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UTILIZATION OF ALEWIVES BY INSHORE PISCIVOROUS FISHES IN LAKE MICHIGAN [1]

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Introduction

The alewife (Alosa pseudoharengus) was discovered in Lake Michigan in 1949 (Miller, 1957). It soon became abundant, and by 1966 accounted for 68% of the commercial fish catch (U.S. Department of the Interior, 1968) and over 80% of the poundage in experimental trawls (Smith, 1968). During most of the year, alewives inhabit deep water. However, they spawn during May-August in inshore waters where resident warm-water fish are abundant. The effects of tremendous numbers of this exotic species on inshore fish are not known. Alewives could be quite detrimental because they may compete successfully for the zooplankton necessary to survival of young game fish. On the other hand, they may be beneficial by serving as food for game fish. In order to assess the latter possibility, I examined stomachs of northern pike (Esox lucius), smallmouth bass (Micropterus dolomieui), walleye (Stizostedion vitreum vitreum), burbot (Lota lota), and bowfin (Amia calva) from Little Bay de Noc, Lake Michigan, in 1966-68.

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[1] A contribution from Dingell-Johnson F-27-R and F-31-R, Michigan.

Little Bay de Noc is located in northern Green Bay. My study area of 9 square miles was the bay north of Gladstone, Michigan (Fig. 1). Although its maximum depth is 51 feet, nearly half of the bay is less than 12 feet deep. The substrate in shallow water is predominantly sand, with rock and rubble along the north and west shores. The bottom in deep water is silt. The Whitefish River, largest of the five tributary streams, has a base flow of about 50 cubic feet per second; the other streams range from 0.4 to 4.6 cubic feet per second.[2] The maximum surface water temperature, exclusive of shallow, sheltered bays, was 73 F.

The fish population of Little Bay de Noc consisted predominantly of warm-water species. Northern pike, smallmouth bass and walleye were the principal predators. Smaller populations of burbot and bowfins were also present. Most of the burbot, however, apparently left the study area before the arrival of alewives in late May.

Adult alewives were exceedingly abundant during June-August, and age-0 alewives were abundant during July-September. Yellow perch (Perca flavescens) were common throughout the bay, and large numbers spawned in the Whitefish River estuary in May. American smelt (Osmerus mordax) were very abundant during the spawning season in April, but considerably less abundant at other times. Small forage fish that were abundant included spottail shiners (Notropis hudsonius), johnny darters (Etheostoma nigrum), and trout-perch (Percopsis

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[2] Personal communication, Larry Hough, Engineering Technician, U.S. Geological Survey, Escanaba, Michigan.

omiscomaycus). Other fish that were common in the bay included rock bass (Ambloplites rupestris), pumpkinseeds (Lepomis gibbosus), brown bullheads (Ictalurus nebulosus), black crappies (Pomoxis nigromaculatus), white suckers (Catostomus commersoni) and redhorse (Moxostoma spp.). Young-of-the-year largemouth bass (Micropterus salmoides) were common, but adults were rare. Brown trout (Salmo trutta) and rainbow trout (Salmo gairnderi) were present in small numbers during spawning migrations, and juvenile coho salmon (Oncorhynchus kisutch), from a plant in the Whitefish River, migrated through the bay in April-May, 1968.

Methods

Predatory fish were caught with gill nets, trap nets, a pound net and electrofishing gear. The gill nets were fished on the bottom and were made of five 5- by 25-foot panels of 1 1/2-, 2-, 2 1/2-, 3-, and 4-inch mesh (stretch measure). Trap nets were either 3 feet or 6 feet deep, and similar to the model described by Crowe (1950). The pound net had a pot 33 feet square and 10 feet deep, and made of 1 1/2-inch stretch mesh. Electrofishing was done with a boom shocker equipped with a 3-phase, 180-cycle generator. Voltage was controlled to maintain an output of approximately 7 amperes. Generally, fish were removed from the nets and stomach sampled within 24 hours of capture. Electrofishing was done at night, and the fish were stomach sampled immediately.

Every 2 weeks during 17 May to 20 October 1966, gill nets were set at eight representative locations, and electrofishing was done at five

locations in shallow water during 17 May to 30 August. Trap nets were fished at two locations on 25 May, 8 June, and 21 June. During 5 May to 27 September 1967, gill nets were set at three representative locations at 3-week intervals. Trap nets were set at various locations, generally in water less than 12 feet deep, during 20 June to 24 August. During 17 April to 3 May 1968, gill nets and trap nets were intensively fished in and near the estuary of the Whitefish River. From 7 May to 24 October 1968, gill nets were set at the same locations and time intervals as in 1967. The pound net was fished from 27 April to 3 June, 10 to 21 June and 10 September to 25 October 1968. The collecting sites, except for trap net sets and gill net sets of 17 April to 3 May 1968, are shown in Figure 1.

The relative abundance of forage fish in water less than 3 feet deep was determined by electrofishing; in deeper water, by small-mesh gill nets and by trawl. In shallow water, forage fish longer than 3 inches were collected in 1966 while collecting predators with electrofishing gear. Electrofishing was also done at 3-week intervals from 20 June to 23 October 1968 at four stations. The stations were selected primarily to sample young-of-the-year alewives, but all fish less than 4 inches long were collected. In deeper water, a small-mesh gill net made up of six 6- by 25-foot panels of 3/4-, 7/8-, 1-, 1 1/4-, 1 1/2- and 1 3/4-inch mesh (stretched measure) was attached to the larger-mesh net used to collect predators; these nets were fished together in 1967 and 1968. Trawl hauls were made with a 16-foot try net at four locations in August 1966.

The study was divided into three time periods: before alewives were abundant in the spring (17 April-16 May), while alewives were abundant (17 May-31 August), and after most of the mature alewives had left the bay (1 September-24 October). These periods will subsequently be referred to as "spring," "summer," and "fall." Extensive collecting done during the 3 years of the study indicated that no drastic changes occurred in the populations of either predators or prey. Therefore, the data from all years have been combined. Table 1 shows numbers of predator fish caught according to season and gear.

Predatory fish were measured to total length in millimeters and weighed to the nearest 0.01 kilogram (4-tenths of an ounce) before their stomach contents were removed. The contents were preserved in 10% formalin for later identification in the laboratory. Whole fish in the stomachs were measured to the nearest centimeter, total length. When fish were partially digested, measurements were made of various undigested parts. The relationship of these partial measurements to total length was derived from whole fish (Table 2). Of the fish eaten, 74% were identified and their lengths measured or estimated from partial measurements. The weight of fish was determined from length-weight relationships derived from whole specimens. Invertebrates were seldom important in the diet of the fish that I examined, so usually they were not weighed.

Although the metric system was used for original measurements and in statistical tests, results are presented here in the English system.

Abundance of prey

In water less than 3 feet deep, the shocker collections (Table 3) showed that forage fish longer than 3 inches in June and early July were mostly adult alewives. Yellow perch and rock bass were common throughout the summer. In 1968, the shocker collections of fish less than 4 inches (Table 4) showed that small alewives and yellow perch were abundant. In addition, these collections showed that several centrarchids, spottail shiners, trout-perch, and johnny darters were also important components of the shallow-water fish population.

In deeper water, forage fish collected with the gill nets were generally over 3 inches long. Smelt were abundant in early May, and alewives were abundant in June and July. Yellow perch and spottail shiners were common throughout the year. Trout-perch were important but less numerous. The average numbers of forage fish collected per gill net at three stations in 1967 and 1968 are shown in Table 5. Fish less than 3 inches long, of the species caught in the gill net, were common in the trawl hauls.

In summary, I judge the following forage fish were abundant: alewives, smelt, spottail shiners, trout-perch, yellow perch, johnny darter and small centrarchids.

Foods of piscivorous fishes

Northern pike

Stomachs of 405 pike were examined; 204 contained identifiable food (Table 6). The pike averaged 19.4 inches long, with a range of 5.2 to 38.0. Smelt were found in 41% of the pike caught in the spring and accounted for 76% of the total weight of food. Perch were second in weight but their importance in the diet was extremely small since only one perch was found. Alewives occurred in 25% of the summer-caught pike and comprised 66% of the total weight of food. Smelt, rock bass, and trout-perch, in approximately equal weights, comprised most of the remainder of the summer foods. During the fall, smelt again contributed the most to the pike diet.

The average weight of prey eaten during the spring, summer and fall was respectively 0.85, 0.46 and 0.12 ounce per pike. These averages do not truly indicate the feeding rates because the average sizes of the pike were 23.1, 19.6 and 18.0 inches during these periods. To compensate for differences in size of pike, I converted the reconstructed weight of prey to unit weight of prey per unit weight of pike. This still did not sufficiently eliminate bias due to size of pike because there was a trend for small pike to have a greater weight of prey per unit weight of pike. In addition, the proportion of small (<15 1/2 inches) and large (>27 1/2 inches) pike was greater in the summer and fall than in the spring. To compare feeding rates during the three periods, the above biases were eliminated by using only pike 15 1/2 to 27 1/2 inches in

length. The average lengths of pike used to compare feeding rates were 21.8, 20.8 and 21.0 inches in the spring, summer and fall, respectively. Analysis of variance showed that there was a statistical difference in feeding rates; $F(2; 264) = 8.71^{**}$. The means and their 95% confidence limits were: spring, 1.70 ± 0.24; summer, 1.32 ± 0.23; fall, 0.31 ± 0.23 ounce per pound of pike. Significantly less food was eaten in the fall. Higher feeding rates in the spring and summer were associated with the abundant smelt and alewife populations.

Generally, the larger pike fed on larger prey (Table 7). A coefficient of determination, r^2 (Woolf, 1968), was calculated to describe the relationship between the average length of prey in each pike and the length of the pike. An r^2 of 0.29 indicated much variation in size selectivity.

Young-of-the-year alewives were seldom eaten by northern pike, but adults from 5 1/2 to 7 inches were extensively preyed upon by pike over 12 inches. Spottail shiners were not eaten until they were about 2 inches long, and pike over 23 1/2 inches long did not contain any. Adult smelt in the range 4 1/2-7 inches were eaten readily by pike over 12 inches. Trout-perch in the range 3 1/2-4 1/2 inches were preyed upon by pike of 8-27 1/2 inches.

Pike preyed extensively on alewives and smelt to the virtual exclusion of yellow perch. Elsewhere, northern pike fed extensively on perch (Seaburg and Moyle, 1964). The apparent absence of predation on perch in Little Bay de Noc was probably influenced by the sheer

abundance of alewives and smelt. The chance of pike encountering the migrating or spawning alewives and smelt may have been much greater than the chance of encountering the more sedentary and less abundant perch. Besides, there is a strong possibility that pike preferred the soft-rayed fish. Pike which were observed in aquaria selected soft-rayed fish over spiny-rayed fish of similar size (Beyerle and Williams, 1968). These workers hypothesized that not only may a dense population of soft-rayed fish act as a buffer between northern pike and spiny-rayed fish, but it may also enhance the feeding intensity and growth of pike. My findings support Beyerle's and Williams' hypothesis. In Little Bay de Noc, perch were seemingly saved from northern pike by smelt and alewives. Also, the heavy diet of soft-rayed fishes may well have influenced the fast growth rate of northern pike in Little Bay de Noc, which exceeded the rate in other waters where alewives and smelt were less abundant (Wagner, 1968).

Smallmouth bass

Stomachs of 112 smallmouth bass that averaged 12.7 inches long (range 5.7 to 19.1) were examined (Table 8). The three bass taken in the spring contained no identifiable fish. Of the 87 sampled in summer, 66% contained food. Alewives contributed 60% of the total weight of fish eaten, but only 10% of the bass had eaten alewives. Small game fish (rock bass, yellow perch and young northern pike) contributed 24% of the weight of prey fish. Fish remains were found in 9 of 22 stomachs collected in the fall, but none could be identified. Bass ate

crayfish in all three seasons. Webster's (1954) study of smallmouth bass in Cayuga Lake, New York, showed that alewives and crayfish were the most important foods consumed by bass comparable in size to those of my study.

The small average size of prey fish eaten (Table 9) suggests that the bass did not prefer items as large as mature alewives but may have fed on them mainly because of their abundance. Unlike pike, larger smallmouth bass showed no tendency to feed on larger prey (Table 9).

Walleyes

I examined stomachs of 103 walleyes that averaged 21.2 inches long (range 10.0 to 28.1). In the spring, smelt contributed 94% of the weight of identifiable foods. Alewives were found in 31% of the walleyes sampled during the summer, and composed 71% of the total weight of food (Table 10). During the fall, only young-of-the-year bullheads, alewives and smelt were eaten, which contributed little to the diet because of their small size (Table 11).

The average size of walleyes collected in the fall was smaller than in the spring and summer. Feeding rates were compared by converting the weight of prey in each stomach to unit weight of prey per unit weight of walleye. Unlike the northern pike, there was no trend for smaller walleyes to contain a greater weight of prey per pound of body weight. The average weight of fish eaten in the spring, summer and fall was 0.61, 0.85 and 0.20 ounce of prey per pound of walleye,

respectively. Despite the apparent differences in feeding rates, analysis of variance showed that the rates were not significantly different; $F(2; 100) = 1.89$. This was due to the small sample size in the fall and to the large variation in the amount eaten by individual walleyes which resulted in a large error mean square, or sampling variation.

The larger walleyes were inclined to eat larger prey (Table 11). The coefficient of determination between predator length and prey length was 0.18. However, there was considerable deviation from the trend. Adult alewives were eaten by walleyes as small as 15 1/2 inches, and a walleye of 25 1/2 inches, taken in the fall, had eaten 9 young alewives (2.0-2.8 inches) plus 17 bullheads (1.6-2.4 inches).

A recently stocked coho salmon was the only game fish among the 106 fish eaten by walleyes. It is particularly unusual that no yellow perch were found. Eschmeyer (1950) found that perch were the most important food of walleyes in Gogebic Lake, Michigan. Eschmeyer also summarized data from other studies which showed that walleyes feed heavily on yellow perch. However, it appears that in Little Bay de Noc, smelt and alewives served as buffers for perch and other small game fish.

Burbot

The 43 burbot examined averaged 22.9 inches long and ranged from 16.2 to 28.1 inches. In early spring, burbot, that were seemingly concentrated near the estuary of the Whitefish River, fed almost entirely

on smelt (Table 12). As the smelt run declined, they fed on perch. Smelt contributed 76%, and perch 20%, to the diet by weight. During the summer, when burbot were scattered about the bay, alewives were the only fish eaten. Burbot probably fed heavily on alewives in this season, since four of the five sampled had an average of 2.6 ounces in their stomachs. Johnny darters were the most numerous prey species in the fall, but the weight was only 0.08 ounce per burbot.

Beetle larvae (36) and mayfly nymphs (49), the only invertebrates found, were eaten by five burbot. The total weight of insect larvae was only 0.2% of the total weight of all foods eaten.

The feeding rates of burbot varied greatly among the three periods. The average weight of food per stomach during the spring, summer and fall was 5.7, 2.2, and 0.1 ounces, respectively. The gluttony of burbot in the spring was demonstrated quite well by a 27 1/2-inch burbot that had eaten 29 smelt plus 4 unidentified fish; the weight (not reconstructed) of the stomach contents was 21.8 ounces, or 18% of the total weight of this burbot. Two smaller burbot also had stomach contents that comprised 18% of their total weight.

There was evidence that burbot selected smaller smelt. Smelt collected on 18 April 1968 with a gill net in the Whitefish River estuary were compared with those found in 13 burbot caught in the same area at the same time. The gill net was made of six 5- by 25-foot panels of 3/4- to 2-inch mesh (stretch measure) graded in 1/4-inch intervals. I assumed that the graded mesh took a representative sample

of the smelt run. Length frequencies of 1,004 smelt from the gill net and of 159 smelt in burbot stomachs are shown in Figure 2. The apparent scarcity of large smelt (> 8.0 inches) in the burbot diet compared to the numbers of large smelt available was highly significant (chi-square = 76.17, 16 d.f., $p < 0.001$).

There was considerable variation between size of burbot and size of prey (r^2, the coefficient of determination = 0.21). In general, the larger burbot fed on larger prey (Table 13). In comparing burbot size to number of prey eaten, the larger burbot did not eat more organisms than smaller burbot ($r^2 = 0.01$). My conclusion agrees with that of Clemens (1951) who stated, "As the burbot increase in size they do not appear to eat greater numbers of fish but to take larger fish."

Because of their small numbers, burbot were not important predators of alewives in Little Bay de Noc. However, their inclination to consume many fish and the intensive predation on alewives by the few burbot in the bay during the summer suggest that they may well be important predators of alewives in the winter when both species inhabit deep areas of Lake Michigan.

Clemens (1951) and Van Oosten and Deason (1938) also found that burbot of the same size that I sampled fed mostly on fish but that a significant amount of invertebrates were also eaten. In my study practically no invertebrates were eaten, possibly because of the abundant alewives and smelt.

Bowfin

Smelt were found in 3 of the 9 spring-caught bowfins, and alewives were in 3 of 19 collected in the summer (Table 14). No other forage fish were identified. Crayfish were found in 59% of all bowfins collected. The high frequency of occurrence suggests that crayfish are probably the most important item in the diet. However, as Lagler and Applegate (1942) noted, the hard exoskeletons of crayfish tend to withstand the digestive processes longer than the soft bodies of fish. Thus, the smelt and alewives may have been more important components of the diet than indicated by the food remains.

Discussion

During June to August, exceedingly large numbers of alewives entered Little Bay de Noc to spawn. Their large numbers and presence in all areas of the bay made them a readily available food supply and they provided a substantial portion of the food of northern pike, smallmouth bass, walleye and burbot. In other waters, pike and walleyes are know to prey heavily on yellow perch. They did not prey on the abundant perch population in Little Bay de Noc, strongly suggesting that perch were buffered from pike and walleyes by the abundant alewife population. Northern pike also grew faster in Little Bay de Noc than is reported for other waters, probably because of the

abundant food supply provided by alewives. I conclude that mature alewives were beneficial to northern pike, walleyes and yellow perch.

Young-of-the-year alewives were present in large numbers from July to September but apparently because of their small size, were not readily eaten by the predators.

Acknowledgements

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Table 1.--Numbers of predator fish, collected by gear and season, Little Bay de Noc, 1966-68

(Number of stomachs with food, in parentheses)

Species and period	Gear				Total [1]
	Gill net	Trap net	Pound net	Shocker	
Northern pike					
Spring	27 (19)	36 (22)	1 (0)	..	64 (41)
Summer	137 (63)	42 (22)	5 (5)	55 (33)	239 (123)
Fall	95 (36)	..	3 (1)	1 (0)	102 (40)
Smallmouth bass					
Spring	1 (0)	2 (2)	..	..	3 (2)
Summer	3 (1)	66 (44)	..	18 (12)	87 (57)
Fall	..	..	21 (9)	..	22 (9)
Walleye					
Spring	1 (0)	22 (10)	..	..	23 (10)
Summer	14 (7)	21 (13)	..	27 (14)	62 (34)
Fall	10 (7)	..	8 (4)	..	18 (11)
Burbot					
Spring	3 (2)	30 (30)	..	..	33 (32)
Summer	4 (3)	..	1 (1)	..	5 (4)
Fall	2 (2)	..	3 (3)	..	5 (5)
Bowfin					
Spring	1 (0)	8 (5)	..	..	9 (5)
Summer	8 (6)	3 (2)	..	7 (6)	19 (15)
Fall	..	..	1 (0)	..	1 (0)

[1] Five angler-caught fish included in total.

Table 2. --Body measurements, expressed as percentage of total length, of various prey species in Little Bay de Noc

(Range, in parentheses)

	Prey species				
	Alewife	Smelt	Yellow perch	Trout-perch	Spottail shiner
Number examined	10	6	3	3	3
Range in length (inches)	5.6-7.0	3.0-7.6	5.2-6.0	3.0-3.7	3.3-4.1
Measurement:					
Tip of snout to posterior margin of opercle	22 (21-22)	..	..	26 (25-26)	..
Tip of snout to posterior margin of supraoccipital	16 (15-17)	13 (13-14)	..	22 (20-23)	..
Origin of dorsal fin to tip of snout	38 (36-39)	44 (41-45)	..	..	..
Origin of dorsal to end of compressed caudal fin	64 (63-65)	..	..	66 (65-67)	..
Origin of anal fin to tip of snout	60 (59-62)	..	58 (58-59)	..	..
Origin of anal fin to end of compressed caudal fin	41 (37-42)	38 (36-39)	43 (42-45)	..	46 (45-48)
Caudal fin base to end of longest ray in upper lobe of caudal fin	20 (19-21)	..	17 (16-18)	..	19 (18-20)
Caudal fin base to end of longest ray in lower lobe of caudal fin	22 (21-24)	..	16 (14-17)	..	21 (20-22)

Table 3. --Forage fish collected per hour of electrofishing at five stations, Little Bay de Noc, 1966. Only fish 3 to 8 inches long included.

Species	Dates of collection						
	June		July			August	
	6-7	20-22	1-6	15-20	29-31	15-17	29-31
Alewife	261	358	120	11	4	..	..
Yellow perch	34	20	68	52	38	30	29
Rock bass	31	18	56	41	29	36	30
Pumpkinseed	20	6	18	21	12	18	12
Spottail shiner	6	2	1	2	4	1	1
Trout-perch	4	5	..	..	1	..	..
White sucker	2	1	2	2	..	..	..
Brown bullhead	..	..	..	4	..	1	3
Smallmouth bass	..	..	..	..	..	1	3

Table 4. --Forage fish collected per hour of electrofishing, Little Bay de Noc, 1968. Fish over 4 inches long not included.

Species	Dates of collection						
	June	July		Aug.	Sept.	Oct.	
	20	9-10	31	20-21	11	2-5	23
Alewife	..	5	241	1,033	41	1	..
Yellow perch	13	64	77	101	162	98	104
Black crappie	..	..	64	130	81	104	174
Pumpkinseed	..	10	75	6	28	32	3
Spottail shiner	1	10	19	22	8	29	37
Johnny darter	..	21	7	20	17	17	7
Largemouth bass	1	2	24	25	7	1	..
Rock bass	..	1	14	2	5	17	..
Trout-perch	..	..	6	10	6	..	1
White sucker	..	6	2	..	..	..	9

Table 5.--Average number of forage fish collected per gill net at three stations, Little Bay de Noc, 1967-68

Dates of collection	Species				
	Alewife	Yellow perch	Smelt	Spottail shiner	Trout-perch
May 4-9	..	21	251	26	3
May 23-29	< 1	13	4	11	3
June 13-20	223	36	2	10	11
July 6-10	198	25	2	11	5
July 25-31	116	26	4	9	1
August 15-21	37	16	4	10	1
September 6-11	8	28	15	11	6
September 26-October 2	< 1	18	22	12	5
October 23-24	..	13	20	1	5

Table 6. --Foods found in northern pike from Little Bay de Noc, 1966-68

	Frequency of occurrence			Percentage of total weight of prey,[1] and number of items in parentheses		
	Spring	Summer	Fall	Spring	Summer	Fall
Alewife	..	25	5	..	66 (76)	28 (7)
Smelt	41	4	12	76 (69)	8 (13)	45 (13)
Spottail shiner	2	4	4	2 (3)	2 (10)	9 (4)
Northern pike	2	1	..	1 (1)	<1 (3)	..
Trout-perch	8	5	..	8 (10)	5 (16)	..
Yellow perch	2	2	1	13 (1)	3 (5)	14 (1)
Rock bass	..	2	..	..	6 (5)	..
Smallmouth bass	..	2	1	..	1 (5)	3 (1)
Other fish[2]	..	3	2	..	8 (9)	1 (4)
Unidentified fish	19	9	15	(14)	(22)	(19)
Crayfish	..	1	..	..	(2)	..
Mayfly nymphs and dragonfly adults	..	2	8	..	(4)	(13)

[1] Includes only the prey fish that could be identified and measured. Weight was: spring--54.3 ounces; summer--110.9 ounces; fall--12.6 ounces.

[2] Includes bowfin, golden shiner (Notemigonus crysoleucas), white sucker, ninespine stickleback (Pungitius pungitius), white bass (Roccus chrysops), pumpkinseed, largemouth bass, and johnny darter.

Table 7. --Average length (inches) of fish eaten by northern pike of different sizes in Little Bay de Noc, 1966-68

(Number of prey fish measured, in parentheses)

Prey species	Size group of northern pike (inches)								
	3.9-7.8	7.9-11.7	11.8-15.7	15.8-19.6	19.7-23.6	23.7-27.5	27.6-31.4	31.5-35.4	35.5-39.3
Alewife	..	0.8 (1)	6.4 (6)	6.0 (26)	6.0 (20)	5.5 (19)	6.1 (10)	6.7 (1)	..
Smelt	3.9 (1)	..	3.7 (6)	5.0 (10)	5.6 (35)	5.9 (19)	5.9 (1)	6.0 (7)	5.7 (16)
Spottail shiner	..	3.5 (7)	2.7 (5)	3.8 (4)	3.5 (1)	..	..	..	..
Northern pike	..	3.3 (2)	3.1 (1)	..	6.3 (1)	..	..	..	..
Trout-perch	..	3.3 (4)	3.2 (8)	3.6 (4)	4.2 (7)	4.3 (3)	..	..	..
Yellow perch	..	..	..	4.9 (2)	5.2 (4)	10.2 (1)	..	..	..
Rock bass	..	3.1 (1)	..	..	..	4.9 (2)	..	5.1 (2)	..
Smallmouth bass	..	3.3 (3)	3.1 (2)	3.5 (1)	..	..	..	..	..
Other fish [1]	1.0 (2)	2.6 (6)	2.0 (2)	4.1 (2)	..	..	9.4 (1)	..	..
Average and total	2.0 (3)	3.1 (24)	3.8 (30)	5.3 (49)	5.5 (68)	5.5 (44)	5.4 (12)	5.9 (10)	5.7 (16)

[1] Includes bowfin, golden shiner, white sucker, ninespine stickleback, white bass, pumpkinseed, largemouth bass and johnny darter.

Table 8. --Foods found in smallmouth bass from Little Bay de Noc, 1966-68

	Frequency of occurrence			Percentage of total weight of prey,[1] and number of items in parentheses		
	Spring	Summer	Fall	Spring	Summer	Fall
Alewife	..	10	..	..	60 (10)	..
White suckers	..	1	..	..	2 (1)	..
Spottail shiner	..	5	..	..	7 (6)	..
Brown bullhead	..	1	..	..	<1 (3)	..
Northern pike	..	7	..	..	19 (6)	..
Yellow perch	..	5	..	..	1 (4)	..
Johnny darter	..	10	..	..	6 (33)	..
Rock bass	..	2	..	..	4 (4)	..
Unidentified fish	33	42	41	(1)	(92)	(11)
Crayfish	33	21	4	(1)	(19)	(1)
Mayfly nymphs	..	2	..	..	(2)	..

[1] Includes only the prey fish that could be identified and measured. Weight was: summer--14.2 ounces.

Table 9.--Average length (inches) of fish eaten by smallmouth bass of different sizes in Little Bay de Noc, 1966-68

(Number of prey measured, in parentheses)

Prey species	Size group of smallmouth bass (inches)		
	7.9-11.7	11.8-15.7	15.8-19.6
Alewife	5.8 (3)	5.8 (7)	..
White suckers	..	3.5 (1)	..
Spottail shiner	2.8 (2)	3.5 (2)	3.0 (2)
Brown bullhead	1.2 (3)	..	..
Northern pike	4.8 (5)	6.3 (1)	..
Yellow perch	1.7 (3)	2.4 (1)	..
Johnny darter	1.8 (7)	1.8 (26)	..
Rock bass	1.2 (3)	..	3.5 (1)
Average and total	2.8 (26)	2.8 (38)	3.1 (3)

Table 10.--Foods found in walleyes from Little Bay de Noc, 1966-68

	Frequency of occurrence			Percentage of total weight of prey,[1] and number of items in parentheses		
	Spring	Summer	Fall	Spring	Summer	Fall
Alewife	..	31	16	..	71 (33)	40 (14)
Coho salmon	4	..	..	6 (1)	..	..
Smelt	39	..	6	94 (25)	..	25 (4)
White suckers	..	3	..	..	26 (2)	..
Spottail shiner	..	3	..	..	1 (2)	..
Brown bullhead	..	3	6	..	<1 (7)	35 (17)
Trout-perch	..	2	..	..	1 (1)	..
Unidentified fish	26	29	56	(9)	(23)	(12)
Mayfly nymphs	..	2	6	..	(54)	(45)

[1] Includes only the prey fish which could be identified and measured. Weight was: spring--12.1 ounces; summer--39.2 ounces; fall--2.5 ounces.

Table 11. --Average length (inches) of fish eaten by walleyes of different sizes in Little Bay de Noc, 1966-68

(Number of prey measured, in parentheses)

Prey species	Size group of walleyes (inches)					
	7.9-11.7	11.8-15.7	15.8-19.6	19.7-23.6	23.7-27.5	27.6-31.4
Alewife	..	2.4 (5)	5.8 (5)	5.7 (23)	3.5 (13)	6.3 (1)
Coho salmon	..	..	..	5.1 (1)	..	..
Smelt	..	..	3.8 (5)	5.0 (10)	5.5 (14)	..
Spottail shiner	2.8 (1)	..	..	..	3.5 (1)	..
White sucker	..	..	..	9.8 (1)	9.8 (1)	..
Brown bullhead	..	..	1.3 (7)	..	1.9 (17)	..
Trout-perch	..	..	..	4.3 (1)	..	..
Average and total	2.8 (1)	2.4 (5)	3.4 (17)	5.6 (86)	3.7 (46)	6.3 (1)

Table 12.--Foods found in burbot from Little Bay de Noc, 1966-68

	Frequency of occurrence			Percentage of total weight of prey,[1] and number of items in parentheses		
	Spring	Summer	Fall	Spring	Summer	Fall
Alewife	..	80	..	..	100 (12)	..
Smelt	64	..	..	76 (234)	..	..
Spottail shiner	6	..	..	< 1 (5)	..	..
Yellow perch	27	..	..	20 (18)	..	..
Johnny darter	3	..	40	< 1 (1)	..	72 (29)
Rock bass	3	..	20	3 (1)	..	28 (1)
Unidentified fish	45	40	100	(37)	(3)	(8)
Mayfly nymphs and beetle larvae	9	40	20	(5)	(2)	(78)

[1] Includes only the prey fish which could be identified and measured. Weight was: spring--190.6 ounces; summer--10.7 ounces and fall--0.6 ounce.

Table 13.--Average length (inches) of fish eaten by burbot of different sizes in Little Bay de Noc, 1966-68

(Number of prey measured, in parentheses)

Prey species	Size group of burbot (inches)			
	15.7-19.6	19.7-23.6	23.7-27.5	27.6-31.4
Alewife	..	5.9 (4)	6.0 (8)	..
Smelt	5.6 (20)	5.6 (85)	5.7 (95)	5.8 (34)
Spottail shiner	..	3.7 (4)	2.8 (1)	..
Yellow perch	..	5.6 (7)	6.8 (8)	6.3 (3)
Johnny darter	1.4 (27)	1.4 (2)	2.0 (1)	..
Rock bass	..	2.4 (1)	7.5 (1)	..
Average and total	3.1 (47)	5.4 (103)	5.8 (114)	5.9 (37)

Table 14.--Foods found in bowfin from Little Bay de Noc, 1966-68

	Frequency of occurrence[1]		Percentage[2] of total weight of prey, and number of items in parentheses	
	Spring	Summer	Spring	Summer
Alewife	..	16	..	100 (3)
Smelt	33	..	100 (4)	..
Unidentified fish	22	16	(4)	(3)
Crayfish	33	74	(4)	(38)

[1] A single bowfin collected in the fall contained no food.

[2] Includes only the prey fish which could be identified and measured. Weight was: spring--1.6 ounces; summer--2.3 ounces.

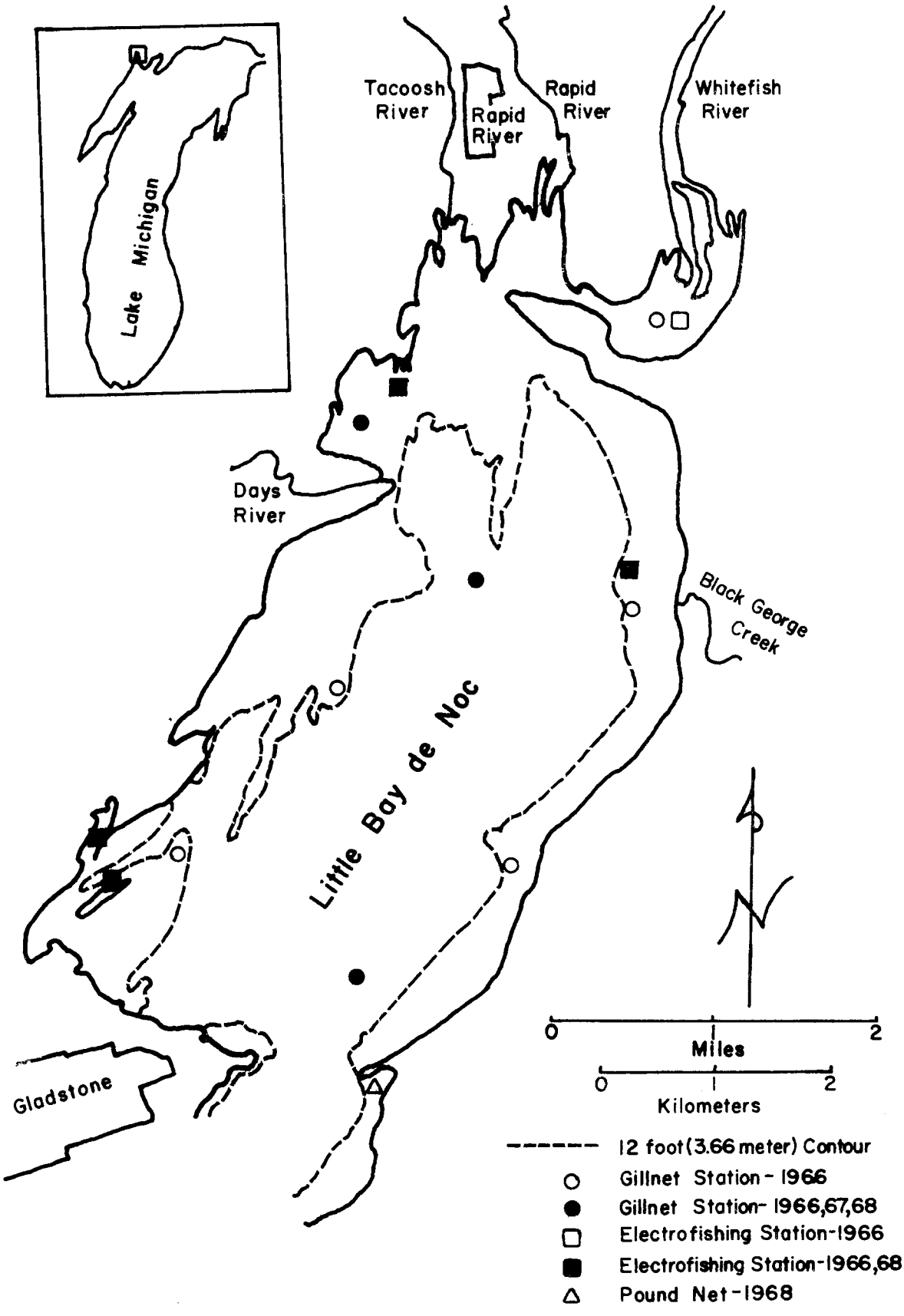

Figure 1.--Fish collection station, Little Bay de Noc, 1966-68.

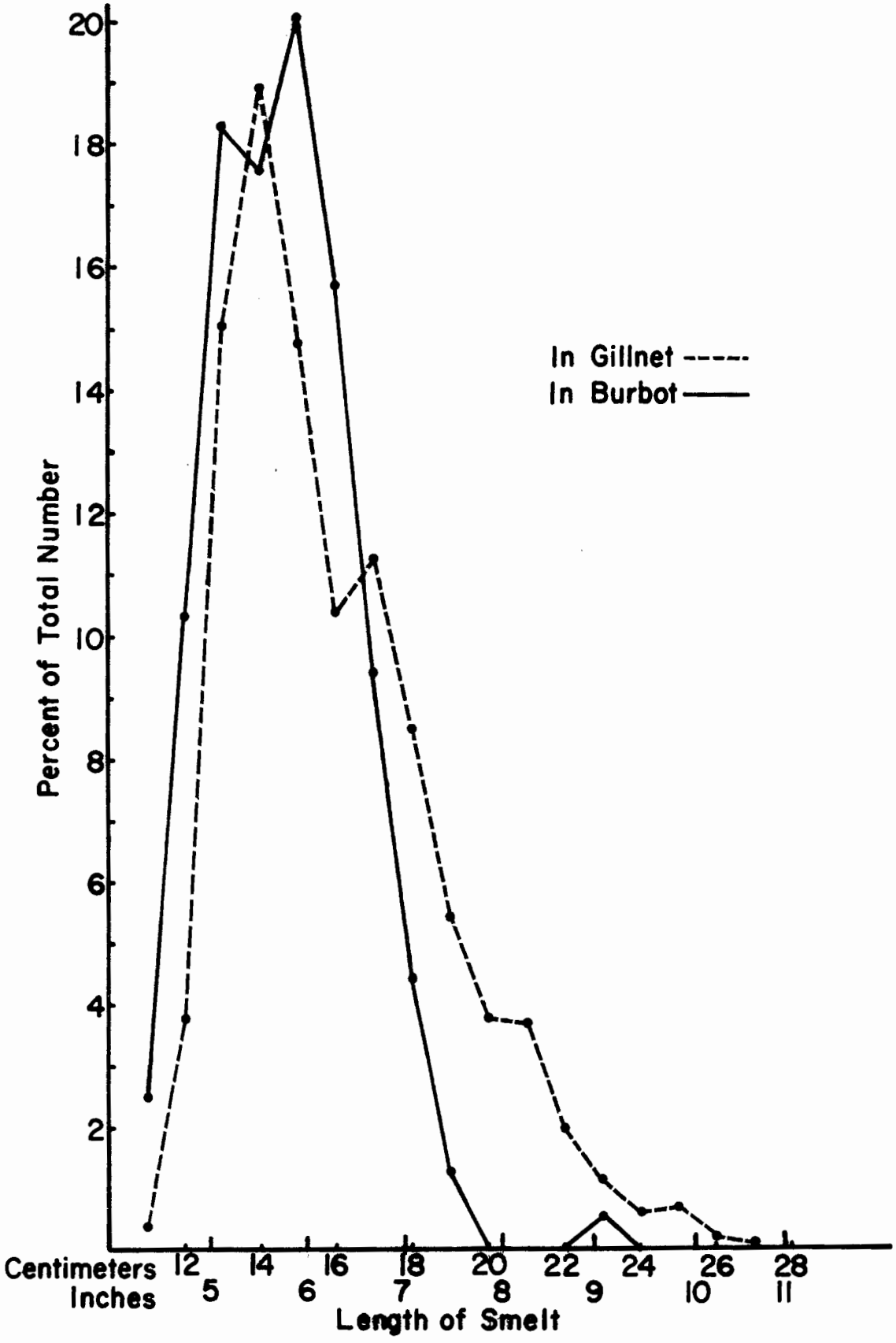

Figure 2. --Length frequency of smelt from a gill net and from burbot stomachs collected in or near the estuary of the Whitefish River, 18-20 April 1968.

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