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Food and feeding habits of young pike, Esox lucius L., and associated fishes in Peterson's Ditches, Houghton Lake, Michigan[1]

[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

Stomach contents of 551 young pike (11-152 millimeters in length), 345 small yellow perch and 431 other fish representing 18 species were examined. All specimens were collected from an area widely used by spawning pike from Houghton Lake, Michigan. Organisms utilized for food by young pike included Entomostraca, insects (chiefly Chironomidae), tadpoles, minnows, darters, and other pike. As pike increased in size they passed through a definite feeding succession of Entomostraca to insects to vertebrates (chiefly fish). Cannibalism was extensive, as shown by the fact that 19.7 percent of 203 pike 21 millimeters or more in total length collected in 1939 had eaten other pike.

Smallest pike found to be cannibals were 21 millimeters long. Competition between young pike and most other species of fish for invertebrate food was very evident. The yellow perch was by far the most important fish predator of young pike. Competition for food, predation and cannibalism were important factors in the high mortality of young pike in their first few weeks of life.

Introduction

In the past, most of the investigation of food habits of pike (Esox lucius) has been directed toward fish of comparatively large size with little attention to very small individuals. The present examination of the food habits of very small pike and fishes associated with them represents one phase of the detailed life history study of pike made by W. F. Carbine at Houghton Lake, Roscommon County, Michigan, in 1939, 1940 and 1942. Data for this report were collected during the spring and summer of 1939 and 1940 from the drainage ditches which enter Houghton Lake in the immediate vicinity of Peterson's Resort and which served as a spawning ground for adult pike and rearing ground for the young. A description of these ditches, which drain surrounding marshes, has been given previously (Carbine, 1942). A complete count was made of all adult pike migrating from the lake into the ditches in 1939, 1940 and 1942. Accurate counts were also obtained of the number of young pike migrating from the ditches into the lake during the first two years. In 1942, a reliable estimate of the number of migrating young was made. These data (Carbine, 1944) are summarized as follows:

	1939	1940	1942
Number of spawning females	125	65	56
Number of spawning males	280	81	70
Number of migrating young	7,239	1,495	8,000

Calculations show that the mortality of eggs and young pike on the spawning grounds was approximately 99.82, 99.93 and 99.56 percent for 1939, 1940 and 1942, respectively (Carbine, 1944). Although fewer eggs were deposited in the marshes each succeeding year, observations indicated that large numbers of fry survived through hatching and the period of yolk absorption each year and appeared to be as numerous in 1940 as in corresponding periods in 1939 and 1942. Gradually the number of young observed each year dwindled even before most of them had reached a length of 1 inch.

Pike fry began to migrate from the marshes and ditches into Houghton Lake when they had attained a length of about 20 millimeters, and a large percentage of the total number of migrants entered the lake within 6 weeks after hatching began. Some individuals remained in the ditches until late summer, when the former spawning area largely dried up. Along with the spawning pike, small yellow perch (Perca flavescens) and many other species of fish 2-4 inches in length moved from the lake into the ditches and were present in the spawning area during the ensuing months. In the spring of 1939, these fish were allowed to enter the ditches for only one day, further entry being prevented by a weir. In 1940 and 1942 they were not hindered from entering the ditches during the entire period of investigation. This association of young pike, and various other species is a natural condition which unquestionably had an important bearing on the survival and growth of the former.

Collection of specimens and methods of stomach analysis

Collection of young pike, yellow perch and 18 other species of fish was effected by the use of seines, dip nets, minnow traps and weirs. From May 6 to July 3, 1949, 33 collections of pike and 11 collections of other fish were secured. In 1940, 17 collections of pike and 13 collections of other fishes were obtained from May 6 to June 13. Species of fish other than pike collected in sufficient numbers for stomach analyses are listed in Table 1.

Table 1.

Species of fish collected for stomach analyses found associated with young pike.[1]

Species		Year collected	
Common name	Scientific name	1939	1940
Yellow perch	Perca flavescens (Mitchill)	x	x
Bluegill	Lepomis m. macrochirus (Rafinesque)	x	...
Rock bass	Ambloplites r. rupestris (Rafinesque)	x	...
Pumpkinseed	Lepomis gibbosus (Linnaeus)	x	...
Brook stickleback	Eucalia inconstans (Kirtland)	x	x
Western mudminnow	Umbra limi (Kirtland)	x	x
Blackside darter	Hadropterus maculatus (Girard)	x	...
Iowa darter	Poecilichthys exilis (Girard)	x	x
Northern creek chub	Semotilus a. atromaculatus (Mitchill)	x	x
Northern redbelly dace	Chrosomus eos (Cope)	x	x
Western golden shiner	Notemigonus crysoleucas auratus (Rafinesque)	x	x
Brassy minnow	Hybognathus hankinsoni (Hubbs)	x	...
Bluntnose minnow	Hyborhynchus notatus (Rafinesque)	x	x
Northern common shiner	Notropis cornutus frontalis (Agassiz)	x	...
Blackchin shiner	Notropis heterodon (Cope)	x	...
Northern blacknose shiner	Notropis h. heterolepis (Eigenmann and Eigenmann)	x	x
Great Lakes spottail shiner	Notropis h. hundsonius (Clinton)	x	x
Rosyface shiner	Notropis rubellus (Agassiz)	x	x
Northern mimic shiner	Notropis v. volucellus (Cope)	x	x

[1] Identified by Walter R. Crowe

In the laboratory the total length of each fish was recorded to the nearest millimeter, and the stomach removed and opened under a low power, wide field binocular microscope. Food organisms were removed, identified, counted, and the volume of each kind of organism either measured by water displacement or estimated. In summarizing the data obtained, frequency of occurrence and percentage of total food volume were considered in determining the importance of various food organisms in the diets of the fishes concerned. Only those stomachs containing food were used in the calculation of the percentages of various food items in the stomachs. Qualitative examination of stomachs and intestines of pike and other fishes revealed that the contents were very similar in most individuals; therefore stomach contents alone were itemized in the food study.

Pike smaller than 40 millimeters in length were placed in 5-millimeter size groups, and larger individuals in 10- and 20-millimeter size groups. Analyses of food were made on a basis of these divisions. An individual food analysis was made for each collection of perch but other species were grouped together without regard for size or collection date.

Size at which pike begin to feed

Fourteen fry 10-11 millimeters in length, collected in 1940, still carried a considerable amount of yolk and had taken no food. Two individuals 11 millimeters in length obtained in 1939 showed no trace of the yolk sac and had been actively feeding. One contained a Chydorus and a Simocephalus; the other, 2 Chydorus, 2 Canthocamptus and 1 ostracod. Ten individuals 12 millimeters in length secured in 1939 showed no trace of yolk remaining and all had eaten several kinds of Cladocera, Copepoda and Ostracoda. Number of food organisms ranged from 2 to 24. In 1940, 2 of 4 pike 12 millimeters in length still showed traces of yolk and had taken no food. The other two contained Simocephalus and Chydorus and had completely absorbed the yolk sac. Eight fry 13 millimeters in length all had

eaten quantities of copepods, cladocerans and ostracods. One specimen contained 64 entomostracans, and a chironomid larva and pupa. Food organisms in the stomachs of these 8 fry varied in number from 7-66. It appears that active feeding in pike fry begins when a length of 11-12 millimeters is reached and may occur even before the yolk sac is completely absorbed.

Food of young pike

A total of 651 specimens was examined, of which 318 obtained in 1939 and 233 secured in 1940 contained food material. Data obtained from stomach examination substantiated observations as to the voracious nature of the species. From the time feeding begins fry attack and devour prey of comparatively large size. Small pike were frequently observed lying quietly in wait for prey and dashing out to engulf swimming entomostracans and insects or to attack another pike. Feeding apparently occurred in a variety of habitats for not only were free swimming organisms eaten, but judging from the number of chironomid larvae and ostracods in the diet, a considerable amount of foraging occurred on or near the bottom. Tadpoles and minnows were eaten as soon as the pike were large enough to handle them. Cannibalism, which began at a length of 21 millimeters, was very apparent, particularly among the pike collected in 1939.

Feeding habits of young pike are closely related to their size and can be divided into three stages. The first, lasting from the time they begin to feed until they reach a length of about 25 millimeters, is one of feeding mainly upon Entomostraca. In the second stage, evident in fish about 26-50 millimeters in length, the food volume consists primarily of immature aquatic insects. In the third stage, characteristic of pike larger than about 50 millimeters, the diet is composed almost entirely of fish and other vertebrates. There is a great deal of overlapping shown in the feeding habits of young pike of all sizes but in general the feeding sequence, as they increase in size, is Entomostraca to insects to fish. This sequence has been found to occur during the development

of many predaceous fishes (Adams and Hankinson, 1928; DeRyke, 1922; Ewers, 1934; Forbes, 1888; Pearse, 1918; Surber, 1941; Tester, 1932 and others).

Close agreement in the relative importance of major groups of food organisms entering into the diet in both 1939 and 1940 is very apparent (Tables 2 and 3). The same food trends are evident for both years, and the feeding succession of Entomostraca to insects to vertebrates (chiefly fish), as shown in Figs. 1 and 2, was very pronounced.

Crustacean food.--Food first taken by young pike consisted primarily of Cladocera, of which the smaller forms, chiefly Chydorus, Pleuroxus and Scapholeberis, predominated. Larger forms such as Simocephalus and Eurycercus were eaten more frequently by fish in the 21-25 millimeter group. Daphnia and Bosmina were eaten infrequently, and Polyphemus appeared only in stomachs collected on June 5 and 8, 1940. Copepods were a major food item for pike up to 26 millimeters long but rapidly diminished in importance as fish grew larger. Cyclops was most abundant in stomachs. Canthocamptus, Diaptomus and Osphranticum occurred less frequently. Ostracoda were eaten consistently although in small quantities by fish up to 70 millimeters in length. Stomachs of 77.4 percent of the pike under 21 millimeters and 39.1 percent of all those under 60 millimeters obtained in 1939 contained Entomostraca exclusively. In 1940, 68.7 percent of fish under 21 millimeters and 43.4 percent of those under 60 millimeters had eaten only Entomostraca.

Insect food.--Although insects formed an appreciable percentage of the total volume of food of pike from 11-70 millimeters in length, they were of greatest importance in the diet of fish between 26 and 50 millimeters long. Insect food consisted entirely of larvae, pupae and nymphs of aquatic forms. Midge larvae and pupae, principally Chironomidae, formed the bulk of the insect food although beetle larvae, mayfly nymphs (Blasturus and Ephemerella),and dragonfly nymphs were consumed frequently.

Table 2.

Occurrence of major groups of food organisms in stomachs of young pike collected in 1939.

Size group (millimeters)	Number of pike	Entomostraca		Insects		Vertebrates		Average number of organisms per stomach
		Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	
11-15	56	100.0	65.9	16.1	34.1	0.0	0.0	9.3
16-20	59	98.3	58.8	28.8	41.2	0.0	0.0	12.8
21-25	56	80.4	21.6	51.8	38.0	25.0	40.4	26.3
26-30	34	73.5	5.0	58.8	31.2	32.3	63.8	7.5
31-35	25	60.0	2.5	72.0	47.0	24.0	50.0	7.8
36-40	16	31.2	8.7	87.5	41.7	18.7	49.6	8.8
41-50	9	44.4	0.7	55.5	13.9	44.4	85.4	3.9
51-60	24	25.0	0.3	50.0	11.4	45.8	88.3	3.8
61-80	12	0.0	0.0	16.6	04	66.7	97.7	0.7
81-100	7	0.0	0.0	0.0	0.0	100.0	100.0	0.6
101-152	20	0.0	0.0	15.0	Trace	85.0	99.6	1.4

Table 3.

Occurrence of major groups of food organisms in stomachs of young pike collected in 1939.

Size group (millimeters)	Number of pike	Entomostraca		Insects		Vertebrates		Average number of organisms per stomach
		Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	
11-15	21	100.0	68.2	33.3	31.8	0.0	0.0	32.0
16-20	59	100.0	75.7	28.8	23.8	0.0	0.0	54.3
21-25	35	100.0	62.7	60.0	37.3	0.0	0.0	78.7
26-30	24	91.7	15.6	83.3	75.6	4.2	8.8	29.1
31-35	15	86.7	7.4	80.0	41.9	13.3	47.4	13.0
36-40	17	64.7	9.0	64.7	65.8	5.8	22.9	9.0
41-50	39	53.8	5.0	56.4	26.3	7.7	65.1	7.3
51-60	10	50.0	1.5	60.0	48.0	30.0	50.5	2.4
61-80	2	0.0	0.0	50.0	10.7	50.0	89.3	1.5
81-100	4	0.0	0.0	25.0	2.9	100.0	97.1	1.2
101-136	7	0.0	0.0	0.0	0.0	100.0	100.0	1.0

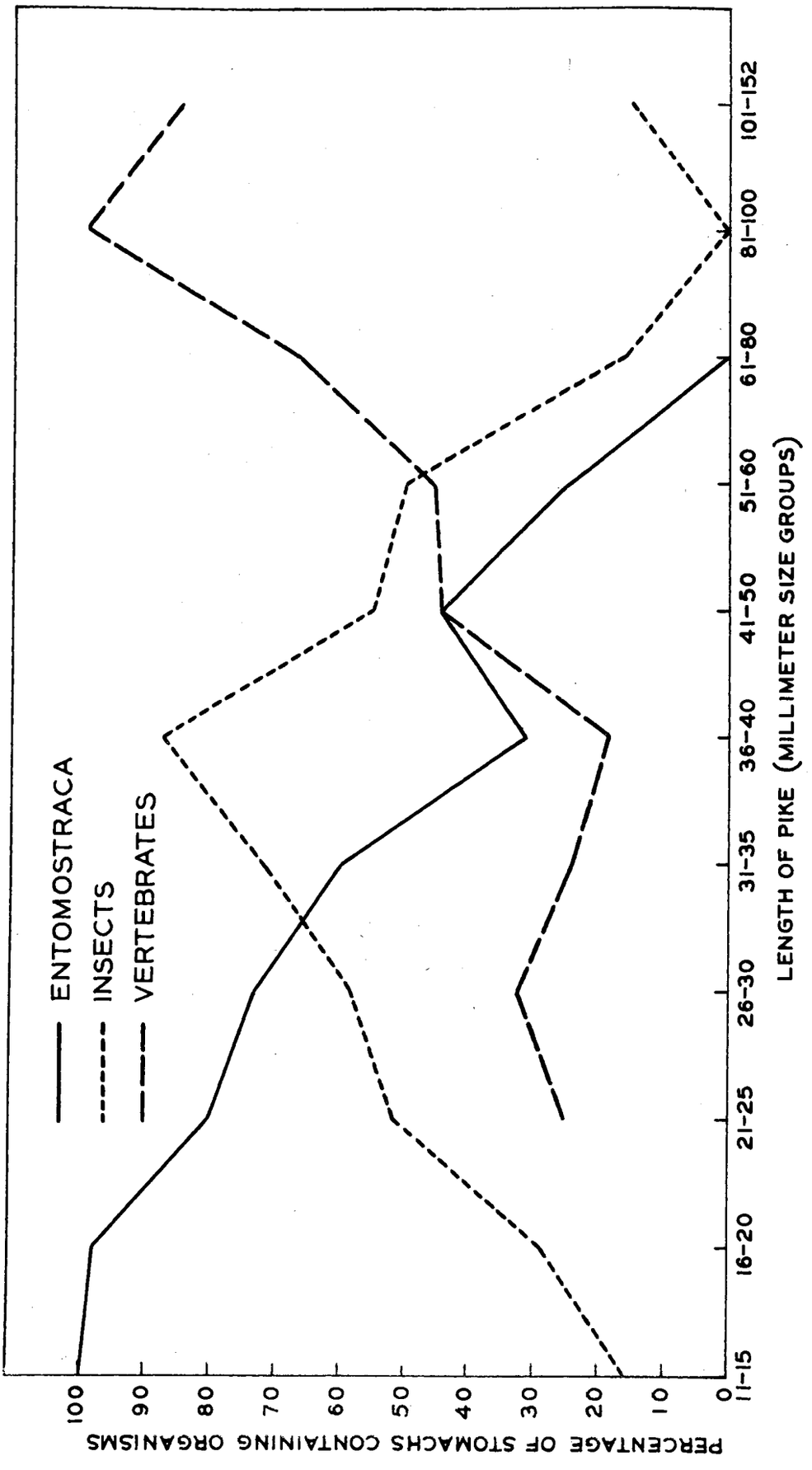

Figure 1. Frequency of occurrence of major groups of good organisms in stomachs of pike collected in 1939

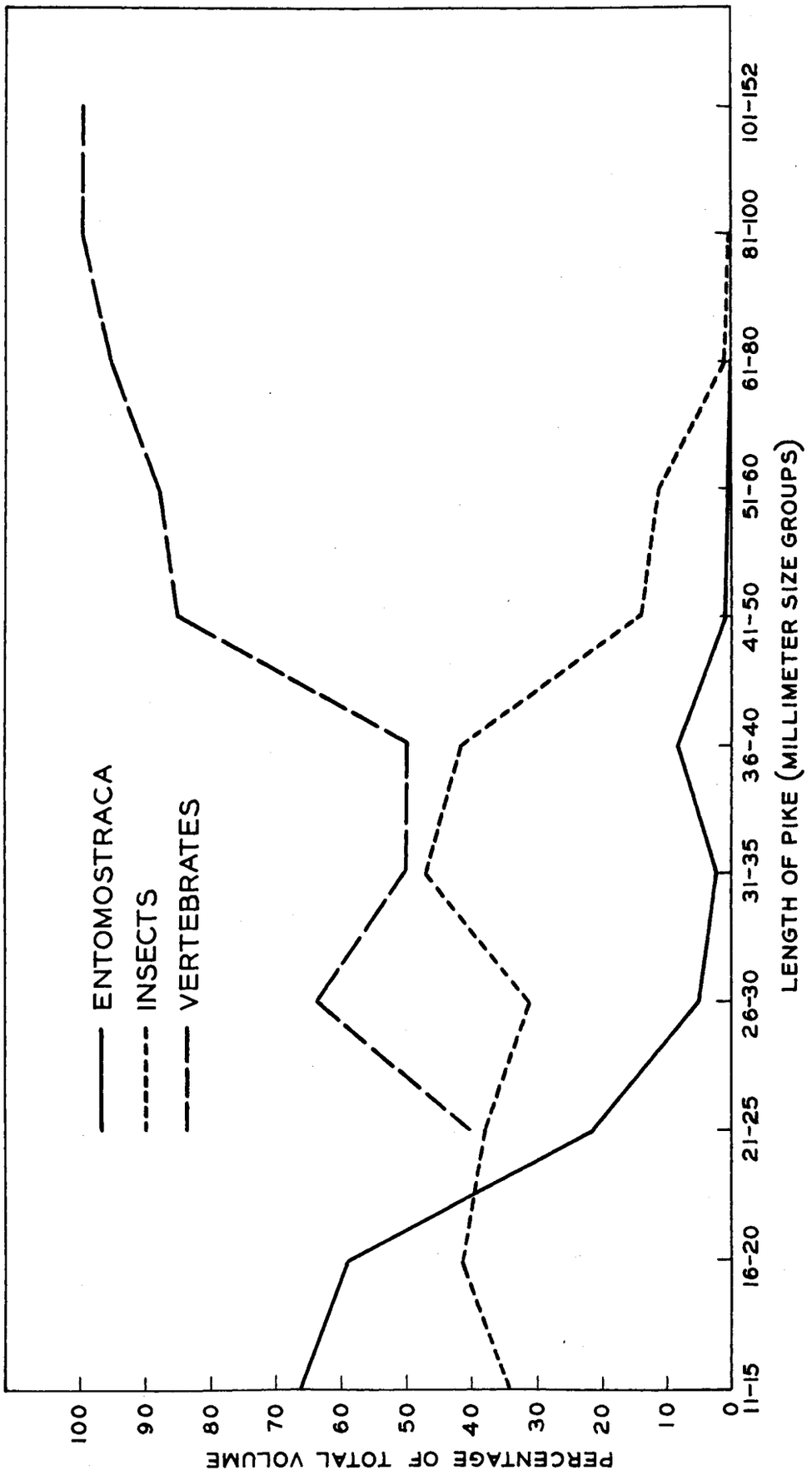

Figure 2. Percentage of total food volume composed of major groups of food organisms in stomachs of pike collected in 1939

Vertebrate food.--Tadpoles, which appeared in the ditches in late May, were eaten by all sizes of pike from 26-152 millimeters but were consumed much more frequently by larger specimens. These amphibians formed 7.6, 13.3 and 37.4 per cent of the total food volume of all pike collected in both years in the 21-40, 41-80 and 81-152 millimeter size groups, respectively. Fish, other than pike, did not appear in the stomach contents of pike smaller than 51 millimeters but formed an increasingly large part of the food of larger specimens. Northern mimic shiner, rosyface shiner, bluntnose minnow, golden shiner, creek chub, brook stickleback and brassy minnow were identified in the stomachs.

Other pike formed the chief vertebrate constituent of the diet of specimens 21-80 millimeters in length captured in 1939. Fourteen (25 per cent) members of the 21-25 millimeter size group and 11 (32.2 per cent) of those in the 26-30 millimeter group collected in 1939 had eaten other pike. Judging from the stomach contents, cannibalism was much more extensive in 1939 than in 1940. In the latter year only 7 stomachs of the total number examined contained other pike. Table 4 shows the relative length of cannibal pike and those which were eaten. Minimum difference in length between predator (23 millimeters) and prey (16 millimeters) was 7 millimeters. The fact that young pike eat others of nearly two-thirds their own length is ample demonstration of their voracity and indicates that their predisposition to eat each other is an important factor in reducing their own population.

Other food.--Few organisms, other than those previously discussed, appeared in the stomachs. Snails occurred in 4 specimens and Hydracarina in 2 individuals. Plant debris was found in a few stomachs of fish over 80 millimeters in length but was undoubtedly taken while capturing animal food organisms.

Table 4.

Comparison between the lengths of cannibal pike and pike found in their stomachs. Fish collected in 1939.

Size group (millimeters)	Number of specimens	Number of stomachs containing pike	Cannibal pike (Total length-millimeters)			Prey (pike) (Total length-millimeters)		
			Minimum	Maximum	Average	Minimum	Maximum	Average
21-25	56	14	21	25	23.3	11	17	14.1
26-30	34	11	26	30	27.8	12	20	15.1
31-35	25	5	31	35	32.4	13	18	15.6
36-40	16	2	36	37	36.5	15	20	17.5
41-50	9	0	...	...	...	...	...	...
51-60	24	4	52	60	55.6	8	30	13.2
61-80	12	2	74	78	76.0	44	45	44.5
81-100	7	1	94	94	94.0	20	20	20.0
101-152	20	1	102	102	102.0	...	...	...

Comparison of organisms eaten by pike and those found in plankton samples

In order to compare the plankton organisms found in the habitat with those in the stomachs, four plankton samples (20-50 gallons of water strained through a plankton net for each sample) were obtained at the same time and place that collections of pike were made. Comparison of the relative abundance of various genera of Entomostraca--all other plankton organisms were excluded since they were not eaten--with those consumed by young pike show that in two instances many of the microcrusteans were eaten in direct proportion to their abundance (Table 5). In the other two cases much less agreement in relative abundance is evident. It is possible that the small number of stomachs collected on those dates on which relative numbers of organisms eaten and those in plankton samples showed little correspondence and did not give a representative picture of the feeding habits of the pike population at that time. It should be noted that nauplii, generally abundant in the plankton samples, were not eaten. Although the data are not conclusive, it appears that young pike are opportunistic in their feeding and tend to eat those organisms which are most abundant providing they are large enough to interest them. Since Entomostraca are so important in the diet of pike in their first few weeks of life, it is probable that the abundance or dearth of these organisms is an important factor in the initial survival of the fry.

Effect of change in food habits on growth rate of young pike

Growth rate of pike (Carbine, 1942) showed a marked increase after the average length of fish had reached 44.2 millimeters in 1939 and 39.3 millimeters in 1940. Vertebrates and large insects formed the bulk of the food of fish in the 41-50 millimeter group in both years. The increased daily

Table 5.

Comparison of Entomostraca eaten by pike with Entomostraca found in plankton samples. [1]

Date sample collected	Number of stomachs with contents	Size range of pike (millimeters)	Stomach contents (Entomostraca) Organism	Total number of organisms in stomachs	Percentage of total number of organisms in stomachs	Plankton sample (Entomostraca) Organism	Total number of organisms in sample	Percentage of total number of organisms in sample
May 10, 1940	14	13-16	Chydorus	523	87.6	Chydorus	3,540	81.1
			Cyclops	35	5.9	Cyclops	255	5.8
			Simocephalus	22	3.7	Bosmina	180	4.1
			Canthocamptus	6	1.0	Nauplii	135	3.1
			Ostracoda	5	0.8	Ostracoda	120	2.8
			Scapholeberis	5	0.8	Simocephalus	60	1.4
			Bosmina	1	0.2	Scapholeberis	45	1.0
						Canthocamptus	30	0.7
May 11, 1940	8	13-14	Chydorus	121	69.5	Cyclops	1,243	44.7
			Pleuroxus	21	12.1	Nauplii	990	35.6
			Canthocamptus	14	8.1	Chydorus	370	13.3
			Ostracoda	12	6.9	Canthocamptus	104	3.7
			Cyclops	6	3.4	Ostracoda	44	1.6
						Pleuroxus	30	1.1
May 25, 1940	23	20-33	Chydorus	648	47.5	Chydorus	182	32.6
			Cyclops	373	27.4	Cyclops	109	19.5
			Pleuroxus	183	13.5	Pleuroxus	85	15.2
			Ostracoda	99	7.4	Ostracoda	61	10.9
			Simocephalus	40	2.9	Canthocamptus	61	10.9
			Diaptomus	10	0.7	Nauplii	36	6.5
			Canthocamptus	9	0.6	Scapholeberis	12	2.2
			Scapholeberis	1	Trace	Bosmina	12	2.2
May 28, 1940	8	25-29	Simocephalus	27	45.8	Chydorus	160	46.8
			Pleuroxus	12	20.2	Ostracoda	44	12.9
			Ostracoda	6	10.2	Cyclops	44	12.9
			Chydorus	4	6.8	Pleuroxus	19	5.4
			Cyclops	4	6.8	Simocephalus	15	4.4
			Osphranticum	3	5.1	Canthocamptus	15	4.4
			Eurycercus	1	1.7	Bosmina	15	4.4
			Scapholeberis	1	1.7	Polyphemus	15	4.4
			Diaptomus	1	1.7	Nauplii	15	4.4

[1] Plankton samples counted and organisms identified by L. Edward Perry.

growth rate in June coincided very closely with the appearance of larger food items (particularly fish) in the diet of pike collected at that time. Since increased growth rate occurred at a size which corresponded rather closely with the size at which transition from invertebrate to vertebrate food was very evident, it appears that an accelerated growth rate is correlated with the change to a vertebrate diet.

Competition for food between young pike and other fish

That competition for various food organisms existed between the pike and other species of fish present in the ditches was clearly shown by analysis of the stomach contents of yellow perch (Tables 6 and 7) and other species of fish (unpublished). The degree of competition is evident in the relative abundance of various types of food in the stomachs of different species and different size groups of pike (Table 8). What bearing competition for food had on survival and growth of young pike cannot be determined since no information is available concerning the adequacy or inadequacy of the natural food supplies available. However, competition necessarily reduced the food supply and may have been a factor in the mortality of young pike.

Crustacean food.--Most species of fish ate entomostracans to some extent and offered competition to pike up to 40 millimeters in length and particularly to those under 20 millimeters. The brook stickleback, golden shiner, blacknose minnow, spottail shiner, and mimic shiner consumed considerable quantities of Entomostraca. These organisms occurred in 47.3-90.0 percent of the stomachs of these fish and formed from 16.0-57.7 percent of the total food volume.

Insect food.--Competition for insects between young pike and other fish associated with them was very pronounced. Larvae and pupae, particularly those of the Chironomidae, were consumed by all sizes of pike, yellow perch and most other fish. Those fish which fed on chironomids extensively and thereby competed directly with pike, particularly those in the 21-50 millimeter

Table 6.

Summary of stomach contents of all yellow perch collected in 1939. Number of stomachs with contents 78, without 17.

(L = larvae, P = pupae, N = nymph)

Organisms	Number of stomachs containing organisms	Percentage of stomachs containing organisms	Most organisms in any stomach	Average number of organisms in stomachs containing them	Percentage of total number of organisms	Percentage of total volume
Entomostraca	16	20.5	461	66.6	79.2	6.0
Cladocera	11	14.1	62	18.4	15.1	2.3
Copepoda	9	11.5	450	95.8	64.1	3.5
Malacostraca						
Amphipoda	3	3.8	3	1.7	.4	Trace
Insecta	69	88.5	21	3.7	19.6	69.4
Diptera	20	25.7	18	6.3	9.4	13.8
Chironomidae (L)	8	10.2	3	1.5	.9	1.0
Chironomidae (P)	13	16.6	18	7.9	7.6	10.5
Culicidae (L)	6	7.7	5	2.0	.9	2.3
Ephemeroptera (N)	58	74.3	6	2.4	10.2	55.6
Coleoptera (L)	1	1.3	1	1.0	Trace	Trace
Vertebrates						
Pike	8	10.2	3	1.2	.8	24.6

Average number of organisms per stomach 17.2
Average volume per stomach in cubic centimeters 0.027

Table 7.

Summary of stomach contents of all yellow perch collected in 1940. Number of stomachs with contents 267, without 280.

(L = larvae, P = pupae, N = nymph, A = adult)

Organism	Number of stomachs containing organisms	Percentage of stomachs containing organisms	Most organisms in any stomach	Average number of organisms in stomachs containing them	Percentage of total number of organisms	Percentage of total volume
Entomostraca	72	26.9			55.1	0.9
Cladocera	48	17.9	48	8.8	11.5	0.5
Copepoda	45	16.8	391	35.4	43.6	0.4
Ostracoda	1	0.4	2	2.0	Trace	Trace
Malacostraca						
Amphipoda	2	0.8	6	3.5	0.2	0.1
Insecta	201	75.3			42.7	29.1
Diptera	141	52.8	49	9.1	34.9	10.8
Chironomidae (L)	132	49.4	47	5.8	20.9	5.8
Chironomidae (P)	111	41.6	33	4.9	13.9	3.2
Culicidae (L)	3	1.1	1	1.0	Trace	0.1
Anthomyidae (L)	1	0.4	5	5.0	0.1	1.7
Odonata						
Anisoptera (N)	9	3.3	22	4.3	1.1	0.5
Zygoptera (N)	7	2.8	19	5.8	1.1	0.8
Ephemeroptera (N)	12	4.5	13	2.7	0.9	0.6
Ephemeroptera (A)	8	3.0	8	3.6	0.8	9.3
Trichoptera (L)	32	12.0	12	2.3	2.0	6.5
Coleoptera (L)	27	10.1	16	2.8	1.9	0.6
Vertebrates	67	25.1			2.0	69.8
Amphibia (Tadpole)	1	0.4	1	1.0	Trace	0.7
Fish			3		2.0	69.1
Pike	63	23.6	3	1.1	2.0	68.9
Cyprinidae	1	0.4	1	1.0	Trace	0.1
Fish remains	2	0.8	1	1.0	Trace	0.1

Average number of organisms per stomach 13.7.
Average volume per stomach in cubic centimeters 0.044

Table 8.

Comparison of food eaten by various size groups of pike with diet of other species of fish. Data collected in 1939 and 1940 combined.

Species	Stomachs with contents	Entomostraca		Insects		Pike		Other vertebrates (Fish and tadpoles)		Algae and plant debris	
		Percentage of stomachs containing organisms	Percentage of total food volume	Percentage of stomachs containing organisms	Percentage of total food volume	Percentage of stomachs containing organisms	Percentage of total food volume	Percentage of stomachs containing organisms	Percentage of total food volume	Percentage of stomachs containing material	Percentage of total food volume
Pike (11-20 millimeters)	195	99.5	67.3	25.6	32.7	...	...	...	...	...	...
Pike (21-40 millimeters)	222	77.5	15.7	65.3	47.3	14.9	25.3	2.3	10.0	0.5	Trace
Pike (41-80 millimeters)	94	38.3	1.5	50.0	20.0	9.6	23.5	17.3	54.2	12.8	0.8
Pike (81-152 millimeters)	38	...	...	10.6	Trace	13.2	6.5	73.7	91.5	10.6	2.0
Yellow perch	345	25.5	1.7	78.3	35.4	20.6	62.0	1.2	0.7	...	...
Pumpkinseed	13	23.1	Trace	92.3	96.8	...	...	...	...	...	...
Bluegill	1	...	...	100.0	100.0	...	...	...	...	...	...
Rock bass	2	...	...	100.0	100.0	...	...	...	...	...	...
Brook stickleback	10	90.0	32.4	70.0	67.6	...	...	...	...	...	...
Mudminnow	19	31.6	4.5	68.4	59.1	...	...	5.3	4.5	31.6	Trace
Blackside darter	24	8.4	Trace	100.0	100.0	...	...	...	...	...	...
Iowa darter	46	43.5	3.8	93.5	96.2	...	...	...	...	4.3	Trace
Creek chub	11	...	...	63.6	7.9	9.1	1.4	18.2	76.2	9.1	14.4
Redbelly dace	36	30.6	Trace	55.6	21.2	...	...	...	...	38.9	78.8
Brassy minnow	20	...	...	...	...	...	...	...	...	100.0	100.0
Golden shiner	35	71.4	57.7	20.0	11.5	...	...	...	...	40.0	30.8
Bluntnose minnow	48	31.2	Trace	16.7	2.2	...	...	...	...	83.3	97.0
Common shiner	18	...	...	94.4	83.3	...	...	...	...	5.5	16.7
Blackchin shiner	20	20.0	4.4	80.0	81.5	5.0	14.1	...	...	5.0	Trace
Blacknose shiner	34	85.3	48.0	41.2	36.0	...	...	...	...	20.6	16.0
Spottail shiner	25	48.0	46.2	40.0	30.7	...	...	...	...	24.0	23.1
Rosyface shiner	14	14.3	4.7	100.0	95.3	...	...	...	...	...	...
Mimic shiner	55	47.3	16.0	38.2	36.9	3.6	14.4	...	...	43.6	30.4

size group, were: yellow perch, brook stickleback, mudminnow, Iowa darter, creek chub, bluntnose minnow, redbelly dace, common shiner, blackchin shiner, blacknose shiner, spottail shiner, rosyface shiner, and mimic shiner. Effect of competition for insects, particularly chironomids, on the survival and growth of young pike cannot be accurately evaluated. Nevertheless, it is not improbable that the total competition for what may have been a limited insect food supply may have affected pike adversely during the insect feeding stage.

Vertebrate food.--Very little competition existed between the pike and other fish for tadpoles and minnows. Yellow perch, mudminnows and creek chubs consumed minnows to a limited extent and ate few tadpoles. If it is considered that young pike themselves are food for other pike, then perch would be a competitor of some importance for they no doubt decreased the number of pike fry available to the cannibals in the population.

Predators of young pike

In view of the small number of young pike that survived the first few weeks after hatching, there is no doubt that predation played an important role in the reduction of the population (Carbine, 1942, 1944). Perch and other fish present in the ditches consumed many young and the pike themselves were responsible in large measure for the reduction in numbers through cannibalism. Yellow perch (61-120 millimeters in total length) present in both years but more abundant in 1940 proved to be a most important fish predator. Of the 345 yellow perch stomachs which contained food, 71 (20.6 percent) contained one or more pike, which constituted 62.0 percent of the total volume of stomach contents. Most pike eaten by perch ranged from 12-36 millimeters in length (average length about 25 millimeters). The extent to which pike were eaten by perch in both 1939 and 1940 is shown in Table 9. Average length of pike eaten was about

Table 9.

Extent to which young pike were eaten by perch shown for each perch collection in 1939 and 1940.

Collection date	Number of perch stomachs with contents	Percentage of stomachs containing pike	Percentage of total food volume composed of pike
1939			
May 9	52	7.7	3.0
May 12-16	2	0.0	0.0
May 20	6	66.7	88.2
May 23-24	11	0.0	0.0
May 27	7	0.0	0.0
1940			
May 13	25	8.0	19.2
May 22	5	40.0	94.3
May 27	14	14.4	65.7
May 28	45	22.2	87.5
May 29	15	13.3	51.8
May 30	19	36.8	95.9
May 31	32	25.0	76.1
June 1	31	45.2	87.0
June 2	16	25.0	73.9
June 3	13	30.8	75.0
June 4	7	28.6	83.3
June 5	20	30.0	63.8
June 8	25	0.0	0.0
Total	345	20.6	62.0

one-third of the average length of the perch which ate them and is probably near the maximum size prey that these fish could eat with ease. By May 27, 1939 and June 8, 1940, the average length of pike was 44.2 and 38.3 millimeters, respectively, and indicates they were reaching sufficient size that perch were no longer able to feed freely upon them. This probably explains why no small pike were found in perch stomachs collected on May 23-24 and 27, 1939 and on June 8, 1940.

Of all other fish collected in 1939 and 1940, only the creek chub, blackchin shiner and mimic shiner contained pike. It is not improbable, however, that most fishes associated with the pike fry consumed them to some extent. On May 8, 1942, the trap at the fry weir contained 21 pike, 5 pumpkinseeds and 4 mudminnows. The pumpkinseeds contained a total of 12 pike and the mudminnows a total of 16. This high incidence was no doubt due to the availability of the pike fry in the trap.

Other animals such as birds, dragonfly and damselfly nymphs, beetle larvae and water bugs (Belostomatidae) were observed to capture and eat young pike (notes of William F. Carbine).

Discussion and conclusions

It is evident from the data obtained that predation, cannibalism and competition for available food between young pike and the species associated with them in the ditches was indeed a factor in the high mortality rate. The greater abundance of small yellow perch and other fish in the ditches in 1940 than in 1939 no doubt contributed significantly to the lower production in 1940. Observations on the number of perch and other fish present in 1942 are incomplete; therefore no comparison with other years is possible.

In 1939 pike fry began to migrate from the ditches into Houghton Lake on May 12, 10 days after hatching, at an average length of 19 millimeters, and 85.4 percent of the total migrants moved into the lake in the succeed-

ing 20-day period. In 1940, the first young (average length 23 millimeters) moved to the lake on May 25, 22 days after the first fry were observed in the ditches, and only 24.9 percent of the total run of fish entered the lake in the following 7-day period. The 12-day delay in the beginning of the lakeward migration of fry in 1940 offered greater opportunity for extensive losses in the ditches and marshes through predation and cannibalism than in the previous year. Since more young moved downstream from the marshes to the lake on bright days than on cloudy days, an extended period of overcast weather, such as occurred in 1940, would offer more favorable conditions for losses due to the causes mentioned above. A reduction in the number of predators in the spawning marshes may not necessarily result in a lessened mortality of young pike because cannibalism, known to be the chief cause of pike mortality in experimental ponds (Carbine, 1945), would still occur to reduce the population to a low level.

Although competition, predation and cannibalism unquestionably cause the loss of many young pike, other unfavorable conditions such as low water levels and limited spawning areas are no doubt of great significance in the survival of the young on the spawning grounds.

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