eight specimens (2.9-4.8 centimetres) from Lake Mendota, Wisconsin, which were collected in 1914. The food consisted of Cladocera—six per cent., chironomid pupae and adults—fifty-four per cent., ephemerid nymphs—thirty-one per cent., and oligochaetes—nine per cent. The food of two larger specimens (5.9 and 7.8 centimetres) consisted of dipterous larvae and adults—fifteen per cent. and *Corixa*—eighty-five per cent.

Wickliff (1920) presents one of the most important food studies on small bass. He examined 313 specimens (0.85 to 6.5 centimetres) from the western end of Lake Erie, Ohio. Copepods were found in 61.0 per cent., Cladocera in 39.9 per cent., chironomid larvae in 19.8 per cent., chironomid pupae in 27.4 per cent., ephemerid nymphs in 12.1 per cent., adult insects in 24.9 per cent., fish in 17.8 per cent., and crayfish in 1.3 per cent. of the stomachs. Quoting the author: "The food cycle seems to be copepods and cladocerans of an almost pure diet to 15 mm.; then from 16 to 45 mm. mixed with these are mayfly nymphs, midge larvae and pupae, with fish and adult insects; and above 45 mm. fish, adult insects, and crayfish are important."

Hayford (1921) states that "Stomach examinations of young bass carried on at the Hackettstown station (New Jersey) show that during the first few weeks of their existence their food consists almost entirely of microcrustacea, the predominating organisms in their order of importance being *Cyclops*, *Simocephalus*, *Chydorus*, and *Scapholeberis*."

Pearse (1921) found that nine bass (4.6-5.7 centimetres) from Green Lake, Wisconsin, ate Cladocera—forty-one per cent., chironomid larvae and pupae—forty-seven per cent., ephemerid nymphs—three per cent., amphipods—eight per cent., a few miscellaneous insects and a small quantity of plant material.

Pearse (1921a) found the food of three small bass in Wisconsin lakes to consist of Cladocera—about one to ten per cent., chironomids—about fifty per cent., *Corixa*—16.7 per cent., and fish—6.7 per cent.

Moore (1922) working on Lake George, New York, found that in the stomachs of forty-six bass fry and fingerlings (1.4-5.3 centimetres) Cladocera occurred most abundantly; chironomid larvae, pupae and adults, ephemerid nymphs and miscellaneous insects were next in importance; small Crustacea were present in small quantities. In the stomachs of sixty-eight specimens of bass fry (about 1 centimetre) from ponds, Cladocera, copepods, and chironomid larvae, pupae and adults occurred abundantly while ephemerid nymphs were present

in small quantities. In the stomachs of fingerlings (up to 8 centimetres), in addition to the above organisms, odonate nymphs and miscellaneous insects were abundant while caddis larvae, amphipods, water mites, and fish remains also occurred.

Clemens and others (1923) record the results of an examination of six bass (2.6-3.3 centimetres) from Lake Nipigon, Ontario, as copepods, Cladocera, chironomid larvae and pupae, mayfly nymphs, Corixidae, and fish remains.

Clemens and others (1924) further record the food of three specimens (3.0-3.4 centimetres) as fish—ninety to ninety-five per cent., and miscellaneous (copepods, Cladocera, chironomids, ephemerids and *Corixa*)—five to ten per cent.

Greeley (1927) states that one small bass from the Genesee River system, New York, ate phyllopods, copepods, chironomid larvae and other Diptera, and ephemerid nymphs.

Sibley (1929) examined three specimens (6-9.5 centimetres) from the Lake Erie drainage basin, New York, and found the food to consist of fish—100 per cent.

Rimsky-Korsakoff (1930) found that sixteen small bass (2.4-6.5 centimetres) from the Lake Champlain watershed, New York, ate fish—sixty per cent., ephemerid nymphs—twenty-seven per cent., adult insects—six per cent., Crustaceans—two per cent., plant material—one per cent., and miscellaneous—three per cent.

Sibley and Rimsky-Korsakoff (1931) examined seventy-two small bass (1.7-3.9 centimetres) from the St. Lawrence watershed, New York: "The small bass from Sucker and Little Sucker brooks had eaten 40 per cent young fish, and 60 per cent aquatic insects, while those from Trout brook had eaten only water boatmen. A series of 56 small bass were secured from lake Ozonia. Mayflies and midge larvae made up about 30 per cent of the total while plankton crustacea formed 70 per cent. The Cladocera were very much more abundant than the Copepoda."

From the summary of the literature on the food of bass fry and fingerlings, it may be seen that the food consists in

order of importance of Cladocera, copepods, chironomid (midge) larvae, pupae and adults, ephemerid (mayfly) nymphs, corixids (water boatmen), aquatic insects, fish, and crayfish. Wickliff (1920) and others point out a change in diet from Cladocera, copepods and chironomid larvae to larger insects and thence to fish and crayfish, with growth. The data given by most investigators confirm this correlation.

Young and Adult Bass

Forbes (1880) examined the stomachs of ten fish from the waters of Illinois and found the food to consist of fish (*Percina caprodes* and *Noturus flavus*), crayfish, amphipods, isopods, and odonate nymphs.

Forbes and Richardson (1908) examined the stomachs of three individuals from waters of Illinois and found their contents to consist "wholly of fishes and crayfishes, approximately a third of the first and two-thirds of the second".

Reighard (1915) gives the results of an examination of the stomachs of eight bass from Douglas Lake, Michigan. Crayfish occurred in six stomachs. Other food organisms present were fish, leopard frogs, and the large cladoceran *Leptodora*.

Pearse (1918) examined four specimens (13.2-18.1 centimetres) from Lake Monona, Wisconsin. The food consisted of fish (*Lepomis*, a minnow, and fish remains), insects (corixids, chironomid larvae and ephemerid nymphs), and plant material.

Pearse (1921) found in two bass (39.2 and 39.5 centimetres) from Green Lake, Wisconsin, perch, fish remains, and a grasshopper.

Pearse (1921a) reports that twenty-one bass in Lake Geneva, Wisconsin, ate crayfish—20.6 per cent., vertebrates—33 per cent., insects—43.0 per cent., and a few Cladocera. In Lake Pepin, Wisconsin, twelve bass ate crayfish—9.1 per cent., fish—56.5 per cent., insects—29.8 per cent., and Entomostracans—5.7 per cent. In Lake Michigan two bass ate fish—98.5 per cent., and plant material—1.5 per cent.

Greeley (1927) examined thirteen specimens from the Genesee River system, New York. The food consisted of crayfish—fifty-six per cent., fish (*Eupomotis gibbosus*, *Hyperlelium nigricans*, and minnows)—18.4 per cent., aquatic insects—24.2 per cent., and terrestrial insects—1.4 per cent.

Eaton (1928) gives the results of an examination of the stomachs of fifty-nine bass from Finger Lakes, in the Oswego watershed, New York, which was made by Dr. Charles K. Sibley. The food consisted of crayfish—40.7 per cent., fish (sculpins, sticklebacks, perch, and minnows)—34.2 per cent., *Gammarus*—4.7 per cent., and insects (ephemerids, Trichopterans, and chironomids)—20.4 per cent.

Allin (1929) found that four bass (26.0-38.0 centimetres) from Silver Creek of the Erie-Niagara watershed, New York, ate crayfish—sixty-four per cent., and fish—thirty-six per cent.

Reighard (1929) found that the stomachs of three bass (39-42 centimetres) from Whitefish Lake, Michigan, contained a crayfish, a fish (probably cisco), and a leopard frog. In Loon Lake, the stomach of one bass (37 centimetres) contained a small sculpin, a dragonfly nymph, and several trichopterous larvae.

Rimsky-Korsakoff (1930) examined the stomachs of eight bass from the Lake Champlain watershed, New York. The food of five specimens (13.0 centimetres) consisted of adult insects (Orthoptera, Hymenoptera, and Diptera)—ninety per cent., and Coleoptera larvae—ten per cent., while that of three larger specimens (16.7-28.5 centimetres) consisted of fish (perch and unidentified fish)—sixty-seven per cent., crayfish—three per cent., adult insects (Coleoptera)—thirteen per cent., and miscellaneous—seventeen per cent.

Sibley and Rimsky-Korsakoff (1931) state that thirty-four of forty-seven bass (7.3-31 centimetres) from the St. Lawrence watershed, New York, contained food. "Three specimens had eaten nothing but crayfish. Eighteen had eaten surface drift and aquatic insects. The other thirteen had eaten fish."

From this summary of the findings of various investigators it may be seen that, in general, the food of young (larger than fingerling) and adult bass consists mostly of fish and crayfish with a smaller percentage of insects. All the investigators report the presence of fish of various species in the stomachs. Crayfish were eaten by bass in most of the bodies of water. The percentage of insects eaten seems to vary considerably and probably depends on the relative abundance of insects as compared to other food organisms which are present in each of the bodies of water.

MATERIALS, METHODS, AND PRESENTATION OF DATA

As mentioned above, the material for this investigation was collected during the summers of the years 1928 to 1931. In 1928, 140 specimens from Georgian Bay were examined. These were taken from various localities from Whalens Island to Sans Souci. In 1929, stomachs of 109 adult black bass were obtained from Lake Nipissing, a large body of water to the east of Georgian Bay. In addition, the stomachs of eighty-six black bass frys and fingerlings from this lake were examined. In 1930, fifty-three specimens, and in 1931, 126 specimens were taken in Perch Lake, a small irregularly-shaped body of water two miles long and less than a quarter of a mile wide which lies three miles to the south-east of the South River, Lake Nipissing. In 1929, eighteen specimens were obtained from Phantom Lake, a larger body of water near Perch Lake. The stomachs of six black bass from the Oxtongue River in the Muskoka district, and two small bass from the Grand River in southern Ontario were examined also.

Most of the larger specimens of small-mouthed black bass were caught by still-fishing with hook and line, using earthworms as bait. In Georgian Bay and Perch Lake, a few were obtained by the use of gill nets. Bass fry were taken in the neighbourhood of nests with a dip net. A few fingerlings were caught by means of a hand seine. It is believed that the various methods of capture employed were not selective as to the feeding habits of bass captured. In each size group no

significant difference could be observed in the food of adult bass taken on worms, spoons, or in gill nets.

At Georgian Bay and Lake Nipissing, pails containing formalin were placed at several hotels and fishing camps and anglers deposited the stomachs of bass into these containers. Although no data are available on the lengths of the fish from which these stomachs were obtained, they are valuable in determining the food of adult fish. As anglers are not permitted to keep fish under ten inches (25.4 centimetres) in length, it is presumed that all these stomachs are from fish greater than that length.

Small specimens were preserved whole in a five to ten per cent. solution of formalin. Stomachs of larger specimens were removed and were either tied up, numbered, and preserved in large jars, or the contents of each were preserved in a separate vial.

Large organisms like crayfish and fish were identified with the aid of a simple lens. For smaller organisms, a binocular dissecting microscope was used.

In making food studies of bass fry and other adult fish which feed on small organisms, some authors have considered only the frequency of occurrence of the various organisms in the stomachs in drawing their conclusions. The organism which occurs in the greatest percentage of the stomachs is considered the most important food item. This method of presenting the results completely neglects to consider the importance of the relative size of the food constituents.

Another method which is adopted is to consider the total food in each stomach as 100 per cent. and, by counting or estimating the number or quantity of each kind of organism, to give to each a certain percentage of the total. By obtaining an average of these percentages for all the stomachs, a more accurate idea is given of the relative importance of the organisms in the diet of the fish. This method does not consider the actual volume of the contents of each individual stomach. In averaging the percentages of the various constituents, each stomach is assumed to have the same volume. When the food organisms vary greatly in size, this is apt to give a distorted idea of their relative importance. To take an extreme case, suppose one stomach contained one small insect while another contained one large fish. If the volume were not considered, the first stomach would be recorded as 100 per cent. insect and the second as 100 per cent. fish, and the food from a consideration of these two stomachs would be fifty per cent. insect and fifty per cent. fish. These results are obviously distorted.

The third method, used by certain trout investigators, involves an estimation of the percentage of each kind of organism in the stomach and, in addition, the determination of the volume of the total stomach content for each stomach. The actual volume of each kind of organism for each stomach is then calculated and the percentage of that organism for all the stomachs is figured on the volume of the total food content. In the example, if the volume of the contents of the first stomach was one cubic millimetre, and that of the second nine cubic millimetres, the food of the fish from these two specimens, based on percentage volume, would be ten per cent. insect and ninety per cent. fish. In this instance, this last method gives a much more accurate idea of the relative importance of the two food items.

The last method was followed in dealing with the stomachs examined and the percentages in the tables, unless stated otherwise, refer to the actual percentage volume of each kind of organism which occurred. In measuring the volume of the contents of each stomach, the excess water was first removed by blotting with filter paper. The contents were then dropped into a ten cubic centimetre or a twenty-five cubic centimetre graduated cylinder partially filled with water, and the volume of water displaced was measured. When considering the stomachs of bass fry and larger fish which contained but very small quantities of food, the volume was estimated.

An effort was made to portray graphically the importance

of the larger groups of organisms in the diet of the bass. In some cases it was found that the method of analysis used tended to mask the importance of the frequency of occurrence of certain smaller organisms. In stomachs of bass within a certain size range from Perch Lake, insects occurred very frequently and undoubtedly formed an important food item. In a small percentage of the stomachs, larger organisms—fish and crayfish—were found. The volume of the few large organisms was much greater than the volume of the more frequently occurring insects. A considerable number of insects would have to be taken to make up for one large fish. These insects, however, would be taken one at a time and, being smaller, would digest much more rapidly than the fish. This might tend to lower the total insect content relative to the total fish content. In any case, in order to take into consideration both the frequency of occurrence and the percentage by volume in presenting a graphical summary of the results, diagrams have been constructed in two dimensions. The relative importance of each kind of food is indicated by the size of a rectangle. The horizontal distance represents the percentage by volume of the total food content; the vertical distance, the percentage frequency of occurrence of the organism in the stomachs. If both factors were considered of equal importance, the horizontal and vertical distances should be equal. But, as has already been pointed out, the percentage by volume appears to be considerably more important and accordingly the vertical scale has been arbitrarily fixed as forty per cent. of the horizontal scale.

The standard lengths of the specimens are given in centimetres. The standard length is the length measured from the tip of the lower jaw to the end of the vertebral column at the base of the tail. The total length, expressed in inches, is the length from the tip of the lower jaw to the fork of the tail. Figure 1 offers a convenient method of converting the standard length in centimetres into the total length in inches and *vice versa*. The graph is based on standard and total length measurements from a large number of specimens.

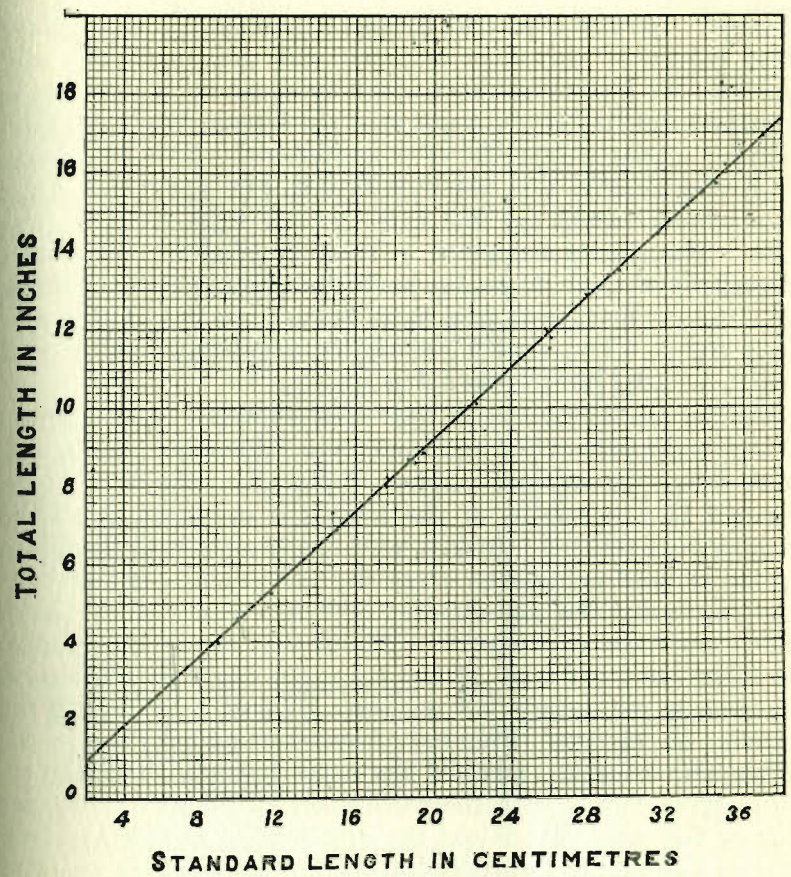

FIGURE 1. A graph for converting standard length in centimetres into total length in inches

FOOD OF SMALL-MOUTHED BLACK BASS FRY IN LAKE NIPISSING IN 1929 AND 1930

The stomachs of eighty-six small bass from 1.0 to 7.9 centimetres in length were examined. These fry were taken mostly in the vicinity of bass nests at the Goose Islands, Lake Nipissing. The bass were found to start feeding while a considerable amount of yolk still remained in the yolk-sac. Food was found in a few specimens one day after they had risen from the nests when they had reached a length of 0.9 centi-

metres. All the stomachs examined, except two, contained food material. In order to detect any change in diet with growth, the results of the stomach analyses were arranged in groups according to the lengths of the fish, each group representing a length interval of 1 centimetre. The first group (1-2 centimetres) was subdivided into two groups of equal size interval while the last three groups were considered as one. The results are given in table 1. Table 2 presents a summary of table 1, giving both the percentage by volume and the percentage frequency of occurrence of the principal food items. The results are shown graphically in figure 2 which is based directly on table 2.

The results show that bass in the smallest length group (1-1.5 centimetres) fed exclusively on Copepoda, Cladocera, and insect larvae and pupae. Copepoda, chiefly *Cyclops*, formed 66.8 per cent. of the food and occurred in all the stomachs examined. Insects were the second most abundant group of food organisms, occurring in forty-five per cent. of the stomachs and constituting 21.8 per cent. of the food. They consisted exclusively of chironomid larvae and pupae. In eighty-five per cent. of the stomachs occurred Cladocera, forming a volume of 11.3 per cent. These were mostly the smaller water fleas—*Bosmina*, *Acroperus*, and *Chydorus*—although there were traces of the large *Leptodora*. These results agree closely with those obtained by Wickliff (1920) for fish of this size. He found the first food of the bass to consist of Cladocera, Copepoda, and Chironomidae, in order of importance. However, *Daphnia*, *Diaphanosoma*, and *Sida* were the commonest Cladocera in the stomachs he examined. In addition to larvae and pupae, he found chironomid adults in small quantities in this length group.

It may be seen from the tables and figure that in the next size group (1.5-2 centimetres) the copepod content was much smaller (26.6 per cent.) occurring in seventy-nine per cent. of the stomachs and consisting mostly of a large species of *Diaptomus*. In the groups of larger fish, Copepoda decreased in volume and frequency until they constituted finally but 15.3 per cent. of the food in the stomachs of bass between four

TABLE 1 Food of eighty-six small-mouthed black bass fry and fingerlings of Lake Nipissing in 1929 and 1930

Length in centimetres		1–1.5	1.5–2	2–3	3–4	4–5	5–8
Number of stomachs with contents		27	24	13	12	6	4
Pisces	*Perca flavescens*	..	..	..	..	16.7	41.6
	Cottus	..	..	..	..	16.7	..
	Cyprinidae	..	..	21.5	15.7	..	..
	Unidentified remains	..	..	10.0	32.3	40.8	4.2
Crustacea	Decapoda—*Cambarus propinquus*	..	..	..	..	..	45.0
	Copepoda—*Cyclops*	66.8	4.4	6.1	3.9	0.3	..
	Diaptomus	..	22.2	..	..	..	..
	(*Argulus*)	..	..	..	..	15.0	..
	Cladocera—*Acroperus*	2.1	0.6	1.8	..	..	..
	Leptodora	0.1	..	..	6.1	..	..
	Bosmina	8.4	..	7.2	..	..	..
	Chydorus	0.7	..	1.1	..	..	..
	Sida	..	..	6.4	..	..	..
	Alona	..	4.7	..	..	..	..
	Daphnia	..	11.1	..	..	..	..
	Unidentified	..	..	..	..	0.1	..
Insecta	Diptera—Chironomidae — larvae, pupae and adults	21.8	13.8	21.4	11.4	6.2	..
	Ephemerida—*Baetis* and *Ecdyonurus*—nymphs and adults	..	35.2	13.9	12.2	1.3	..
	Coleoptera—*Hydrophilus* — larvae, *etc.*	..	7.6	..	11.4	..	..
	Hemiptera—Corixidae—larvae	..	..	1.4	4.4	1.2	4.2
	Homoptera—Cicadellidae—adult	..	..	..	0.9	..	..
	Unidentified remains	..	..	4.6	1.7	1.7	1.7
Miscellaneous	Ostracoda, Isopoda, Arachnida, *etc.*	..	0.4	0.7	..	..	..
	Plant material—Algae, *etc.*	0.1	..	2.9	..	..	3.3

to five centimetres and occurred in but two of the six stomachs examined. The chief copepod of this group is a large parasitic form (*Argulus*) which was found in but one stomach. The inclusion of this rare form was undoubtably accidental. If it were not included in calculating the results, the average

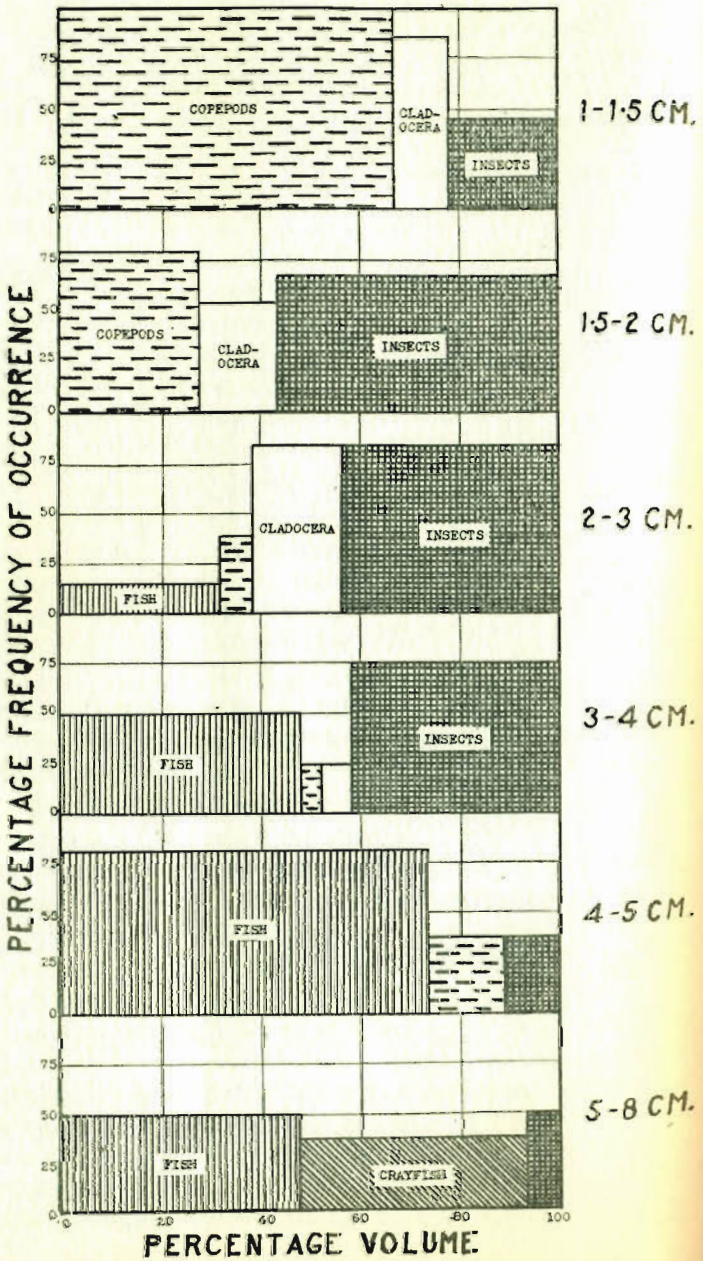

FIGURE 2. The food of eighty-six small-mouthed black bass fry and fingerlings of Lake Nipissing in 1929 and 1930

TABLE 2. Summary of the food of eighty-six small-mouthed black bass fry and fingerlings of Lake Nipissing in 1929 and 1930

Length in centimetres	1-1.5	1.5-2	2-3	3-4	4-5	5-8
Number of stomachs with contents	27	24	13	12	6	4
A. Percentage volume						
Fish	..	..	31.5	48.0	74.2	45.8
Crayfish	..	..	..	..	..	45.0
Copepods	66.8	26.6	6.1	3.9	(15.3)	..
Cladocera	11.3	16.4	17.2	6.1	0.1	..
Insects	21.8	56.6	41.3	42.0	10.4	5.9
B. Percentage frequency of occurrence						
Fish	..	..	15	50	83	50
Crayfish	..	..	..	..	..	33
Copepods	100	79	38	25	(33)	..
Cladocera	85	54	85	25	17	..
Insects	45	67	85	75	33	50

copepod content would constitute but 0.3 per cent. of the total.

As groups of successively larger fry were considered, the percentage volume of Cladocera first increased and then decreased to 0.1 per cent. in the four to five centimetre group. In order of importance, the Cladocera found in the larger fry were *Daphnia*, *Bosmina*, *Leptodora*, *Sida*, *Alona*, *Acroperus*, and *Chydorus*.

As the Copepoda and Cladocera content decreased, the insect content at first increased and then decreased in importance as larger organisms—fish and crayfish—entered into the diet. Chironomid larvae and pupae formed a decreasing percentage of the food. Larger insect larvae and adults entering into the diet of fry of greater length caused the relatively large total insect content in the second, third, and fourth length groups. Mayfly (Ephemerida) nymphs and adults belonging to the genus *Baetis* and the genus *Ecdyonurus* formed a considerable percentage of the insects which occurred in these three groups. Chironomid adults, occurring

first in the two to three centimetre group tended to increase the percentage of Chironomidae in that group. Other larvae and adults belonging to the orders Coleoptera, Hemiptera, and Homoptera, were present in smaller quantities. Wickliff found that the insect content, principally Chironomid pupae and adult insects, was relatively more important in the food of the bass of Lake Erie.

Small minnows and unidentified fish remains occurred first in the two to three centimetre group, where they formed 31.5 per cent. of the food and occurred in fifteen per cent. of the stomachs. As the bass became larger, the fish content increased in importance until the fry were large enough to take both small fish and small crayfish. In addition to minnows, small perch and sculpins were found in the stomachs of larger fry.

Only four specimens were available in the largest group of bass fry examined (five to eight centimetres). In this group small crayfish (*Cambarus propinquus*) occurred for the first time. The inclusion of crayfish decreased the relative importance of the fish content. In the bass fry examined by Wickliff, crayfish occurred in the four to five centimetre group. As this author treated his data from the point of view of frequency of occurrence, he did not consider the crayfish content important in the diet of fish of this size.

Plant material was found in but small quantities and probably did not form a significant part of the food of young bass.

Although the results presented are based on relatively few specimens in the larger length groups, it is believed that the numbers are sufficient to justify the following conclusions.

The choice of food organisms on the part of growing fry of small-mouthed black bass in Lake Nipissing is positively correlated with the size of the fry themselves. This conclusion was also reached by Wickliff in the case of the fry of the small-mouthed black bass of Lake Erie, and by Turner and Kraatz (1920) working on the food of the fry of the large-mouthed black bass.

Figure 2 shows the following changes in the food of bass fry of Lake Nipissing. At first the fry feed exclusively on Copepoda, Cladocera, and insects. As they increase in size they take larger organisms. The Copepoda and Cladocera decrease in importance as the insect content increases. Small midge (Chironomidae) larvae and pupae are replaced by larger larvae, nymphs, and adult insects. Gradually the insects decrease in importance as fish enter into the diet. After the fry have reached a length of about five centimetres, their food consists mainly of fish and crayfish with a small percentage of insects.

FOOD OF ADULT SMALL-MOUTHED BLACK BASS

Georgian Bay

In table 3 the results of the examination of adult bass stomachs from Georgian Bay are summarized. Of the 140 stomachs examined but ninety-eight (70 per cent.) had food

TABLE 3. Food of ninety-eight adult small-mouthed black bass of Georgian Bay in 1928

		Number containing organism	Volume in cubic millimetres	Per cent. volume	Total per cent. volume
Pisces	*Perca flavescens*	6	183	4.2	27.7
	Cyprinidae	1	120	2.8	
	Unidentified remains	49	901	20.7	
Crustacea	Decapoda—*Cambarus propinquus*	54	2272	52.3	71.7
	Cambarus virilis	10	475	10.9	
	Cambarus bartonii	3	162	3.7	
	Cambarus remains	14	210	4.8	
Insecta	Ephemerida—*Hexagenia*—nymphs	4	5	0.4	0.4
	Odonata—nymphs	2	5		
Miscellaneous	Miscellaneous	5	2		
	Fish eggs and plant material	13	6	0.2	0.2

content. The greater number were obtained from anglers and the lengths of these fish were not available.

It may be seen that crayfish, occurring in over seventy-five per cent. of the stomachs, constituted 71.7 per cent. of the food of these adult bass. *Cambarus propinquus*, the smallest of the three species of crayfish found in the stomachs, formed by itself 52.3 per cent. of the total volume and was the most important single food organism.

Fish formed 27.7 per cent. of the food and occurred in fifty-seven per cent. of the stomachs. A large percentage of the fish content was partially digested and could not be further identified. However, a number of yellow perch (*Perca flavescens*) and one minnow (Cyprinidae) were recognized.

The insect content was practically negligible (0.4 per cent.). The principal insects were mayfly nymphs (Ephemerida) of the genus *Hexagenia*, dragonfly, and damselfly nymphs (Odonata). Corixid nymphs and chironomid larvae were each found in one stomach. Two stomachs contained terrestrial beetles and three contained unidentifiable insect remains.

On arranging the few specimens of known lengths into length groups having a four-centimetre size interval, it was found that the fish content tended to increase in volume and frequency as the bass increased in size. The food of the largest specimen examined (34.4 centimetres) consisted entirely of fish—a perch of eight centimetres and the remains of two fish (probably perch) of five centimetres.

These results show that the food of adult bass of Georgian Bay in 1928 consisted mainly of two kinds of organisms—crayfish (71.7 per cent.) and fish (27.7 per cent.). Fish seemed to be a more important food item as the bass increased in size. The insect content was practically negligible.

Lake Nipissing

The stomachs of 109 bass, of which 106 (97 per cent.) contained food material, were examined from Lake Nipissing in 1929. The results (table 4) are similar to those obtained in the case of bass from Georgian Bay. Crayfish of three

species were again the most important food item with a slightly greater percentage volume (79.0 per cent. as opposed to 71.7 per cent.). As before, *Cambarus propinquus* formed over half the total food content. Perch, small pike (*Esox lucius*), a minnow, and unidentified fish remains made up the remainder of the food. In Lake Nipissing insects were again a negligible food item. Corixidae, caddis larvae, and midge larvae replaced the mayfly, dragonfly and damselfly nymphs of the Georgian Bay stomachs. In general, as in Georgian Bay, larger bass tended to eat more fish than smaller bass.

TABLE 4. Food of 106 adult small-mouthed black bass of Lake Nipissing in 1929

		Number containing organism	Volume in cubic millimetres	Per cent. volume	Total per cent. volume
Pisces	*Perca flavescens*	9	542	8.7	20.6
	Boleosoma nigrum	1	37	0.6	
	Esox lucius	2	185	3.0	
	Unidentified remains	28	519	8.3	
Crustacea	Decapoda—*Cambarus propinquus*	52	3400	54.7	79.0
	Cambarus virilis	8	595	9.6	
	Cambarus bartonii	2	80	1.3	
	Cambarus remains	39	838	13.4	
Insecta	Hemiptera — Corixidae — adults	3	8	0.4	0.4
	Trichoptera—larvae	3	14		
	Coleoptera—adults	1	2		
	Miscellaneous	2	+		
Miscellaneous	Fish eggs and plant remains	3	+	+	+

Perch Lake

Perch Lake, a small body of water near Lake Nipissing, is probably typical of hundreds of similar lakes scattered over the Pre-Cambrian area of southern Ontario. The shore of this

small lake is similar in character to that of Lake Nipissing where bass are found, except that it is fringed for the most part with overhanging, bushy vegetation. Crayfish occur in much smaller numbers along the shores of this lake than along those of Lake Nipissing. On the surface of the lake, protected from the wind by the surrounding vegetation and neighbouring hills, semi-aquatic insects are found in greater abundance than on the wind-swept surface of a larger lake.

Specimens of bass were obtained from Perch Lake in order to compare their food with that of bass in larger bodies of water. The greater number of the bass examined were smaller than those from Lake Nipissing and Georgian Bay as all fish caught were taken regardless of size. The stomachs of 179 bass, ranging in length from 8.9 to 37.2 centimetres were examined. Of these, 123 (60 per cent.) contained food material.

Table 5 gives a summary of the total food content of the bass stomachs examined in this lake. As might be expected, crayfish did not form such a large percentage of the food as in the two previous analyses. They formed 39.2 per cent. of the food and occurred in thirty-one per cent. of the stomachs. This is in marked contrast to Georgian Bay and Lake Nipissing where they formed 71.7 per cent. and 79.0 per cent. of the food and occurred in seventy-five per cent. and ninety-four per cent. of the stomachs respectively. Again *Cambarus propinquus* was the most important of the three species of crayfish.

The yellow perch is found in great abundance in Perch Lake as its name suggests. It formed seventy-five per cent. of the fish taken in seine hauls along the shore. In the bass stomachs it was the most important individual food item. In addition to perch, a small sucker, Iowa darters, and a minnow(?) occurred in the stomachs, bringing the total volume of fish to 49.7 per cent. of the total stomach contents—more than twice that found for fish in the two other bodies of water.

The total insect content amounted to 5.3 per cent., insects being found in sixty-six per cent. of the stomachs. It will be shown later that, in spite of the small volume of insects,

TABLE 5. *Food of 123 young and adult small-mouthed black bass of Perch Lake in 1930 and 1931.*

		Number containing organism	Volume in cubic millimetres	Per cent. volume	Total per cent. volume
Amphibia	Tadpole	10	58	3.9	3.9
Pisces	*Perca flavescens*	10	426	28.6	49.7
	Catostomus commersonii	1	20	1.3	
	Oligocephalus exilis	1	3	0.2	
	Hyborhynchus notatus?	1	16	1.0	
	Unidentified remains	19	276	18.6	
Crustacea	Decapoda—*Cambarus propinquus*	18	336	22.6	39.2
	Cambarus virilis?	1	21	1.4	
	Cambarus bartonii	1	121	8.1	
	Cambarus remains	19	105	7.1	
	Cladocera—*Leptodora kindtii*	26	26	1.7	1.7
Insecta	Hemiptera—Gerridae	7	5	0.3	5.3
	Diptera—Chironomidae—larvae, pupae and adults	12	8	0.5	
	Coleoptera—terrestrial and aquatic	6	8	0.5	
	Hymenoptera—Formicidae	31	47	3.2	
	Orthoptera—Gryllidae	2	1	0.1	
	Odonata—Coenagrionidae—adult	1	1	0.1	
	Miscellaneous—Trichoptera—larvae; Ephemerida—nymphs, *etc.*	3	+	+	
	Unidentified remains	26	8	0.6	
Miscellaneous	Plant material	7	2	0.2	0.2

TABLE 6. Food of 123 young and adult small-mouthed black bass of Perch Lake in 1930 and 1931 arranged in length groups.

	Length in centimetres	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40
	Number of stomachs with contents	3	37	39	18	14	8	3	1
Amphibia	Tadpole	...	...	7.1	10.6	15.7	...	...	...
Pisces	*Perca flavescens*	...	23.8	2.0	...	46.6	36.6	62.0	...
	Catostomus commersonii	...	11.3	...	...	...	...	...	...
	Oligocephalus exilis	54.0	...	...	...	...	...	...	...
	Hyborhynchus notatus?	...	...	6.1	...	...	...	...	...
	Unidentified remains	...	1.9	12.8	5.9	3.3	36.4	...	100.0
Crustacea	Decapoda—*Cambarus propinquus*	...	34.0	36.9	61.7	20.3	...	38.0	...
	Cambarus virilis?	...	...	...	...	...	3.6	...	...
	Cambarus bartonii	...	...	...	...	...	20.8	...	...
	Cambarus remains	18.0	2.2	23.2	10.7	6.9	2.6	...	...
	Cladocera—*Leptodora kindtii*	20.0	7.0	3.6	2.0	...	...	...	...
Insecta	Hemiptera—Gerridae	2.0	1.5	0.7	+	...	...	...	...
	Diptera—Chironomidae—larvae, pupae and adults	...	1.1	0.2	3.5	+	...	...	...
	Coleoptera—terrestrial and aquatic species	...	0.2	0.6	0.8	3.1	...	...	...
	Hymenoptera—Formicidae	...	15.2	3.7	3.8	3.4	...	...	...
	Orthoptera—Gryllidae	...	...	0.5	...	...	...	...	...
	Odonata—Coenagrionidae—adult	...	...	0.5	...	...	...	...	...
	Miscellaneous—Trichoptera—larvae; Ephemerida—nymphs, *etc.*	...	...	0.3	...	...	...	...	...
	Unidentified remains	6.0	1.5	1.1	1.0	0.7	...	...	...
Miscellaneous	Plant material	...	0.3	0.7	+	+	...	...	...

they form an important food item for fish of the smaller length groups. Surface and aerial insects constituted about eighty per cent. of all the insects eaten. Flying ants (Formicidae) were found most frequently and formed 3.2 per cent. of the total food. Water striders (Gerridae), an adult damselfly (Coenagrionidae), midge adults, and a small number of terrestrial insects—beetles, crickets, *etc.*—were other insects taken at the surface. Aquatic insects formed the remaining twenty per cent. of the total insect content. These consisted of midge larvae and pupae, an adult aquatic beetle and beetle larvae, mayfly nymphs, and caddis larvae.

Many tadpoles occur in Perch Lake. These formed 3.9 per cent. of the food of the bass and were found in ten per cent. of the stomachs. Tadpoles were not found in bass stomachs from Georgian Bay and Lake Nipissing. The rocky, exposed shores where bass abound are not the usual habitat of tadpoles.

The large water flea (*Leptodora kindtii*) formed 1.7 per cent. of the food of the bass. Cladocera were not found in the stomachs of adult bass of the two larger bodies of water.

Plant material formed a negligible volume in the stomachs.

While bass of Perch Lake eat mostly fish and crayfish, insects and tadpoles also enter into the diet. Although the relatively large insect content may be due to the large number of stomachs of small fish in the analysis compared to the larger bodies of water, the comparison of stomach contents of medium-sized fish from each indicates that the difference is caused largely by the presence of large numbers of insects in and around the small lake.

In order to determine any changes in food with increase in length, the bass were divided into length groups increasing regularly by four centimetres. The results are given in detail in table 6 and a summary of the percentage volume and percentage frequency of the five principal kinds of food is given in table 7. Figure 3, based on table 7, shows the results graphically.

Fish were found in the stomachs of bass in all the length

groups. It may be seen that the percentage volume was at first large. As the bass increased in size, the fish content at first decreased in percentage volume and then increased again in the largest length groups. In contrast to this, the crayfish content was at first small, then increased in percentage volume to its maximum (72.4 per cent.) when the fish content was smallest (5.9 per cent). In the larger groups crayfish formed a smaller percentage volume again. There are two explanations for this relationship. Fish and crayfish are the two largest and most important organisms utilized by bass of all larger sizes as food. If the fish eat these two organisms indiscriminately, the reciprocal relation is the natural outcome. In any group the greater the percentage volume of fish that is eaten, the smaller will be the percentage volume of crayfish. If this be true, then the more or less gradual decrease in fish content and increase in crayfish content in the smaller groups, and the subsequent increase of fish and decrease of crayfish content of the larger groups is purely a chance relation and is not significant. If this be so, the examination of a larger number of stomachs would disprove the relation as far as it concerned the gradual change with increasing length.

On the other hand, if the change is significant it may be caused by a combination of all or part of the following factors: (1) the ability of growing bass to take food of increasing size; (2) the relative abundance of available food organisms of a suitable size as the bass increases in length; and (3) a difference in habitat of small, medium, and large-sized bass. In connection with the last, small bass feed along the shore where crayfish are numerous while large bass prefer deeper water. This might explain the larger percentage of fish and correspondingly smaller percentage of crayfish in the food of larger bass. It is possible that this part of the relationship, at least, is significant. The same tendency was noticed in the food of bass of the two larger bodies of water.

In order to test the crayfish-fish relationship further, the existing length groups were subdivided into smaller groups, each of which increased by two centimetres. The relationship observed above was no longer evident. The number of

fish in each of the smaller groups was not sufficient to justify any conclusions.

Tadpoles first occurred in ten per cent. of the stomachs of fish of the sixteen to twenty centimetre group with a volume of 7.1 per cent. Both the percentage volume and percentage frequency of occurrence increased in the next two length groups but tadpoles were not found in the stomachs of larger fish. It was mentioned above that tadpoles are probably included in the diet because they occur in abundance in the lake. Their absence in the food of large bass might be due to the apparent difference of habitat of small and large bass noted above.

In the first five length groups, insects occurred in a larger percentage of the stomachs than any other group of organisms and thus must be considered an important food item. They formed a volume of 19.5 per cent. in the twelve to sixteen centimetre group and gradually became less important as the fish increased in size. They did not occur in stomachs of fish larger than twenty-eight centimetres.

Perch Lake, a small, warm body of water, was found to be rich in zooplankton. *Leptodora kindtii*, the largest of the water fleas, formed 20.0 per cent. of the food of bass in the smallest length group but gradually decreased in importance as the bass increased in size. It was not found in stomachs of bass greater than twenty-four centimetres. It was mentioned above that Cladocera were not found in the stomachs of adult bass of Georgian Bay and Lake Nipissing. Moreover, they were not found in stomachs of fry greater than five centimetres in length in the latter body of water.

Reighard (1915) reports the presence of *Leptodora* in the stomach of a bass from Douglas Lake, Michigan.

In brief, bass of Perch Lake eat a greater percentage of fish and a smaller percentage of crayfish than the bass of Georgian Bay and Lake Nipissing, but these items are again the two most important food organisms found in the stomachs. Small and large bass ate a larger percentage of fish than crayfish, while medium-sized bass ate a larger percentage of crayfish than fish. Surface and aerial insects and Clad-

ocera are important food items of smaller bass but are not eaten by large fish. Tadpoles enter into the diet of bass of medium size. On the whole, the diet of the bass of Perch Lake is more varied than that of bass in the larger bodies of water owing to the abundance of insects and the presence of two additional food organisms in large quantities.

Other Waters

In an analysis of the stomach contents of eighteen bass, from twenty-four to thirty-three centimetres in length, taken in 1930 from Phantom Lake, near Lake Nipissing, crayfish formed 71.7 per cent., fish 4.0 per cent., insects 22.6 per cent., and plant material 1.7 per cent. of the food. The insects were mostly flying ants (Formicidae).

In 1930 the insect content of the bass stomachs from Perch Lake was also higher than in 1931. In the few stomachs examined, the fish content is relatively small.

Six black bass, 9.9 to 13.4 centimetres in length, from the Oxtongue River in the Muskoka district were examined. The food consisted of twenty per cent. fish and eighty per cent. insects. The insects were mostly caddis and midge adults. Of two stomachs of small bass from the Grand River in southern Ontario, one was void of contents and the other contained three mayfly nymphs of the genus *Ecdyonurus*. The large percentage of insects in the stomachs of the few specimens of bass taken in rivers is noticeable.

FOOD OF FISH COMMONLY ASSOCIATED WITH SMALL-MOUTHED BLACK BASS

Rock bass (*Ambloplites rupestris*):—In Georgian Bay rock bass are very numerous and enter into competition with the black bass for spawning areas. The food of forty rock bass, ten to seventeen centimetres in length, consisted of 28.5 per cent. fish, 60.4 per cent. crayfish, 10.2 per cent. insects, and 0.9 per cent. plant material. In comparing this with table 3, it may be seen that rock bass eat the same kinds of food as small-mouthed black bass.

In Lake Nipissing rock bass are much less abundant than in Georgian Bay. An examination of the stomachs of twelve fish, thirteen to nineteen centimetres in length, showed them to have eaten 19.1 per cent. fish, 64.6 per cent. crayfish, 16.1 per cent. insects, and 0.2 per cent. plant material.

In both bodies of water, *Perca flavescens* and *Cambarus propinquus* were the two most important individual food organisms of the rock bass. Fish and crayfish, the food of adult black bass, together formed about eighty-five per cent. of the food of the rock bass.

Yellow pickerel (*Stizostedion vitreum*):—Pickerel were very scarce in the regions in which bass were studied in Georgian Bay.

In Lake Nipissing they are very abundant and their relationship to the black bass is similar to that of the rock bass of Georgian Bay. The food of sixteen specimens thirty-four to forty centimetres in length, consisted of 48.3 per cent. fish, mostly perch, 22.9 per cent. crayfish, and 28.1 per cent. insects. Fish and crayfish together formed 71.2 per cent. of their food.

Common pike (*Esox lucius*):—In both Georgian Bay and Lake Nipissing pike are taken in the same waters as black bass. In Georgian Bay eleven pike, thirty to sixty-four centimetres in length, had eaten 53.8 per cent. fish and 46.2 per cent. crayfish, while in Lake Nipissing ten pike, thirty-five to fifty-eight centimetres long, had eaten 36.3 per cent. fish and 59.4 per cent. crayfish. In the first case fish and crayfish formed 100 per cent., and in the second ninety-six per cent. of the food of pike.

Long-nosed gar pike (*Lepisosteus osseus*):—In Georgian Bay the gar pike is fairly abundant. The food of seventeen specimens, fifty-three to eighty-one centimetres long, consisted of 100 per cent. fish, mostly perch and minnows. The gar pike is seldom taken in Lake Nipissing.

These four species were the most important fish commonly associated with the bass in the two large bodies of water.

In Perch Lake, none of the fish listed above occur.

Suckers, sunfish, perch, and large-mouthed black bass were taken in the same gill nets as small-mouthed black bass in the lake. The food of the large-mouthed black bass consisted of fish and crayfish and a relatively large percentage of tadpoles and insects. The food of the other three species was mostly insects and bottom organisms, although crayfish were eaten by perch.

The question of food competition does not seem a vital issue in any of the waters studied. At present in Perch Lake and in the two larger bodies of water, the yellow perch, one of the most important food items of the bass and its associates, is present in great abundance. It is possible that selective fishing of large bass in Perch Lake has resulted in the presence of a relatively large number of small bass compared to the other bodies of water. If the natural balance were restored, an increased number of large bass feeding on perch would probably reduce the numbers of this food organism in the lake.

An average of two crayfish counts on rocky, protected shores of Lake Nipissing showed that there were about six crayfish per square metre present, from which it may be concluded that crayfish are fairly abundant along the shores of this lake where bass abound.

SUMMARY

The small-mouthed black bass of Ontario eat similar food to the bass which have been investigated in other regions.

Food taken by small-mouthed black bass fry and adults is conditioned by the size of the food organism in relation to the size of the bass and by the relative abundance of food organisms of suitable size in a particular habitat.

Accordingly, the food taken by bass fry undergoes definite changes as the fry increase in size. Copepoda, Cladocera, and small chironomid larvae and pupae are replaced by larger insects. Fish entering into the diet gradually replace insects. Finally, when the fry are about five centimetres in length, the food consists of fish, crayfish, and insects and is similar to that of adult bass. In Lake Nipissing the insect content continues to decrease until it is a negligible item in the food of large fish.

In large bodies of water like Georgian Bay and Lake Nipissing the food of adult bass consists of about seventy-five per cent. crayfish, chiefly *Cambarus propinquus*, and about twenty-five per cent. fish, mostly *Perca flavescens* with a negligible percentage of insects. Large adult bass tend to eat a larger percentage of fish than small adult bass.

In a small body of water like Perch Lake, fish and crayfish are still the most important food organisms, but insects are found in a large percentage of the stomachs of smaller bass and form an important food item. A large percentage of the insects eaten are surface or aerial insects.

Other organisms that are present in abundance in a small lake may be incorporated into the diet. A large percentage of Cladocera was found in the stomachs of smaller bass of Perch Lake. They decreased in importance as the fish grew larger. Tadpoles formed an increasing percentage of the food of medium-sized bass but were not taken by the few specimens of large fish examined.

In Perch Lake small and large bass ate a large percentage of fish and a small percentage of crayfish while medium-sized bass ate a large percentage of crayfish and a small percentage of fish. This relationship may or may not be significant.

The specimens of bass examined from two Ontario rivers indicate that fish in this habitat probably eat a large percentage of insects.

Competition for fish and crayfish, the chief food of the bass, might occur between the black bass and several species of predaceous fish commonly associated with it. In all cases the competition does not appear to be seriously detrimental to the bass as the present food supply seems adequate to support all species.

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