Food habits of adult yellow perch and smallmouth bass in Nebish Lake, Wisconsin : with special reference to zooplankton density and composition. No. 149 1984

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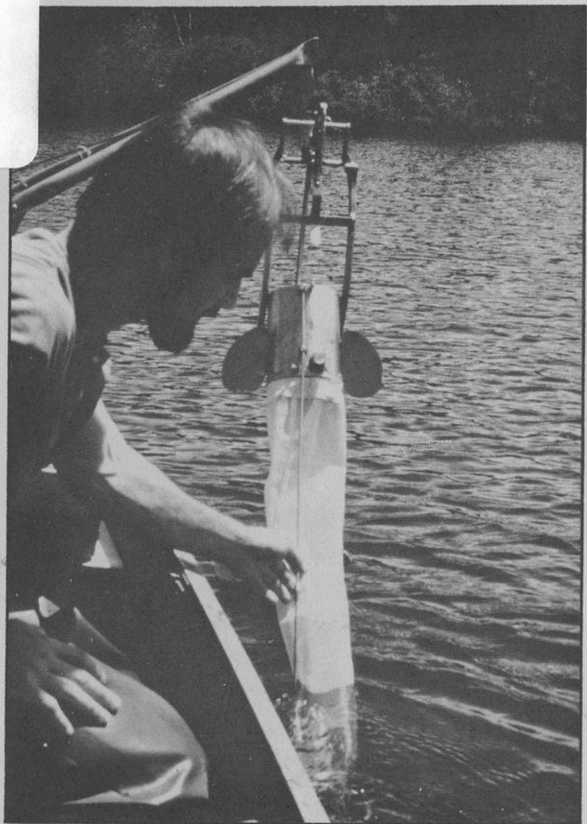

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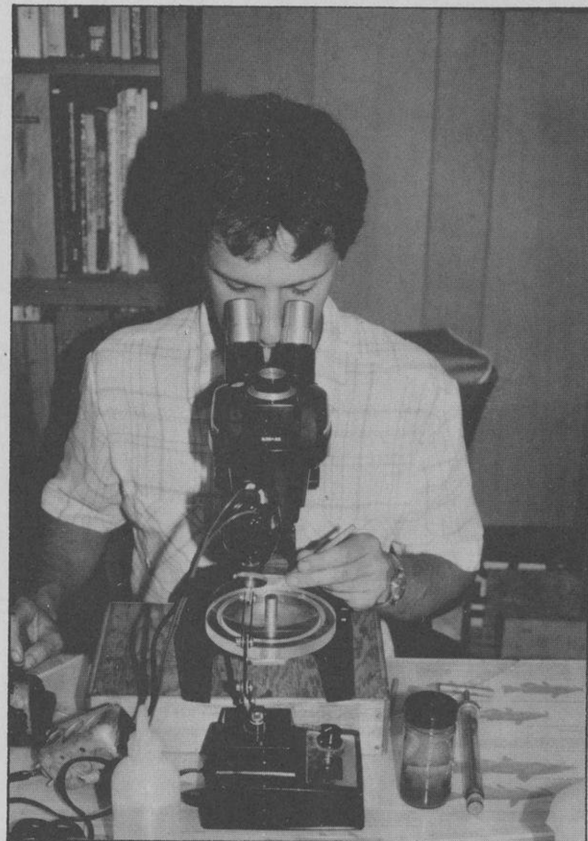

Food Habits of Adult Yellow Perch & Smallmouth Bass in Nebish Lake, Wisconsin —

With Special Reference to Zooplankton Density and Composition

ABSTRACT

This 5-year study was done to determine the ecological relationships and compatibility of yellow perch and smallmouth bass sharing a water body. The research objectives were: 1) to measure zooplankton density and composition and relate that to food habits of adult yellow perch; and 2) to examine the dietary overlap between adult yellow perch and smallmouth bass. Zooplankton was sampled from May-September throughout 1977-81, and stomachs from angler-caught adult yellow perch and smallmouth bass were collected during the same months and years.

The mean density of cladocerans in Nebish Lake was higher in spring and fall than in summer, and *Daphnia* sp. was the most abundant cladoceran in every month except July. The only other significant cladocerans were *Holopedium gibberum* (most abundant cladoceran in July) and *Diaphanosoma leuchtenbergianum*, both of which exhibited midsummer pulses. The mean density of copepods was highest in May and June, but their densities were considerably less than the density of cladocerans.

Of the two major zooplankton taxa ingested--*Daphnia* sp. and *H. gibberum*--yellow perch generally selected the larger individuals. In terms of their food preferences, they favored *Leptodora kindtii* and *Eurycerus lamellatus*, both of which were present in very low densities in the samples, and *Daphnia* sp. Perch exhibited a slight negative selection for *H. gibberum* and a strong negative selection for *D. leuchtenbergianum* and copepods.

Dipterans were the major food item of yellow perch during May-July, but cladocerans were most important during August and September. Amphipods were also important in May, but less so from June-September. The frequency of occurrence and importance of most aquatic insects was highest in May and June, and then declined from July-September. The consumption of fishes by adult yellow perch, although never very high, was greatest during July.

For smallmouth bass, insects were the most frequent item in the stomachs collected in May and June, while decapods (*Orconectes propinquus*) were the most frequent item from July-September. However, yellow perch and unidentified fishes (most were probably yellow perch) comprised the highest percent volume of food in May, while decapods comprised the highest during June-September. Other than in 1978, when dipterans were most frequent, decapods comprised the highest frequency, volume, and index of importance each year.

Dietary overlap between adult yellow perch and smallmouth bass was apparent for ephemeropterans and odonates in June and July, hemipterans and megalopterans in September, and dipterans throughout May-September. However, because of the relatively small percent of the total volume that these taxa comprised in smallmouth bass stomachs, competition for food resources between adult yellow perch and smallmouth bass in Nebish Lake would not seem to be severe.

KEY WORDS: Food Habits, Food Selectivity, Smallmouth Bass, Yellow Perch, Wisconsin, Zooplankton

Food Habits of Adult Yellow Perch and Smallmouth Bass in Nebish Lake, Wisconsin — With Special Reference to Zooplankton Density and Composition

by

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INTRODUCTION

The purpose of this paper is to describe monthly and annual changes in zooplankton density and composition in relation to the food habits of adult yellow perch (*Perca flavescens*) and smallmouth bass (*Micropterus dolomieui*) in Nebish Lake during 1977-81.

When attempting to explain ecological relationships in a water body, other authors have indicated the importance of understanding the food habits and amount of dietary overlap between fish species (Clady 1974; Hubert 1977; Elrod et al. 1981; Wallace 1981). In this paper we attempt to analyze and discuss the degree of dietary overlap between adult yellow perch and smallmouth bass and to compare the degree of overlap during May-September. Such an analysis should assist managers in determining whether these two species are compatible in the same water body.

STUDY AREA AND HISTORICAL BACKGROUND

Nebish Lake is a clear water, infertile (total alkalinity of 15-19 mg/l) seepage lake. It is located on undeveloped state-owned land in the Northern Highland State Forest in Vilas County in north central Wisconsin (latitude 46°04′; longitude 89°35′) (Fig. 1). The lake has a surface area of 38 hectares, a maximum depth of 15 m, and a shoreline length of 5.1 km. The bottom contour is irregular with a sharp dropoff along most of the perimeter, which limits the abundance of rooted aquatic plants.

Prior to fall 1966, the sport fish community of Nebish Lake was comprised of several warm water species, most of which had been introduced (Kempinger and Christenson 1978). Originally the lake was thought to contain only three species: smallmouth bass, rock bass (*Ambloplites rupestris*), and yellow perch (Hile and Juday 1941). In October 1966, Nebish Lake was chemically treated with 1.0 mg/l emulsifiable rotenone, and subsequent netting and electrofishing surveys indicated that all fishes had been eliminated. Since that date, it has been illegal to use minnows for bait in Nebish Lake. In spring 1967, 38 adult smallmouth bass and 33 adult yellow perch were stocked to re-establish these two species in the lake. Also in the spring of 1967, 4,500 age 0+ brown trout (*Salmo trutta*) and 4,500 young-of-the-year rainbow trout (*Salmo gairdneri*) were introduced to provide fishing for a few years until the smallmouth bass and yellow perch populations became established.

During 1968-76, 9,885 smallmouth bass and 30,129 yellow perch were harvested by 11,392 anglers (Christenson et al. 1982). No trout were caught after 1974. During 1977-81, an 8-inch minimum length limit regulated the harvest of smallmouth bass, and during that time 7,297 anglers harvested 6,630 smallmouth bass and 15,180 yellow perch (Serns 1984). During 1968-81, no panfish or game fish species other than yellow perch and smallmouth bass were caught either by angling or in annual fyke netting and electrofishing samplings. A few adult bluntnose minnows (*Pimephales notatus*) and hornyhead chubs (*Nocomis biguttatus*) were collected but all were removed.

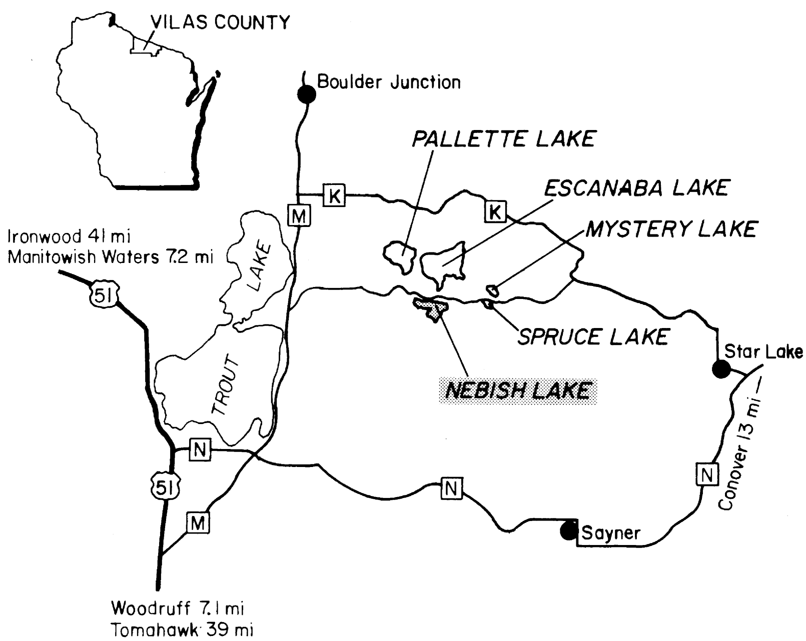


FIGURE 1. *Location of Nebish Lake and the other four lakes in the Northern Highland Fishery Research Area, Vilas County.*

METHODS

Zooplankton were collected biweekly in Nebish Lake from early or mid-May through late September or early October during 1977-81. The zooplankton were collected using a Clarke-Bumpus sampler (No. 2 mesh net; 0.366-mm aperture diameter) towed horizontally at the surface and at 3.4 m intervals down to 10.2 m. Each 3-minute tow was made at a speed of about 4.8 km/hour and each tow strained more than 1,000 liters of water. Samples were preserved immediately in the field in 3% Formalin. Three 3-ml subsamples were later analyzed independently of each other in a 3-ml circular counting cell (Priegel 1970).

Cladocerans were identified to species except for *Daphnia* sp. (identified to genus), and copepods to subclass except for the calanoid copepod, *Epischura lacustris*. A sample of the zooplankton collected on each sampling date was measured with an ocular micrometer (total length to the nearest 0.1 mm), excluding spines and antennae.

The mean number per liter in the entire water column for each sampling day was calculated by weighting each horizontal tow according to the stratum thickness. The tows with a stratum thickness over 3 meters were weighted as 1.0, while the surface tow, with a thickness of only 1.5 meters, was weighted as 0.5, i.e., surface tow (0-1.5 m) weighted 0.5; 3.4 m tow (1.6-5.2 m) weighted 1.0; 6.8 m tow (5.3-8.1 m) weighted 1.0; and 10.2 m tow (8.2-12.0 m) weighted 1.0. The mean number of each organism per liter from each stratum was summed, and the total was divided by 3.5 to estimate the density of that organism in the entire water column.

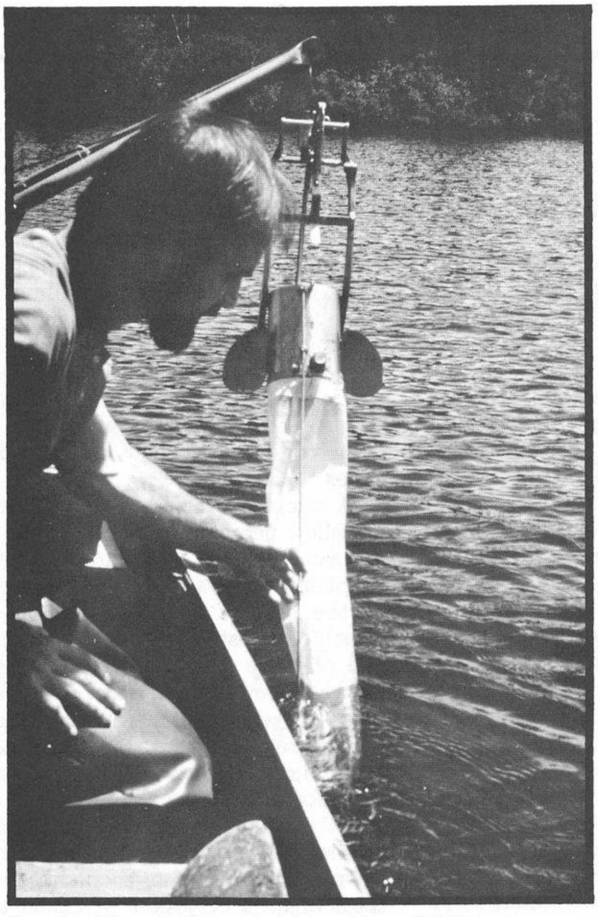
Lake water temperatures were recorded from surface to bottom at 0.3-m intervals on dates of zooplankton collections using a Model FT-3 Applied Research® hydrographic thermometer.

Stomachs were collected (usually 25 of each species) from angler-caught yellow perch and smallmouth bass from May-September of 1977-81. Each stomach was removed, wrapped in cheesecloth, and preserved in 10% Formalin. The total length (to nearest 2.5 mm) and weight (to the nearest 4.5 g) was recorded for each fish, and these data along with the date of capture were included with the stomach in the cheesecloth wrapping.

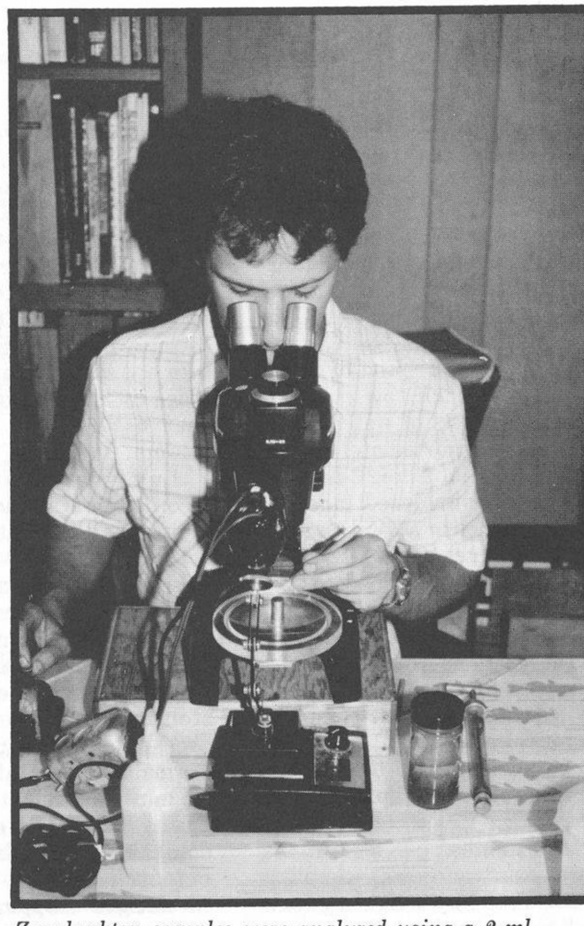
Stomach contents were later identified and counted. Ingested organisms were grouped by class (zooplankton), order (insects), or species (fish). (See Table 1.) Volumes of the food items eaten by smallmouth bass were determined. Indices of the importance of the various food items were determined for both yellow perch and smallmouth bass, and comparisons were made to determine the extent of overlap. Also, the importance of food items for each species was examined by month to determine the seasonal significance of these organisms in the diet of both fishes.

A sample of the cladocerans, found in yellow perch stomachs collected on the same date as the Clarke-Bumpus zooplankton tows, were also measured to the nearest 0.1 mm. The mean length of ingested zooplankton vs. the size of those collected from the lake were compared to determine size selectivity of yellow perch when ingesting various zooplankton taxa. Food selection indices (Strauss 1979) were calculated for various zooplankton by subtracting the percentage of total zooplankton in the environment from the percentage of total zooplankton in the stomachs of yellow perch on the same date.

Smallmouth bass and yellow perch were captured in the spring with fyke nets.



Zooplankton were sampled biweekly using a Clarke-Bumpus sampler.



Zooplankton samples were analyzed using a 3-ml circular counting chamber mounted on the base of a microscope.

RESULTS AND DISCUSSION

ZOOPLANKTON DENSITY AND COMPOSITION

Table 1 shows the food contained in the stomachs of angler-caught smallmouth bass and yellow perch. The mean density of cladocerans was higher in spring (May and June) and fall (September). (See Table 2.) *Daphnia* sp. was the most abundant taxon of cladocerans in every month except July. While *Daphnia* sp. reached its peak in spring and fall, *Holopedium gibberum* peaked in June and July, and *Diaphanosoma leuchtenbergianum* peaked in August. The other species of cladocerans were never very abundant in any sampling month (Table 1). The variability in the density of the major cladoceran and copepod taxa in each year is shown in Appendix Figures 1 and 2.

The mean density of copepods was highest in May and June, but the density of copepods was considerably less than that of cladocerans in each sampling month. Calanoid copepods, including *Epischura lacustris*, had their highest densities in spring, while cyclopoid copepods were most abundant in mid-late summer (Append. Fig. 2).

Several authors have noted seasonal differences in zooplankton taxa in lakes in the northern United States. Noble (1975) reported that *Daphnia* sp. exhibited spring and fall pulses and low abundances during midsummer, while *D. leuchtenbergianum* displayed a mid-late summer pulse in Oneida Lake, New York. Hall (1964) reported similar observations for *Daphnia galeata* in Base Line Lake, Michigan, and attributed low densities in midsummer to yellow perch predation. In a zooplankton study in several Ontario lakes, Jermolajev and Fraser (1982) reported that *H. gibberum* was most abundant in summer.

A comparison of mean annual zooplankton densities for 1977-81 (May-September combined) showed cladocerans to be most numerous in 1978 and 1981 and copepods in 1979 and 1981 (Table 3). *Daphnia* sp. was by far the most abundant cladoceran in each year, with its highest densities in 1978 and 1981. *H. gibberum* was the second most abundant cladoceran in each year and had its highest densities in 1980 and high densities in both 1977 and 1981. The abundance of both calanoid and cyclopoid copepods was highest in 1979, while their second highest densities occurred in 1981 (Table 3).

TABLE 1. *Food contained in the stomachs of angler-caught smallmouth bass and yellow perch during May-September, 1977-81.*

Food Item	Common Name
Bryozoa*	Sea mosses
Anthropoda	
Crustacea	
Branchiopoda	
Cladocera	Water fleas
Copepoda	Cyclops
Ostracoda	Seed shrimps
Malacostraca	
Amphipoda	Scuds
Decopoda	Crayfish
Arachnoidea	
Hydracarina	Water mites
Insecta	
Ephemeroptera	Mayflies
Odonata	Dragonflies, Damselflies
Hemiptera	True bugs
Trichoptera	Caddis flies
Megaloptera	Alderflies
Coleoptera	Beetles
Diptera	Flies
Gastropoda*	Snails
Pelecypoda*	Clams, mussels
Pisces	
Percidae	Yellow perch
Centrarchidae	Smallmouth bass

*These food items were found in the stomachs of yellow perch, but not in the stomachs of smallmouth bass.

TABLE 2. *Mean densities of zooplankton during May-September, 1977-81, by month.**

Taxon	May**	June**	July**	August**	September**
Cladocera					
Holopedium gibberum	1.0 (1.2)	1.4 (1.1)	2.8 (2.3)	0.6 (0.7)	0.3 (0.3)
Diaphanosoma leuchtenbergianum	<0.1	<0.1	0.1 (0.4)	0.5 (0.7)	0.3 (0.3)
Daphnia sp.	12.7 (12.7)	8.9 (7.2)	1.5 (3.0)	3.4 (3.4)	8.0 (4.1)
Bosmina longirostris	0.1 (0.2)	0.0	0.0	0.0	0.0
Eurycerus lamellatus	0.0	0.0	0.0	0.0	<0.1
Polyphemus pediculus	0.0	0.0	<0.1	<0.1	<0.1
Leptodora kindtii	<0.1	<0.1	<0.1	<0.1	<0.1
Total Cladocera	13.8	10.3	4.4	4.5	8.6
Copepoda					
Calanoida					
Epischura lacustris	0.2 (0.2)	0.1 (0.2)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
Other calanoida	0.8 (0.7)	0.5 (0.6)	0.1 (0.1)	0.1 (0.2)	0.1 (0.1)
Cyclopoida	0.1 (0.1)	0.1 (0.1)	0.4 (0.6)	0.4 (0.3)	0.2 (0.2)
Total Copepoda	1.1	0.7	0.6	0.6	0.4

*Units in no./liter of water filtered; standard deviation is in parentheses.
**The number of sampling dates was 8 in May, 10 in June, and 11 in July, August, and September.

TABLE 3. *Mean densities of zooplankton during 1977-81, May-September combined.**

Taxon	1977**	1978**	1979**	1980**	1981**
Cladocera					
Holopedium gibberum	1.2 (1.3)	1.0 (1.7)	0.7 (0.9)	1.7 (2.3)	1.2 (1.3)
Diaphanosoma leuchtenbergianum	0.3 (0.6)	0.2 (0.5)	0.2 (0.4)	0.1 (0.1)	0.2 (0.4)
Daphnia sp.	3.8 (4.0)	12.0 (9.3)	5.8 (8.9)	6.8 (5.2)	8.6 (7.5)
Bosmina longirostris	0.0	0.0	0.0	<0.1	0.1 (0.2)
Eurycerus lamellatus	0.0	0.0	0.0	<0.1	0.0
Polyphemus pediculus	0.0	<0.1	<0.1	<0.1	<0.1
Leptodora kindtii	0.0	<0.1	<0.1	<0.1	<0.1
Total Cladocera	5.3	13.2	6.7	8.6	10.1
Copepoda					
Calanoida					
Epischura lacustris	0.2 (0.2)	0.1 (0.2)	<0.1	0.1 (0.2)	0.1 (0.1)
Other calanoida	0.1 (0.1)	0.2 (0.2)	1.1 (2.2)	0.2 (0.4)	0.5 (0.8)
Cyclopoida	0.3 (0.5)	0.3 (0.4)	0.8 (2.0)	0.2 (0.2)	0.4 (0.5)
Total Copepoda	0.6	0.6	0.6	0.5	1.0

*Units in no./liter of water filtered; standard deviation is in parentheses.
**Number of sampling dates = 11.

Influences on Seasonal Differences in Density

Seasonal differences in zooplankton density during this study may have been due to zooplankton life history patterns, predation by planktivores, interspecific competition among zooplankton, environmental conditions, water temperature, food resources, or a combination of any or all of these parameters.

A comparison of mean surface water temperatures and mean densities of the major cladoceran taxa indicates a negative relationship between the density of *Daphnia* sp. and a rise in surface water temperatures, while the abundance of *H. gibberum* and *D. leuchtenbergianum* appeared to be positively influenced by a rise in surface temperature (Fig. 2). Cyclopoid copepods also appeared to respond positively to higher water temperatures, while the calanoids seemed to be somewhat negatively affected (Fig. 2). A comparison of mean surface water temperatures and densities of the other zooplankton taxa indicated no obvious relationships, mainly because of only slight variability in the mean annual (May-September) surface water temperature over the 5-year period.

The midsummer decline in the abundance of *Daphnia* sp. seemed to coincide well with an increase in the surface water temperatures of Nebish Lake (Fig. 2). Other authors have described the apparent affinity of *Daphnia* sp. for cool, well-oxygenated water (Brooks 1959; Hall 1964; Brynildson and Kempinger 1970). Perhaps with the onset of warmer surface water temperatures and thermal stratification in late spring and early summer, and the reduction in dissolved oxygen content in the lower part of the hypolimnion in midsummer (unpublished data, DNR files), the living space for *Daphnia* sp. was reduced to a narrower band. In this narrower band, yellow perch could more effectively prey on them and reduce their numbers, as was noted by Hall (1964) in the Michigan lake he studied.

The relationship between the density of various zooplankton and water temperature observed in Nebish Lake may be real or simply a spurious relationship caused by other phenomena. A possible factor influencing differences in density for various taxa might be predation by fish species. For example the abundance of *H. gibberum* during the midsummer months at depths of 7-10 m may be the result of a predation avoidance response such as moving into a zone with low light intensity to avoid predation by visual predators.

The reduction in the density of *Daphnia* sp. in midsummer coincided well with the increase in density of *H. gibberum* (Fig. 2). This increase in the numbers of *H. gibberum* was possibly due to reduced interspecific competition with *Daphnia* sp. (as their numbers declined) rather than warmer surface waters, since the highest densities of *H. gibberum* were found at depths of about 7 and 10 m (midpoint of thermocline in summer is usually at about 8 m). Other investigators (DeMott and Kerfoot 1982; Smith and Cooper 1982) have suggested that interspecific competition among zooplankton can result in seasonal differences in composition.

Another influence on mean annual densities of zooplankton in Nebish Lake during 1977-81 could be differences in yellow perch density. Although no estimates of the density of young yellow perch were made, population estimates of adults and length-at-age data during 1977-81 (Serns 1984) made it possible to estimate the relative strength of perch year classes during this period. These data indicated that relatively strong yellow perch year classes were produced in 1977 and 1979, and these large year classes may have resulted in lower cladoceran (mainly *Daphnia* sp.) densities in the lake during those years. Noble (1975) reported that *Daphnia* sp. were usually the principal food of young yellow perch in Oneida Lake, New York.

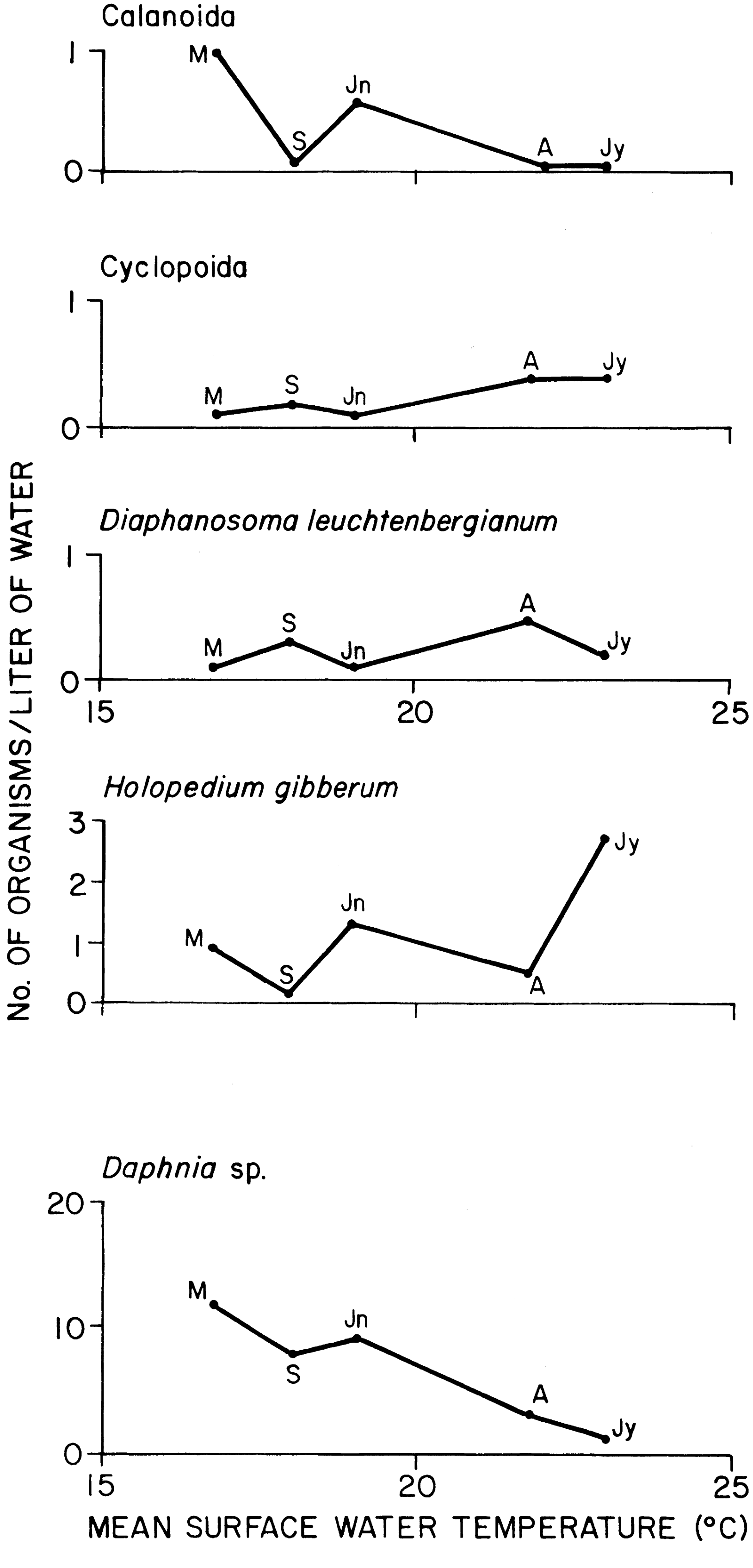


FIGURE 2. *Relationship between monthly mean zooplankton densities and surface water temperatures, 1977-81, by month.*

YELLOW PERCH FOOD HABITS

The food habits of adult yellow perch were quite variable during May-September in the 5-year study (Table 4). Dipterans were the most frequent food item during May-July, while cladocerans were highest in August and September. Amphipods had a high frequency of occurrence and importance factor* in May and then declined throughout June-September. The frequency of occurrence and importance factor values for most of the aquatic insects (ephemeropterans, odonates, trichopterans, megalopterans) were highest in May and June and declined through the summer months, probably as a result of reduced post-emergence densities. Decapods (*Orconectes propinquus*) occurred most frequently in June. Fish consumption, although never very high in any month, was greatest during July (Table 4). Crustaceans comprised the highest percentage of total food items consumed by perch in every month but July of the period May-September, 1977-81 (Fig 3). Insects made up the highest percentage of total food items eaten by perch in July.

The frequency of occurrence and importance factor values for the food items consumed by adult yellow perch varied slightly from year to year, but no trend over the 5-year period was evident for any particular taxa (Table 5).

Other authors have indicated that chironomids (Diptera) are important food items along with other insects, cladocerans, and amphipods (Tharratt 1959; Clady 1974; Elrod et al. 1981). Decapods may have been moderately abundant in perch stomachs in June because the young-of-the-year crayfish begin to leave the female's abdomen then and disperse in the lake, thus becoming more vulnerable to predation.

The food habits of yellow perch in this study may be biased because the stomachs were collected from angler-caught fish and, therefore, several hours may have elapsed from the time a fish was caught until its stomach was excised and preserved. As a result, this procedure probably underestimated the quantity of zooplankton ingested, as Gannon (1976) reported that *Daphnia* sp. cannot be identified in the stomachs of alewives (*Alosa pseudoharengus*) after 2.5 hours. Gannon (1976) also found that *Chironomus* sp. could be identified by their head capsules even after 4.5 hours in alewife stomachs. This disparity in the effects of digestion on subsequent identification of ingested prey would lead to biases in determining the importance of various food items.

*Importance factor = % frequency of occurrence plus % of total food items.

TABLE 4. *Summary statistics and percent frequency of occurrence (FO), percent of total food items (TFI), and importance factors (IF)* for food items in the stomachs of angler-caught yellow perch during May-September, 1977-81, by month.*

Summary Statistic	May	June	July	August	September
No. of stomachs analyzed	60	121	119	124	126
No. with food (%)	49 (81.7)	93 (76.9)	76 (63.9)	102 (82.3)	105 (83.3)
Total no. food items	1,502	6,170	3,728	6,209	17,445
Food items/stomach with food	30.7	66.3	49.1	60.9	166.1
Avg. yellow perch length (inches) ± SD	9.0 ± 1.1	8.0 ± 1.0	7.9 ± 1.0	8.2 ± 1.0	8.6 ± 1.3
Avg. yellow perch weight (lb) ± SD	0.31 ± 0.12	0.21 ± 0.08	0.21 ± 0.09	0.23 ± 0.08	0.27 ± 0.13

Food Item	May % FO	May % TFI	May IF	June % FO	June % TFI	June IF	July % FO	July % TFI	July IF	August % FO	August % TFI	August IF	September % FO	September % TFI	September IF
Bryozoa	1.7	0.1	1.7	1.7	1.7	3.4	3.4	2.3	5.7	0.8	0.5	1.3	0.0	0.0	0.0
Crustacea															
Cladocera	15.0	18.4	33.4	33.1	46.0	79.1	13.4	19.7	33.1	41.9	60.5	102.4	60.3	90.9	151.2
Copepoda	0.0	0.0	0.0	3.3	0.1	3.4	0.0	0.0	0.0	4.0	0.2	4.2	2.4	<0.1	2.4
Ostracoda	0.0	0.0	0.0	1.7	0.1	1.8	0.0	0.0	0.0	0.8	0.1	0.8	0.8	<0.1	0.8
Amphipoda	51.7	29.9	81.6	38.0	4.3	42.3	27.7	7.2	34.9	17.7	4.5	22.2	8.7	0.3	9.0
Decapoda	11.7	0.8	12.5	21.5	0.7	22.2	12.6	0.7	13.3	9.7	0.2	9.9	0.8	<0.1	0.8
Arachnoidea															
Hydracarina	8.3	0.7	9.0	10.7	0.8	11.5	0.8	2.1	2.9	3.2	0.4	3.6	1.6	0.1	1.6
Insecta															
Ephemeroptera	18.3	1.1	19.4	26.4	17.3	43.7	18.5	31.2	49.7	7.3	0.2	7.5	3.2	<0.1	3.2
Odonata	30.0	4.9	34.9	19.8	0.8	20.6	22.7	3.0	25.7	18.5	0.7	19.2	10.3	0.1	10.4
Hemiptera	1.7	<0.1	1.7	0.8	<0.1	0.8	0.0	0.0	0.0	1.6	<0.1	1.6	7.9	0.1	8.0
Trichoptera	23.3	4.8	28.1	20.7	3.7	20.7	16.0	1.9	17.9	9.7	2.1	11.8	4.8	0.1	4.9
Megaloptera	16.7	3.2	19.9	9.9	0.3	9.9	10.1	0.5	10.6	9.7	0.7	10.4	10.3	0.2	10.5
Colcoptera	1.7	<0.1	1.7	4.1	0.1	4.1	6.7	0.3	7.0	2.4	0.3	2.7	1.6	0.6	2.2
Diptera	56.7	28.4	85.1	52.9	23.8	52.9	39.5	28.4	67.9	55.6	26.9	82.5	46.0	6.7	52.7
Unidentified	5.0	0.2	5.2	0.8	<0.1	0.8	3.4	0.1	3.5	1.6	<0.1	1.6	3.2	<0.1	3.2
Gastropoda	3.3	0.4	3.7	0.0	0.0	0.0	5.9	1.0	6.9	12.1	2.1	14.2	3.2	0.1	3.3
Pelecypoda	3.3	0.2	3.5	2.5	0.1	2.6	1.7	0.1	1.8	5.6	0.5	6.1	2.4	0.6	3.0
Pisces															
Yellow perch	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.1	2.6	3.2	0.1	3.3	0.0	0.0	0.0
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Unidentified	1.7	6.9	8.6	3.3	0.1	3.4	14.3	1.1	15.4	4.0	0.1	4.1	0.0	0.0	0.0

*IF = Importance Factor = % frequency of occurrence + % of total food items.

For the two major zooplankton taxa (*Daphnia* sp. and *H. gibberum*), a monthly comparison of their mean length in yellow perch stomachs vs. their lengths in Clarke-Bumpus tows indicated that the perch generally selected the larger individuals (Table 6). In 12 of 13 monthly comparisons from 1977-81, ingested *Daphnia* sp. had greater mean total lengths than those from lake samples, while ingested *H. gibberum* were larger in 7 of 10 comparisons (Table 6).

Galbraith (1967) reported that yellow perch in two Michigan lakes were size selective in their predation on *Daphnia* sp., stating that perch usually only consumed *Daphnia* sp. over 1.3 mm in size. In our study, we found that the mean length of ingested zooplankton was less than 1.3 mm in only 1 of the 23 comparisons. (In that one case, the mean length was 1.2 mm.) Thorpe (1977*a*) reported that in Sweden's Lake Gjokvatn, perch (*Perca fluviatilis*),

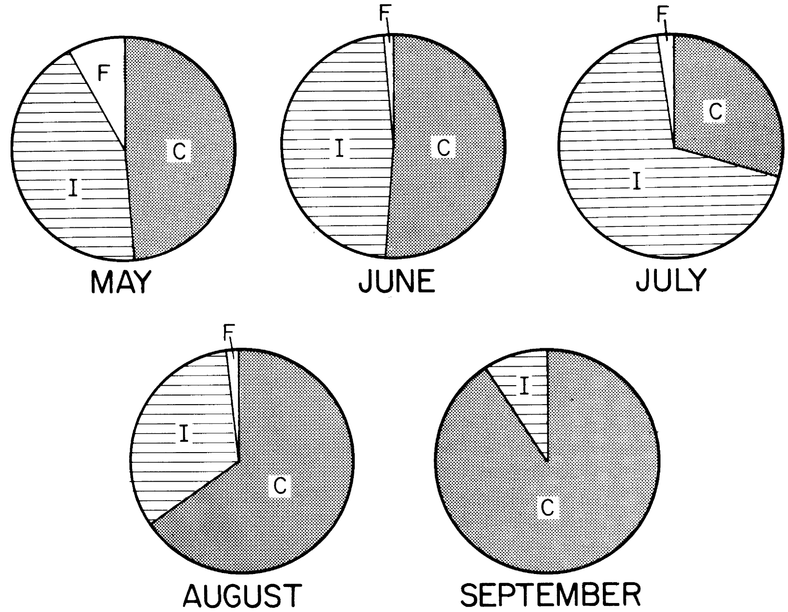


FIGURE 3. *Percent of total food items comprised of crustaceans (C), insects (I), and fish (F) in yellow perch stomachs, 1977-81, by month .*

TABLE 5. *Summary statistics and percent frequency of occurrence (FO), percent of total food items (TFI), and importance factors (IF)* for food items in the stomachs of angler-caught yellow perch during 1977-81, May-September combined.*

Summary Statistic	**1977**	**1978**	**1979**	**1980**	**1981**
No. of stomachs analyzed	102	122	92	123	111
No. with food (%)	94 (92.2)	100 (82.0)	62 (67.4)	89 (72.4)	83 (74.8)
Total no. food items	7,525	10,622	2,005	3,917	10,985
Food items/stomach with food	80.1	106.2	32.3	44.0	132.3
Avg. yellow perch length (inches) ± SD	8.4 ± 1.0	8.5 ± 1.3	8.0 ± 1.0	8.2 ± 1.0	8.2 ± 1.1
Avg. yellow perch weight (lb) ± SD	0.25 ± 0.10	0.27 ± 0.12	0.21 ± 0.10	0.23 ± 0.10	0.23 ± 0.10

	1977			1978			1979			1980			1981		
Food Item	% FO	% TFI	IF	% FO	% TFI	IF	% FO	% TFI	IF	% FO	% TFI	IF	% FO	% TFI	IF
Bryozoa	0.0	0.0	0.0	2.5	1.2	3.7	1.1	1.5	2.6	0.8	0.6	1.4	3.6	0.3	3.9
Crustacea															
Cladocera	39.2	65.2	104.4	35.3	53.8	89.1	31.5	46.8	78.3	35.0	70.2	105.2	34.2	82.1	116.3
Copepoda	2.0	0.1	2.1	3.3	<0.1	3.3	3.3	0.1	3.4	1.6	0.1	1.7	0.9	<0.1	0.9
Ostracoda	3.9	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	<0.1	0.9
Amphipoda	28.4	3.9	32.3	30.3	5.1	35.4	20.7	11.7	32.4	17.9	1.8	19.7	31.5	1.4	32.9
Decapoda	15.7	0.4	16.1	9.8	0.2	10.0	4.3	0.3	4.6	5.7	0.3	6.0	21.6	0.3	21.9
Arachnoidea															
Hydracarina	2.9	0.1	3.0	7.4	0.5	7.9	2.2	3.9	6.1	4.9	0.5	5.4	4.5	0.1	4.6
Insecta															
Ephemeroptera	21.6	6.5	28.1	21.3	10.2	31.5	8.7	1.1	9.8	6.5	7.6	14.1	12.6	3.2	15.8
Odonata	27.5	1.4	28.9	20.5	0.8	21.3	19.6	1.4	21.0	10.6	0.6	11.2	17.1	0.5	17.6
Hemiptera	0.0	0.0	0.0	7.4	0.2	7.6	1.1	0.1	1.2	0.0	0.0	0.0	3.6	0.1	3.7
Trichoptera	18.6	0.8	19.4	15.6	0.3	15.9	8.7	6.0	14.7	8.9	1.7	10.6	12.6	2.0	14.6
Megaloptera	15.7	0.5	16.2	15.6	0.6	16.2	8.7	0.6	9.3	7.3	1.0	8.3	6.3	0.2	6.5
Coleoptera	1.0	0.2	1.2	2.5	<0.1	2.5	2.2	5.3	7.5	4.1	0.3	4.4	3.6	0.1	3.7
Diptera	60.8	19.8	80.6	63.1	26.7	89.8	40.2	18.5	58.7	40.7	11.4	52.1	37.8	7.6	45.4
Unidentified	1.0	<0.1	1.0	5.0	<0.1	5.0	1.1	0.1	1.2	5.7	0.2	5.9	0.9	<0.1	0.9
Gastropoda	4.9	0.4	5.3	0.8	<0.1	0.8	12.0	2.1	14.1	3.3	0.4	3.7	6.3	0.9	7.2
Pelecypoda	0.0	0.0	0.0	4.1	0.1	4.2	0.0	0.0	0.0	4.1	0.8	4.9	6.3	1.0	7.3
Pisces															
Yellow perch	1.0	<0.1	1.0	0.0	0.0	0.0	2.2	0.1	2.3	0.0	0.0	0.0	3.6	0.1	3.7
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	6.0	0.2	6.2	4.1	0.1	4.2	6.5	0.4	6.9	2.4	0.1	2.5	5.4	0.2	5.6

*IF = Importance Factor = % frequency of occurrence + % of total food items.

which are considered to be the biological equivalent of *Perca flavescens* (Thorpe 1977*b*), ate *Daphnia galeata* with carapace lengths of 1.2-2.2 mm, whereas those caught in plankton nets ranged from 0.8-1.7 mm.

Linear food selection indices (Strauss 1979) calculated for various zooplankton taxa indicated that yellow perch strongly preferred *Leptodora kindtii* and *Eurycerus lamellatus*, and moderately preferred *Daphnia* sp. (52% of the samples indicated a preference). Yellow perch exhibited negative selection of *H. gibberum* (negative selection values in 61% of the comparisons) and avoided *D. leuchtenbergianum* and copepods (Table 7). Thorpe (1977*a*) reported that copepods were abundant in the plankton of Sweden's Lake Gjokvatn but were hardly touched by perch.

TABLE 6. *Comparison of the mean length of zooplankton ingested by yellow perch vs. those collected in Clarke-Bumpus tows, 1977-81.**

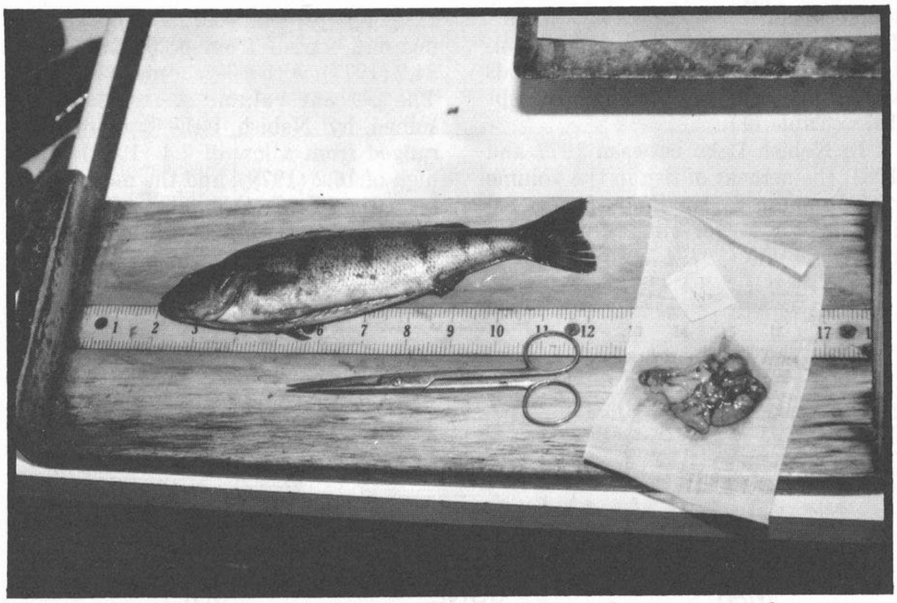
		Daphnia sp.		*Holopedium gibberum*	
Year	Month	Yellow Perch Stomachs	C-B Tows	Yellow Perch Stomachs	C-B Tows
1977	Jun	1.7 (90)**	1.6 (159)	–	–
	Jul	–	–	1.3 (92)	1.0 (222)
	Aug	–	–	1.2 (126)	1.7 (101)
	Sep	1.8 (87)	1.3 (572)	1.4 (17)	1.5 (124)
1978	May	2.2 (42)	1.4 (94)	–	–
	Jun	1.8 (159)	1.8 (65)	1.3 (63)	1.1 (40)
	Aug	–	–	1.3 (97)	1.3 (25)
	Sep	1.7 (251)	1.2 (86)	–	–
1979	May	1.6 (62)	1.1 (60)	–	–
	Jun	1.7 (31)	1.4 (57)	–	–
	Aug	–	–	1.4 (22)	0.6 (61)
	Sep	–	–	1.6 (32)	1.1 (31)
1980	May	2.1 (61)	1.3 (52)	–	–
	Jun	2.1 (60)	1.4 (20)	–	–
	Aug	1.7 (60)	1.1 (61)	1.5 (14)	1.0 (14)
	Sep	1.8 (202)	1.0 (58)	1.5 (19)	0.8 (16)
1981	late July-early August	1.8 (67)	1.2 (45)	–	–
	September	1.7 (393)	1.1 (105)	1.4 (140)	0.8 (12)

*Units in mm.
**Sample size is shown in parentheses.

TABLE 7. *Linear food selection indices* for zooplankton taxa in yellow perch stomachs vs. Clarke-Bumpus samples, 1977-81.*

Year	Date	*Holopedium gibberum*	*Diaphanosoma leuchtenbergianum*	*Daphnia* sp.	*Eurycerus lamellatus*	*Leptodora kindtii*	*Epischura lacustris*	Other Calanoids	Cyclopoids
1977	10 Jun	−0.25	-**	+0.31	-	-	−0.03	−0.03	−0.01
	8 Jul	+0.02	-	−0.02	-	-	-	-	−0.01
	5 Aug	+0.83	-	−0.07	-	+0.05	−0.06	-	−0.25
	2 Sep	+0.08	−0.02	−0.01	-	+0.01	−0.02	-	−0.04
1978	26 May	−0.04	-	+0.07	-	-	−0.01	−0.02	−0.01
	9 Jun	+0.08	+0.01	+0.02	-	-	−0.05	−0.05	−0.01
	4 Aug	+0.23	−0.04	+0.17	-	+0.32	−0.04	−0.14	−0.50
	1 Sep	+0.03	−0.04	+0.05	-	+0.02	0.02	−0.01	−0.04
1979	13 May	-	-	+0.07	-	-	-	−0.06	-
	14 Jun	-	-	+0.04	-	-	-	−0.03	-
	9 Aug	−0.80	−0.02	+0.01	+0.01	+0.83	-	−0.01	−0.02
	6 Sep	−0.03	−0.26	−0.31	-	+0.88	−0.02	−0.11	−0.14
1980	23 May	−0.08	-	+0.24	-	-	−0.04	−0.10	−0.02
	6 Jun	−0.04	-	−0.28	-	+0.26	-	−0.02	-
	20 Jun	+0.67	-	−0.66	-	-	−0.01		
	3 Jul	−0.96	-	−0.01	-	-	-	−0.03	-
	18 Jul	−0.43	-	−0.21	-	+0.33	-	-	−0.03
	1 Aug	−0.11	−0.08	−0.69	+0.65	+0.32	−0.01	−0.01	−0.08
	29 Aug	−0.04	−0.02	−0.19	-	+0.22	-	-	−0.05
	30 Sep	−0.02	−0.02	+0.09	-	-	-	−0.02	−0.03
1981	22 May	−0.02	-	+0.11	-	-	-	−0.07	-
	5 Jun	−0.75	-	−0.69	-	-	−0.01	−0.13	−0.01
	3 Jul	−0.29	+0.20	−0.69	-	+0.20	-	−0.01	−0.01
	31 Jul	−0.16	−0.24	+0.47	+0.16	+0.09	−0.04	−0.01	−0.27
	11 Sep	-	-	+0.02	-	-	-	-	−0.01
	26 Sep	+0.02	-	-	-	-	-	−0.01	−0.01
Total No. +		8 (35)[a]	2 (18)	13 (52)	3 (100)	12 (100)	0 (0)	0 (0)	0 (0)
Total No. −		15 (65)	9 (82)	12 (48)	0 (0)	0 (0)	13 (100)	19 (100)	20 (100)

*Linear food selection index = ri − Pi, where ri = relative proportion of prey item in stomach and Pi = relative proportion of prey item in habitat.
**Dashes indicate dates when no organisms belonging to that taxon were collected in the Clark-Bumpus tows or found in yellow perch stomachs.
[a]Percent is shown is parentheses.



Stomach samples collected from angler-caught yellow perch were wrapped in cheesecloth and preserved for later analysis.

SMALLMOUTH BASS FOOD HABITS

In smallmouth bass stomachs, insects were most frequent in May (ephemeropterans, dipterans, and unidentified insects) and June (dipterans and unidentified insects), while decapods were most frequent during July-September (Table 8). Yellow perch and unidentified fishes comprised the highest percent volume of prey during May, while decapods dominated the volume eaten during June-September (Fig. 4). Other than during the month of May, decapods were highly utilized as food items by smallmouth bass (Fig 5). Importance indices* were highest for ephemeropterans and unidentified fishes in May, while during June-Sep-

*Importance indices = % frequency of occurrence + % of total volume (see Fig. 5). This differs from the importance factor, which is % frequency of occurrence + % of total food items.

TABLE 8. *Summary statistics and percent frequency of occurrence (FO), percent of total food volume (Vol.), and importance indices (II)* for food items in the stomachs of angler-caught smallmouth bass during May-September, 1977-81, by month.*

Summary Statistic	May	June	July	August	September	May-September 1977-81
No. of stomachs	64	123	124	125	131	567
No. with food (%)	54 (84.4)	98 (79.7)	83 (75.0)	105 (84.0)	101 (77.1)	451 (79.5)
Total no. food items	903	3,966	475	1,199	536	7,079
Food items/ stomach with food	16.7	40.5	5.1	11.4	5.3	15.7
Avg. length (inches) ± SD	10.8 ± 1.8	9.7 ± 1.3	9.4 ± 1.5	9.4 ± 1.3	9.7 ± 1.7	9.8 ± 1.5
Avg. weight (lb) ± SD	0.63 ± 0.50	0.43 ± 0.21	0.45 ± 0.42	0.41 ± 0.21	0.47 ± 0.41	0.48 ± 0.35

	May			June			July			August			September			May-September 1977-81		
Food Item	% FO	% Vol.	II	% FO	% Vol.	II	% FO	% Vol.	II	% FO	% Vol.	II	% FO	% Vol.	II	% FO	% Vol.	II
Crustacea																		
Cladocera	0.0	0.0	0.0	5.7	0.0	5.7	6.4	0.0	6.4	4.9	0.5	5.4	1.3	0.0	1.3	3.7	0.1	3.8
Copepoda	0.0	0.0	0.0	0.9	0.0	0.9	2.4	0.0	2.4	0.0	0.0	0.0	0.6	0.0	0.6	0.8	0.0	0.8
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Amphipoda	19.1	0.7	19.8	8.4	0.1	8.5	8.4	0.1	0.9	0.1	0.1	2.4	1.6	0.0	1.6	6.4	0.2	6.6
Decapoda	6.3	14.4	20.7	37.8	61.9	99.7	37.0	83.4	120.4	58.5	80.6	139.1	46.3	83.2	129.5	37.2	64.7	101.9
Arachnoidea																		
Hydracarina	1.4	0.0	1.4	0.8	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4
Insecta																		
Ephemeroptera	39.2	14.3	53.5	27.7	5.9	33.6	20.2	1.0	21.2	19.0	3.1	22.1	8.2	0.2	8.4	22.9	4.9	27.8
Odonata	16.7	11.0	27.7	25.5	5.4	30.9	14.5	1.4	15.9	35.7	5.2	40.9	20.4	4.2	24.6	22.6	5.4	28.0
Hemiptera	14.4	2.7	17.1	4.1	0.0	4.1	0.0	0.0	0.0	9.3	1.1	10.4	5.4	0.1	5.5	6.6	0.8	7.4
Trichoptera	10.6	0.7	11.3	4.2	0.0	4.2	4.0	0.2	4.2	2.3	0.7	3.0	0.8	0.1	0.9	4.4	0.3	4.7
Megaloptera	3.6	0.0	3.6	3.2	0.0	3.2	0.0	0.0	0.0	12.5	0.1	12.6	8.5	0.0	8.5	5.6	<0.1	5.6
Coleoptera	4.2	1.4	5.6	0.8	0.0	0.8	0.8	0.0	0.8	1.7	1.1	2.8	0.0	0.0	0.0	1.5	0.5	2.0
Diptera	33.2	1.9	35.1	47.1	5.8	47.1	24.2	0.1	24.3	29.6	0.3	29.9	20.5	0.2	20.7	29.8	1.7	31.5
Unidentified	33.6	2.5	36.1	51.6	7.8	51.6	19.3	1.3	20.6	16.8	0.7	17.5	36.6	3.2	39.8	30.0	3.1	33.1
Pisces																		
Yellow perch	5.8	18.9	24.7	3.2	8.9	12.1	9.6	9.2	18.8	0.8	0.2	1.0	1.4	2.3	3.7	4.2	7.9	12.1
Smallmouth bass	0.0	0.0	0.0	0.8	0.0	0.8	0.8	0.5	1.3	0.8	0.4	1.2	1.4	4.3	5.7	0.8	1.0	1.8
Unidentified	13.4	31.8	45.2	19.3	5.2	25.7	25.7	2.8	28.5	8.5	7.1	15.6	6.9	2.3	9.2	14.8	9.8	24.6

*II = Importance Index = % frequency of occurrence + % volume.

tember decapods had the highest importance index (Table 8).

In every year of the study except 1978 (when dipterans were the most frequent food item), decapods comprised the highest frequency of occurrence, percent volume, and importance index for prey items ingested by smallmouth bass (Table 9).

Importance factors calculated as the sum of the percent frequency of occurrence and percent of total food items (TFI) were highest for ephemeropterans and dipterans in smallmouth bass caught in May, while dipterans had by far the highest importance factor value of all food items ingested by smallmouth in June (Table 10). Decapods had the highest importance factors in July, August, and September, although ephemeropterans, dipterans, odonates, and unidentified insects also had high importance factors in some of these months. The highest importance factors for yellow perch and unidentified fishes occurred during July (Table 10). Insects comprised the highest percentage of total food items consumed by smallmouth in each month of the study period with crustaceans (mostly decapods) having the next highest percentage during June-September (Fig. 6).

Dipterans registered the highest importance factors of all prey items ingested by smallmouth bass during 1977, 1978, and 1980. Unidentified insects and ephemeropterans were important in the diet of smallmouth bass collected in 1979 and 1981, and decapods were important in each year except 1978 (Table 11).

In Nebish Lake between 1977 and 1981, the percent of fish in the volume of food eaten by smallmouth bass 8.0 inches and larger ranged from 7.2 (1977) to 15.5 (1979), with a mean of 11.3. The percent volume of decapods ingested varied from 68.6 (1978) to 84.2 (1977), with a 5-year mean of 77.1. The percent volume of insects consumed by Nebish Lake smallmouth ranged from a low of 7.4 (1980) to a high of 16.2 (1978), and the mean during 1977-81 was 11.6. These values of the percent by volume of food closely parallel those reported for smallmouth

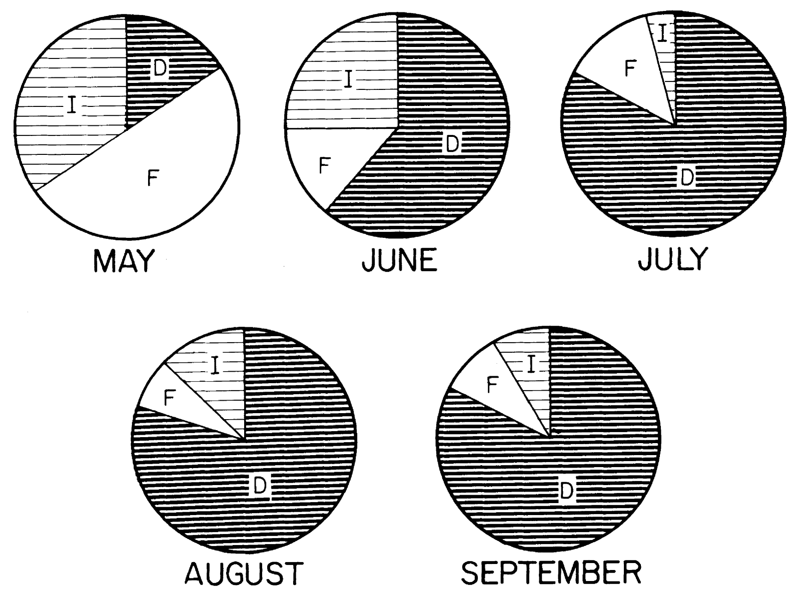


FIGURE 4. *Percent volume of decapods (D), insects (I), and fish (F) in smallmouth bass stomachs, 1977-81, by month.*

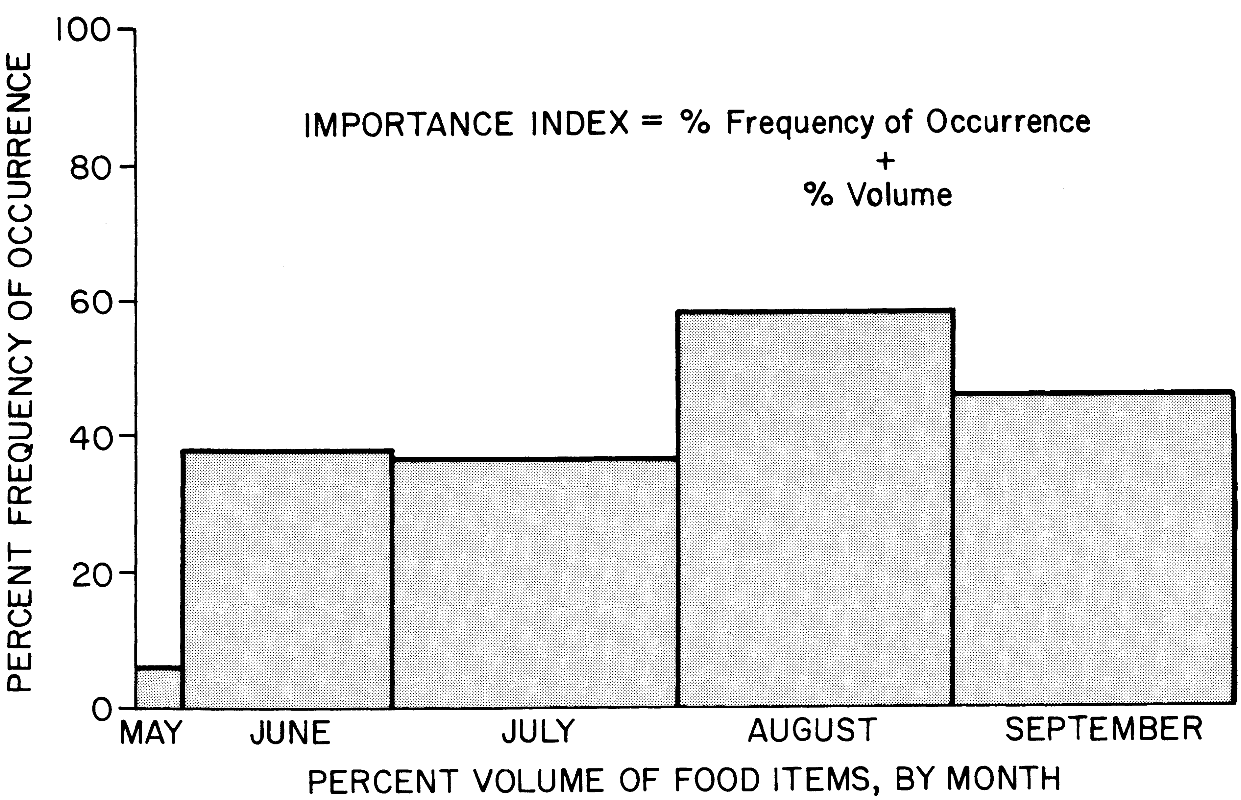


FIGURE 5. *Importance index of decapods in smallmouth bass stomachs, 1977-81, by month.*

TABLE 9. *Summary statistics and percent frequency of occurrence (FO), percent of total food volume (Vol.), and importance indices (II)* for food items in the stomachs of angler-caught smallmouth bass during 1977-81, May-September combined.*

Summary Statistic	1977	1978	1979	1980	1981
No. of stomachs	101	126	104	125	111
No. with food (%)	76 (75.2)	97 (77.0)	88 (84.6)	98 (78.4)	94 (84.7)
Total no. food items	1,467	3,366	884	638	724
Food items/stomach with food	19.3	34.7	10.0	6.5	7.7
Avg. length (inches) ± SD	9.4 ± 1.2	9.9 ± 2.0	9.4 ± 1.1	9.9 ± 1.5	9.6 ± 1.5
Avg. weight (lb) ± SD	0.41 ± 0.22	0.57 ± 0.56	0.40 ± 0.17	0.47 ± 0.33	0.43 ± 0.30

Food Item	1977 % FO	1977 % Vol.	1977 II	1978 % FO	1978 % Vol.	1978 II	1979 % FO	1979 % Vol.	1979 II	1980 % FO	1980 % Vol.	1980 II	1981 % FO	1981 % Vol.	1981 II
Crustacea															
Cladocera	2.0	0.0	2.0	3.2	0.3	3.5	4.8	<0.1	4.8	4.0	0.0	4.0	6.3	<0.1	6.3
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	1.0	<0.1	1.0	0.0	0.0	0.0	3.6	<0.1	3.6
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	1.0	<0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	2.0	0.1	2.0	4.8	<0.1	4.8	2.9	0.1	3.0	8.0	0.1	8.1	6.3	<0.1	6.3
Decapoda	48.5	84.2	132.7	22.2	68.6	90.8	46.2	69.9	116.1	45.6	82.6	128.2	46.0	80.1	126.1
Arachnoidea															
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0	1.0	<0.1	1.0	0.8	<0.1	0.8	0.0	0.0	0.0
Insecta															
Ephemeroptera	14.9	0.6	15.5	32.5	5.3	37.8	25.0	3.8	28.8	15.2	0.4	15.6	17.1	0.8	17.9
Odonata	29.7	5.4	35.1	19.0	2.9	21.9	28.9	5.8	34.7	17.6	4.1	21.7	24.3	4.4	28.7
Hemiptera	1.0	0.0	1.0	7.1	0.3	7.4	11.5	0.8	12.3	3.2	0.3	3.5	4.5	0.1	4.6
Trichoptera	2.0	0.0	2.0	4.0	<0.1	4.0	2.9	<0.1	2.9	5.6	0.1	5.7	3.6	0.2	3.8
Megaloptera	6.9	0.1	7.0	10.3	0.4	10.7	3.9	0.2	4.1	5.6	<0.1	5.6	1.8	<0.1	1.8
Coleoptera	0.0	0.0	0.0	0.8	<0.1	0.8	1.9	<0.1	1.9	2.4	0.1	2.5	0.9	<0.1	0.9
Diptera	23.8	1.3	25.1	45.2	6.4	51.6	34.6	0.1	34.7	18.4	0.2	18.6	24.3	0.2	24.5
Unidentified	23.8	1.2	25.0	23.0	0.9	23.9	38.5	3.7	42.2	30.4	2.2	32.6	40.5	5.7	46.2
Pisces															
Yellow perch	2.0	0.5	2.5	2.4	3.2	5.6	5.8	10.1	15.9	3.2	7.5	10.7	6.3	5.5	11.8
Smallmouth bass	1.0	4.2	5.2	0.0	0.0	0.0	1.9	1.5	3.4	0.8	1.0	1.8	0.9	0.6	1.5
Unidentified	15.8	2.5	18.3	11.1	22.8	22.8	23.1	3.9	27.0	11.2	1.5	12.7	11.7	2.8	14.5

*II = Importance Index = % frequency of occurrence + % volume.

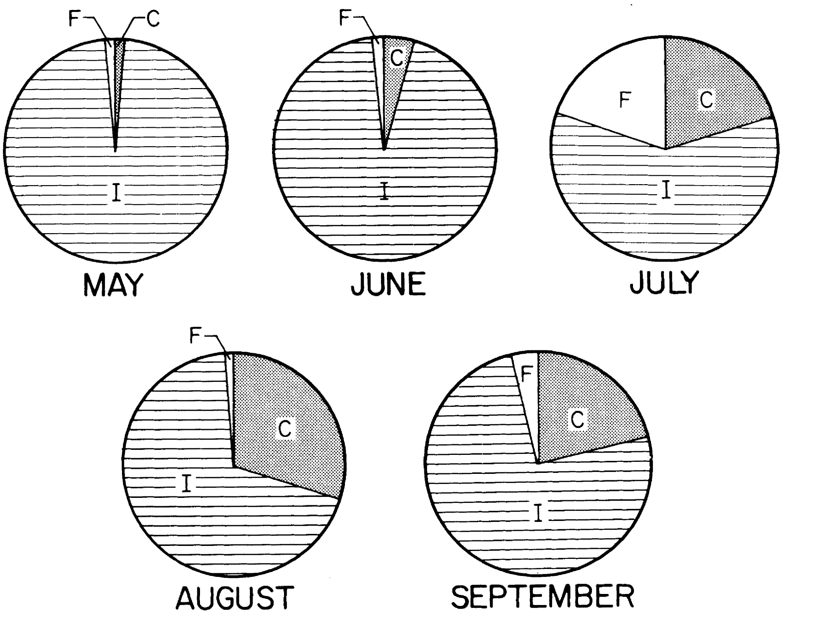
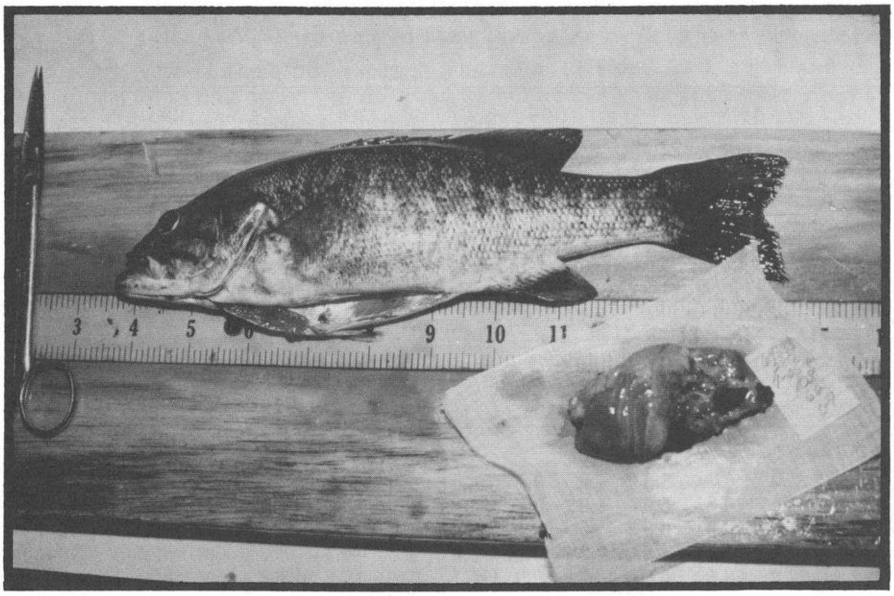


FIGURE 6. *Percent of total food items comprised of crustaceans (C), insects (I), and fish (F) in smallmouth bass stomachs, 1977-81, by month.*

bass in several Ontario lakes. Tester (1932) reported that for adult smallmouth, decapods (crayfish) form approximately 60-90% of the food volume, fishes 10-30%, and aquatic and terrestrial insects 0-10%.

Food habits of smallmouth bass reported by others have generally indicated that bass are more piscivorous than we found. Hubert (1977) reported that the diet of smallmouth bass from 200-299 mm (about 8-12 inches) was 66% fish (by volume), 25% decapods, and 9% insects in Pickwick Reservoir, Alabama. Applegate et al. (1967) reported that fish (mostly threadfin and gizzard shad) contributed 94% of the total volume of food eaten by smallmouth 8.0 inches and larger in Bull Shoals Reservoir, Arkansas. Adult smallmouth in Katherine Lake, Michigan, ate 24-34% fish by volume during the summer months, while the volume of decapods ranged from a high of 31% in June to a low of 2% in August-September (Clady 1974). The reduced amount of fish in the diet of Nebish Lake smallmouth in comparison to those in other waters is probably the result of a lack of other fishes (other than yellow perch) in the lake.



Stomach samples collected from angler-caught smallmouth bass were wrapped in cheesecloth and preserved for later analysis.

DIETARY OVERLAP

A comparison of the monthly importance factor values of food items consumed by adult yellow perch and smallmouth bass indicated an overlap in the selection of ephemeropterans and odonates in June and July, hemipterans and megalopterans in September, and dipterans throughout the period of May-September (Table 12). Using the importance factor as an indicator, annual comparisons of diet overlap suggested similar use of odonates in 1977-79 and dipterans in each of the 5 years of study (Table 13).

However, because the importance factor combines only the values of frequency of occurrence and percent of total food items, it does not give an accurate indication of volume ingested, especially for the smallmouth bass. Even though in some months and years the frequency of occurrence and percent of total food items were high for dipterans ingested by smallmouth, the percent volume values never exceeded 6% in any month or 7% in any year (all months combined). Although percent volume data was not determined for

TABLE 10. *Summary statistics and percent frequency of occurrence (FO), percent of total food items (TFI), and importance factors (IF)* for food items found in the stomachs of angler-caught smallmouth bass during May-September, 1977-81, by month.*

Summary Statistic	May	June	July	August	September
No. of stomachs analyzed	64	123	124	125	131
No. with food (%)	54 (84.4)	98 (79.7)	93 (75.0)	105 (84.0)	101 (77.1)
Total no. food items	903	3,966	475	1,199	536
Food items/stomach with food	16.7	40.5	5.1	11.4	5.3
Avg. length (inches) ± SD	10.8 ± 1.8	9.7 ± 1.3	9.4 ± 1.5	9.4 ± 1.3	9.7 ± 1.7
Avg. weight (lb) ± SD	0.63 ± 0.50	0.43 ± 0.21	0.45 ± 0.42	0.41 ± 0.21	0.47 ± 0.41

	May			June			July			August			September		
Food Item	% FO	% TFI	IF	% FO	% TFI	IF	% FO	% TFI	IF	% FO	% TFI	IF	% FO	% TFI	IF
Crustacea															
Cladocera	0.0	0.0	0.0	5.7	0.4	6.1	6.4	2.2	8.6	4.9	15.3	20.2	1.3	4.1	5.4
Copepoda	0.0	0.0	0.0	0.9	<0.1	0.9	2.4	1.1	3.5	0.0	0.0	0.0	0.6	0.6	1.2
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	19.1	1.4	20.5	8.4	1.9	10.3	0.8	0.2	1.0	2.3	4.8	7.1	1.6	0.6	2.2
Decapoda	6.3	0.4	6.7	37.8	1.4	39.2	37.0	16.7	53.7	58.5	9.8	68.3	46.3	16.0	62.3
Arachnoidea															
Hydracarina	1.4	0.3	1.7	0.8	<0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insecta															
Ephemeroptera	39.2	34.3	73.5	27.7	10.2	37.9	20.2	27.6	47.8	19.0	16.6	35.6	8.2	3.7	11.9
Odonata	16.7	2.6	19.3	25.5	1.1	26.6	14.5	4.8	19.3	35.7	7.2	42.9	20.4	10.9	31.3
Hemiptera	14.4	0.9	15.3	4.1	0.1	4.2	0.0	0.0	0.0	9.3	3.3	12.6	5.4	2.1	7.5
Trichoptera	10.6	2.7	13.3	4.2	0.4	4.6	4.0	3.4	7.4	2.3	0.7	3.0	0.8	0.2	1.0
Megaloptera	3.6	0.2	3.8	3.2	0.2	3.4	0.0	0.0	0.0	12.5	3.2	15.7	8.5	3.6	12.1
Colcoptera	4.2	2.2	6.4	0.8	<0.1	0.8	0.8	0.2	1.0	1.7	0.1	1.8	0.0	0.0	0.0
Diptera	33.2	51.9	85.1	41.3	80.9	122.2	24.2	16.3	40.5	29.6	33.6	63.2	20.5	32.0	52.5
Unidentified	33.6	2.6	36.2	43.8	3.7	47.5	19.3	8.5	27.8	16.8	4.2	21.0	36.6	25.6	62.2
Pisces															
Yellow perch	5.8	0.2	6.0	3.2	0.4	3.6	9.6	7.3	16.9	0.8	0.1	0.9	1.4	1.0	2.4
Smallmouth bass	0.0	0.0	0.0	0.8	<0.1	0.8	0.8	0.2	1.0	0.8	0.1	0.9	1.4	0.5	1.9
Unidentified	13.4	0.3	13.7	19.3	0.3	19.6	25.7	12.3	38.0	8.5	0.3	8.8	6.9	1.7	8.6

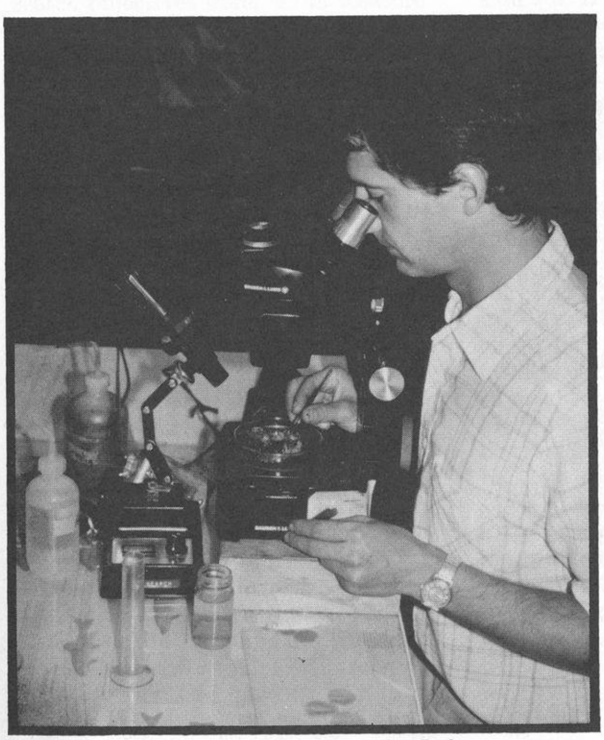
*IF = Importance Factor = % frequency of occurrence + % of total food items.

TABLE 11. *Summary statistics and percent frequency of occurrence (FO), percent of total food items (TFI), and importance factors (IF)* for food items in the stomachs of angler-caught smallmouth bass during 1977-81, May-September combined.*

Summary Statistic	1977	1978	1979	1980	1981
No. of stomachs	101	126	104	125	111
No. with food (%)	76 (75.2)	97 (77.0)	88 (84.6)	98 (78.4)	94 (84.7)
Total no. food items	1,467	3,366	884	638	724
Food items/stomach with food	19.3	34.7	10.0	6.5	7.7
Avg. length (inches) ± SD	9.4 ± 1.2	9.9 ± 2.0	9.4 ± 1.1	9.9 ± 1.5	9.6 ± 1.5
Avg. weight (lb) ± SD	0.41 ± 0.22	0.57 ± 0.56	0.40 ± 0.17	0.47 ± 0.33	0.43 ± 0.30

Food Item	1977 % FO	1977 % TFI	1977 IF	1978 % FO	1978 % TFI	1978 IF	1979 % FO	1979 % TFI	1979 IF	1980 % FO	1980 % TFI	1980 IF	1981 % FO	1981 % TFI	1981 IF
Crustacea															
Cladocera	2.0	0.1	2.1	3.2	3.9	7.1	4.8	5.9	10.7	4.0	0.4	4.4	6.3	4.0	10.3
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	1.2	0.0	0.0	0.0	3.6	0.8	4.4
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	2.0	3.5	5.5	4.8	0.3	5.1	2.9	0.6	3.5	8.0	2.5	10.5	6.3	1.4	7.7
Decapoda	48.5	5.5	54.0	22.2	1.4	23.6	46.2	7.1	53.3	45.6	14.0	59.6	46.0	10.4	56.4
Arachnoidea															
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	1.1	0.8	0.2	1.0	0.0	0.0	0.0
Insecta															
Ephemeroptera	14.9	1.7	16.6	32.5	11.3	43.8	25.0	35.5	60.5	15.2	6.3	21.5	17.1	36.2	53.3
Odonata	29.7	4.3	34.0	19.0	1.0	20.0	28.9	5.0	33.9	17.6	6.9	24.5	24.3	7.3	31.6
Hemiptera	1.0	0.1	1.1	7.1	0.6	7.7	11.5	5.1	16.6	3.2	0.8	4.0	4.5	2.5	7.0
Trichoptera	2.0	0.3	2.3	4.0	0.5	4.5	2.9	1.6	4.5	5.6	4.2	9.8	3.6	0.7	4.3
Megaloptera	6.9	0.7	7.6	10.3	1.0	11.3	3.9	0.7	4.6	5.6	1.1	6.7	1.8	0.4	2.2
Coleoptera	0.0	0.0	0.0	0.8	<0.1	0.8	1.9	0.2	2.1	2.4	2.4	4.8	0.9	0.1	1.0
Diptera	23.8	79.8	103.6	45.2	78.1	123.3	34.6	11.7	46.3	18.4	43.1	61.5	24.3	14.2	38.5
Unidentified	23.8	2.0	25.8	23.0	1.5	24.5	38.5	21.3	59.8	30.4	10.9	41.3	40.5	17.0	57.5
Pisces															
Yellow perch	2.0	0.6	2.6	2.4	0.1	2.5	5.8	1.3	7.1	3.2	1.8	5.0	6.3	2.5	8.8
Smallmouth bass	1.0	0.1	1.1	0.0	0.0	0.0	1.9	0.3	2.2	0.8	0.2	1.0	0.9	0.1	1.0
Unidentified	15.8	1.3	17.1	11.1	0.4	11.5	23.1	3.1	26.2	11.8	5.2	17.0	11.7	2.4	14.1

*IF = Importance Factor = % frequency of occurrence + % of total food items.



Inside the laboratory at the Escanaba Lake research station, a project biologist analyzes the stomach contents of a smallmouth bass.

food items eaten by yellow perch, dipterans probably comprised a much greater percentage of the total volume in perch stomachs compared to smallmouth stomachs. For smallmouth bass, the only month that decapods did not dominate the percent volume of food was May, when fishes comprised 51% of the total volume.

For both species, mean lengths at the various ages increased during 1977-81 (Serns 1984), compared to 1972-76 (Kempinger et al. 1982). For yellow perch, the mean lengths from 1977-81 were above average when compared with those at the same ages in northwestern Wisconsin seepage lakes (Snow 1969). For smallmouth bass, they are higher than the averages for those bass from Michigan, Minnesota, and Wisconsin (Carlander 1977). It appears that dietary overlap between adult yellow perch and smallmouth bass was minimal in Nebish Lake and probably was a primary reason these two species have remained compatible and apparently in balance in this water body.

TABLE 12. *Comparisons of monthly importance factors* of food items consumed by yellow perch (YP) vs. smallmouth bass (SMB) during May-September, 1977-81, by month.*

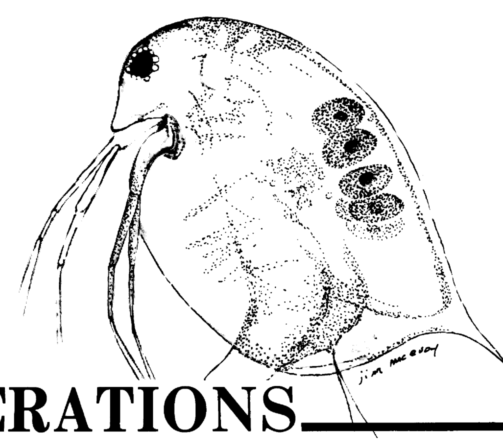
Food Item	May YP	May SMB	June YP	June SMB	July YP	July SMB	August YP	August SMB	September YP	September SMB	Average (All months & all years) YP	Average (All months & all years) SMB
Bryozoa	1.7	0.0	3.4	0.0	5.7	0.0	1.3	0.0	0.0	0.0	2.4	0.0
Crustacea												
Cladocera	33.4	0.0	79.0	6.1	33.1	8.6	102.4	20.2	151.2	5.4	79.8	8.1
Copepoda	0.0	0.0	3.4	0.8	0.0	3.5	4.2	0.0	2.4	1.2	2.0	1.1
Ostracoda	0.0	0.0	1.8	0.0	0.0	1.0	0.8	0.0	0.8	0.0	0.7	0.2
Amphipoda	81.6	20.5	42.3	10.3	34.9	1.0	22.2	7.1	9.0	2.2	38.0	8.2
Decapoda	12.5	6.7	22.2	39.2	13.3	53.7	9.9	68.3	0.8	62.3	11.7	46.0
Arachnoidea												
Hydracarina	9.0	1.7	11.5	0.8	2.9	0.0	3.6	0.0	1.6	0.0	5.7	0.5
Insecta												
Ephemeroptera	19.4	73.5	43.7	37.9	49.7	47.8	7.5	35.6	3.2	11.9	24.7	41.3
Odonata	34.9	19.3	20.6	26.6	25.7	19.3	19.2	42.9	10.4	31.3	22.2	27.9
Hemiptera	1.7	15.3	0.8	4.2	0.0	0.0	1.6	12.6	8.0	7.5	2.4	7.9
Trichoptera	28.1	15.3	24.4	4.6	17.9	7.4	11.8	3.0	4.9	1.0	17.4	5.9
Megaloptera	19.9	3.8	10.2	3.4	10.6	0.0	10.4	15.7	10.5	12.1	12.3	7.0
Coleoptera	1.7	6.4	4.2	0.8	7.0	1.0	2.7	1.8	2.2	0.0	3.6	2.0
Diptera	85.1	85.1	76.7	122.2	67.9	40.5	82.5	63.2	52.7	52.5	73.0	72.7
Unidentified	5.2	36.2	0.8	47.5	3.5	27.8	1.6	21.0	3.2	62.2	2.9	38.9
Gastropoda	3.7	0.0	0.0	0.0	6.9	0.0	14.2	0.0	3.3	0.0	5.6	0.0
Pelecypoda	3.5	0.0	2.6	0.0	1.8	0.0	6.1	0.0	3.0	0.0	3.4	0.0
Pisces												
Yellow perch	0.0	6.0	0.0	3.6	2.6	16.9	3.3	0.9	0.0	2.4	1.2	6.0
Smallmouth bass	0.0	0.0	0.0	0.8	0.0	1.0	0.0	0.9	0.0	1.9	0.0	0.9
Unidentified	8.6	13.7	3.4	19.6	15.4	38.0	4.1	8.8	0.0	8.6	6.3	17.7

*Importance Factor (IF) = % frequency of occurrence + % of total food items.

TABLE 13. *Comparisons of monthly importance factors* for food items consumed yellow perch (YP) and smallmouth bass (SMB) during 1977-81, May-September combined.*

Food Item	1977 YP	1977 SMB	1978 YP	1978 SMB	1979 YP	1979 SMB	1980 YP	1980 SMB	1981 YP	1981 SMB	Average YP	Average SMB
Bryozoa	0.0	0.0	3.7	0.0	1.6	0.0	1.4	0.0	3.9	0.0	2.1	0.0
Crustacea												
Cladocera	104.4	2.1	89.1	7.1	77.3	9.6	105.1	4.4	116.3	10.3	98.4	6.7
Copepoda	2.1	0.0	3.3	0.0	3.4	1.2	1.7	0.0	0.9	4.4	2.3	1.1
Ostracoda	4.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.8	0.2
Amphipoda	32.3	5.5	35.4	5.1	32.4	3.4	19.7	10.5	32.9	7.7	30.5	6.4
Decapoda	16.1	54.0	10.0	23.6	4.7	53.1	6.0	59.6	21.9	56.4	11.7	49.3
Arachnoidea												
Hydracarina	3.0	0.0	7.9	0.0	6.1	1.1	5.3	1.0	4.6	0.0	5.4	0.4
Insecta												
Ephemeroptera	28.1	16.1	31.5	43.8	9.9	59.5	14.1	21.5	15.8	53.3	19.9	38.9
Odonata	28.9	34.0	21.2	20.0	21.0	33.7	11.2	24.5	17.6	31.6	20.0	28.8
Hemiptera	0.0	1.1	7.5	7.7	1.1	16.5	0.0	4.0	3.7	7.0	2.5	7.3
Trichoptera	19.4	2.3	15.9	4.5	20.1	4.5	10.7	9.8	14.6	4.3	16.1	5.1
Megaloptera	16.2	7.6	16.2	11.3	9.3	4.5	8.3	6.7	6.5	2.2	11.3	6.5
Coleoptera	1.2	0.0	2.5	0.8	8.6	2.3	4.4	4.8	3.7	1.0	4.1	1.8
Diptera	80.6	103.6	89.8	123.3	58.7	45.9	52.1	61.5	45.4	38.5	65.3	74.6
Unidentified	2.0	25.8	2.5	24.5	1.1	54.9	5.9	41.3	0.9	57.5	2.5	40.8
Gastropoda	5.3	0.0	0.8	0.0	14.1	0.0	3.6	0.0	6.3	0.0	6.0	0.0
Pelecypoda	0.0	0.0	4.2	0.0	0.0	0.0	4.8	0.0	6.3	0.0	3.1	0.0
Pisces												
Yellow perch	1.0	2.6	0.0	2.5	2.3	7.0	0.0	5.0	3.7	8.8	1.4	5.2
Smallmouth bass	0.0	1.1	0.0	0.0	0.0	2.2	0.0	1.0	0.0	1.0	0.0	1.1
Unidentified	6.2	17.1	4.2	11.5	6.9	26.1	2.5	17.0	5.6	14.1	5.1	17.2

*Importance Factor (IF) = % frequency of occurrence + % of total food items.



MANAGEMENT CONSIDERATIONS

This study indicated the amount of dietary overlap between adult smallmouth bass and yellow perch was not severe in Nebish Lake. Since chemical treatment in the fall of 1966 and restocking with adult smallmouth bass and yellow perch in 1967 (Christenson et al. 1982), growth of the two species has been good (Kempinger et al. 1982; Serns 1984). These two species appear to be compatible, and this species combination should be considered for introduction or reintroduction into chemically rehabilitated, low alkalinity lakes in northern Wisconsin.

Despite the lack of other fishes in Nebish Lake as a food source for smallmouth bass, growth was good when compared with other waters in the northern Midwest. Decapods comprised a high percentage of the volume of food ingested — 77.1% during the 5-year study period — by Nebish Lake smallmouth bass. When considering smallmouth for introduction into a water body, an assessment of the potential food sources should be made. If forage fishes are not present in good numbers, it would be desirable to have adequate numbers of decapods (crayfish) for prey.

SUMMARY

A 5-year study was conducted on Nebish Lake to determine the food habits and compatibility of yellow perch and smallmouth bass in an infertile northern Wisconsin lake. The research objectives were: 1) to measure zooplankton density and species composition, and relate that to food habits of adult yellow perch; and 2) to examine the dietary overlap between adult yellow perch and smallmouth bass. These objectives were accomplished by sampling zooplankton and stomachs of angler-caught yellow perch and smallmouth bass during May-September from 1977-81.

Daphnia sp., the most abundant cladoceran in Nebish Lake in every month except July, exhibited spring and fall pulses. *Holopedium gibberum* and *Diaphanosoma leuchtenbergianum*, the only other important species of cladocerans collected, exhibited midsummer pulses. The mean density of copepods was greatest in May and June, but their densities were much lower in each month than the density of cladocerans. Annual mean densities during the 5 years were higher for cladocerans in 1978 and 1981 and for copepods in 1979 and 1981. *Daphnia* sp., by far the most abundant cladoceran in each year, had its highest densities in 1978 and 1981.

Of the two major zooplankton taxa ingested by yellow perch, *Daphnia* sp. and *H. gibberum*, the larger individuals were selected. Yellow perch exhibited a positive selection for *Leptodora kindtii*, *Eurycerus lamellatus* and *Daphnia* sp. Perch exhibited a slight negative selection for *H. gibberum*. Even though many were eaten, they were present in perch stomachs at a lower percentage than they were found in the lake's plankton community. They also exhibited a strong negative selection for *D. leuchtenbergianum* and copepods.

Dipterans were the major food items of yellow perch during May-July, while cladocerans were most important in August and September. Amphipods were important to the yellow perch diet in May, but their consumption declined during June-September. The frequency of most aquatic insects in the stomachs of adult yellow perch was highest in May and June and then decreased from July-September, probably as a result of reduced post-emergence densities. The consumption of fishes by adult yellow perch, never high in any month, was highest during July.

Decapods (*Orconectes propinquus*) were by far the most important food item for Nebish Lake smallmouth bass. Other than in 1978, when dipterans were the most frequent food item, decapods comprised the highest percent frequency of occurrence, percent volume, and index of importance in each of the other 4 years. Insects were the most frequent food item in smallmouth stomachs collected in May and June, while decapods were the most frequent item from July through September. Yellow perch and unidentified fishes (most were probably young yellow perch) comprised the highest percent volume of food ingested by smallmouth in May, but decapods represented the greatest percent volume of food consumed by bass during June-September.

An overlap in food selection by yellow perch and smallmouth bass was identified for ephemeropterans and odonates (June and July), hemipterans and megalopterans (September) and dipterans (May-September). Because of the relatively small percent of total volume that these taxa comprised in smallmouth bass stomachs, competition between perch and bass for available food resources did not appear to be severe. The bulk of the food volume ingested by smallmouth during May-September was comprised of decapods. Decapods were not an important food item for adult perch.

Because of the limited dietary overlap between yellow perch and smallmouth bass in this study, we propose that this species combination be considered for introduction (reintroduction) into chemically rehabilitated soft water lakes in northern Wisconsin having physical and biological characteristics similar to Nebish Lake.

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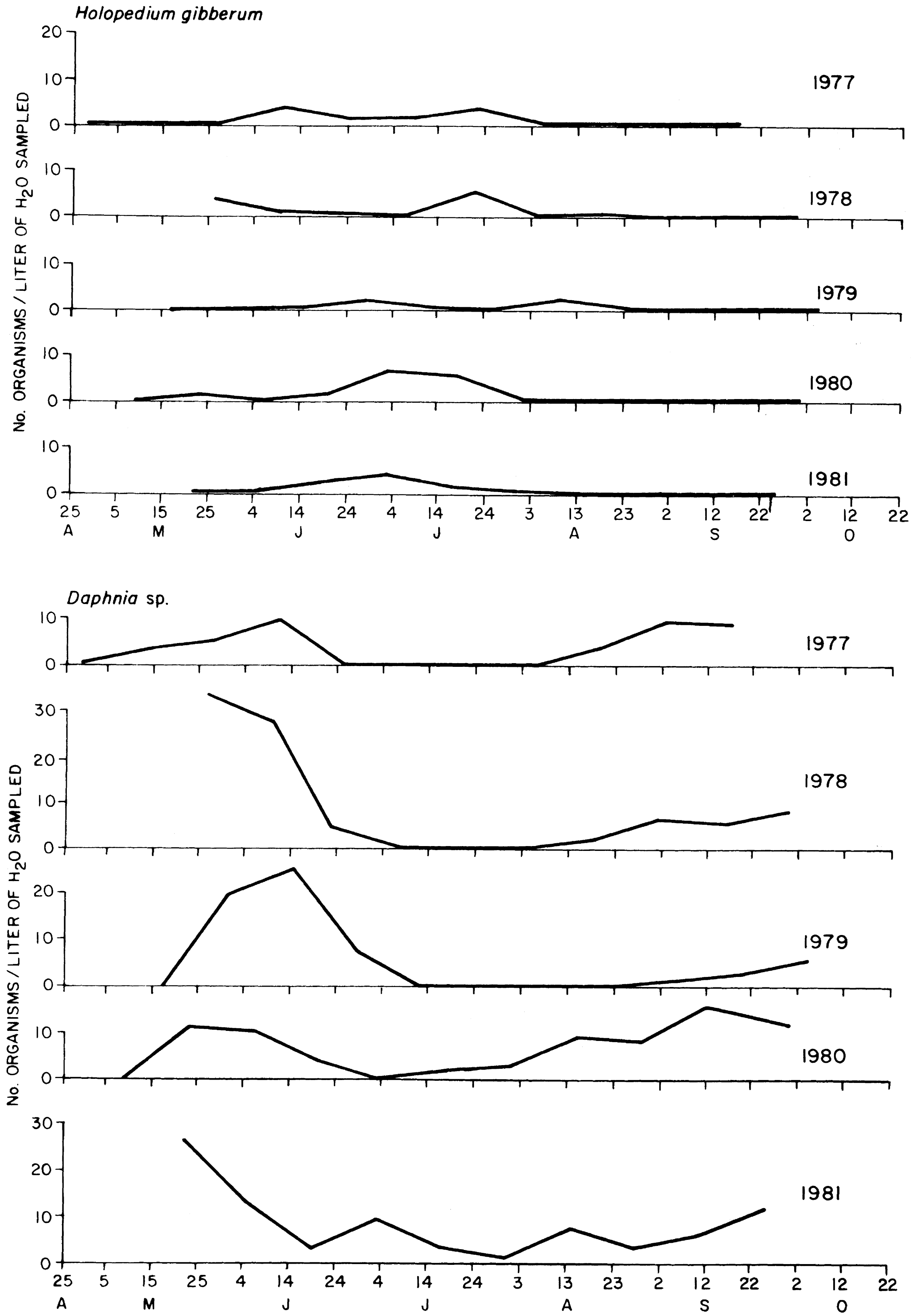
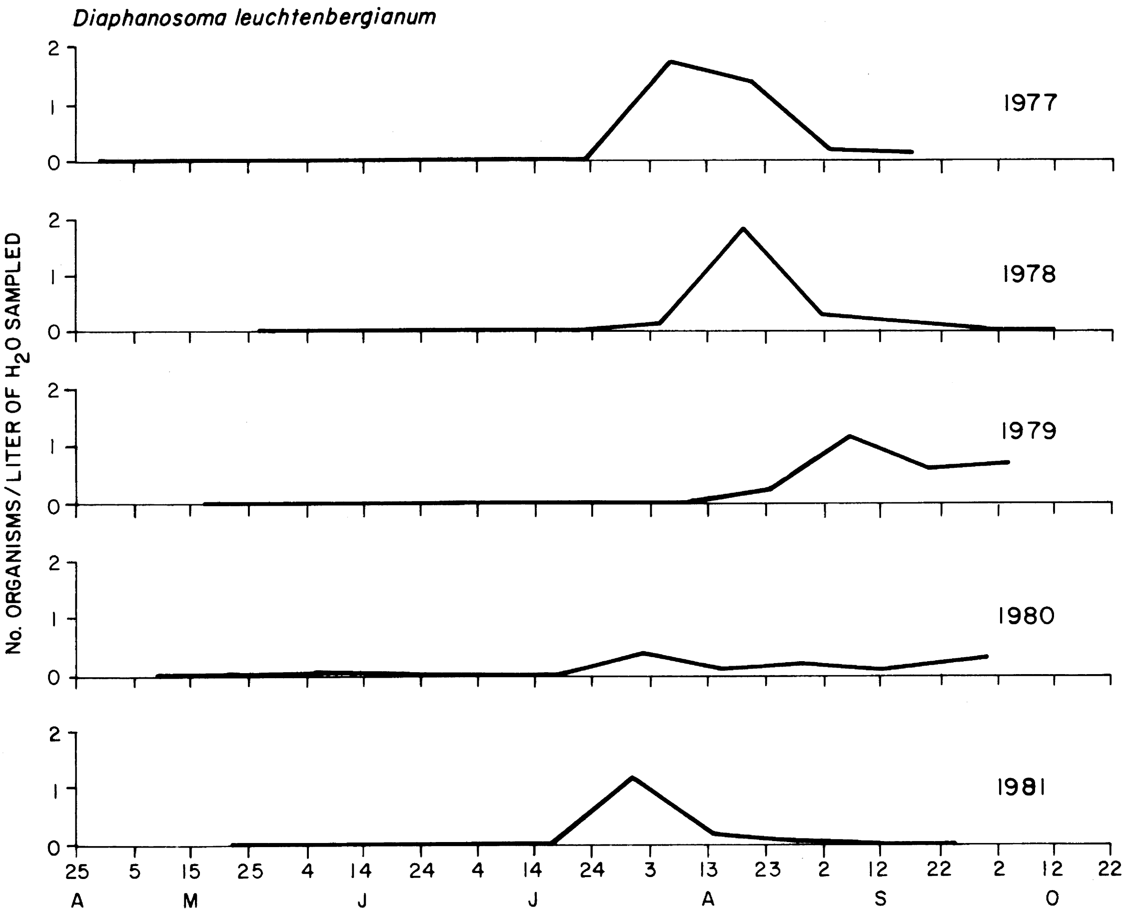
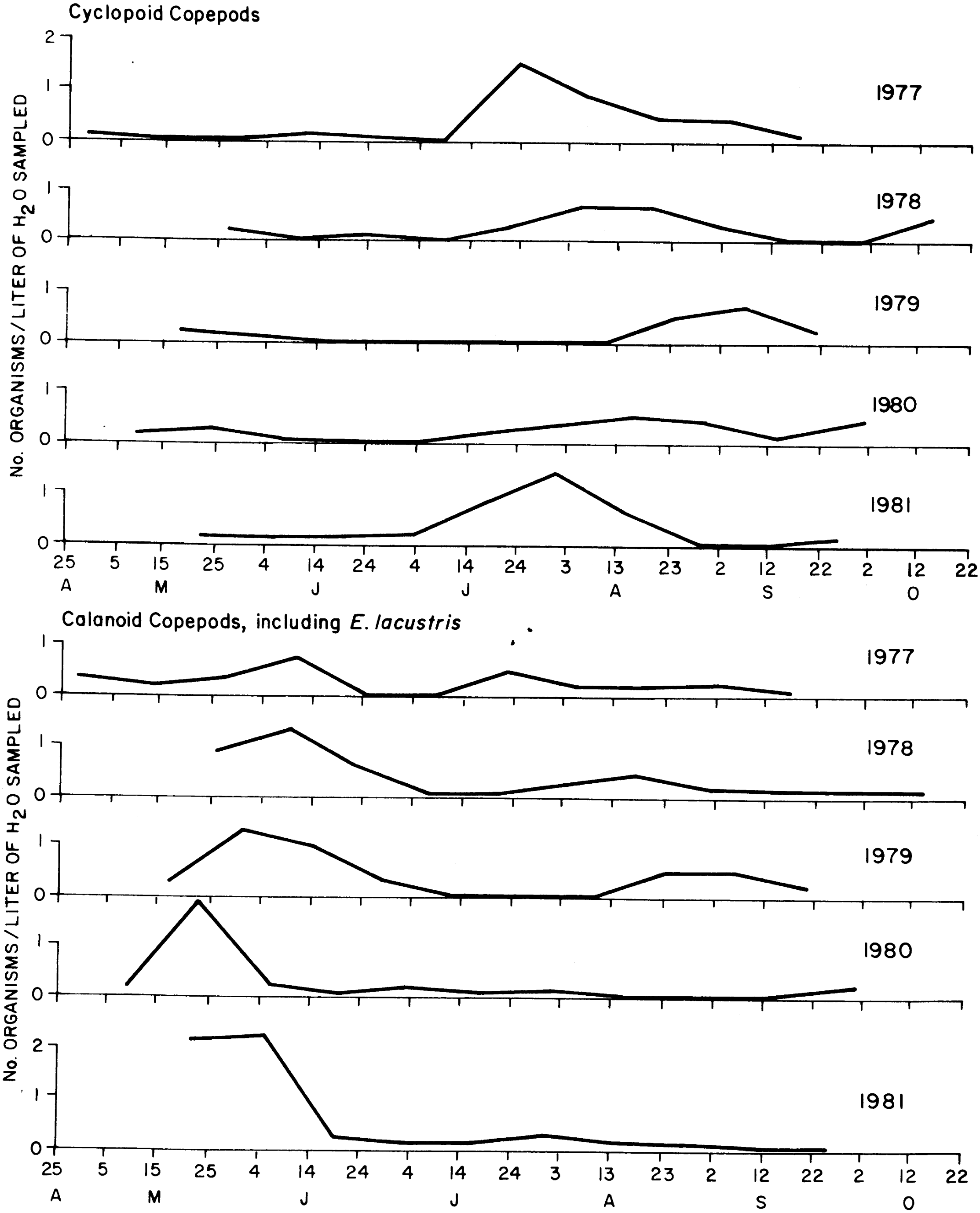
APPENDIX



APPENDIX FIGURE A.1. *Densities of the cladoceran taxa collected on various sampling dates, 1977-81.*



APPENDIX FIGURE A.1. *Densities of the cladoceran taxa collected on various sampling dates, 1977-81 .*



APPENDIX FIGURE A.2. *Densities of cyclopoid and calanoid copepods collected on various sampling dates, 1977-81.*

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