Technical Papers

OF THE U.S. FISH AND WILDLIFE SERVICE

98. Food of Alewives, Yellow Perch, Spottail Shiners, Trout-Perch, and Slimy and Fourhorn Sculpins in Southeastern Lake Michigan

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Technical Papers.—This publication series of the Fish and Wildlife Service (formerly the Bureau of Sport Fisheries and Wildlife) comprises reports of investigations related to sport fish and sport fisheries. Each is published as a separate paper, but for economy several may be issued in a single cover. The Service distributes a limited number of these reports for the use of Federal and State agencies and cooperators. See Technical Papers 66 and 67 (in one cover) for list of issues prior to Technical Paper 53.

53. Chronic Effects of Methoxychlor on Bluegills and Aquatic Invertebrates, by Harry D. Kennedy, Lafayette L. Eller, and David F. Walsh. 1970. 18 pp.
54. Annotated List of the Parasites of Bluefish *Pomatomus saltatrix*, by Herbert G. Anderson, Jr. 1970. 15 pp.
55. Effects of Malathion on Two Warmwater Fishes and Aquatic Invertebrates in Ponds, by Harry D. Kennedy and David F. Walsh. 1970. 13 pp.
56. Changes in the Fish Population in Lake Francis Case in South Dakota in the First 16 Years of Impoundment, by Charles R. Gasaway. 1970. 30 pp.
57. Biology of the Pile Perch, *Rhacochilus vacca*, in Yaquina Bay, Oregon, by Paul G. Wares. 1971. 21 pp.
58. Gas-Bubble Disease of Salmonids: A Critical Review, by Robert R. Rucker. 1972. 11 pp.
59. Studies of Estuarine Dependence of Atlantic Coastal Fishes. Data Report II: Southern Section, New River Inlet, N. C., to Palm Beach, Fla. *R. V. Dolphin* Cruises 1967–68: Zooplankton volumes, surface-meter net collections, temperatures, and salinites, by John Clark, W. G. Smith, Arthur W. Kendall, Jr., and Michael P. Fahay. 1970. 97 pp.
60. Studies on Selected Myxobacteria Pathogenic for Fishes and on Bacterial Gill Disease in Hatchery-Reared Salmonids, by G. L. Bullock. 1972. 30 pp.

(Papers 61 and 62 are in one cover)

61. Tests of Variations of the Abernathy Salmon Diet, 1970, by Laurie G. Fowler, Joe L. Banks, and Joseph W. Elliott. 1972. 13 pp.
62. Efficacy, Toxicity, and Residues of Nifurpirinol in Salmonids, by Donald F. Amend. 1972. 13 pp.
63. Biological Studies on the Hemoflagellates *Cryptobia cataractae* and *Cryptobia salmonsitica*, by Robert E. Putz. 1972. 25 pp.
64. Alteration Tests of the Abernathy Salmon Diet, 1971, by Laurie G. Fowler and Joe L. Banks. 1972. 12 pp.
65. Handbook of Procedures for Pesticide Residue Analysis, by Roger C. Tindle. 1972. 88 pp.

(Papers 66 and 67 are in one cover)

66. Toxicity of Some Insecticides to Four Species of Malacostracan Crustaceans, by Herman O. Sanders. 1972. 19 pp.
67. Effects of Water Hardness on the Toxicity of Several Organic and Inorganic Herbicides to Fish, by Anthony Inglis and Edward L. Davis. 1972. 22 pp.
68. History of Salmon in the Great Lakes, 1850–1970 by John W. Parsons. 1973. 80 pp.
69. Thermal Characteristics of Lake Michigan, 1954–55, by John F. Carr, James W. Moffett, and John E. Gannon. 1973. 143 pp.
70. Seasonal Variation of Nitrogen, Phosphorus, and Chlorophyll *a* in Lake Michigan and Green Bay, 1965, by Herbert E. Allen. 1973. 23 pp.

(Papers 71 through 82 are in one cover)

71. Ecological Changes During the Transitional Years of Final Filling and Full Impoundment (1966–70) of Lake Oahe, an Upper Missouri River Storage Reservoir, by Fred C. June. 1974. 57 pp.
72. Physical and Chemical Characteristics of Lake Oahe, 1968–69, by James H. Selgeby and William E. Jones. 1974. 18 pp.
73. Invertebrate Macrobenthos of Lake Oahe, 1968–69, by William E. Jones and James H. Selgeby. 1974. 11 pp.

Technical Papers

OF THE U.S. FISH AND WILDLIFE SERVICE

98. Food of Alewives, Yellow Perch, Spottail Shiners, Trout-Perch, and Slimy and Fourhorn Sculpins in Southeastern Lake Michigan

By LaRue Wells

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Washington, D.C. • 1980

Library of Congress Cataloging in Publication Data

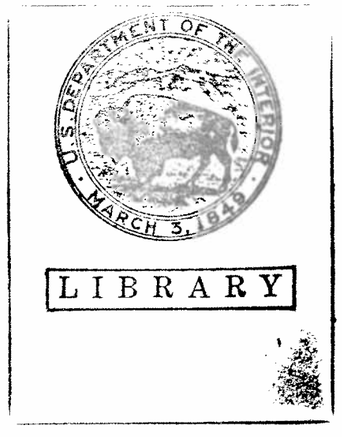
Wells, LaRue.

Food of alewives, yellow perch, spottail shiners, trout-perch, and slimy and fourhorn sculpins in southeastern Lake Michigan.

(Technical papers of the U.S. Fish and Wildlife Service ; 98)

1. Fishes—Michigan, Lake. 2. Fishes—Food. 3. Forage fish—Michigan, Lake. 4. Pontoporeia. I. Title. II. Series: United States. Fish and Wildlife Service. Technical papers of the U.S. Fish and Wildlife Service ; 98.

SH11.A313 no. 98 [QL625.5] 639s [597.092'9774] 79-607916



Food of Alewives, Yellow Perch, Spottail Shiners, Trout-Perch, and Slimy and Fourhorn Sculpins in Southeastern Lake Michigan[1]

By

LaRue Wells

U.S. Fish and Wildlife Service
Great Lakes Fishery Laboratory
1451 Green Road
Ann Arbor, Michigan 48105

Abstract

Stomachs of 1,064 alewives (*Alosa pseudoharengus*), 1,103 yellow perch (*Perca flavescens*), 246 spottail shiners (*Notropis hudsonius*), 288 trout-perch (*Percopsis omiscomaycus*), 454 slimy sculpins (*Cottus cognatus*), and 562 fourhorn sculpins (*Myoxocephalus quadricornis*) from Lake Michigan were examined for food contents. Fish were sampled primarily from March to November and nearly all were caught at the bottom in the southeastern part of the lake near Saugatuck, Michigan. Depths of capture (m) were: alewives, 5 to 110; yellow perch, 5 to 26; spottail shiners, 5 to 31; trout-perch, 9 to 46; slimy sculpins, 31 to 91; and fourhorn sculpins, 73 to 110. Alewives, particularly those less than 140 mm long, fed chiefly on zooplankton; *Pontoporeia* usually constituted most of the rest of the food, although *Mysis* and immature midges were occasionally eaten in considerable quantity. Yellow perch ate primarily *Pontoporeia*, fish, fish eggs, *Mysis*, and crayfish; *Pontoporeia* was consumed most heavily by perch less than 250 mm long and those in relatively deep water, fish (mainly slimy sculpins) by those 200 mm long or longer, *Mysis* by those in deep water, and crayfish by those on rocky bottom. Spottail shiners fed most commonly on immature midges, *Pontoporeia*, zooplankton, fingernail clams, and (in July only) fish eggs; immature midges were eaten mainly by shiners in shallow water; and *Pontoporeia* by those in deeper areas. The diet of trout-perch was strongly dominated by *Pontoporeia* and immature midges. Slimy sculpins ate *Pontoporeia* almost exclusively. Fourhorn sculpins fed almost entirely on *Mysis* and *Pontoporeia*; *Pontoporeia* was particularly important in the diet of the larger fish.

The need for data on life histories of Great Lakes fishes has grown in recent years, partly as a result of greatly expanded programs for management of the fish stocks, but also due to increased public concern over effects of man-induced changes in the environment. The data are needed by those engaged in such diverse activities as determining the number of predators (e.g., stocked salmon and trout) that can be supported by the forage base of a given lake, preparing environmental impact statements, and studying the paths of chemical contaminants through biological systems. Although the literature pertaining to the Great Lakes has enlarged greatly in recent years, it nevertheless remains deficient in information on life histories of fishes; consequently, investigators requiring such data often must seek it in files of unpublished material. A search for unpublished data, although occasionally useful, is often extremely time-consuming and otherwise unsatisfactory. The purpose of the present paper is to make more readily available certain life history information relating specifically to the food of six fishes common in southeastern Lake Michigan—the alewife (*Alosa pseudoharengus*), yellow perch (*Perca flavescens*), spottail shiner (*Notropis hudsonius*), trout-perch (*Percopsis omiscomaycus*), slimy sculpin (*Cottus cognatus*), and fourhorn sculpin (*Myoxocephalus quadricornis*).

Of the study species as they occur in Lake Michigan proper, only the alewife has been the subject of considerable food-habits investigation: in shallow Indiana waters (Rhodes et al. 1974; Webb and McComish 1974; and Rhodes and McComish 1975), and in Wisconsin (Morsell and Norden 1968; Norden 1968). Feeding habits have been discussed for trout-perch in the area of a power plant in the extreme southeastern part of the lake (Tomlinson and Jude 1977), and for yellow perch (Hauer 1975) and spottail shiners (Anderson and Brazo 1978) at a power plant site in the east-central part. Data have also been reported for alewives (Morsell and Norden 1968; Gannon 1972), yellow perch

[1]Contribution 547 of the Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service.

(Toth 1959; Dodge 1968), and spottail shiners (Basch 1968) in various portions of Green Bay, most of which is environmentally distinct from the lake proper. Three of the Green Bay reports (Toth 1959; Basch 1968; Gannon 1972) presented little more than a general overview. The food of slimy and deepwater sculpins in Lake Michigan has not been previously described.

Methods and Materials

Collections (except for a few of the alewives) were made off Saugatuck, Michigan, from the U.S. Fish and Wildlife Service research vessel *Cisco*, in 1965 (mostly), 1966, 1972, 1974, and 1975. Most of the fish were collected with bottom trawls, but some alewives were caught in mid-water trawls, and some alewives and nearly all yellow perch in bottom gill nets. Among fish caught at the bottom, most were from smooth bottom (sand, silt, or mud); some alewives and yellow perch came from a rocky area. Details such as depths of collection and numbers of specimens varied considerably among species, and are given in later sections for individual species.

All specimens except some of the perch were preserved whole (abdomen incised) in 10% formalin and taken to the Great Lakes Fishery Laboratory (GLFL). There, stomach contents were analyzed under a binocular microscope, usually at a magnification of 9X. Stomach contents of 65% of the perch were examined fresh on shipboard, without magnification. The total length and sex of each fish were recorded with the food data. Fish that did not contain identifiable food are not included in this report.

Stomach analyses included a consideration of both number and volume of each food item. First, counts were made of individuals of each item, with two exceptions: the numbers of fish eggs exceeding about 100 in yellow perch stomachs were estimated, usually on the basis of actual counts of eggs in fractions of the total contents; and zooplankters in alewife stomachs were neither counted nor were their numbers estimated. After the counts were completed, visual estimates were made of the percentage contribution of each item to the total volume of identifiable food. The volume data provide the basis for most of the discussion that follows. I used the actual counts in the report only to show maximum numbers of different food items observed in stomachs of each fish species. The meticulous separation of stomach contents required to obtain the counts, however, provided excellent preparation for estimates of the percentages of the total volume contributed by each item. I regard these visual estimates to be equally adequate for this study as any I might have derived from tedious volumetric measurements (e.g., in a graduated centrifuge tube) of food items that were usually partly digested and often fragmented. I agree with Hynes (1950), who suggested that sophisticated methods of measuring food volumes may give spurious impressions of accuracy.

Percentages of total volume made up by each item for a group (e.g., a size category) of fish represent simple unweighted averages of data for individual stomachs in the group; i.e., each stomach was given equal weight regardless of the total volume of food it contained.

Data for the sexes were combined in all species, after preliminary examination failed to show any obvious differences in food according to sex.

Food of the Various Species

Alewives

The following observations were derived from 1,064 alewives—835 from smooth bottom, 141 from rocky bottom, and 88 from mid-water. Fish from smooth bottom were obtained with trawls during January, March through August, and November, in either 1965 or 1966. Depth of capture ranged from 5 to 110 m. Fish were 44-213 mm long, 87% falling in the 120- to 199-mm range. Collections from rocky bottom were made with gill nets in May and June 1966. Nets were fished overnight at depths of 9-15 m. Fish lengths ranged from 131 to 207 mm. Mid-water collections were made with a trawl fished on 20 August 1965 along a transect from Saugatuck to Racine, Wisconsin. Samples were taken near midday and near mid-lake where bottom depth was 159 m, and at night on the west side of the lake where bottom depths were 46, 73, and 110 m. At each sampling depth the trawl was towed obliquely through the upper 38 m of the water column. Probably most, if not all, fish came from strata more than 11 m beneath the surface, i.e., below the epilimnion. Observations with underwater television a few days before mid-water samples were taken (GLFL, unpublished data) showed that except for young of the year, which were lacking in the samples, alewives avoided the warm epilimnial waters (temperature about 20 C) prevailing in southern Lake Michigan at that time. Fish lengths ranged from 78 to 207 mm, of which 75% were 120-199 mm.

Inasmuch as preliminary examination indicated that food of alewives from smooth bottom and from rocky bottom were closely similar, all data from bottom collections were combined. The food data (Table 1) are presented separately by depth of collection (5-18, 22-64, and 73-110 m) for fish from bottom, and by bottom depth at sampling site (46-110, and 159 m) for fish from mid-water; data in each depth category were further separated by length of fish (< 140, 140-179, and > 179 mm). No consideration was given date of collection, since no important seasonal changes in diet among fish in the samples were detected.

Alewives from Bottom

Alewives from bottom, particularly smaller individuals and those from depths of 22-64 m, ate chiefly zooplankton (Table 1). Zooplankton occurred in stomachs of all fish in the smallest size group, except for a few from depths of 5-18 m. It constituted over 90% of the volume of food of small fish from all depths; 63-72% of the volume in each of the other size groups in the 22- to 64-m depth range; and 20-63% of the volume in the rest of the size and depth categories.

Pontoporeia made up the bulk of the diet not contributed by zooplankton except at depths of 5-18 m, where it was eaten only sparingly. It was consumed by fish of all sizes, but most commonly by large ones. *Pontoporeia* was particularly prominent in fish from depths of 73-110 m, where it constituted 54 and 73% of the volume in the intermediate and largest length categories, respectively. Immature midges (larvae and pupae combined) made up most of the food other than zooplankton at depths of 5-18 m, composing 7, 19, and 30% of the volume among alewives in the successively larger length categories. Fish eggs, bryozoan statoblasts, and algae at 5-18 m or *Mysis* at 73-110 m occasionally made up 5-7% of the volume of food in a fish length category. Twelve additional items occurred in the stomachs—some rather frequently (Table 1)—but only ostracods, terrestrial insects, mayfly nymphs, and macrophyte remains ever contributed more than trace amounts to the volume of food.

The main purpose of sampling in the rocky area, a favored spawning ground of yellow perch, was to investigate the possibility of alewife predation on perch eggs. This aspect of alewife feeding was of special significance because alewives have been implicated in a precipitous decline of yellow perch that occurred in Lake Michigan in the early and middle 1960's (Smith 1970; Wells and McLain 1973). None of the alewives from rocky bottom, most of which were caught during the perch spawning season, contained perch eggs. Further information (GLFL, unpublished data), not given elsewhere in this report, showed that no perch eggs had been eaten by 201 additional alewives containing food, caught on perch spawning grounds in Lake Michigan near Michigan City, Indiana, during the perch spawning season of 1966. These results, though not conclusive, suggest that alewife predation on perch eggs occurs uncommonly, if at all. Probably the eggs are protected by the gelatinous material in which they are imbedded.

Alewives from Mid-water

Alewives from mid-levels fed even more heavily on zooplankton than did those collected at the bottom; every fish contained this food item (Table 1). In the samples taken where bottom depths were 46-110 m, the only food organisms of consequence besides zooplankton were *Mysis* and *Pontoporeia*. Although neither contributed much to the diet of smaller fish, *Mysis* made up 22%, and *Pontoporeia* 10%, of the volume of food of fish over 179 mm long. Less important items included bryozoan statoblasts, terrestrial insects, immature midges, and algae. Where bottom depth was 159 m, all stomachs contained only zooplankton and trace quantities of algae. *Pontoporeia* and *Mysis* were lacking in these stomachs, probably because the levels at which the samples were collected were well above those occupied by these organisms in daytime.

Supplementary Data on Food of Alewives

Zooplankton.—I collected some general information regarding the various components of zooplankton in the alewife diet, although I did not make detailed taxonomic separations of the organisms, which often numbered several thousand individuals in a single stomach.

Copepods and cladocerans each contributed heavily to the food of alewives. Both were common in the diet of fish taken on all collection dates, except that cladocerans were rare in January–March and absent in April. The most frequently eaten zooplankter was the copepod *Cyclops bicuspidatus*, which occurred in the diet year-round and at all depths. The cladoceran *Bosmina longirostris* ranked second; it was observed in stomachs taken from all depths and in all months except April; however, it was abundant only during July–November.

I identified four taxons of copepods besides *C. bicuspidatus*. *Limnocalanus macrurus* was abundant in stomachs collected in March and April, and was present in smaller numbers in most other collections. It did not occur in fish from very shallow water (all collected when nearshore waters were warm) or from mid-water. *Diaptomus* spp. was eaten year-round and at all depths, occasionally in large numbers. *Epischura lacustris* was common in the diet during July–November, but lacking at other times. Harpactacoids occurred in stomachs collected during May–November, occasionally in rather large numbers. Their absence in stomachs taken from January to April was probably related to depths of sampling; few of the samples taken during that period were from depths of 37 m or

Table 1. *Food items (percentage of total volume and, in parentheses, frequency of occurrence) in stomachs of alewives caught on bottom or in mid-water in southeastern Lake Michigan, 1965-66.*[a]

	Type of collection, depth of collection (m), fish length (mm), and (in parentheses) number of fish																			
	Bottom								Mid-water											
	5-18 m		22-64 m				73-110 m			46-110 m[b]				159 m[b]						
Food item	<140	140-179	>179	<140	140-179	>179	<140	140-179	>179	<140	140-179	>179	<140	140-179	>179	<140	140-179	>179	<140	140-179	>179
	(76)	(312)	(48)	(43)	(248)	(62)	(12)	(140)	(35)	(25)	(33)	(12)	(16)	(16)	(2)						
Rhabdocoel cocoon		T (2)				T (1)															
Nematode		T (4)	T (4)		T (1)	T (5)															
Bryozoan statoblast	T (9)	1 (12)	5 (13)		T (2)																
Snail		T (4)	T (2)		T (3)	T (10)				T (4)											
Fingernail clam		T (4)	T (2)		T (10)	T (13)		T (1)	T (6)												
Leech		T (1)	T (2)					T (1)													
Zooplankton	92 (97)	63 (85)	42 (63)	97 (100)	72 (89)	63 (82)		5 (19)	7 (60)	2 (4)	6 (21)	33 (12)									
Ostracod	1 (20)	2 (19)	3 (19)		T (11)	T (19)			73 (86)			10 (25)									
Mysis	T (1)	T (2)	T (8)		1 (10)	1 (8)		T (1)		1 (16)	1 (3)										
Pontoporeia	T (1)	5 (9)	8 (19)	3 (5)	27 (48)	34 (58)				2 (12)	3 (15)										
Terrestrial insects	T (1)	1 (4)	4 (6)		T (2)	1 (2)		T (1)													
Mayfly nymph		T (T)	2 (2)																		
Immature midge	7 (28)	19 (48)	30 (63)		T (9)	T (7)		T (1)													
Water mite		T (1)	T (1)		T (1)	T (2)															
Fish eggs	T (1)	6 (11)	T (4)					T (1)	T (3)												
Fish scales	T (1)	T (1)							T (8)	T (8)	T (3)	T (8)	T (100)	T (100)							
Algae	T (20)	3 (22)	5 (21)		T (9)	T (5)															
Duckweed		T (T)	T (2)																		
Macrophyte remains		1 (1)	1 (2)		T (1)	T (3)															

[a]T = Trace (less than 0.5%).
[b]Depths shown for mid-water collections are bottom depth; at each sampling site, mid-water trawls were hauled obliquely from a depth of 38 m to the surface.

less, the depth range from which all alewives containing harpactacoids were taken.

I observed six species of cladocerans in addition to *B. longirostris*. *Polyphemus pediculus* was present in stomachs only in July and August, but was occasionally numerous, especially in samples from shallow water. *Daphnia retrocurva* was occasionally in the diet from July to November; it occurred in stomachs from all depths. (Ephippia of *Daphnia* appeared rather frequently in the stomachs collected in November.) *Holopedium gibberum* was present in stomachs collected from July to November at all depths, but was most common in fish from shallow water. *Leptodora kindti*, present in the diet in July–November, was occasionally consumed in large numbers in August. *Chydorus sphaericus* was common in the diet in August, and eaten in smaller numbers in July. *Eurycercus lamellatus* was observed in stomachs in July and August, but never in large numbers.

Other food.—All fish eggs identified in the stomachs were alewife eggs. The midges were from the genera *Paracladopelma*, *Parachironomus*, *Polypedilum*, and *Chironomus*, and the subfamily Orthocladiinae. The snails were *Valvata perdepressa* and *Limnaea*, and the fingernail clams were *Sphaerium nitidum* and *Pisidium*. The terrestrial insects were Diptera, Coleoptera, Hymenoptera, and Hemiptera. The most conspicuous alga was the large colonial *Botryococcus braunii*, but I also observed diatoms, as well as green and blue-green algae.

Maximum numbers of various nonzooplankton food items in individual alewife stomachs were as follows: fish eggs, 496; ostracods, 363; *Pontoporeia*, 252; bryozoan statoblasts, 178; midges, 37; fingernail clams, 37; snails, 11; *Mysis*, 10; rhabdocoel cocoons, 9; nematodes, 5; water mites, 3; terrestrial insects, 2; and leeches, 1.

Overall Importance of Various Food Items to Alewives

The domination of the diet of alewives in southeastern Lake Michigan by zooplankton may be even more pronounced than my data suggested. Zooplankton was a particularly important food of alewives from mid-water, a component of the alewife population that was poorly represented in the collections. The diet at mid-depths must be given considerable weight in estimates of the overall importance of various food items, because alewives in the pelagic zone often (probably usually) constitute a sizable segment of the total population in Lake Michigan (GLFL, unpublished data).

Although *Pontoporeia* was easily the second most important item of diet, usually constituting the bulk of nonzooplankton food, it may not be as important overall as my observations suggested. *Pontoporeia*'s contribution was greatest on bottom in deeper waters, where alewives concentrate only during the coldest months (Wells 1968), when food consumption is presumably low.

Mysis, although not well represented in stomach contents of fish from the bottom, may nevertheless be of considerable importance in the total diet of alewives, since it was common in the stomachs of larger alewives sampled at night at mid-depths. A more extensive analysis of the food of alewives from mid-water is necessary, however, before a sound estimate of the importance of this organism in the diet can be made.

The only other food of consequence seemed to be immature midges. However, they were prominent in the diet of only the alewives taken at 5-18 m; consequently I do not believe that their overall importance is great, because it seems unlikely that the alewife normally spends a major portion of its life on bottom at depths less than 18 m.

Results of Previous Studies

Previous studies have generally emphasized the importance of zooplankton in the diet of Lake Michigan alewives. In Indiana studies, zooplankton made up about 72% of the volume of identifiable food in alewives collected at 10 m during June–October (Rhodes and McComish 1975), and 45% in alewives collected at 5-15 m in May–October (Webb and McComish 1974). Morsell and Norden (1968) reported that zooplankton was the most important food of alewives in Milwaukee Harbor (collections made in June–July), and in open Lake Michigan at depths less than 1 m (June–August), and was a major component in terms of frequency of occurrence, of the diet in open Lake Michigan at depths of 9-30 m (May–October). Norden (1968) found that larval alewives collected from shallow water near Milwaukee during August–October had fed mainly on cladocerans and copepods.

Nonzooplankton items previously identified in the food of alewives from Lake Michigan proper have been generally similar to those I have described. Except for two organisms of special interest—*Pontoporeia* and alewife larvae—they are not discussed here.

Pontoporeia was found by Morsell and Norden (1968) to be the principal food of large alewives collected in Wisconsin waters at depths of 9 m or more. In terms of dry weight, it contributed heavily to the food of fish longer than 139 mm from depths of 9-30 m, and of fish longer than 119 mm from depths greater than 30 m. The authors stated, however, that their method of computing relative dry weights may have biased the results in favor of *Pontoporeia*, at the expense of zooplankton.

Larval alewives were reported in the food of adult alewives in Indiana waters (Rhodes et al. 1974; Webb and McComish 1974). The fish that had eaten larvae were collected at 5-15 m during August–October, and larvae composed well over half the volume of the diet in September. Fish larvae have not otherwise been mentioned in studies of food of Great Lakes alewives, except for unidentified larvae in a single stomach from Green Bay (Gannon 1972).

Yellow perch

Of 1,103 yellow perch used in this study, 573 were from smooth bottom and 530 from rocky bottom. Most were taken at depths of 5-18 m, but a few from smooth bottom came from depths of 20-26 m. Most perch were collected with gill nets (a few with trawls) in July and August 1965 (381 fish); in May and July–October 1972 (540); and in September–October 1974 (182). Fish lengths ranged from 150 to 349 mm. Nearly all fish less than 200 mm long were in the 1965 collections, and nearly all those over 250 mm long were in the 1972 and 1974 samples. The perch collected in 1972 and 1974 were examined without magnification aboard the *Cisco*. A few small food items (e.g., ostracods and rhabdocoel cocoons) probably were overlooked, but any such omissions should have been inconsequential. Judging by the contents of stomachs analyzed in the laboratory, the small items were generally unimportant, especially among fish as large as those that constituted the bulk of samples examined on shipboard.

Since food of yellow perch from smooth bottom and rocky bottom obviously differed in important respects, I considered the data from the two areas separately (Table 2). Data were further separated by collection period, depth of capture, and length for fish from smooth bottom; and by collection period and length for fish from rocky bottom. The fish were divided into three length categories: small, 150-199; medium, 200-249; and large, 250-349 mm.

Perch from Smooth Bottom

Yellow perch from smooth bottom ate chiefly *Pontoporeia*, fish, fish eggs, and *Mysis*, each of which occasionally made up all or nearly all the volume of food in fish of a given season, size, or depth category (Table 2). *Pontoporeia* was commonest in the diet of fish in the two smallest length classes and of those taken in the summer and from the deeper water. In August–September samples from depths of 13-22 m, *Pontoporeia* made up 98, 88, and 63% of the volume of food of perch in the successively larger size categories. Fish were consumed only by perch 200-249 or 250-349 mm long, with a single exception (the stomach of one perch in the smallest size class contained fish). Fish occasionally constituted the bulk of the diet of medium-sized and large perch—particularly the largest ones. Fish eggs were observed only in samples taken in May and July and were especially important in July, when they made up over 80% of the volume of food in fish of each of the three length groups at 5-13 m. *Mysis* contributed heavily to the diet of only the perch taken in October at depths of 20-26 m. In these samples *Mysis* made up 100, 87, and 46% of the volume of food in the successively larger size groups of perch.

Most important of the other items in the diet of yellow perch from smooth bottom were snails, leeches, zooplankton, crayfish, caddisflies, and midges; each occasionally made up 2 to 14% of the volume of food in a length or depth category, or collection period. Other items (Table 2) occurred only in trace amounts.

Perch from Rocky Bottom

Yellow perch from rocky bottom ate considerably greater quantities of crayfish than did those from smooth bottom (Table 2). Crayfish contributed most heavily to the diet of larger perch, making up about two-thirds of the volume of food in each of the two largest size categories in July–September. *Pontoporeia*, fish, and fish eggs made up most of the rest of the diet, although fish and fish eggs were less important than they were in perch from smooth bottom. *Pontoporeia* and fish eggs were eaten mainly by small or medium-sized perch, and fish mainly by the larger ones.

Other organisms eaten in more than trace amounts by perch from rocky bottom included snails, *Mysis*, terrestrial insects, and immature midges.

Supplementary Data on Food Items

Five species of fish were eaten by yellow perch. The slimy sculpin was by far the most common; individuals in stomachs were 25 to 105 mm long (average 73 mm). Alewives made up the next largest portion of the fish in the diet; most were young of the year 60-100 mm long (eaten mainly in October), but some were adults as long as 172 mm. Other fish eaten, all in small numbers, were trout-perch, 35-120 mm long; spottail shiners, 100-112 mm; and ninespine sticklebacks (*Pungitius pungitius*), 40-82 mm.

Fish eggs in the diet in May were those of the slimy sculpin; eggs consumed in July were not positively identified, but most appeared to be those of the alewife. Also identified in stomach contents were the crayfish *Orconectes propinquus;* the midge larvae *Chironomus, Procladius, Polypedilum, Paracladopelma, Monodiamesa*, and *Cryptochironomus;* larvae of the caddisfly *Molanna;* terrestrial Diptera; the fingernail

Table 2. *Food items (percentage of total volume and, in parentheses, percent frequency of occurrence) in stomachs of yellow perch collected on smooth or on rocky bottom in southeastern Lake Michigan, 1965-1974.*[a]

Bottom type, month of collection, depth of collection, fish length class and (in parentheses) number of fish (fish length classes: S [small], 150-199 mm; M [medium], 200-249 mm; L [large], 250-349 mm)

Food item	Smooth bottom																						Rocky bottom				
	May		July					August and September						October					May		July-September			October	
	18 m		5-13 m			15-18 m		9-11 m			13-22 m			13 m		20-26 m			18 m		5-15 m			13 m	
	M (7)	L (7)	S (84)	M (65)	L (11)	S (31)	M (45)	S (3)	M (20)	L (18)	S (14)	M (94)	L (44)	M (7)	L (12)	S (5)	M (24)	L (82)	M (56)	L (32)	S (11)	M (113)	L (264)	M (7)	L (47)
Rhabdocoel cocoon			T (18)	T (17)																					
Nematode				T (2)																					
Snail			2 (7)	T (9)		2 (2)	3 (18)					2 (4)									1 (9)	2 (4)			
Fingernail clam			T (6)	T (11)		T (2)	T (20)				T (29)	T (53)					T (4)					T (4)			T (2)
Leech		14 (14)				12 (26)	8 (27)					T (7)													
Zooplankton			4 (39)	4 (40)			T (4)																		
Ostracod			T (18)	T (15)			T (7)					T (3)										T (1)			
Mysis	9 (29)										T (7)	T (2)				100 (100)	87 (88)	46 (50)	3 (4)	3 (3)					
Pontoporeia	20 (29)		T (26)	3 (32)		63 (94)	64 (82)	100 (100)	20 (20)	6 (6)	98 (100)	88 (95)	63 (68)					T (1)	T (2)		64 (64)	9 (10)	6 (6)	43 (43)	1 (6)
Crayfish				4 (6)						11 (11)		3 (5)	9 (11)						4 (4)		17 (27)	67 (68)	68 (72)	29 (29)	40 (51)
Terrestrial insect			T (1)	T (3)																	9 (9)				
Caddisfly larva			T (8)	2 (3)		T (7)	T (18)		10 (10)	12 (17)		1 (4)	1 (2)												
Immature midge			4 (66)	4 (68)		8 (68)	12 (76)		T (5)		1 (50)	T (53)									9 (18)	1 (4)			
Fish	43 (43)	75 (86)		1 (2)			2 (2)		70 (70)	72 (72)	1 (7)	6 (7)	27 (34)	100 (100)	100 (100)		13 (17)	54 (56)	39 (43)	81 (88)		20 (20)	26 (27)	29 (29)	59 (68)
Fish eggs	29 (29)	11 (14)	90 (100)	82 (94)	100 (100)	14 (19)	10 (13)												54 (59)	16 (19)		2 (4)			

[a]T = Trace (less than 0.5%).

clams *Pisidium* and *Sphaerium*; the snails *Lymnaea*, *Valvata*, *Physa*, and *Amnicola*; leeches of the Erpobdellidae; and the cladoceran zooplankter *Eurycercus lamellatus*.

Maximum numbers of various food items observed in single stomachs were as follows: fish eggs, 4,000 (estimated); *Pontoporeia*, 425; zooplankters, 322; immature midges, 160; rhabdocoel cocoons, 75; snails, 20; caddisfly larvae, 17; ostracods, 16; leeches, 16; fingernail clams, 9; fish, 4; crayfish, 4; terrestrial insects, 3; and nematode, 1.

Results of Previous Studies

In a study conducted by Hauer (1975) in east-central Lake Michigan near Ludington, Michigan (about 145 km north of Saugatuck), yellow perch ate about the same food as did the perch from rocky bottom in the present study. Hauer's fish were collected at depths of 6-14 m, where bottom was mostly a mixture of sand and rock, during April-November. Perch 136-235 mm long fed chiefly on *Pontoporeia* and fish, and larger ones ate mainly fish and crayfish. Most fish in the diet were slimy sculpins, alewives, ninespine sticklebacks, and johnny darters (*Etheostoma nigrum*).

Spottail shiners

The analysis of diet of spottail shiners is based on 246 fish caught in March-August and November, in either 1965 or 1966. The shiners were taken at depths of 5-18 m, except for those collected in March, which were from depths of 24-31 m. Their lengths ranged from 62 to 143 mm; 79% were 90-120 mm long.

Since food habits did not vary consistently with length, I grouped all sizes for analyses. Differences did occur, however, according to season and depth, necessitating the following separation of data: March-June plus November, 5-13 and 18-31 m; July, 5 and 13 m; and August, 13 and 18 m.

Spottail shiners ate mostly immature midges, *Pontoporeia*, fish eggs, fingernail clams, and zooplankton (Table 3). Among shiners taken in March-June and November, the diet at 5-13 m was mainly immature midges, which made up 75% of the volume and occurred in 87% of the stomachs; at 18-31 m, it was predominantly *Pontoporeia*, which contributed 86% of the volume and occurred in all the stomachs. Among the fish collected in July, those from a depth of 5 m fed heavily on fish eggs (73% of food volume), and those from 13 m consumed chiefly fingernail clams (44%), zooplankton (20%), and immature midges (18%). Prominent in the diet of spottail shiners caught in August at 13 m were immature midges (48% of volume) and zooplankton (37%), and at 18 m, *Pontoporeia* (63%).

Organisms that occurred in the stomachs in much smaller quantities, but occasionally in more than trace volumes, were rhabdocoel cocoons, snails, leeches, ostracods, terrestrial insects, and caddisfly larvae.

Midges identified in the stomachs were mostly Chironominae (many *Chironomus*, a few *Microtendipes*), but several Orthocladiinae also were present. Zooplankters were predominantly the cladoceran *Eurycercus lamellatus*, although the copepods *Cyclops bicuspidatus* and to a lesser extent Harpacticoida were also represented. Terrestrial insects were Coleoptera (Curculionidae and Staphylinidae), Diptera, Hymenoptera, and Hemiptera; snails were *Lymnaea emarginata* (mostly) and *Valvata sincera*; fingernail clams were *Sphaerium striatinum*, *S. nitidum*, and *Pisidium*; fish eggs were mostly those of alewives (a few of trout-perch); and leeches were Erpobdellidae.

Maximum numbers of various items in individual stomachs were as follows: fish eggs, 759; *Pontoporeia*, 413; zooplankters (all *Eurycercus*), 259; immature midges, 207; rhabdocoel cocoons, 35; fingernail clams, 33; snails, 22; ostracods, 5; caddisfly larvae, 3; bryozoan statoblasts, terrestrial insects, and water mites, 2 each; and leeches, 1.

Spottail shiners occupying a surge-zone near Ludington (Anderson and Brazo 1978) fed much more heavily on terrestrial insects than did the shiners in the present study. This item constituted 44% of the volume of food (data for spring, summer, and fall combined) in the surge-zone study; most important by far, among other food items, were fish eggs in spring (71% of volume) and summer (25%) and midges in fall (45%). The authors suggested that terrestrial insects are highly available in the surge-zone because many are washed into that area from debris along the beaches during heavy seas.

Trout-Perch

Stomachs for food analysis came from 288 trout-perch collected from March to August and in November, either in 1965 or 1966. Depth of capture ranged from 9 to 46 m. Fish varied in length from 40 to 172 mm, but 87% were 80-139 mm long.

Food did not differ noticeably with size of fish, but it did change with either depth or season, or both. However, I was unable to separate the effects of these two factors with certainty because sampling depths varied considerably on the different sampling dates. I am confident, however, that depth was much the more influential factor of the two. Therefore, I separated the data according to two depth intervals —9 to 13 and 18 to 46 m—and combined data for all seasons and fish lengths.

Table 3. *Food items (percentage of volume and, in parentheses, percent frequency of occurrence) in stomachs of spottail shiners collected in southeastern Lake Michigan, 1965-66.*[a]

Food item	Months and depths (m) of collection and (in parentheses) number of fish					
	March-June, plus November		July		August	
	5-13 m (68)	18-31 m (54)	5 m (41)	13 m (52)	13 m (22)	18 m (9)
Rhabdocoel cocoon	T (T)	2 (2)		1 (10)	T (5)	T (22)
Bryozoan statoblast			T (2)	T (2)		
Snail	5 (7)	2 (4)		T (2)		
Fingernail clam	1 (7)	3 (7)		44 (62)	9 (23)	14 (33)
Leech		2 (2)				
Zooplankton	T (4)		3 (12)	20 (63)	37 (73)	6 (11)
Ostracod	T (12)	4 (7)		1 (31)	T (5)	T (22)
Pontoporeia	19 (34)	86 (100)		2 (6)	3 (14)	63 (89)
Terrestrial insect	T (2)		4 (5)	2 (8)	3 (27)	1 (22)
Caddisfly larva				1 (10)		
Immature midge	75 (87)	2 (4)	21 (42)	18 (44)	48 (82)	15 (44)
Water mite	T (2)				T (5)	
Fish eggs			73 (76)	12 (27)		
Algae				T (2)		

[a]T = Trace (less than 0.5%).

Pontoporeia and immature midges strongly dominated the diet of trout-perch (Table 4). Among fish from depths of 9 to 13 m, each of these items occurred in 81% of the stomachs; midges made up 53% and *Pontoporeia* 43% of the volume. At 18-46 m, *Pontoporeia* contributed 80% of the volume and midges 16%. The only other organisms of any consequence were zooplankton (3% of volume) in fish collected at 9-13 m and *Mysis* (4%) in fish taken at 18-46 m.

Midges identified in stomachs of trout-perch were mostly *Chironomus* but also included *Paracladopelma*, *Cryptochironomus*, and *Tanytarsus*, except that in fish from the deepest areas (31-46 m), they were all *Heterotrissocladius*. Zooplankters were mainly the cladoceran *Eurycercus lamellatus*, although a few copepods—*Cyclops bicuspidatus*, *C. vernalis*, and Harpacticoida—were among them.

Table 4. *Food items (percentage of volume and, in parentheses, percent frequency of occurrence) in stomachs of trout-perch collected in southeastern Lake Michigan, 1965-66.*[a]

Food item	Depth (m) and (in parentheses) number of fish	
	9-13 (144)	18-46 (144)
Nematode	1 (4)	T (1)
Leech	T (1)	T (1)
Zooplankton	3 (44)	T (3)
Ostracod	T (3)	T (1)
Mysis		4 (9)
Pontoporeia	43 (81)	80 (94)
Terrestrial insect	1 (1)	
Immature midge	53 (81)	16 (44)
Fish eggs	T (2)	

[a]T = Trace (less than 0.5%).

Table 5. *Food items (percentage of volume and, in parentheses, percent frequency of occurrence) in stomachs of slimy sculpins collected in southeastern Lake Michigan, 1965-66.*[a]

Food item	Depth (m) and (in parentheses) number of fish	
	31-64 (331)	73-91 (123)
Rhabdocoel cocoon	T (11)	T (7)
Nematode	T (T)	
Bryozoan statoblast	T (T)	
Fingernail clam	T (1)	1 (3)
Ostracod		1 (12)
Mysis	1 (2)	T (1)
Isopod	T (T)	
Pontoporeia	97 (100)	94 (99)
Immature midge	2 (5)	T (2)
Fish eggs	T (T)	4 (27)

[a]T = Trace (less than 0.5%).

Maximum numbers of each organism in individual stomachs were as follows: *Pontoporeia*, 122; immature midges, 74; zooplankters, 35 (all *Eurycercus*); *Mysis*, 3; ostracods, 3; fish eggs, 2; and nematodes, leeches, and terrestrial insects, 1 each.

The present findings concerning the food of trout-perch are similar to those reported for a previous Lake Michigan study based on samples collected at depths of 6 and 9 m in an area about 80 km south of Saugatuck (Tomlinson and Jude 1977). In that study, as in mine, immature midges (mostly *Chironomus*) and *Pontoporeia* occurred most frequently among organisms eaten by trout-perch. Zooplankton, represented primarily by the cladoceran *Eurycercus* and the copepod *Cyclops*, also was important.

Slimy sculpins

I examined the food in stomachs of 454 slimy sculpins collected at depths of 31-91 m during April–November 1965 and March–June 1966. The length range was 29-118 mm; 87% were 40-99 mm long.

Food of slimy sculpins in the samples did not vary according to size of fish, but appeared to differ slightly according to depth of capture and, at least for fish eggs, according to season. The data for all lengths and dates were combined and separated into two depth categories, 31-64 and 73-91 m.

Slimy sculpins fed primarily on *Pontoporeia* (Table 5). With only a single exception, this amphipod occurred in every stomach. It made up 97% of the volume of food at 31-64 m, and 94% at 73-91 m. In fish collected at 31-64 m, nearly all the rest of the food consisted of immature midges (2% of volume) and *Mysis* (1%); rhabdocoel cocoons were observed in 11% of the stomachs, but contributed only a small fraction of the volume. At 73-91 m, most of the diet, aside from *Pontoporeia*, consisted of fish eggs, which occurred in 27% of the stomachs and made up 4% of the volume; and ostracods and fingernail clams, each contributing 1% of the volume.

Fish eggs occurred in the diet primarily in March, in fish collected at 73-91 m. Inasmuch as no collections were made at 31-64 m in March, I do not know whether sculpins at these shallower depths also ate fish eggs during this month. However, they probably did not, to any appreciable extent. The only fish eggs likely to be available to slimy sculpins in March are those of the bloater (*Coregonus hoyi*) and the fourhorn sculpin, both of which spawn mostly at depths greater than 73 m (Wells 1966; GLFL, unpublished data).

Other items eaten by slimy sculpins, but always in small quantity, included nematodes, bryozoan statoblasts, and isopods.

Maximum numbers of each food item observed in individual stomachs were as follows: fish eggs, 32; *Pontoporeia*, 20; rhabdocoel cocoons, 16; ostracods, 11; fingernail clams (*Pisidium*), 7; immature midges (*Heterotrissocladius*), 5; *Mysis*, 2; and bryozoan statoblasts, nematodes, and isopods (*Asellus*), 1 each.

Fourhorn Sculpins

I analyzed the stomach contents of 562 fourhorn sculpins collected each month from March to September and in November, in either 1965, 1966, 1974, or 1975. All were taken at depths of 82 or 91 m, except for 14 at 73 m and 21 at 110 m. The fish thus were collected from only the shallower portion of the primary depth range of the species in southeastern Lake Michigan, which is about 82 to at least 146 m (Wells 1968; GLFL, unpublished data). Fish lengths ranged from 50 to 172 mm.

No obvious relation existed between food and date or depth of capture. Since food varied somewhat with size of fish, the data for fish less than 100 mm long are presented separately from those for larger fish. Only 21 of 126 fish in the smaller length group were less than 70 mm long, and only 9 of the 436 larger fish were longer than 132 mm.

Fourhorn sculpins fed almost exclusively on *Pontoporeia* and *Mysis* (Table 6). Among fish less than 100 mm long, each item occurred in slightly more than two-thirds of the stomachs; *Mysis* made up 54% of the total volume and *Pontoporeia* the rest, except for trace amounts of ostracods and fish eggs. Among the larger fish, *Pontoporeia* was much the more commonly eaten of the two major items; it contributed 78% of the total volume of food and occurred in 91% of the stomachs. Corresponding figures for *Mysis* were 21 and 48. The only other food consumed by larger fish in more than minute quantities consisted of fish eggs, which occurred in 14% of the stomachs and constituted 2% of the volume. The eggs eaten in November were those of the fourhorn sculpin itself; those at other times of the year were not identified.

Table 6. *Food items (percentage of volume and, in parentheses, percent frequency of occurrence) in stomachs of fourhorn sculpins collected in southeastern Lake Michigan, 1965-75.*[a]

Food item	Fish length (mm) and (in parentheses) number of fish	
	50-99 (126)	100-172 (436)
Fingernail clam		T (2)
Ostracod	T (2)	T (T)
Mysis	54 (68)	21 (48)
Pontoporeia	46 (69)	78 (91)
Terrestrial insect		T (1)
Immature midge		T (1)
Fish eggs	T (6)	2 (14)

[a]T = Trace (less than 0.5%).

Maximum numbers of each item in individual stomachs were as follows: fish eggs, 110; *Pontoporeia*, 67; *Mysis*, 12; ostracods, 6; fingernail clams, 2; and immature midges and terrestrial insects, 1 each.

Overall Contributions of Important Food Items to the Diet of Six Lake Michigan Species

Of the combined total of 23 items observed in the stomachs (Tables 1-6), 8 were of particular importance: *Pontoporeia*, zooplankton, *Mysis*, immature midges, fish eggs, fish, crayfish, and fingernail clams. A general summary of the overall (volume) contributions of these items to total food volume follows.

Pontoporeia was the most commonly eaten of all the food items. It made up nearly the entire diet of slimy sculpins, and was a major constituent of the diet of the other species, often constituting the most important food of fish of at least some size or depth categories.

Zooplankton was the principal food of alewives, and made up a substantial part of the diet of spottail shiners. It was also eaten in small quantities by yellow perch and trout-perch. If earlier life stages had been included among the fish samples, the proportion of

zooplankton in the stomach contents of all species obviously would have been greater.

Mysis was especially important to fourhorn sculpins, making up most of the food that was not *Pontoporeia*. It also contributed significantly to the diet of alewives in mid-water, and appeared occasionally in stomachs of all other species except spottail shiners.

Immature midges made up a major portion of the food of spottail shiners and trout-perch. Additionally, they were consumed in considerable quantities by alewives in shallow water (though probably not on the whole making up a significant portion of the diet of this species) and in small amounts by all other species.

Fish eggs were occasionally fed upon heavily by yellow perch and spottail shiners, and were eaten in small amounts by each of the other species.

Fish were often the most important food of yellow perch in the largest size category (250-349 mm long) and were commonly eaten by those of medium size (200-249 mm); however, they were not observed in stomachs of other species.

Crayfish made up a sizable portion of the diet of yellow perch on rocky bottom, but were consumed only sparingly by that species on smooth bottom, and not at all by other species.

Fingernail clams at times contributed substantially to the diet of spottail shiners, and occurred in small numbers in stomachs of each of the other species except trout-perch.

Acknowledgments

I thank C. Ayers, who analyzed a large portion of the stomachs; S. Jorgenson and R. House for their shipboard examination of many of the yellow perch stomachs; and J. Hiltunen for his assistance in identifying benthic organisms.

References

Anderson, R. C., and D. Brazo. 1978. Abundance, feeding habits, and degree of segregation of the spottail shiner (*Notropis hudsonius*) and longnose dace (*Rhinichthys cataractae*) in a Lake Michigan surge zone near Ludington, Michigan. Mich. Acad. 10(3):337-346.

Basch, R. E. 1968. Age, growth and food habits of the spottail shiner, *Notropis hudsonius* (Clinton), in Little Bay de Noc, Lake Michigan. M.S. Thesis, Michigan State University, East Lansing. 53 pp.

Dodge, K. E. 1968. Food habits of the yellow perch, *Perca flavescens* (Mitchill), Little Bay de Noc, Lake Michigan. M.S. Thesis, Michigan State University, East Lansing. 48 pp.

Gannon, J. E. 1972. A contribution to the ecology of zooplankton Crustacea of Lake Michigan and Green Bay. Ph.D. Thesis, University of Wisconsin, Milwaukee. 257 pp.

Hauer, F. R. 1975. Comparison of preoperational and operational abundance, age, length-weight relationships, and food habits of yellow perch, *Perca flavescens* (Mitchill), in Lake Michigan and the Ludington pumped storage reservoir. M.S. Thesis, Michigan State University, East Lansing. 75 pp.

Hynes, H. B. N. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies on the food of fishes. J. Anim. Ecol. 19(1):36-58.

Morsell, J. W., and C. R. Norden. 1968. Food habits of the alewife, *Alosa pseudoharengus* (Wilson) in Lake Michigan. Proc. Conf. Great Lakes Res. 11:96-102.

Norden, C. R. 1968. Morphology and food habits of the larval alewife, *Alosa pseudoharengus* (Wilson) in Lake Michigan. Proc. Conf. Great Lakes Res. 11:103-110.

Rhodes, R. J., and T. S. McComish. 1975. Observations on the adult alewife's food habits (Pisces: Clupeidae: *Alosa pseudoharengus*) in Indiana's waters of Lake Michigan in 1970. Ohio J. Sci. 75(1): 50-55.

Rhodes, R. J., D. A. Webb, and T. S. McComish. 1974. Cannibalism by the adult alewife (*Alosa pseudoharengus*) in southern Lake Michigan. Proc. Conf. Great Lakes Res. 17:593-595.

Smith, S. H. 1970. Species interactions of the alewife in the Great Lakes. Trans. Am. Fish. Soc. 99:754-765.

Tomlinson, J. C., and D. J. Jude. 1977. Food of the trout-perch, *Percopsis omiscomaycus*, in southeastern Lake Michigan. Presented at 20th Conference on Great Lakes Research, International Association for Great Lakes Research, Ann Arbor, Mich., May 10-12, 1977. (Unpubl. manuscr.)

Toth, R. J. 1959. Studies on the life history of the yellow perch, *Perca flavescens* (Mitchill), in Big Bay de Noc, Lake Michigan. M.S. Thesis, Michigan State University, East Lansing. 86 pp.

Webb, D. A., and T. S. McComish. 1974. Food habits of adult alewives in Lake Michigan near Michigan City, Indiana, in 1971 and 1972. Proc. Indiana Acad. Sci. 83:179-184.

Wells, L. 1966. Seasonal and depth distribution of larval bloaters (*Coregonus hoyi*) in southeastern Lake Michigan. Trans. Am. Fish. Soc. 95:388-396.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U.S. Fish Wildl. Serv., Fish Bull. 67(1):1-15.

Wells, L., and A. L. McLain. 1973. Lake Michigan: Man's effect on native fish stocks and other biota. Great Lakes Fish. Comm., Tech. Rep. 20. 55 pp.

GPO 855 - 007

74. Limnetic Crustacean Zooplankton of Lake Oahe, May-October 1969, by James H. Selgeby. 1974. 11 pp.
75. Species and Age Composition of Trap Net Catches in Lake Oahe, South Dakota, 1963–67, by James A. Gabel. 1974. 21 pp.
76. Evaluation of Trawls for Monitoring and Harvesting Fish Populations in Lake Oahe, South Dakota, by William R. Nelson and Marvin F. Boussu. 1974. 15 pp.
77. Age, Growth, and Maturity of Thirteen Species of Fish from Lake Oahe during the Early Years of Impoundment, 1963–68, by William R. Nelson. 1974. 29 pp.
78. Population Trends, Growth, and Movement of Bigmouth Buffalo, *Ictiobus cyprinellus*, in Lake Oahe, 1963–70, by Thomas E. Moen. 1974. 20 pp.
79. Goldeye, *Hiodon alosoides*, in Lake Oahe: Abundance, Age, Growth, Maturity, Food, and the Fishery, 1963–69, by Grant L. Miller and William R. Nelson. 1974. 13 pp.
80. The Commercial Fishery in Lake Oahe, North and South Dakota, 1964–70, by Joseph H. Higham. 1974. 15 pp.
81. Age, Growth, Sexual Maturity, and Food of Channel Catfish in Central Lake Oahe, 1968–69, by Victor J. Starostka and William R. Nelson. 1974. 13 pp.
82. An Experimental Trap Net Fishery, Lake Oahe, South Dakota, 1965, by James A. Gabel. 1974. 9 pp.
83. Atlantic Salmon (*Salmo salar*): an Annotated Bibliography, by Florence T. Wright. 1975. 22 pp.
84. Reproduction of Spotted Bass, *Micropterus punctulatus*, in Bull Shoals Reservoir, Arkansas, by Louis E. Vogele. 1975. 21 pp.
85. Immune Response and Antibody Characterization of the Channel Catfish (*Ictalurus punctatus*) to a Naturally Pathogenic Bacterium and Virus, by Charles M. Heartwell III. 1975. 34 pp.
86. Rainbow Trout Growth in Circular Tanks: Consequences of Different Loading Densities, by James L. Brauhn, Raymond C. Simon, and Walter R. Bridges. 1976. 16 pp.
87. Changes in Young-of-the-year Fish Stocks During and After Filling of Lake Oahe, an Upper Missouri River Storage Reservoir, 1966–74, by Fred C. June. 1976. 25 pp.
88. Acrolein, Dalapon, Dichlobenil, Diquat, and Endothal: Bibliography of Toxicity to Aquatic organisms, by Leroy C. Folmar. 1977. 16 pp.
89. Clinical Methods for the Assessment of the Effects of Environmental Stress on Fish Health, by Gary A. Wedemeyer and William T. Yasutake. 1977. 18 pp.
90. Biology of the Redtail Surfperch (*Amphistichus rhodoterus*) from the Central Oregon Coast, by Donald E. Bennett and Richard S. Wydoski. 1977. 23 pp.
91. Chemical Forest Fire Retardants: Acute Toxicity to Five Freshwater Fishes and a Scud, by W. Waynon Johnson and Herman O. Sanders. 1977. 7 pp.
92. Verification of a Model for Predicting the Effect of Inconstant Temperature on Embryonic Development of Lake Whitefish (*Coregonus clupeaformis*), by William H. Berlin, L. T. Brooke, and Linda J. Stone. 1977. 6 pp.
93. Abundance, Composition, and Distribution of Crustacean Zooplankton in Relation to Hypolimnetic Oxygen Depletion in West-Central Lake Erie, by Roy F. Heberger and James B. Reynolds. 1977. 17 pp.
94. Ecological Effects of Dredging and Dredge Spoil Disposal: A Literature Review, by J. W. Morton. 1977. 33 pp.
95. Lake Francis Case, a Missouri River Reservoir: Changes in the Fish Population in 1954–75, and Suggestions for Management, by Charles W. Walburg. 1977. 12 pp.
96. Neuroendocrine Mediation of Photoperiod and Other Environmental Influences on Physiological Responses in Salmonids: A Review, by Hugh A. Poston. 1978. 13 pp.
97. Toxicity of Three Herbicides (Butyl, Isooctyl, and Propylene Glycol Butyl Ether Esters of 2,4-D) to Cutthroat Trout and Lake Trout, by D. F. Woodward and F. L. Mayer, Jr. 1978. 6 pp.

NOTE: Use of trade names does not imply U.S. Government endorsement of commercial products.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
EDITORIAL OFFICE
AYLESWORTH HALL, CSU
FORT COLLINS, COLORADO 80523

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTERIOR
INT 423

U.S.MAIL

U S DEP OF INTERIOR 039017
OFFICE OF LIBRARY SERV
SERIALS BRANCH
WASHINGTON
DC 20240

NOTE: Mailing lists are computerized. Please return address label with change of address.