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Food Habits of Fishes in Ten New Brunswick Lakes

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FOOD HABITS OF FISHES IN TEN NEW BRUNSWICK LAKES

by

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ABSTRACT

Peterson, R. H., and D. J. Martin-Robichaud. 1982. Food habits of fishes in ten New Brunswick lakes. Can. Tech. Rep. Fish. Aquat. Sci. 1094: iii + 43 p.

The analyses of the stomach contents of 23 species of fish from 10 N.B. lakes are presented, using percent occurrence and relative volumetric importance as parameters. Fish food habits were arrayed in a vector diagram such that food habits are related to trophic level. White suckers, banded killifish, ninespine sticklebacks, and juveniles of white perch and pumpkinseeds, ate mainly dipteran larvae and zooplankton. Brown bullheads, pumpkinseed, white perch, golden shiners, common shiners, and juvenile yellow perch ate dipteran larvae and larger aquatic invertebrates. Fallfish, creek chub, and lake chub relied primarily on larger aquatic insects. Brook trout, yellow perch, and smallmouth bass ate larger aquatic insects and fish. Chain pickerel fed on fish. Fish communities in the lakes are discussed with reference to water chemistry and susceptibilty to potential lake acidification.

Key words: food items, zooplankton, aquatic insects, fish, brook trout, Atlantic salmon, rainbow smelts, chain pickerel, redbelly dace, finescale dace, golden shiner, common shiner, lake chub, creek chub, blacknose shiner, fallfish, pearl dace, white sucker, brown bullhead, American eel, banded killifish, threespine stickleback, ninespine stickleback, white perch, pumpkinseed, smallmouth bass, yellow perch.

RÉSUMÉ

Peterson, R. H., and D. J. Martin-Robichaud. 1982. Food habits of fishes in ten New Brunswick lakes. Can. Tech. Rep. Fish. Aquat. Sci. 1094: iii + 43 p.

On trouvera dans le rapport qui suit les résultats d'analyses des contenus stomacaux de 23 espèces de poissons provenant de 10 lacs du Nouveau-Brunswick. Les pourcentages d'occurrence et l'importance relative des volumes ont été utilisés comme paramètres. Les habitudes alimentaires ont été disposées en un diagramme vertical reliant ces habitudes au niveau trophique. Les meuniers noirs, fondules barrés, épinoches à neuf épines et les jeunes gattes et crapets-soleils se nourrissent principalement de larves de diptères et de zooplancton. Les barbottes brunes, crapets-soleils, gattes, chattes de l'est, ménés à nageoires rouges et jeunes perchaudes mangent surtout des larves de diptères et des grands invertébrés aquatiques. Les ouitouches, mulets à cornes et ménés de lac dépendent en grande partie de grands insectes aquatiques. Les ombles de fontaine, perchaudes et achigans à petite bouche se nourrissent de grands insectes aquatiques et de poissons. Le brochet maillé avale des poissons. Nous examinons les communautés ichtyologiques en relation avec les propriétés chimiques de l'eau et la susceptibilité des lacs à une acidification éventuelle.

INTRODUCTION

Acidic precipitation is now considered a serious freshwater fisheries problem over much of eastern North America (Harvey 1980; Last et al. 1980). The mean annual pH of precipitation in southwestern New Brunswick is now approximately 4.5 (Glass and Brydges 1981). In view of this latter fact, it was decided to survey 10 lakes in southern New Brunswick in the summer of 1978 to establish some baseline data on water chemistry and fish populations to assess possible future changes resulting from acidification. It is intended to repeat the water chemistry aspects of the survey every 5 yr and the fish sampling aspects every 10 yr. The water chemistry portion of the 1978 survey is now in print (Peterson 1980).

The information obtained on the fish populations in these 10 lakes will be presented in two reports. This report will present a summary of the species and numbers of fish sampled from each lake, and an analysis of the stomach contents of representative samples of these fish. A subsequent report will deal with the age-size information obtained from these fish samples.

MATERIALS AND METHODS

GILLNETTING

The gillnets used were experimental nets of knotless nylon with one 6 x 30 ft (1.8 x 9.1 m) panel each of 1/2 in. (1.3 cm) square (1 in. (2.5 cm) stretched); 3/4 in. (1.9 cm) (1 1/2 in. (3.8 cm)); 1 in. (2.5 cm) (2 in. (5.1 cm)); and 1 1/4 in. (3.1 cm) (2 1/2 in. (6.3 cm)) mesh monofilament nylon. The largest fish present in some lakes may not have been fished due to the lack of larger mesh sizes. It is recommended that a panel of 2 in. (5.1 cm) square mesh be included should the sampling be repeated in the future. All nets were disinfected with formalin after each month's fishing was performed. All sets were for 24 ± 5 h, and nets were set at 1000-1500 h.

Nine of the 10 lakes were fished three times (mid-June, early to mid-August, and late September (Table 1)). Chisholm Lake was owned by a private fishing club and was not fished with gillnets. The caretaker recorded lengths and weights, and preserved heads for use in ageing some of the brook trout angled during the summer from Chisholm Lake. This species is thought to be the only fish of sufficient size for gillnetting to be found in this lake.

The approximate locations of the gillnet sets have been included in Peterson (1980). In cases where the nets were set out near the shoreline, the smaller meshes were nearest the shore.

BEACH SEINING

Beach seining (see Table 2 for dates) was performed with 4 x 30 ft (1.2 x 9 m) knotless nylon seines of 1/8 in. (0.3 cm) square mesh. The seines were equipped with float lines, lead lines reinforced with a length of 1/4 in. (0.6 cm) iron chain, and contained a 4 x 4 ft (1.2 x 1.2 m) x 2 ft (0.6 m) high bag in the center. An area of suitable shoreline of each lake was usually swept three times - only twice if large numbers of fish were taken per sweep - and up to five times if few fish were obtained. Successive sweeps were usually over adjacent segments of the shoreline.

Typically, the seine was carried out to a depth of 4 ft (1.2 m), stretched fully in a parallel orientation to the shoreline, and swept to the margin, drawing the seine up onto the emergent part of the beach.

All fish caught by both methods were preserved in 10% formalin, with fish over 10 cm in length being slit ventrally.

ANALYSES OF STOMACH CONTENTS

All fish collected were identified to species, weighed, measured for standard length, and numbered in increasing order of size for each species in each collection. If the number of fish collected for a given species of a collection totalled 10 or fewer, the stomachs of all fish were analyzed. For collections up to 100 fish, one additional fish was chosen for stomach analysis for each additional 10 fish. If the collection exceeded 100 fish, one additional fish was chosen for each additional 100 fish in the collection. Fish used for stomach analyses were selected at regular intervals over the entire size range in the collection. Excised stomachs, including proximal portions of the esophagus and the pyloric sphincter, were preserved in 90% alcohol.

Stomachs, before and after removal of contents, were blotted and weighed. Recognizable organisms were identified to the lowest taxonomic level possible - usually order or family, occasionally to genus. Selected zooplankton specimens were identified to species. Numbers of each taxon were counted in each stomach analyzed. In a few instances, the relative importance of various taxa was assessed volumetrically according to the method of Hynes (1950).

Data analysis

Most of the conclusions drawn on food habits of the various species are based upon the percent occurrence of the various taxa in the diet (i.e. percent of stomachs analyzed containing a particular taxon) (Holmes and Pitelka 1968).

The percent overlap (Morisita 1959; Horn 1966) was calculated among various species in a given lake and for the same species among lakes:

$$\frac{2\,\Sigma X_i\ Y_i}{\Sigma X_i^{\,2} + \Sigma Y_i^{\,2}}$$

where X_i and Y_i are the proportions of the ith food category in the diet of species X and Y. A minimum sample size of 10 stomachs was utilized for percent overlap analyses (Obrebski and Sibert 1976). A minimum value of 0.7 was arbitrarily chosen to indicate significant overlap in the diets - a more conservative value than 0.6 as chosen by Zaret and Rand (1971).

In addition to the overlap analysis, a vectorial representation of the food habits of the various species was examined. This method projected the components of a species' diet onto a grid, the axes of which represent various categories of food organisms. As an example (Fig. 1) we have arbitrarily chosen four categories: zooplankton (cladocera, copepods), smaller insect larvae and other invertebrates of similar size (e.g. chironomid and heleid larvae, amphipods), larger aquatic insects (mayflies, caddisflies, dragonflies, etc.), and vertebrates (other fish, salamanders, mammals). The length of each axis corresponds to 1.0 or 100% of the diet. If a certain species eats only other fish, then it would occupy a position at the end of that axis. If, as is usually the case, a fish is more cosmopolitan in its food habits (e.g. 20% fish, 60% larger aquatic insects, 20% smaller aquatic insects), then its position on the grid may be determined by vectors. Vectors are laid out whose lengths are proportional to the percentage of that particular category in the diet and whose directions are parallel to the axis of that category. Thus, in the example above, a vector of length 0.2 is measured from the origin (0) along the "fish" axis; from the end of this vector one projects a vector, 0.6 in length, parallel to the "large insect" axis. The final vector, of 0.2 length, is projected from the head of the last vector in a direction parallel to the "small insect" axis. The final position of this species diet is 0.6 along the "large insect" axis (at arrow). For comparison, we have included the vectorial representation of another species whose diet was composed of 10% large insects, 70% small insects, and 20% zooplankton. The sequence followed in laying out the vectors does not affect the final position. It is also true that the final position is ambiguous in that it can be reached by several vector combinations. For example, the position "$\vdash\!\!-$" (Fig. 1) could also be attained with a diet composition 80% large insects and 20% zooplankton. The quadrant in which the vector resultant appears, however, is usually a good indication of the species' dominant food items. The more specialized a species is toward a particular category (i.e. the greater the dominance), the further out along the corresponding axis and the closer to it the resultant will lie. Conversely, a perfect "generalist" would be positioned on the origin, so proximity to the origin indicates the degree to which food habits are generalized.

The assignment of food categories to the various axes is, of course, arbitrary as is the number of axes used. More narrowly defined food habits among species could be analyzed, such as preference for various genera of mayflies. Care must be taken, however, to arrange it so that food items most nearly alike in terms of preference are placed on adjacent axes. If items nearly alike in terms of preference are placed on opposite axes, then the vectors may cancel each other out.

Indices of fullness (C_r = wt of food in stomach/wt of fish x 100) (Gascon and Leggett 1977) were also calculated when sufficient data were present.

RESULTS

SPECIES AND NUMBER OF FISH SAMPLED

A total of 23 species was captured in the 10 lakes in 1978 (Table 3), with an average of 7.4 species per lake. Mill Lake yielded the greatest number of species with 15 and Chisholm Lake the least with two. In general, the larger lakes tended to yield more species, although the scatter is considerable (Fig. 2). No doubt some species were missed in many of the lakes as all habitat types were not fished. Rainbow trout were stocked in Creasey Lake from 1959-62 (Smith 1968), but none was collected in this survey.

BEACH SEINING

The banded killifish was the most ubiquitous species, being present in 8 of the 10 lakes (Table 3). Ninespine sticklebacks and white suckers were collected from 7 of the 10 lakes. American eels were captured only from Kerr and Wheaton Lakes, but the presence of eels was evident (from damage to gillnetted fish) in Creasey, Stein, Mill, Robin Hood, and Bolton Lakes.

The most abundant species taken in the beach seining was the banded killifish, accounting for about 80% of the total number of fish caught (Table 4). About two-thirds of the killifish seined were from Creasey Lake, with Wheaton and Robin Hood Lakes also yielding large numbers. All three lakes were seined in sandy areas with gradual slopes, affording an extensive littoral zone. Emergent vegetation was present, but not dense.

The ninespine stickleback, the second most abundant species captured, was taken in largest numbers in Mosquito, Robin Hood, and Chisholm Lakes. The population in Chisholm Lake, which has a dense growth of submergent vegetation, was particularly dense. Usually, ninespine sticklebacks were not abundant where killifish were taken in large numbers (Creasey, Wheaton, Bolton, Stein) and vice versa (Kerr, Mosquito, Mill, Chisholm). In general, killifish were more prevalent in open shallow water with extensive areas of sandy bottom. Sticklebacks prevailed where the sediment was more flocculent, with dense submergent vegetation. The seining sites at Mosquito and Mill Lakes were sandy, but had numbers of boulders, as was the case at Kerr Lake.

Mill Lake was unique in that the most abundant stickleback was the threespine.

Seining in Robin Hood Lake yielded large numbers of both killifish and sticklebacks. This sampling area had an extensive sandy beach covered with flocculent material, and patches of submergent vegetation, which the sticklebacks may have occupied.

The seining sites at Kerr, Robin Hood, and Bolton Lakes were near outlets (Kerr) or inlets (Robin Hood, Bolton), which may explain the higher diversity of species collected at these sites. Primarily riverine species, such as redbelly dace, finescale dace, common shiner, creek chub, and fallfish, may have been collected at these sites due to their proximity to streams. Redbelly dace were much more abundant in the outlet stream of Creasey Lake than in the lake proper.

The juveniles of species such as white perch, chain pickerel, and white sucker were taken by beach seining in June and August, but not September. By this time, they may have moved to deeper water. Juvenile yellow perch and smallmouth bass, on the other hand, were abundant in the September beach seining.

Brook trout were in the littoral zone of Creasey Lake in late September and were apparently foraging on the schools of killifish.

A shoreline segment of Mud Lake was rotenoned in the August fishing, the poison yielding only juvenile smallmouth bass.

GILLNETTING

Gillnetting appears to select for active, schooling species, such as white perch and golden shiners. Brook trout, white suckers, yellow perch, fallfish, and brown bullheads are also readily caught by this method (Table 5). More sedentary or territorial species, such as smallmouth bass and chain pickerel, tend not to be taken in numbers so that gillnet captures may not provide a very good indication of population densities. Stein and Wheaton Lakes are known to have large populations of smallmouth bass, which is not reflected in the number netted.

FOOD HABITS

The results of analyses of the stomach contents from representatives of each of the fish species sampled are presented below.

Brook trout (Salvelinus fontinalis (Mitchill))

The stomachs of 17 trout (9.1-30.6 cm long) from Creasey Lake were examined (5 from June sampling, 12 from September). The results were pooled for all 17 fish as there was no obvious difference in food habits (from the limited sample) with either season or fish size. The two most important items in the diet of these trout were fish, and terrestrial insects falling into the lake (Fig. 3A). Of the fish consumed, 13 were ninespine sticklebacks, 19 were banded killifish, and 3 were unidentified. Sixteen of the killifish had been consumed by the four trout seined from the littoral zone in September (9.1-17.0 cm in length), where obviously they had moved into the shallows to exploit this abundant food source. The stomach of the 17-cm trout contained nine killifish, while the others contained two or three each.

Terrestrial insects formed another major component of the diet of Creasey Lake trout. Many of these were flying ants which had apparently swarmed over the lake. Three stomachs from the September sampling contained over a hundred of them each. Large aquatic insect larvae (Odonata, Trichoptera, Coleoptera) were also frequent items in the diet. Several of the adult Diptera were identified to be in the family Empididae.

The Creasey Lake trout stomachs were nearly full at all times of the year (Table 6).

The Mosquito Lake brook trout were feeding primarily on terrestrial insects; again, most of them were flying ants (Fig. 3B). Of the 8 fish eaten, 5 were ninespine sticklebacks and 3 were unidentified - probably cyprinids.

The Mill Lake trout were sampled in September and, like the Creasey Lake trout, had been feeding heavily (Table 6). Terrestrial insects, Ephemeroptera and Coleoptera, and fish were the most important items in the diet (Fig. 3C). One of the fish was identified as a yellow perch.

The 5 trout taken from Stein Lake were notable in that they were feeding on small food items, such as Chaoborus larvae, chironomid pupae, or hydrocarina (Fig. 3D). The lack of fish in the diet of these large trout (also true of the smallmouth bass from Stein Lake) may reflect the low production of forage fishes due to the lack of littoral habitat. The indices of fullness were also lowest for the Stein Lake brook trout (Table 6).

Only 2 trout sampled from Kerr Lake had intact viscera. One contained two unidentified fish, and the other three pelecypoda.

The one trout stomach sorted from Chisholm Lake (June) contained 37 pupae of Chaoborus flavicans, 35 oligochaetes, 7 Ephemeroptera, 25 Plecoptera nymphs, 2 Odonata nymphs, and 1 coleopteran.

In general, brook trout down to the 8-10 cm size were feeding primarily on terrestrial insects, small fish, and large aquatic insect larvae.

Atlantic salmon (landlocked form) (Salmo salar Linnaeus)

The single specimen of salmon (22.1 cm) from Robin Hood Lake upon which stomach analysis was performed had ingested 3 fish, 2 of which were ninespine sticklebacks.

Rainbow smelt (Osmerus mordax (Mitchill))

Two smelt stomachs from Mill Lake were examined. The first (1.7 cm long), from the June 13 beach seining had nothing in its stomach. The second (4.4 cm), from the September 25 beach seining, contained 12 chironomid adults.

Chain pickerel (Esox niger Lesueur)

Three chain pickerel were taken from Bolton Lake. The stomachs of all 3 contained fish. The largest pickerel (54 cm) had eaten a white perch and an unidentified fish. The 34.5-cm pickerel contained 2 yellow perch, while the small pickerel (13.5 cm) contained a fish identified as probably a killifish.

Northern redbelly dace (Chrosomus eos Cope)

Redbelly dace were sampled from Robin Hood, Creasey, and Mosquito Lakes. Those from Robin Hood (3) and Creasey (8) were immature specimens and contained nothing identifiable in their stomachs. The single mature specimen from Mosquito Lake contained three chironomid larvae.

Finescale dace (Chrosomus neogaeus (Cope))

One finescale dace (5.3 cm) stomach was examined from the August beach seining in Kerr Lake. It contained fragments of insects of indeterminate identity (possibly Culicid).

Golden shiner (Notemigonus crysoleucas (Mitchill))

The golden shiner was collected in two New Brunswick lakes, Mud and Mill, in sufficient numbers for an analysis of stomach contents (the one specimen beach seined in Bolton L. was not examined). The main food items in the diet of Mud Lake golden shiners switched from Trichoptera in June to Cladocera in August and September (Fig. 4A-C), probably as a result of changes in relative availability of these organisms. The Trichoptera consumed in June were pharate Phryganeids. Cladocera ingested later in the summer were the most important item in the diet on a volumetric as well as percent occurrence basis (Fig. 5A, B).

The golden shiner diet indicates a diversity of feeding habits. The terrestrial organisms are probably ingested at the surface, while the frequent occurrence of snails and clams indicates bottom foraging. Probably most of the feeding is done at midwater to surface as the most important food items were Cladocera and pharate caddisflies. Zooplankton appear to be the main dietary item when available. The relative scarcity of amphipods in the diet also indicates that bottom feeding is not common - in contrast to the diet of brown bullheads in Mud Lake (discussed later).

The mean indices of fullness (Table 7) are about 0.4 for the two lakes.

Common shiner (Notropis cornutus (Mitchill))

As with most cyprinids, the food items in the common shiner stomachs were macerated.

Most common shiners were taken from Bolton Lake in the June and August beach seinings. Only 2 of 10 stomachs analyzed in June contained food items. Six items were adult terrestrial insects, 18 were adult Chironomidae, 1 was an adult neuropteran (Climacia), and 1 was a chironomid larva. These items indicate primarily surface feeding in June. In contrast, the 15 stomachs ($\bar{L}$ (mean length) = 10.1 cm) analyzed in August all contained filamentous algae, with no animal remains identifiable.

Of the stomach contents of the 3 common shiners ($\bar{L}$ = 6.0 cm) seined in Kerr Lake in June, 1 contained an adult terrestrial insect, and another contained 9 adult chironomids, indicating essentially the same diet as the Bolton Lake shiners in June.

Lake chub (Couesius plumbeus (Agassiz))

The adult lake chub of Mosquito and Mill Lakes were almost exclusively insectivorous, with nymphal Ephemeroptera, Odonata, and aquatic Coleoptera forming the bulk of the diet (Fig. 6A, B). The lake chub were also taking advantage of terrestrial insects flying onto the lake, as one stomach from the Mosquito Lake population (August) contained 100 flying ants. Two adults were gillnetted in Bolton Lake; the June specimen (12.3 cm) contained an ephemeropteran nymph, while the August specimen (11.7 cm) contained a caddis case plus some algae and other vegetation.

One juvenile lake chub was beach seined from Bolton Lake (3.8 cm) and was planktivorous, containing 4 cyclopoid copepods, 1 harpacticoid copepod, 3 ostracods, and 1 chironomid larva.

Creek chub (Semotilus atromaculatus (Mitchill))

Only 1 creek chub stomach was analyzed. The fish (12.5 cm) was beach seined from Robin Hood Lake in August. Its stomach contained unidentifiable adult insect pieces.

Blacknose shiner (Notropis heterolepis Eigenmann and Eigenmann)

The stomach contents of 10 blacknose shiners ($\bar{L}$ = 4.0 cm) beach seined from Kerr Lake were examined; however, only 1 stomach contained identifiable food items - 2 copepod nauplii.

Fallfish (Semotilus corporalis (Mitchill))

The best series of fallfish were obtained from the gillnets set in Robin Hood Lake. A total of 36 stomachs were examined from these fish. Since there were no discernible trends in diet with size or season, the data were pooled (Fig. 7A). Fallfish of this size range (11-25 cm) clearly fed on larger aquatic insects (Trichoptera, Odonata, Coleoptera, etc.) and fish. Three of the 5 fish ingested were identified as ninespine sticklebacks.

A volumetric analysis was performed on 10 of the stomach contents (Fig. 7B) which indicated that Trichoptera were the most important group volumetrically. None of the stomachs containing fish were included in this analysis.

The indices of fullness ranged from 0.180-0.740 (Table 8). The Robin Hood Lake data suggest that feeding may decline somewhat in late September.

Six fallfish stomachs ($\bar{L}$ = 10.3-23.0 cm) were analyzed from the Bolton Lake gillnets. One stomach contained a trichopteran, 1 a dipterous larva, and 1 an Odonata nymph. Of 3 fallfish stomachs from Mill Lake (14.8-16.6 cm), 1 contained an Ephemeroptera nymph, and another 1 adult Ephemeroptera and 1 Odonata nymph. Of 2 fallfish from Mud Lake (22.3-24.1 cm), 1 contained 1 Corixidae, the other 5 corixids.

One juvenile fallfish (3.7 cm) was beach seined from Bolton Lake in August; it contained 1 chironomid larva.

Pearl dace (Semotilus margarita (Cope))

The stomach contents of 11 pearl dace (7.0-8.0 cm) seined from Mill Lake in August were analyzed. Terrestrial insects were the primary food item with 5 of the 10 stomachs containing 1 each. Another stomach contained a trichopteran larva while another contained an unidentified fish ovum. Four stomachs were empty.

White sucker (Catostomus commersoni (Lacépède))

The two most important items in the white sucker diet were Cladocera and larval Chironomidae. There is a consistent trend for the white suckers netted from Mud, Mosquito, Mill, Bolton, and Robin Hood Lakes in that larval chironomids were most important as food items in June, and Cladocera increased in importance later in the summer (Fig. 8-12 incl.), probably reflecting seasonal zooplankton increases in the lakes. Cladocera were also the most numerous items in the stomachs of the suckers netted from Kerr Lake in September (Fig. 13C). The occurrence of larval Heleidae in the diet is notable as these were not found in the stomachs of other species.

Amphipoda were a consistent item of the diet of suckers in Mud and Mosquito Lakes, but did not occur in sucker stomachs from the other lakes. Amphipods were particularly common in the diets of other fish species in Mud Lake where they must be especially abundant.

Juvenile suckers were seined from Mill and Bolton Lakes in June and August (Fig. 10, 11). Their diets were similar to those of larger suckers, except that copepods were eaten in larger numbers, and considerable numbers of rotifers were eaten by the Mill Lake juvenile suckers in August.

On a volumetric basis, Cladocera and Chironomidae were usually the most important items in the diet as well (Fig. 13-15). Occasionally, larger organisms such as Ephemeroptera nymphs (Mill Lake, June; Kerr Lake, June) or Trichoptera larvae (Mud Lake, August) were the most important items volumetrically.

The importance of Cladocera in the sucker diet is somewhat surprising, and may reflect the diurnal movement of Cladocera, which may settle to the bottom during the day. Alternatively, the cladoceran species ingested may be those found on or near the bottom in weedy littoral areas.

Three copepod species were identified from the stomachs analyzed: Bryocamptus zschokkei (Bolton Lake, August), Harpacticoid nordenskioldii (Mill Lake, August), and Eucyclops agilis (Bolton Lake, August).

Brown bullhead (Ictalurus nebulosus (Lesueur))

Brown bullheads were netted from Mud and Mill Lakes. No juveniles were captured, so only the diets of adult individuals were investigated.

The Mill Lake population fed primarily upon mayfly nymphs, mostly of the burrowing type (Ephemeridae) (Fig. 16A). Chironomid larvae were the second most numerous item in the diet. The index of fullness was greater for the September bullheads; however, the numbers of fish obtained were small so the values may have little significance (Table 9).

Mud Lake bullheads took advantage of the abundant Hyalella population, with an average of over 50 of these organisms per stomach (Fig. 16B). Leeches, chironomid, trichopteran, and Heleid larvae were also frequent items in the diet. On a volumetric basis, leeches were a very important item in the diet due to their large size (Fig. 16C).

American eel (Anguilla rostrata (Lesueur))

The sampling methods used in the survey were totally inadequate for eels. Two eels were taken from Kerr Lake - 1 by gillnet, the other in a minnow trap (where it evidently had been eating the other trapped fish). A third, small specimen was taken while seining Wheaton Lake. This latter specimen contained 1 cladoceran, 1 copepod, 1 amphipod, and 1 Trichoptera larva. The 2 eels from Kerr Lake both contained fish remains. In addition, the eel taken in the gillnet had 17 Chaoborus larvae in its stomach.

Banded killifish (Fundulus diaphanus (Lesueur))

While the killifish appears structurally adapted to surface feeding, there were surprisingly few adult insects in the stomachs. The most important dietary items are larval chironomidae, cladocerans, amphipods, and copepods (Fig. 17-21). Larval chironomids tended to be more important dietary items early in the summer (e.g. Bolton, Robin Hood, Creasey Lakes), with microcrustacea becoming more important later. This trend may be the result of seasonal differences in fish size, since the June samples usually represented larger fish on the average. Seasonal fluctuations in cladoceran abundance may also be a factor, as noted for white suckers. Several of the ingested copepods were identified to species as given in Table 10.

Threespine stickleback (Gasterosteus aculeatus Linnaeus)

As with some of the killifish collections, the threespine sticklebacks collected in June were all large, adult specimens which ate primarily Ephemeroptera and larval chironomids (Fig. 22A). The smaller specimens collected in August were eating primarily Cladocera (Fig. 22B).

Ninespine stickleback (Pungitius pungitius (Linnaeus))

Cladocera and copepods are the most important dietary items for the ninespine stickleback (Fig. 23-29). As with banded killifish and threespine sticklebacks, there is a suggestion for some lakes (Chisholm (Fig. 24), Mosquito (Fig. 25), Creasey (Fig. 27)) that the larger fish sampled in June were eating a greater proportion of larger food items, such as larval chironomids, other aquatic insects, and amphipods. The fish eggs and larvae eaten by the Chisholm Lake sticklebacks in June were probably sticklebacks as no other small fish species was present. Indices of fullness for ninespine stickleback stomachs are usually high (Table 11). As with the killifish, some of the food items which were keyed further are listed in Table 12.

White perch (Morone americana (Gmelin))

White perch were sampled from Bolton and Wheaton Lakes, and were subdivided into four size-classes (≤5 cm, >5≤10 cm, >10≤15 cm, >15 cm). The smallest white perch (from Bolton Lake only) were primarily planktivores with a few larval chironomids in the diet (Fig. 30A). Among the copepods ingested by these juvenile white perch were Cyclops vernalis, C. venustus, Macrocyclops albidus, and Eucyclops agilis. The next larger size-class (from Wheaton Lake only) again was mainly planktivorous, with some amphipods and larval chironomids (Fig. 30B). The diet of white perch larger than 10 cm switches from zooplankton to aquatic insects (Fig. 31, 32). Large white perch in Wheaton Lake continued to eat plankton much more heavily than did those in Bolton Lake (Fig. 33). The Ephemeroptera eaten by the large white perch of Bolton Lake were mainly burrowing mayflies of the genus Hexagenia, with some Ephemera. The 3 fish ingested by Wheaton Lake white perch were ninespine sticklebacks, and most of the chironomids eaten by these perch were Dicrotendipes sp.

The number of burrowing mayflies in the Bolton Lake white perch stomachs was constant throughout the summer at about 4 per stomach. Megaloptera were eaten in greatest numbers in June and became less important toward the end of the summer. Due to the larger size of the burrowing mayflies, they were more important on a volumetric basis even in June when the greatest number of Megaloptera were consumed (Fig. 31D). The indices of fullness for white perch stomachs varied widely (Table 13) with a tendency toward lower values in August. This could be due to higher rates of digestion and gastric evacuation at higher temperatures.

Pumpkinseed (Lepomis gibbosus (Linnaeus))

Pumpkinseeds were taken from Mill, Kerr, Mud, and Robin Hood Lakes, with numbers sufficient to make any comments on food habits taken only from the latter two lakes. The Robin Hood seine samples were young-of-the-year, except for one 8.1-cm fish. The stomach of the latter contained chironomid larvae, while the smaller specimens ($\bar{L}$ = 1.7 cm) contained copepods (Eucyclops agilis) almost exclusively (Fig. 34A).

The larger fish taken from Mud Lake were feeding primarily on Hyalella azteca, Trichoptera (Leptoceridae), and larval chironmids with a few Odonata and Corixidae (Fig. 34B). Thus, the pumpkinseed is another species exploiting the apparently large Hyalella and Leptoceridae populations of Mud Lake.

Smallmouth bass (Micropterus dolomieui Lacépède)

The smallmouth bass has been found to be a sensitive species to acidification in Ontario studies (Harvey 1980), with populations being stressed at pH's ≤5.5. The species was found in 5 (Stein, Wheaton, Bolton, Mud, and Mill) of the 10 study lakes. All these populations have probably resulted from stocking procedures. The history of the Wheaton Lake introductions has been documented (Smith 1942). It has been reported by local residents that the smallmouth in Stein Lake have been introduced within the last 20-30 yr.

In Mud Lake, the amphipod, Hyalella, forms an important part of the diet of juvenile bass (Fig. 35A), but apparently did not contribute to their diet in Mill Lake (Fig. 36A). Generalizing for all three lakes in which juvenile bass were taken (Fig. 36B), mayflies, particularly the burrowing type (Hexagenia sp., Ametropus sp.) were the most important food organisms, with chironomid larvae and pupae and terrestrial insects ranking next. Only 1 fish (ninespine stickleback) was found in the juvenile bass stomachs (Mill Lake) (Fig. 36B) - from the largest juvenile in late September at 7.3 cm.

No smallmouths were sampled in the size range 8-13 cm, but this size range probably represents a transition stage from utilization of large insects to utilization of fish as the main food source. Of the 5 stomachs analyzed from fish of 13-20 cm in size, fish were the most numerous food item, forming almost all the diet on a volume basis. One of the 2 fish in these stomachs was a juvenile yellow perch. The Stein Lake bass in this size range had consumed a small mammal (Fig. 36C). The insects consumed by bass of this size were all large organisms - 2 Coleoptera, 1 Odonata nymph, and 1 Ephemeroptera.

Twenty stomachs were analyzed from bass greater than 20 cm in length, with fish being by far the most important food item (in 8 of 20 stomachs) (Fig. 37A). Among the species identified as forage fish, 2 were ninespine sticklebacks. The 4 unidentified fish in the Wheaton Lake bass stomach of 21/06/78 were probably banded killifish as they were not spiny rayed fish, and cyprinids are not abundant in this lake (Fig. 36D). The occasional large insect was eaten (3 caddisflies and 2 Odonata). Amphipods and corixids were still ingested fairly often by the larger Mud Lake bass (Fig. 35B, C).

Indices of fullness for bass stomachs were low in June (Table 14) and higher in the summer. This probably is related to low levels of feeding in the cooler June waters.

Yellow perch (Perca flavescens (Mitchill))

Yellow perch were sampled from Bolton and Mill Lakes. The largest yellow perch (>15 cm) from Mill Lake relied upon smaller fish to meet their food requirements to a large degree (Fig. 38), with 7 fish found in the 22 stomachs. Three of these fish were smaller yellow perch, 2 were ninespine sticklebacks, and the other 3 were not identified. Mayfly nymphs (mostly Hexageneidae) were the other important food items.

Mayflies (mostly Hexageneidae nymphs) were the most encountered food item in the stomachs of 10-15 cm yellow perch (Fig. 39). Only 1 fish (a yellow perch) was encountered with chironomid larvae or pupae present in 2 stomachs.

Yellow perch of 5-10 cm rely heavily on mayfly nymphs as well (Fig. 40A), with chironomids being the only other item present.

Yellow perch were taken from Bolton Lake only by seining and, consequently, only one size-class (>5≤10 cm) was analyzed. The single yellow perch taken in June (9.3 cm) had 2 chironomids, 38 Heleid larvae, 2 Odonata (Ischnura) nymphs, 2 Hexagenia nymphs, and 1 Dixid larva in its stomach. The series of perch taken in August were eating Ephemeroptera nymphs predominantly (Fig. 40B), with smaller numbers of other insects and a few amphipods. Interestingly, the perch taken in September (smaller mean size of 5.9 cm, 7.5 in August), possibly a younger age class (probably 0+), were still mainly planktivorous (Fig. 40C). Therefore, conversion from planktivore to insectivore occurs probably in the 5-7 cm size range. The copepods eaten by this last group of fish were primarily Macrocyclops albidus.

OVERLAP INDICES

Robin Hood Lake

Of the 4 species collected in sufficient numbers for calculation of overlap indices (Table 15), the banded killifish, ninespine stickleback, and white sucker all had nearly identical diets, with Cladocera, copepods, larval chironomidae, and amphipods forming the major components of the diet. The fallfish diet did not overlap with any of the other 3 fish species, with fish and large aquatic insects forming the major part of its diet.

Bolton Lake

As in Robin Hood Lake, the diets of banded killifish and white sucker overlapped almost totally (Table 16). The juvenile yellow perch in Bolton Lake, as discussed under the section for this species, showed heterogeneity in diet. The larger ($\bar{L}$ = 7.5 cm) fish collected in August were mainly insectivores; the smaller ($\bar{L}$ = 5.9 cm) collected in September were planktivores, hence the apparent overlap with both suckers and white perch. The overlap between white perch and larger suckers is somewhat surprising considering the relatively greater utilization of larger aquatic insects by the large white perch.

Creasey Lake

The brook trout diets are obviously totally different from those of banded killifish and ninespine stickleback (Table 17). Unlike the analysis for Robin Hood Lake, the overlap between the killifish and ninespine stickleback diets was not significant. This is due primarily to the heavy utilization of larval chironomids by Creasey Lake killifish. The stickleback relied more heavily on

Cladocera. Cladocera were more important in the diet of Robin Hood Lake killifish.

Mud Lake

Juvenile smallmouth bass diets overlapped significantly with the smaller golden shiners, both being insectivorous (Table 18). Large smallmouth bass showed little overlap with any other group as they are predominantly piscivorous. The strong overlap between brown bullheads and pumpkinseeds reflects importance of amphipods in their diets, while suckers and golden shiners overlap due to the importance of chironomids and Cladocera. The high degree of overlap between bullheads and suckers is surprising and may reflect the heterogeneity in diets as well as the importance of chironomids.

Mosquito Lake

There was little overlap in diet among any of the species analyzed in Mosquito Lake (Table 19).

Kerr Lake

The three species analyzed for Kerr Lake (banded killifish, ninespine stickleback, white sucker) all had very similar diets (Table 20).

Mill Lake

The strongest dietary affinities emerging from the Mill Lake analysis were among ninespine stickleback, threespine stickleback, and white sucker (Table 21). All 3 species fed primarily on Cladocera. The larger yellow perch and lake chub had similar insectivorous diets. Smaller yellow perch and larger white suckers also overlapped considerably due primarily to their common utilization of larval chironomids. Insufficient data were available for Wheaton, Stein, and Chisholm Lakes to run overlap comparisons.

Overlap indices were also calculated to compare diets of the same species among various lakes.

Brook trout

Brook trout diets could be compared for Creasey and Mosquito Lakes (Table 22). The overlap is not quite significant due to the greater incidence of fish in the Creasey Lake trout stomachs.

Banded killifish

The overlap analysis indicates great homogeneity in diet of this species among the various lakes; only 2 of 15 comparisons were less than 0.7 (Table 23).

Yellow perch

The juvenile yellow perch of Mill and Bolton Lakes had very similar diets (Table 24).

White perch

The diets of large white perch in the two lakes showed considerable heterogeneity (Table 25). In Bolton Lake they ate mainly larger aquatic insects, while in Wheaton Lake they consumed large quantities of plankton.

Ninespine stickleback

Stickleback diets were very homogeneous, with only 3 of 15 comparisons being below 0.7 (Table 26).

Smallmouth bass

Juvenile smallmouth bass of both Mill and Mud Lakes ate similar things, mainly aquatic insects (Chironomidae, Ephemeroptera) (Table 27).

Lake chub

The relatively low index for Mill versus Mosquito Lake reflects some heterogeneity in lake chub diets in the two lakes (Table 28).

White sucker

White sucker diets were very homogeneous among lakes, with all comparisons being above 0.7 (Table 29).

VECTORIAL ANALYSIS OF FOOD HABITS

The data obtained from the stomachs of the various species for the 10 lakes will be summarized with the use of vectorial presentation as described in the Methods section.

The chain pickerel's diet is almost totally fish and lies on the "fish" axis (#1, Fig. 44).

The adult brown bullhead is primarily a consumer of invertebrates, with the diet about evenly divided between small (Chironomidae, Amphipoda, etc.) and large (Ephemeroptera, Trichoptera, etc.) aquatic invertebrates (#2, Fig. 41).

The diet of adult white suckers lies in the zooplankton-small invertebrate quadrant, shifted somewhat toward the small invertebrate axis, emphasizing the importance of larval chironomids. The "center of gravity" for the various white sucker vectors (#3, Fig. 41) is 99,168° (99 representing the length of the vector in arbitrary units, 168° the angle relative to the "fish" axis going in a clockwise direction). The points for the various lakes subtended a fairly acute angle of 34° (150-184°).

Only two points are available for juvenile white suckers (#4, Fig. 41). The Mill Lake point suggests greater utilization of zooplankton by juveniles compared to adult suckers. The Bolton Lake juveniles' diet was similar to that of adult suckers generally. However, relatively more zooplankton was ingested when compared with the diet of adult suckers from the same lake.

Both fallfish and lake chub fed primarily on larger aquatic insects as indicated by their proximity to the end of that axis (#6, 7, Fig. 41).

The generalized nature of the common shiner diet (#8, Fig. 41) is reflected in its proximity to the origin. The species utilizes a wide range of organisms from zooplankton to larger aquatic invertebrates. If the vacant quadrant were used to indicate utilization of algae, then the Bolton Lake shiners might approach the origin even more closely as the algae utilized would draw the point in that direction.

Golden shiners are somewhat general feeders as well (#9, Fig. 42), with somewhat lesser emphasis on zooplankton than was the case for the common shiner.

The juvenile smallmouth bass diet is invertebrates with equal amounts of small and large invertebrates contributing (#11, Fig. 42).

Banded killifish rely heavily on small aquatic invertebrates (mainly chironomid larvae) with zooplankton important as well (#12, Fig. 42). The extensive overlap in diet with that of mature white suckers is evident.

The diet of the ninespine stickleback is evenly balanced between zooplankton and smaller aquatic invertebrates (#13, Fig. 42).

The one point for the diet of the threespine stickleback (#14, Fig. 42) indicates a diet similar to that of the ninespine, perhaps with slightly more emphasis on small invertebrates.

Adult white perch are very versatile in their feeding habits (#15, Fig. 42). Wheaton Lake white perch lie within the zooplankton-small invertebrate quadrant, Bolton Lake white perch near the large invertebrate axis, while Beaverskin Lake white perch (unpub. data included here for comparative purposes) eat large numbers of fish. The total angle subtended by these vectors is 160°. Juvenile white perch (<10 cm) feed primarily on zooplankton (#16, Fig. 42).

Adult pumpkinseeds feed on large and small invertebrates in about equal amounts (#17, Fig. 43), while juvenile pumpkinseeds (1.7 cm) are almost totally planktivorous (#18, Fig. 43).

The adult brook trout diet lies in the large invertebrate-fish quadrant (#19, Fig. 43), similar in position to that of the smallmouth bass. Adult yellow perch have diets (#20, Fig. 43) similar to adult brook trout with a bit more emphasis on larger invertebrates as opposed to fish.

Yellow perch 10-15 cm in length (#21, Fig. 43) eat primarily larger invertebrates, while for those 5-10 cm in length (#22, Fig. 43) smaller invertebrates are of greater importance.

The diets of all the species (and various sizes of some species) can be arrayed as in Fig. 44. The array is related to a trophic arrangement with those species and size-classes utilizing zooplankton near the end of the zooplankton axis, and the other species generally falling near an arc passing clockwise to the fish axis. For several species the diet moves along the arc to larger food items as the fish grow in size (e.g. yellow perch - #22-21-20; smallmouth bass - #11-10; pumpkinseed #18-17; white sucker #4-3). It is probably true that proximity of diets on this array is indicative of the degree of interspecific competition in feeding, although other considerations such as manner of foraging and habitat preference are very important.

Further subdivision of the diets might show further differences among species with similar diets. For example, the large invertebrate category might be used as the basis for a similar vector analysis. However, an analysis in greater detail would require more intensive sampling.

SPECIES ASSOCIATIONS AND SUSCEPTIBILITY TO ACIDIFICATION

It was demonstrated (Peterson 1980) that, among the 10 lakes studied, Mosquito, Robin Hood, and Chisholm were the least buffered (0-20 μeq/L bicarbonate). Mosquito may be more sensitive than the other two because it has a smaller drainage area, hence the direct rain impact should make a more important contribution to lake chemistry. Mosquito Lake also has little humic content to protect the fish from solubilization of heavy metals. Creasey and Kerr Lakes are also of low alkalinity (ca. 50 μeq/L) while Mill, Bolton, Stein, Wheaton (ca. 150-200 μeq/L), and particularly Mud Lake (ca. 550 μeq/L), are somewhat better buffered against pH change.

Mosquito and Chisholm, of the most sensitive lakes, and both Creasey and Kerr Lakes in the next category of sensitivity, all have good brook trout populations. The ninespine stickleback is associated with the brook trout in all four of these lakes, and northern redbelly dace in three of the four (Creasey, Mosquito, Robin Hood). Lake chub are also present in Kerr and Mosquito (possibly Creasey as well), while white suckers are present in all these lakes, except possibly Chisholm. The brook trout is one of the more resistant salmonids to low pH with critical pH levels probably somewhere between 4.5-5.0 (Daye and Garside 1976; Trojner 1977). The land-locked salmon population in Robin Hood Lake may be vulnerable, depending upon the pH of tributaries utilized for spawning. White suckers probably have a comparable sensitivity to low pH as brook trout (Harvey 1980).

The pH sensitivity of several fish species in these poorly buffered lakes (lake chub, blacknose shiner, redbelly dace, ninespine stickleback, banded killifish) is not known at present.

Yellow perch and eels are considered to be among the more resistant species to low pH, with critical levels less than 4.5.

Other species which have been found sensitive to acidification (smallmouth bass, brown bullhead) are not present in any of the poorly buffered lakes studied and cannot be considered as endangered by potential acidification.

In summary, it is postulated that the land-locked salmon, brook trout, and white sucker populations of the poorly buffered lakes (Mosquito, Chisholm, Robin Hood) would be most vulnerable to acidification. A decrease of 0.5-1.0 pH unit from mean summer levels of 1978 (pH 5.5-6.5) would probably be damaging. The pH sensitivity of other species in these lakes is not known at present.

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Table 1. Dates of 1978 gillnet operations in the various lakes. Chisholm, a private lake, was not fished with gillnets. The nets were set for about 24 h, overnight, the date listed referring to the date when the nets were lifted.

Lake	June	August	September
Mud	13	10	29
Bolton	13	10	29
Chisholm	-	-	-
Robin Hood	15	15	26
Mosquito	16	15	27
Creasey	20	12	23
Kerr	20	12	23
Stein	14	9	28
Mill	14	16	26
Wheaton	21	9	27

Table 2. Records of beach seining in the various lakes.

Lake	June	August	September
Mud	-	10[a]	-
Bolton	12	9	27
Chisholm	15	11	26
Robin Hood	15	14	25
Mosquito	15	14	26
Creasy	12	9	22
Kerr	12	9	22
Stein	12	-	25
Mill	13	10	25
Wheaton	12	9	22

[a]Mud Lake could not be seined due to drowned timber in the shoreline. A length of shoreline was rotenoned in August.

Table 3. Occurrence of various species in the 10 surveyed lakes.

Species	Creasey	Kerr	Stein	Wheaton	Mosquito	Mill	Robin Hood	Chisholm	Bolton	Mud	Total
Atlantic salmon							X				1
Brook trout	X	X	X		X	X		X			6
Rainbow smelt						X	X				2
Chain pickerel									X		1
N. redbelly dace	X			X	X		X				4
Finescale dace		X									1
Golden shiner						X	X		X	X	4
Common shiner		X							X		2
Lake chub		X			X	X			X		4
Creek chub					X	X	X				3
Blacknose shiner		X									1
Fallfish						X	X		X	X	4
Pearl dace						X					1
White sucker	X	X			X	X	X		X	X	7
Brown bullhead						X				X	2
Eel	a	X	a	X		a	a		a		2
Banded killifish	X	X	X	X	X	X	X		X		8
Threesp. stickleback						X					1
Ninesp. stickleback	X	X		X	X	X	X	X		X[b]	8
White perch				X					X		2
Pumpkinseed		X				X	X			X	4
Smallmouth bass			X	X		X			X	X	5
Yellow perch						X			X		2
Species total	5	10	3	6	7	15	10	2	10	7	74

[a]Presence inferred from damage to fish in gillnets.
[b]Present in smallmouth bass stomach.

Table 4. Numbers of fish sampled in beach seining from the various lakes (number of species).

Species	Creasey	Kerr	Stein	Wheaton	Mosquito	Mill	Robin Hood	Chisholm	Bolton	Mud	Total
					June						
Brook trout	0	0	0	0	1	0	0	1	0		2
Rainbow smelt	0	0	0	0	0	1	0	0	0		1
N. redbelly dace	0	0	0	2	1	0	0	0	0		3
Finescale dace	0	0	0	0	0	0	0	0	0		0
Golden shiner	0	0	0	0	0	0	0	0	0		0
Common shiner	0	3	0	0	0	0	0	0	22		25
Lake chub	0	1	0	0	0	0	0	0	0		1
Creek chub	0	0	0	0	0	0	0	0	0		0
Blacknose shiner	0	7	0	0	0	0	0	0	0		7
Fallfish	0	0	0	0	0	0	11	0	3		14
Pearl dace	0	0	0	0	0	0	0	0	0		0
White sucker	0	0	0	0	0	4	0	0	34		38
Eel	0	1[a]	0	0	0	0	0	0	0		1
Banded killifish	617	0	1	123	0	4	20	0	7		772
Threesp. stickleback	0	0	0	0	0	16	0	0	0		16
Ninesp. stickleback	8	0	0	1	11	5	20	115	0		160
White perch	0	0	0	32	0	0	0	0	23		55
Pumpkinseed	0	0	0	0	0	0	0	0	0		0
Smallmouth bass	0	0	0	0	0	1	0	0	0		1
Yellow perch	0	0	0	0	0	7	0	0	1		8
Total	625	12	1	158	13	38	51	116	90	0	1104(15)
					August						
Brook trout	0	0	0	0	0	0	0	0	0	0	0
Rainbow smelt	0	0	0	0	0	0	1	0	0	0	1
N. redbelly dace	1	0	0	0	0	0	3	0	0	0	4
Finescale dace	0	2	0	0	0	0	0	0	0	0	2
Golden shiner	0	0	0	0	0	0	0	0	1	0	1
Common shiner	0	0	0	0	0	0	0	0	114	0	114
Lake chub	0	0	0	0	0	0	0	0	1	0	1
Creek chub	0	0	0	0	0	1	1	0	0	0	2
Blacknose shiner	0	1	0	0	0	0	0	0	0	0	1
Fallfish	0	0	0	0	0	0	0	0	1	0	1
Pearl dace	0	0	0	0	0	18	0	0	0	0	18
White sucker	0	0	0	0	0	47	3	0	88	0	139
Eel	0	0	0	1	0	0	0	0	0	0	1
Banded killifish	3750	1	0	618	0	0	567	0	119	0	5055
Threesp. stickleback	0	0	0	0	0	78	0	0	0	0	78
Ninesp. stickleback	3	7	0	0	116	19	183	294	0	0	622
White perch	0	0	0	1	0	0	0	0	22	0	23
Pumpkinseed	0	0	0	0	0	0	31	0	0	0	31
Smallmouth bass	0	0	0	0	0	9	0	0	1	152[b]	162
Yellow perch	0	0	0	0	0	16	0	0	35	0	51
Chain pickerel	0	0	0	0	0	0	0	0	1	0	1
Total species	3754	12	0	620	116	188	789	294	383	152	6308(20)

Table 4. (cont'd.)

Species	Creasey	Kerr	Stein	Wheaton	Mosquito	Mill	Robin Hood	Chisholm	Bolton	Mud	Total
					September						
Brook trout	4	0	0	0	0	0	0	0	0	0	4
Rainbow smelt	0	0	0	0	0	1	0	0	0	0	1
N. redbelly dace	8	0	0	0	0	0	0	0	0	0	8
Finescale dace	0	0	0	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0	0	0	0
Common shiner	0	0	0	0	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0	0	0	0	0
Creek chub	0	0	0	0	0	0	0	0	0	0	0
Blacknose shiner	0	2	0	0	0	0	0	0	0	0	2
Fallfish	0	0	0	0	0	0	0	0	0	0	0
Pearl dace	0	0	0	0	0	0	0	0	0	0	0
White sucker	0	0	0	0	0	0	0	0	0	0	0
Eel	0	0	0	0	0	0	0	0	0	0	0
Banded killifish	139	9	153	411	3	1	114	0	59	0	889
Threesp. stickleback	0	0	0	0	0	0	0	0	0	0	0
Ninesp. stickleback	34	61	0	4	22	0	29	178	0	0	318
White perch	0	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	1	0	0	0	0	0	0	0	0	1
Smallmouth bass	0	0	0	0	0	18	0	0	0	0	18
Yellow perch	0	0	0	0	0	78	0	0	58	0	136
Chain pickerel	0	0	0	0	0	0	0	0	0	0	0
Total	175	73	153	415	25	98	144	178	117	0	1377(9)
					Total						
Brook trout	4	0	0	0	1	0	0	1	0	0	6(3)
Rainbow smelt	0	0	0	0	0	2	1	0	0	0	3(2)
N. redbelly dace	9	0	0	2	1	0	3	0	0	0	15(4)
Finescale dace	0	2	0	0	0	0	0	0	0	0	2(1)
Golden shiner	0	0	0	0	0	0	0	0	1	0	1(1)
Common shiner	0	3	0	0	0	0	0	0	136	0	139(2)
Lake chub	0	1	0	0	0	0	0	0	1	0	2(2)
Creek chub	0	0	0	0	0	1	1	0	0	0	2(2)
Blacknose shiner	0	10	0	0	0	0	0	0	0	0	10(1)
Fallfish	0	0	0	0	0	0	11	0	4	0	15(2)
Pearl dace	0	0	0	0	0	18	0	0	0	0	18(1)
White sucker	0	1	0	0	0	51	3	0	122	0	177(4)
Eel	0	1	0	1	0	0	0	0	0	0	2(2)
Banded killifish	4506	10	154	1152	3	5	701	0	185	0	6716(8)
Three-sp. stickleback	0	0	0	0	0	94	0	0	0	0	94(1)
Nine-sp. stickleback	35	68	0	5	149	24	232	587	0	0	1100(7)
White perch	0	0	0	33	0	0	0	0	45	0	78(2)
Pumpkinseed	0	1	0	0	0	0	31	0	0	0	32(2)
Smallmouth bass	0	0	0	0	0	28	0	0	1	152	181(3)
Yellow perch	0	0	0	0	0	101	0	0	94	0	195(2)
Chain pickerel	0	0	0	0	0	0	0	0	1	0	1(1)
Total	3491(4)	97(9)	154(1)	1193(5)	154(4)	324(9)	983(8)	588(2)	590(10)	152(1)	8799(21)

[a]Taken in a minnow trap
[b]Rotenoned.

Table 5. Numbers of fish sampled by gillnetting in the various lakes (number of species).

Species	Creasey	Kerr	Stein	Wheaton	Mosquito	Mill	Robin Hood	Chisholm	Bolton	Mud	Total
					June						
Brook trout	5	0	2	0	0	1	0	12[a]	0	0	20
Rainbow smelt	0	0	0	0	0	0	0	0	0	0	0
N. redbelly dace	0	0	0	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0	0	457	457
Lake chub	0	0	0	0	6	1	0	0	1	0	8
Creek chub	0	0	0	0	0	0	0	0	0	0	0
Fallfish	0	0	0	0	0	0	7	0	1	1	9
White sucker	0	1	0	0	5	20	5	0	9	6	46
White perch	0	0	0	149	0	0	0	0	115	0	264
Pumpkinseed	0	0	0	0	0	1	0	0	0	10	11
Smallmouth bass	0	0	2	2	0	0	0	0	0	6	10
Yellow perch	0	0	0	0	0	41	0	0	0	0	41
Brown bullhead	0	0	0	0	0	1	0	0	0	16	17
Atlantic salmon	0	0	0	0	0	0	0	0	0	0	0
Chain pickerel	0	0	0	0	0	0	0	0	1	0	1
Total	5	1	4	151	11	65	12	12	127	496	884(11)
					August						
Brook trout	0	5	3	0	26	0	0	3[a]	0	0	37
Rainbow smelt	0	0	0	0	0	0	0	0	0	0	0
N. redbelly dace	0	0	0	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	2	2	0	0	128	132
Lake chub	0	0	0	0	3	2	0	0	1	0	6
Creek chub	0	0	0	0	1	0	0	0	0	0	1
Fallfish	0	0	0	0	0	0	19	0	2	0	21
White sucker	0	0	0	0	38	36	18	0	3	11	106
White perch	0	0	0	142	0	0	0	0	24	0	166
Pumpkinseed	0	0	0	0	0	0	0	0	0	3	3
Smallmouth bass	0	0	2	1	0	0	0	0	5	7	15
Yellow perch	0	0	0	0	0	18	0	0	0	0	18
Brown bullhead	0	0	0	0	0	4	0	0	0	46	50
Atlantic salmon	0	0	0	0	0	0	2	0	0	0	2
Chain pickerel	0	0	0	0	0	0	0	0	1	0	1
Total	0[b]	5	5	143	68	62	41	3	36	195	558(13)

Table 5. (cont'd.)

Species	Creasey	Kerr	Stein	Wheaton	Mosquito	Mill	Robin Hood	Chisholm	Bolton	Mud	Total
					September						
Brook trout	13	0	0	0	2	11	0	0	0	0	26
Golden shiner	0	0	0	0	0	4	0	0	0	91	95
Lake chub	0	0	0	0	4	8	0	0	0	0	12
Creek chub	0	0	0	0	0	0	0	0	0	0	0
Fallfish	0	0	0	0	0	3	14	0	4	2	23
White sucker	1	11	0	0	10	65	14	0	5	44	150
White perch	0	0	0	124	0	0	0	0	27	0	151
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	1	0	0	0	0	1	0	2
Yellow perch	0	0	0	0	0	63	0	0	0	0	63
Brown bullhead	0	0	0	0	0	4	0	0	0	0	4
Atlantic salmon	0	0	0	0	0	0	0	0	0	0	0
Chain pickerel	0	0	0	0	0	0	0	0	0	0	0
Total	14	11	0	125	16	158	28	0	37	137	526(9)
					Total						
Brook trout	18	5	5	0	28	12	0	15[a]	0	0	83(6)
Golden shiner	0	0	0	0	0	6	2	0	0	676	684(3)
Lake chub	0	0	0	0	13	11	0	0	2	0	26(3)
Creek chub	0	0	0	0	1	0	0	0	0	0	1(1)
Fallfish	0	0	0	0	0	3	40	0	7	3	53(4)
White sucker	1	12	0	0	53	121	37	0	17	61	302(7)
White perch	0	0	0	415	0	0	0	0	166	0	581(2)
Pumpkinseed	0	0	0	0	0	1	0	0	0	13	14(2)
Smallmouth bass	0	0	4	4	0	0	0	0	6	13	27(4)
Yellow perch	0	0	0	0	0	122	0	0	0	0	122(1)
Brown bullhead	0	0	0	0	0	9	0	0	0	62	71(2)
Atlantic salmon	0	0	0	0	0	0	2	0	0	0	2(1)
Chain pickerel	0	0	0	0	0	0	0	0	2	0	2(1)
Total	19(2)	17(2)	9(2)	419(2)	95(4)	285(8)	79(4)	15 (1)	200(4)	829(6)	2061(13)

[a]Angled.
[b]Several trout eaten by eels.

Table 6. Indices of fullness of brook trout stomachs for various lakes and months of the year (1978). Sample size and mean lengths (cm) are given in parentheses.

Lake	June	August	September
Creasey	0.805(5,16.2)	2.174 (8,25.3)	1.025(4,11.9)
Mosquito	-	0.772(10,24.7)	0.456(2,18.2)
Kerr	-	0.508 (2,20.9)	-
Stein	0.545(2,3.10)	0.193 (3,36.9)	-
Mill	-	-	1.399(9,24.1)

Table 7. Summary of indices of fullness (golden shiner). Sample sizes and mean lengths (cm) are in parentheses.

Lake	June	August	September
Mill		0.75 (2,10.2)	0.24 (3,10.4)
Mud	0.44(35,12.1)	0.59(20,13.0)	0.39(10,13.5)

Table 8. Fullness indices for fallfish. Sample sizes and lengths (cm) are in parentheses.

Lake	June	August	September
Bolton		0.356(6,19.5) 0.746(1, 3.7)	
Robin Hood	0.519(6,17.2)	0.507(10,20.0)	0.336(10,18.3)
Mill	0.726(10,12.4)		0.644 (8,15.5)
Mud			0.180 (2,23.2)

Table 9. Index of fullness for Brown bullhead stomachs. Sample sizes and mean lengths (cm) are in parentheses.

Lake	June	August	September
Mill	0.27(1,18.9)	0.70 (4,19.5)	1.06(4,18.4)
Mud	1.33(9,16.4)	1.12(20,17.9)	

Table 10. Further identification of items in killifish stomachs.

Lake	Date	Species
Robin Hood	14-08-78	*Eucyclops agilis*
Stein	22-09-78	*Macrocyclops albidus*
Creasey	12-06-78	*Latona setifera*
	" " "	*Macrocyclops albidus*
Mill	13-06-78	*Cyclops vernalis*
	" " "	*Eucyclops agilis*
Wheaton	12-06-78	*Cyclops vernalis*
	09-08-78	*Cyclops vernalis*
	22-09-78	*Cyclops vernalis*
	" " "	*Eucyclops agilis*
	" " "	*Macrocyclops albidus*
Creasey	11-09-78	*Macrocyclops albidus*
	09-08-78	*Macrocyclops albidus*

Table 11. Indices of fullness for ninespine sticklebacks. Sample sizes and mean lengths (cm) are in parentheses.

Lake	June	August	September
Mill	0.707(5,4.1)	1.491(10,3.8)	-
Kerr	-	1.929(7,3.5)	1.169(10,4.2)
Robin Hood	1.219(8,4.1)	1.059(16,4.1)	0.758(7,2.7)
Mosquito	-	1.313(11,3.8)	0.968(9, -)
Creasey	1.667(8,4.4)	-	0.363(6,4.1)
Chisholm	1.930(9,5.2)	0.815(26,4.8)	0.478(18,5.0)
Wheaton	-	-	1.071(4,2.9)

Table 12. Further identification of items in nine-spine stickleback stomachs.

Lake	Date	Species
Mosquito	15-06-78	Cyclops sp.
	14-08-78	Macrocyclops albidus
	26-09-78	Acantholebris curvirostris
	" " "	Cyclops vernalis
Creasey	12-06-78	Diaptomus sp.
Kerr	09-08-78	Macrocyclops ater
	" " "	Cyclops vernalis
Robin Hood	15-06-78	Eucyclops agilis
	- -06-78	Hexagenia
	14-08-78	Eucyclops agilis
	26-09-78	Eucyclops agilis
Mill	10-07-78	Eucyclops agilis
Wheaton	22-09-78	Lantanopsis occidentalis (nauplii)
	" " "	Eucyclops agilis
	" " "	Macrocyclops albidus
Chisholm	-08-78	Ishnura
	" "	Aeshna
	26-09-78	Cyclopoida
	" "	Caenis

Table 13. Indices of fullness for white perch stomachs. Sample sizes are in parentheses.

Lake	Size class (cm)	June	August	September
Bolton	>15	0.885(12)	0.245 (8)	0.636(7)
	>10 ≤15	-	0.170 (2)	1.082(2)
	≤5	-	1.660 (5)	-
Wheaton	>15	0.496(16)	0.546(14)	1.112(7)
	>10 ≤15	0.365 (5)	-	0.669(5)
	≤5	1.270 (4)	-	-

Table 14. Indices of fullness of smallmouth bass stomachs. Sample sizes and mean lengths (cm) are in parentheses.

Lake	June	August	September
Mill	-	1.335(8, 4.7)	0.650(5, 6.5)
Bolton	-	1.139(1, 3.7) 0.277(2,21.9)	0.840(1,14.2)
Mud	0.195(6,34.5)	0.466(9, 5.4) 0.911(7,27.8)	-
Stein	0.114(2,26.2)	0.915(1,18.3)	-
Wheaton	0.290(1,38.0)	0.039(1,41.0)	0.601(1,23.4)

Table 15. Diet overlap indices: comparison of fish species within Robin Hood Lake. Data from all fishings are pooled.

Species	n	$\bar{L}$ (cm)	Ninespine stickleback	White sucker	Fallfish
Banded killifish	71	6.2	0.944	1.00	0.46
Ninespine stickleback	38	3.9		0.81	0.36
White sucker	28	21.0			0.45
Fallfish	35	17.1			

Table 16. Diet overlap indices: comparison of fish species within Bolton Lake. Data from all fishings are pooled.

Species	n	$\bar{L}$ (cm)	Yellow perch	White perch	White sucker (>15 cm)	White sucker (≤15 cm)
Banded killifish	29	5.1	0.61	0.50	0.92	0.97
Yellow perch	21	6.8		0.81	0.72	0.64
White perch (10 cm)	42	19.3			0.80	0.43
White sucker (15 cm)	15	26.1				0.76
White sucker (15 cm)	20	9.1				

Table 17. Diet overlap indices: comparison of fish species within Creasey Lake.

Species	n	$\bar{L}$ (cm)	Banded killifish	Ninespine stickleback
Brook trout	21	30.6	0.22	0.09
Banded killifish	174	6.1		0.50
Ninespine stickleback	18	4.2		

Table 18. Diet overlap indices: comparison of fish species within Mud Lake.

Species	n	$\bar{L}$ (cm)	Smallmouth bass (>20 cm)	Brown bullhead	Golden shiner (≤10 cm)	Golden shiner (>10 cm)	White sucker	Pumpkinseed
Smallmouth bass (<10 cm)	15	5.3	0.32	0.52	0.77	0.57	0.67	0.69
Smallmouth bass (>20 cm)	13	30.9		0.25	0.18	0.15	0.13	0.43
Brown bullhead	23	17.9			0.60	0.55	0.86	0.85
Golden shiner (≤10 cm)	10	9.6				0.47	0.55	0.58
Golden shiner (>10 cm)	55	13.2					0.82	0.50
White sucker	28	20.6						0.67
Pumpkinseed	12	9.1						

Table 19. Diet overlap indices: comparison of fish species within Mosquito Lake.

Species	n	$\bar{L}$ (cm)	Ninespine stickleback	Lake chub	White sucker
Brook trout	12	23.6	0.00	0.29	0.00
Ninespine stickleback	32	4.5		0.19	0.40
Lake chub	12	10.5			0.39
White sucker	27	21.0			

Table 20. Diet overlap indices: comparison of fish species within Kerr Lake.

Species	n	$\bar{L}$ (cm)	Banded killifish	White sucker
Ninespine stickleback	17	4.0	0.93	0.85
Banded killifish	10	3.8		0.95
White sucker	12	14.2		

Table 21. Diet overlap indices: comparison of fish species within Mill Lake.

Species	n	$\bar{L}$ (cm)	Yellow perch (>10 cm)	Threespine stickleback	Ninespine stickleback	Smallmouth bass	Lake chub	White sucker (>15 cm)	White sucker (<10 cm)
Yellow perch (<10 cm)	20	6.6	0.61	0.69	0.65	0.74	0.61	0.76	0.59
Yellow perch (>10 cm)	37	17.8		0.50	0.29	0.67	0.79	0.48	0.22
Threespine stickleback	17	-			0.71	0.58	0.45	0.83	0.78
Ninespine stickleback	15	3.9				0.59	0.25	0.86	0.90
Smallmouth bass	20	5.5					0.65	0.57	0.47
Lake chub	10	10.3						0.52	0.17
White sucker (>15 cm)	29	24.3							0.68
White sucker (<10 cm)	14	6.0							

Table 22. Diet overlap indices: comparison of brook trout between lakes.

Lake	n	$\bar{L}$ (cm)	Mosquito Lake
Creasey	21	20.6	0.63
Mosquito	12	23.6	

Table 23. Diet overlap indices: comparison of banded killifish among lakes.

Lake	n	$\bar{L}$ (cm)	Kerr	Stein	Wheaton	Robin Hood	Bolton
Creasey	174	6.1	0.84	0.70	0.93	0.90	0.85
Kerr	10	3.8		0.84	0.84	0.91	0.65
Stein	16	3.5			0.74	0.89	0.53
Wheaton	110	5.5				0.97	0.77
Robin Hood	71	6.2					0.94
Bolton	29	5.1					

Table 24. Diet overlap indices: comparison of juvenile yellow perch between lakes.

Lake	n	$\bar{L}$ (cm)	Bolton Lake
Mill	20	6.6	0.81
Bolton	21	6.8	

Table 25. Diet overlap indices: comparison of white perch between lakes.

Lake	n	$\bar{L}$ (cm)	Bolton Lake
Wheaton	52	16.3	0.64
Bolton	42	19.3	

Table 26. Diet overlap indices: comparison of ninespine sticklebacks among lakes.

Lake	n	$\bar{L}$ (cm)	Lake Kerr	Mosquito	Mill	Robin Hood	Chisholm
Creasey	18	4.2	0.88	0.69	0.89	0.87	0.82
Kerr	17	4.0		0.82	0.95	0.96	0.81
Mosquito	32	4.5			0.68	0.74	0.67
Mill	15	3.9				1.00	1.00
Robin Hood	38	3.9					0.84
Chisholm	5	4.9					

Table 27. Diet overlap indices: comparison of juvenile smallmouth bass between lakes.

Lake	n	$\bar{L}$ (cm)	Mud Lake
Mill	20	5.5	0.80
Mud	15	5.3	

Table 28. Diet overlap indices: comparison of lake chub between lakes.

Lake	n	$\bar{L}$ (cm)	Mosquito Lake
Mill	10	10.3	0.67
Mosquito	12	10.5	

Table 29. Diet overlap indices: comparison of white suckers among lakes.

Lake	n	$\bar{L}$ (cm)	Mosquito	Mill	Robin Hood	Bolton	Mud
Kerr	12	14.2	0.87	-	1.00	1.00	0.90
Mosquito	27	21.0		0.86	0.92	0.92	0.97
Mill	29	24.3			0.92	0.91	0.81
Robin Hood	28	21.0				1.00	0.88
Bolton	15	26.1					0.85
Mud	28	20.6					

The following abbreviations are used in the various figures depicting the food habits of the various species:

Ac.	: Acarina	Hir.	: Hirudinea
A.I.	: adult insects	Hyd.	: Hydracarina
Am.	: Amphipoda	In.	: Insecta
Ann.	: Annelida	Is.	: Isopoda
Ar.	: arachnids	Meg.	: Megaloptera
Cha.	: Chaoborus	9-sp.	: ninespine stickleback
Ch.	: Chironomidae	Od.	: Odonata
Cl.	: Cladocera	Ol.	: Oligochaeta
Col.	: Coleoptera	Os.	: Ostracoda
Cor.	: Corixidae	Pel.	: Pelecypoda
Cop.	: Copepoda	Pla.	: plant material
Dip.	: Diptera	Plec.	: Plecoptera
Dip.A.	: Diptera adults	Rot.	: Rotifera
Dip.L.	: Diptera larvae	Seeds	: seeds
Dip.P.	: Diptera pupae	Sal.	: salamander
Dix.	: Dixidae	Sph.	: Sphaeridae
Ova	: eggs	Si.	: Sisyridae
Eph.	: Ephemeroptera	Te.I.	: Terrestrial insects
F.	: fish	Tr.	: Trichoptera
F.L.	: fish larvae	Turb.	: Turbellaria
F.Sc.	: fish scales	Tip.	: Tipulidae
Ga.	: Gastropoda	Unk.	: unknown
Hel.L.	: Heleidae larvae	Y.P.	: yellow perch
Hem.	: Hemiptera		

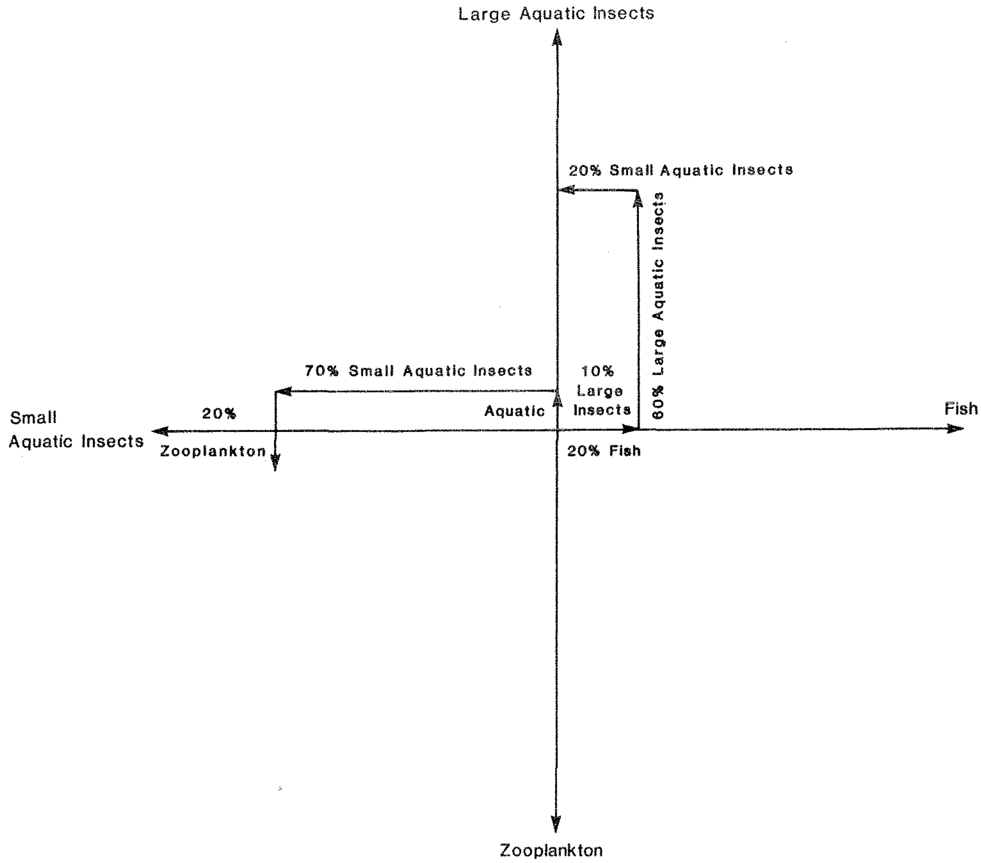


Fig. 1. Demonstration of the vectorial representation of food habits used in this report. Four categories of food (fish, large aquatic insects, small aquatic insects, zooplankton) are represented along the four axes. The vector representing the food habits of a particular fish species is the vector sum of the above four component vectors. Two examples are shown in Fig. 1: a species consuming 80% large aquatic insects and 20% small aquatic insects, and a species consuming 70% small aquatic insects and 20% zooplankton. See text for detailed explanation.

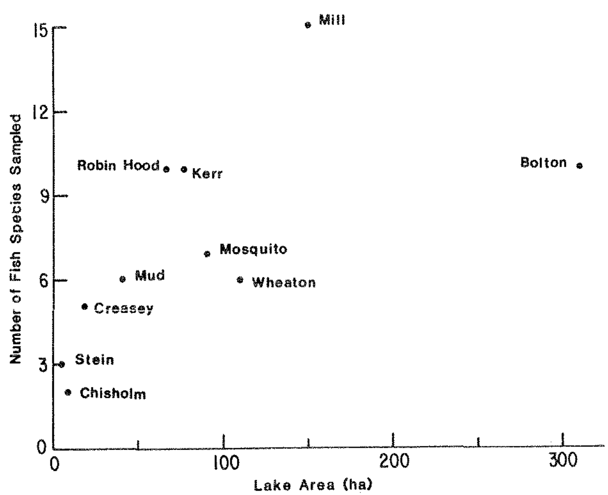


Fig. 2. Numbers of species of fish sampled in the catch of the ten lakes surveyed, as a function of lake surface area.

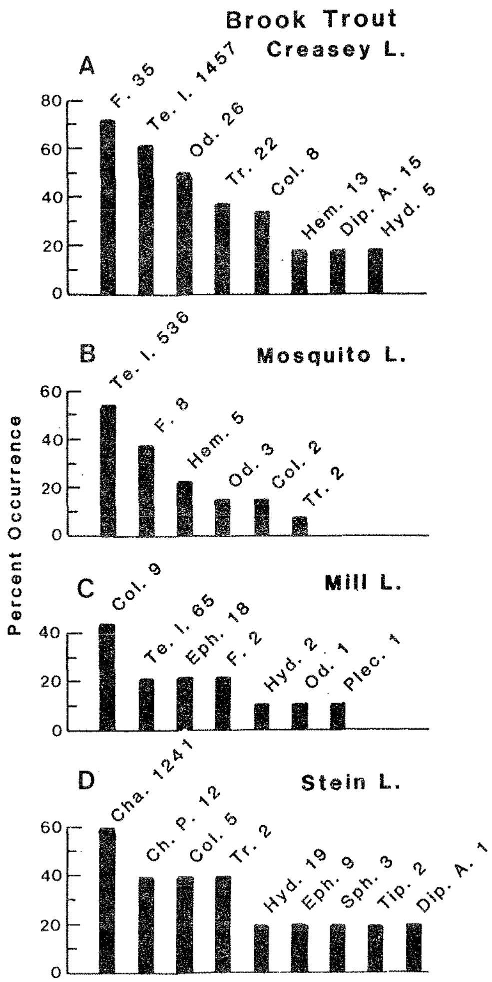


Fig. 3. Percentage of stomachs containing various food items in brook trout from four lakes. Creasey Lake: no. of stomachs analyzed (n) = 21, mean fish length ($\bar{L}$) = 24.0 cm; Mosquito Lake: n = 13, $\bar{L}$ = 22.6; Mill Lake: n = 9, $\bar{L}$ = 24.1; Stein Lake: n = 5, $\bar{L}$ = 34.5.

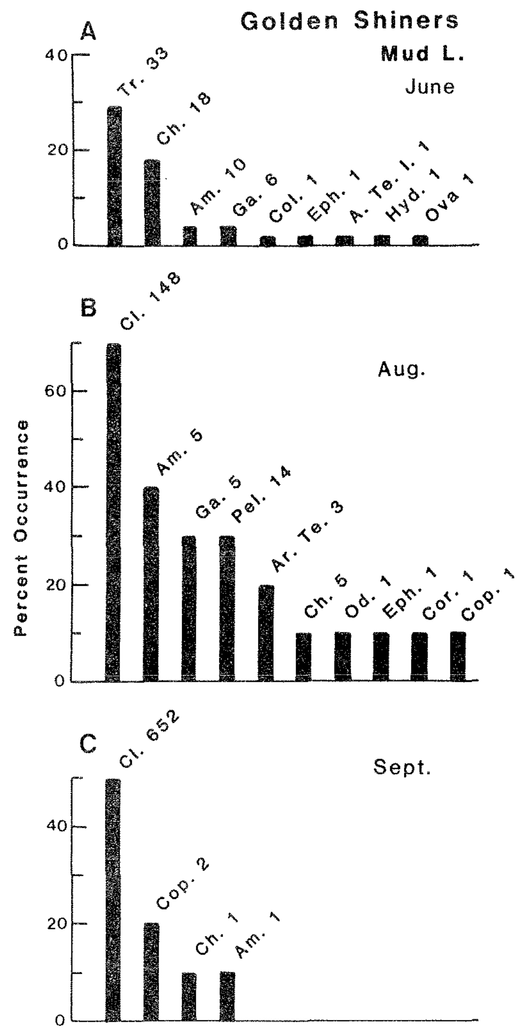


Fig. 4. Percentage of stomachs containing various food items in golden shiners. June: n = 45, $\bar{L}$ = 12.2; August: n = 10, $\bar{L}$ = 13.5; September: n = 10, $\bar{L}$ = 13.5 cm.

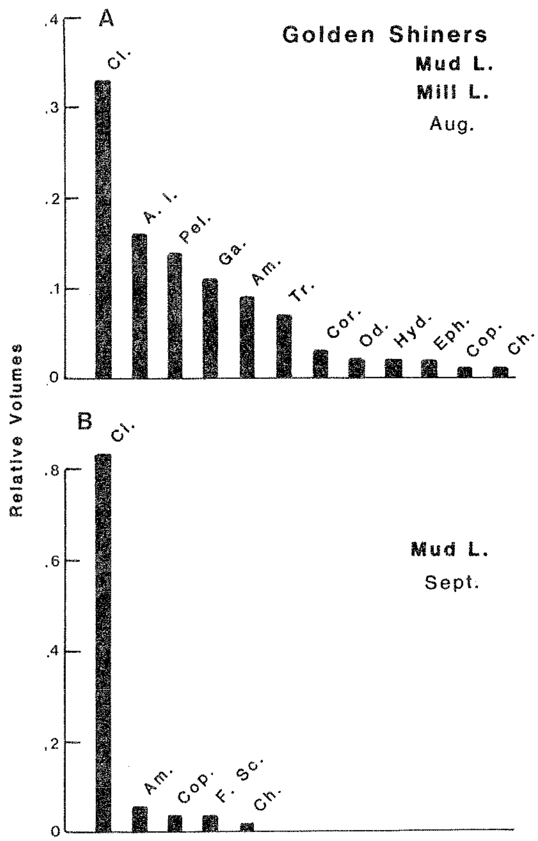


Fig. 5. Relative volumetric importance of various food items in the diet of golden shiners. August: Mud Lake, n = 13; Mill Lake, n = 2; September, n = 6.

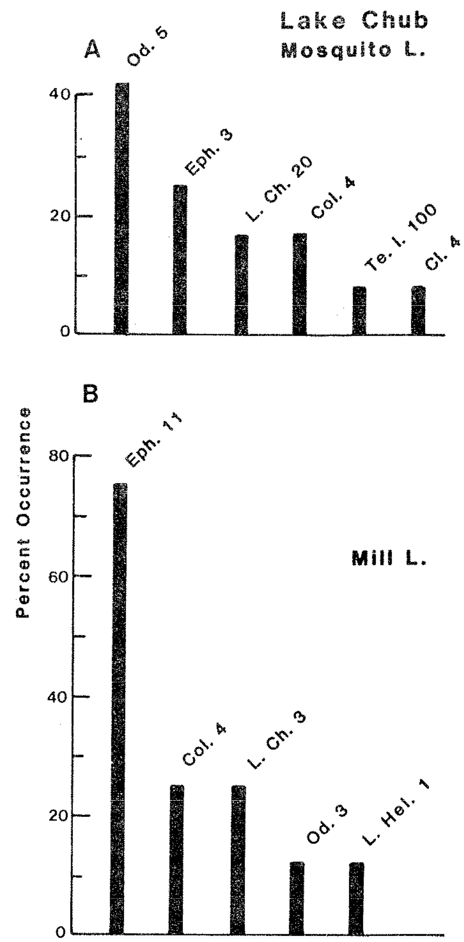


Fig. 6. Percentage of stomachs containing various food items in lake chub. Mosquito Lake: n = 12, $\bar{L}$ = 10.5; Mill Lake: n = 8, $\bar{L}$ = 10.4.

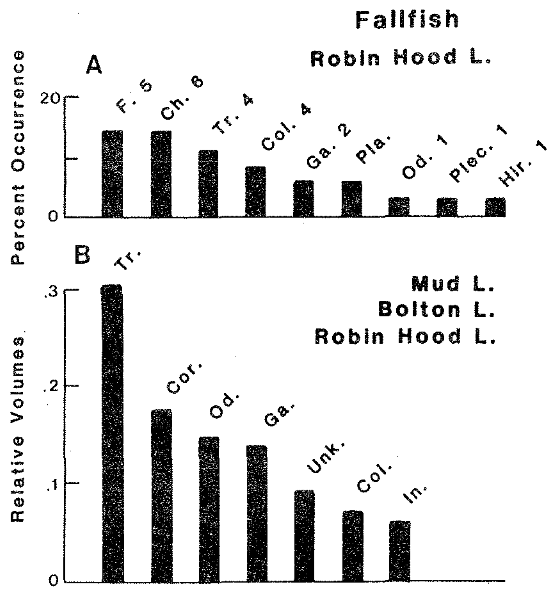


Fig. 7. A. Percentage occurrence of fallfish stomachs containing various food items in ten fallfish stomachs (three lakes combined).

B. Relative volumetric importance of various food items in ten fallfish stomachs (three lakes combined).

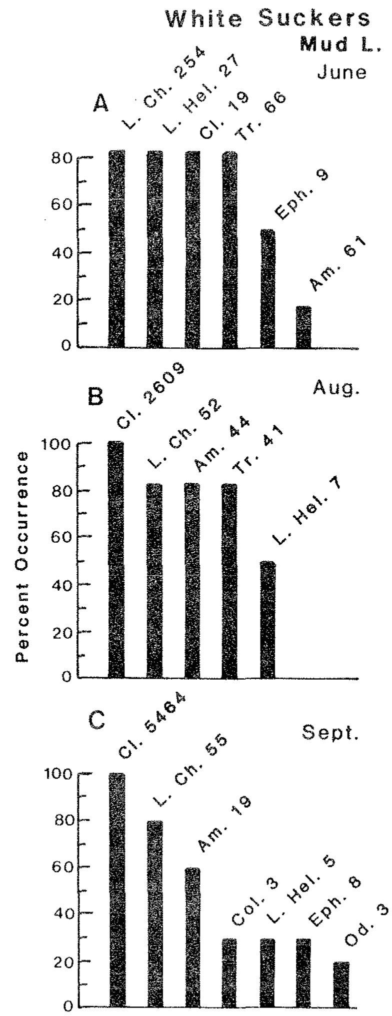


Fig. 8. Percentage of white sucker stomachs containing various food items. June: n = 6, $\bar{L}$ = 16.0; August: n = 6, $\bar{L}$ = 22.8; Sept.: n = 10, $\bar{L}$ = 20.2.

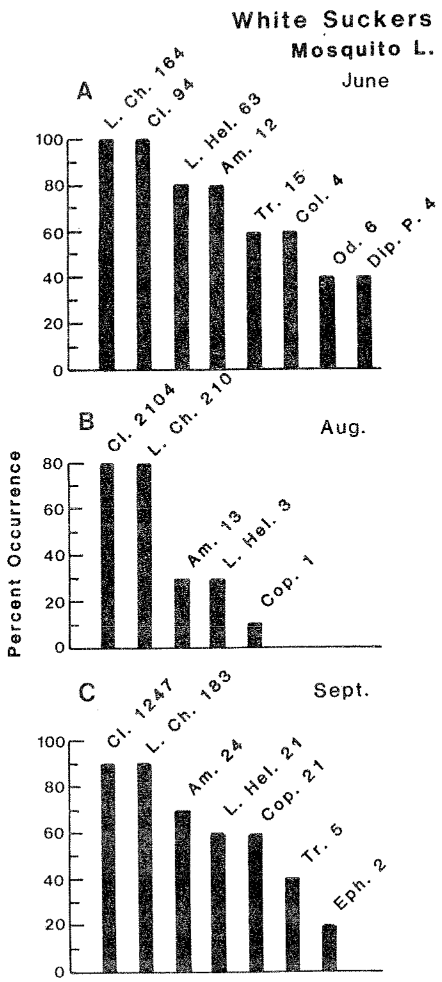


Fig. 9. Percentage of white sucker stomachs containing various food items. June: n = 5, $\bar{L}$ = 22.4; Aug.: n = 10, $\bar{L}$ = 20.1; Sept.: n = 10, $\bar{L}$ = 22.5.

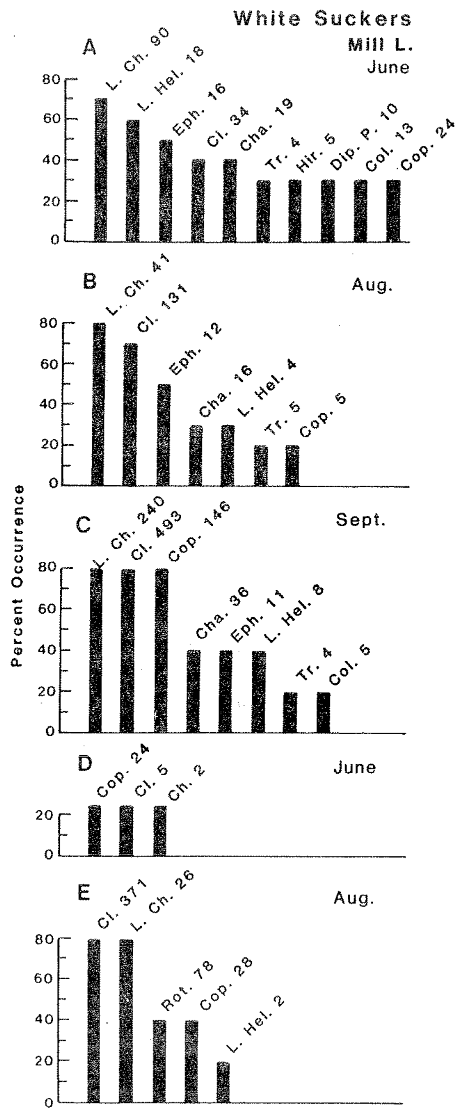


Fig. 10. Percentage of white sucker stomachs containing various food items. A: n = 10, $\bar{L}$ = 22.9; B: n = 10, $\bar{L}$ = 26.3; C: n = 10, $\bar{L}$ = 21.4; D: n = 4, $\bar{L}$ = 7.8; D: n = 10, $\bar{L}$ = 5.2.

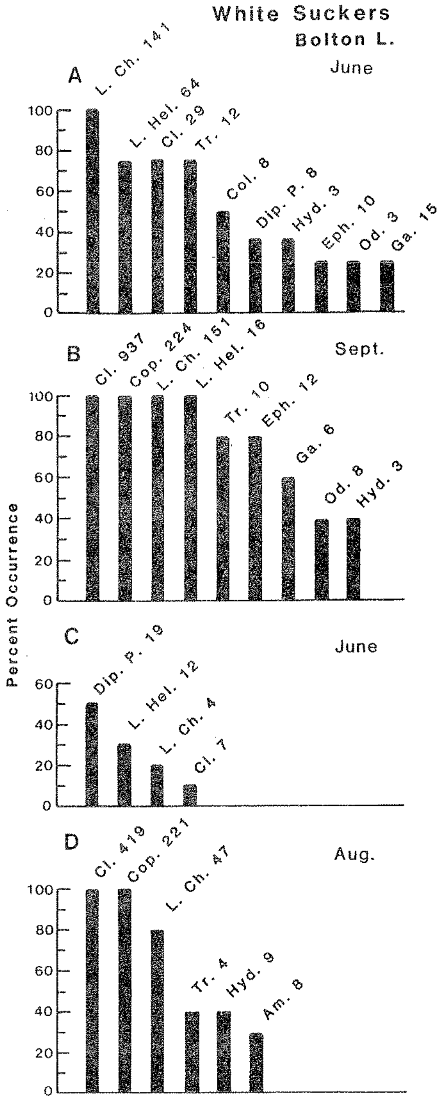


Fig. 11. Percentage of white sucker stomachs containing various food items. A: n = 8, $\bar{L}$ = 25.4; B: n = 5, $\bar{L}$ = 27.3; C: n = 10, $\bar{L}$ = 8.7; D: n = 10, $\bar{L}$ = 9.6.

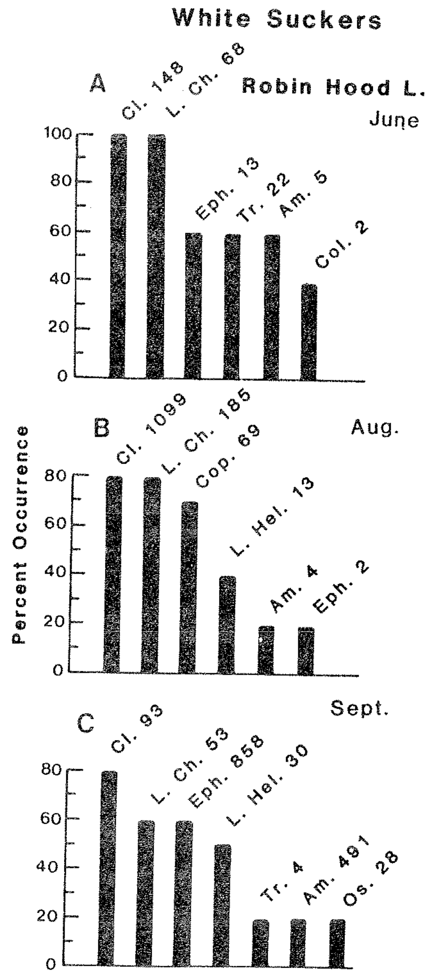


Fig. 12. Percentage of white sucker stomachs containing various food items. A: n = 5, $\bar{L}$ = 24.0; B: n = 10, $\bar{L}$ = 19.6; C: n = 10, $\bar{L}$ = 21.8.

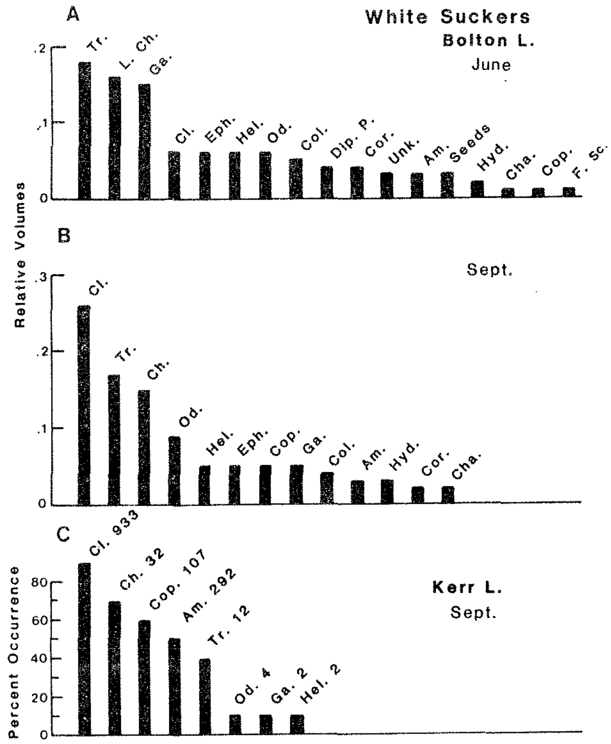
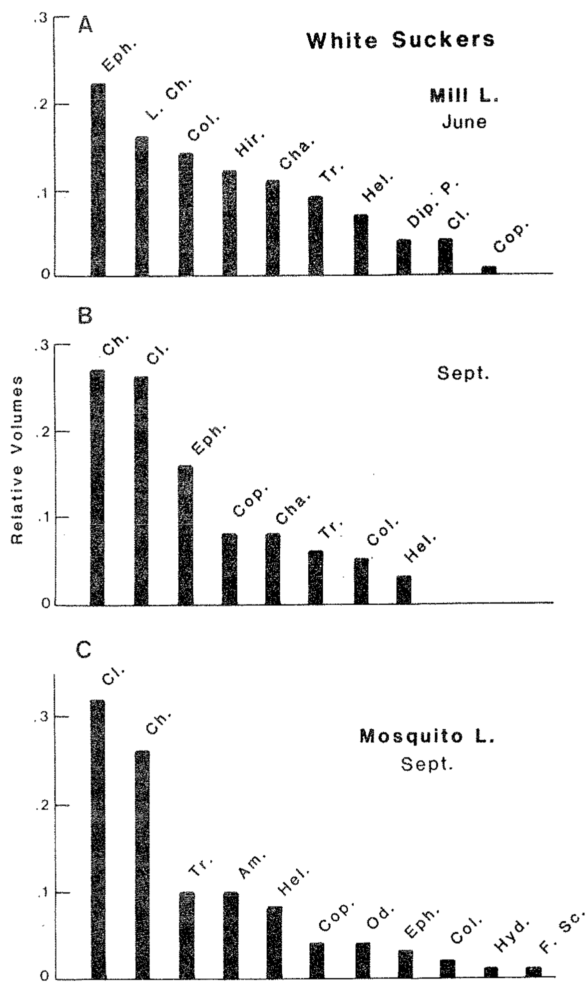


Fig. 13. A, B: Relative volumetric importance of various food items in white sucker stomachs.

C: Percentage of white sucker stomachs containing various food items (n = 10, $\bar{L}$ = 14.2).



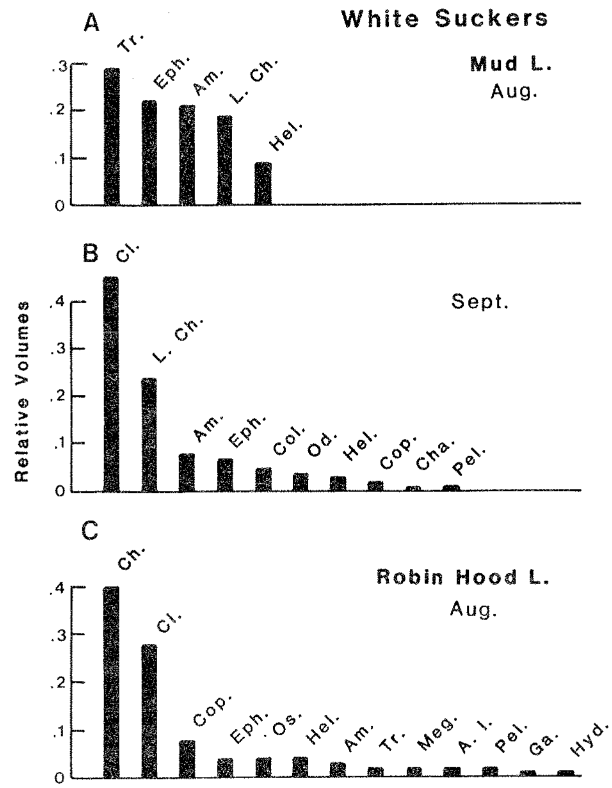


Fig. 14-15. Relative volumetric importance of various food items in white sucker stomachs.

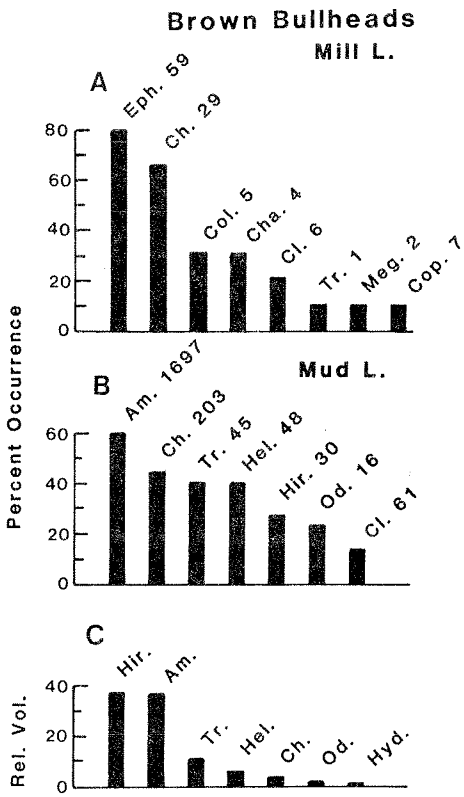


Fig. 16. A, B: Percentage of brown bullhead stomachs containing various food items. A: n = 9, $\bar{L}$ = 19.0; B: n = 29, $\bar{L}$ = 17.4.

C: Relative volumetric importance of various food items in stomachs of brown bullheads from Mud Lake in August, n = 7.

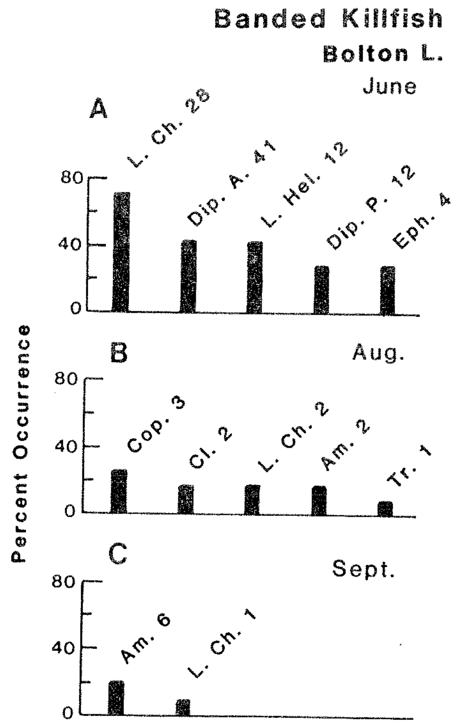


Fig. 17. Percentage of banded killifish stomachs containing various food items. A: n = 7, $\bar{L}$ = 7.8; B: n = 12, $\bar{L}$ = 3.3; C: n = 10, $\bar{L}$ = 5.9.

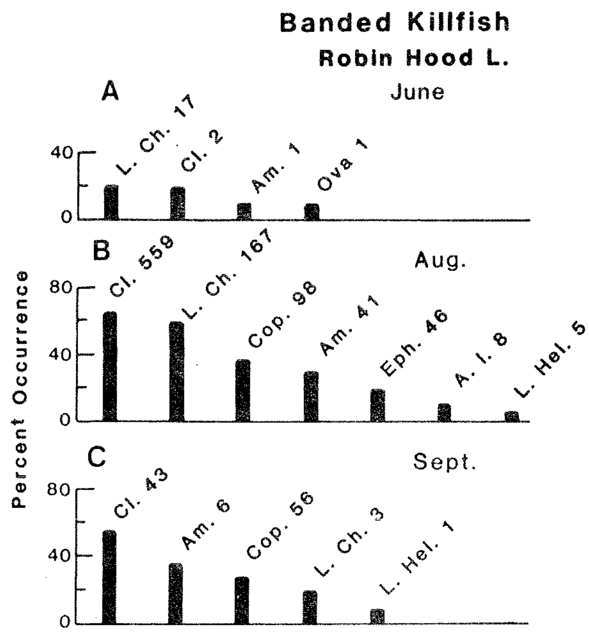


Fig. 18. Percentage of banded killifish stomachs containing various food items. A: n = 10, $\bar{L}$ = 7.4; B: n = 47, $\bar{L}$ = 6.0; C: n = 11, $\bar{L}$ = 6.5.

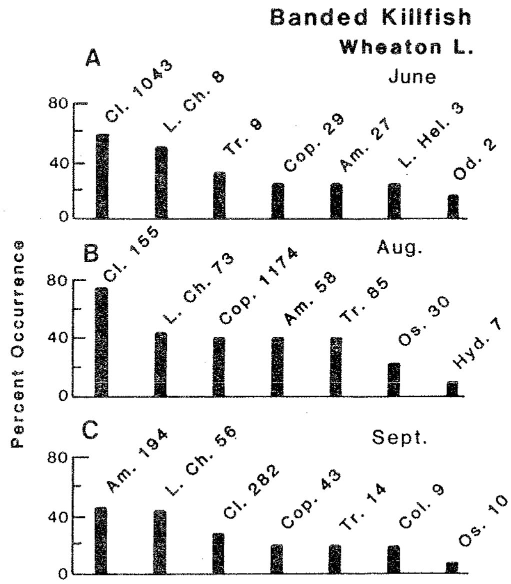


Fig. 19. Percentage of banded killifish stomachs containing various food items. A: n = 12, $\bar{L}$ = 8.5; B: n = 52, $\bar{L}$ = 3.9; C: n = 4.0, $\bar{L}$ = 4.6.

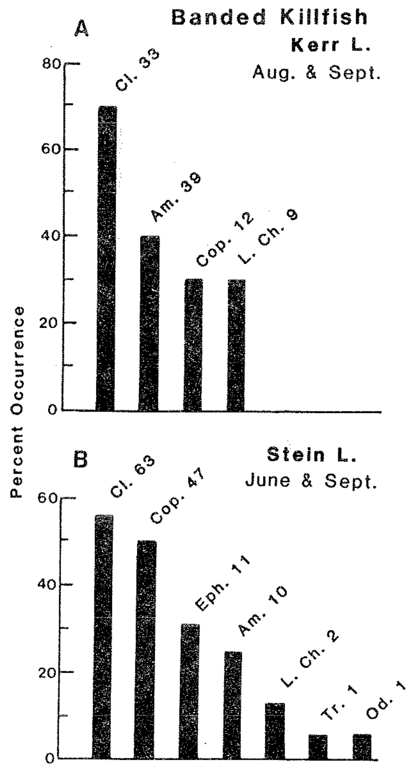


Fig. 21. Percentage of banded killifish stomachs containing various food items. A: n = 10, $\bar{L}$ = 3.5; B: n = 16, $\bar{L}$ = 3.5.

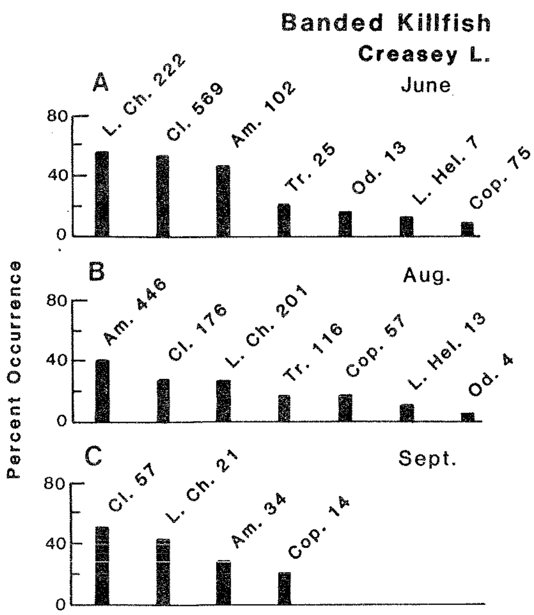


Fig. 20. Percentage of banded killifish stomachs containing various food items. A: n = 59, $\bar{L}$ = 6.0; B: n = 100, $\bar{L}$ = 6.5; C: n = 14, $\bar{L}$ = 3.6.

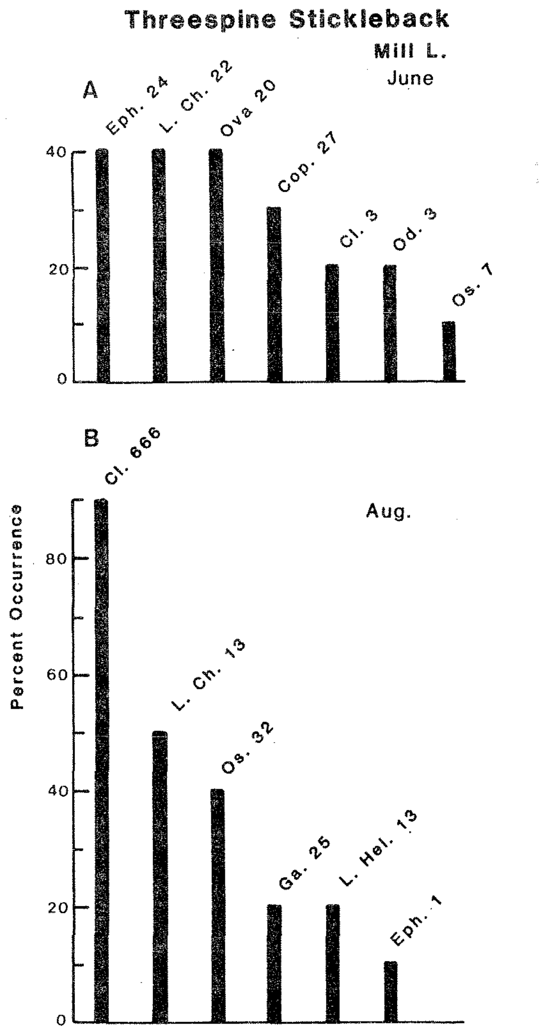


Fig. 22. Percentage of threespine stickleback stomachs containing various food items. A: n = 10, $\bar{L}$ = 5.5, B: n = 10, $\bar{L}$ = 3.8.

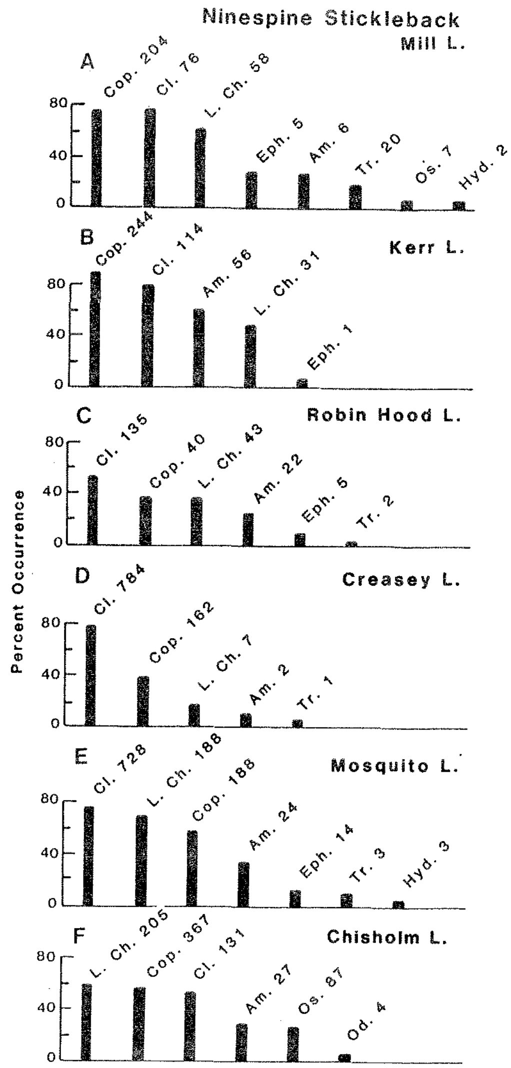


Fig. 23. Percentage of ninespine stickleback stomachs containing various food items, for all months combined. A: n = 15, $\bar{L}$ = 3.9; B: n = 17, $\bar{L}$ = 3.9; C: n = 38, $\bar{L}$ = 4.0; D: n = 18, $\bar{L}$ = 4.0; E: n = 32, $\bar{L}$ = 4.5; F: n = 59, $\bar{L}$ = 4.8.

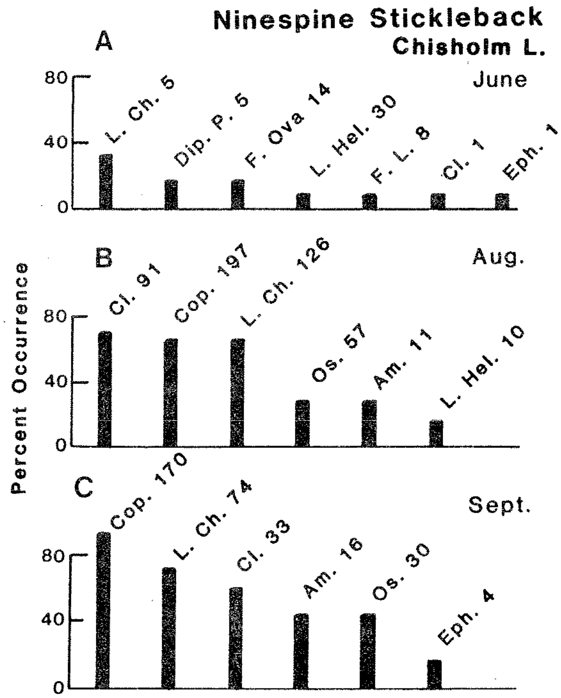


Fig. 24. Percentage of ninespine stickleback stomachs containing various food items. A: n = 12, $\bar{L}$ = 5.0; B: n = 29, $\bar{L}$ = 4.7; C: n = 18, $\bar{L}$ = 4.8.

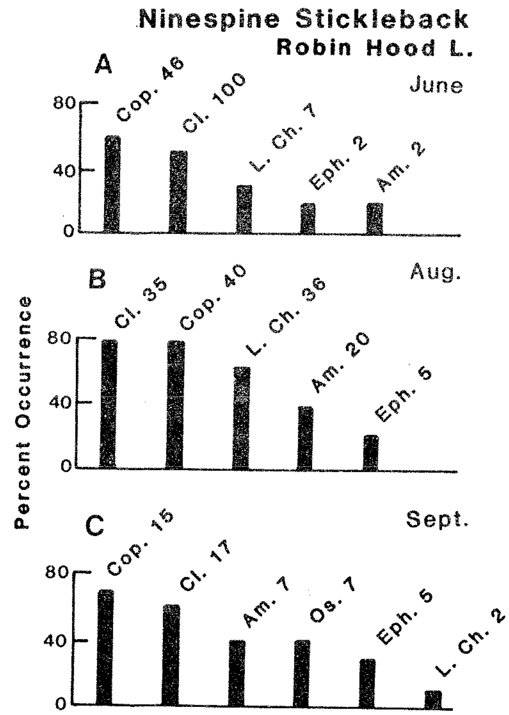


Fig. 26. Percentage of ninespine stickleback stomachs containing various food items. A: n = 10, $\bar{L}$ = 4.7; B: n = 18, $\bar{L}$ = 4.4; C: n = 10, $\bar{L}$ = 3.6.

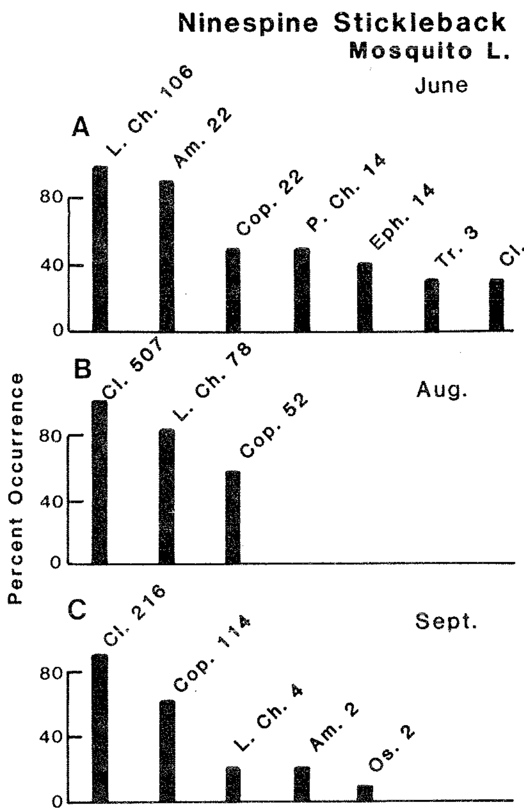


Fig. 25. Percentage of ninespine stickleback stomachs containing various food items. A: n = 10, $\bar{L}$ = 4.9; B: n = 12, $\bar{L}$ = 3.8; C: n = 10, $\bar{L}$ = 4.9.

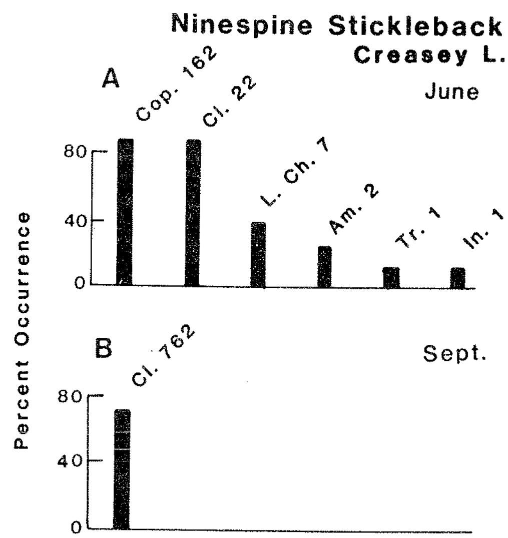
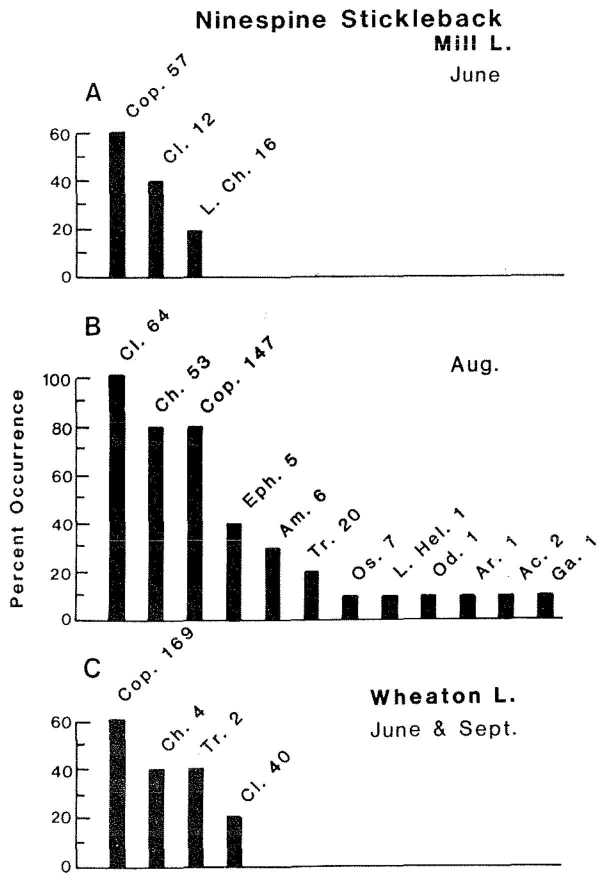


Fig. 27. Percentage of ninespine stickleback stomachs containing various food items. A: n = 8, $\bar{L}$ = 4.4; B: n = 10, $\bar{L}$ = 4.1.



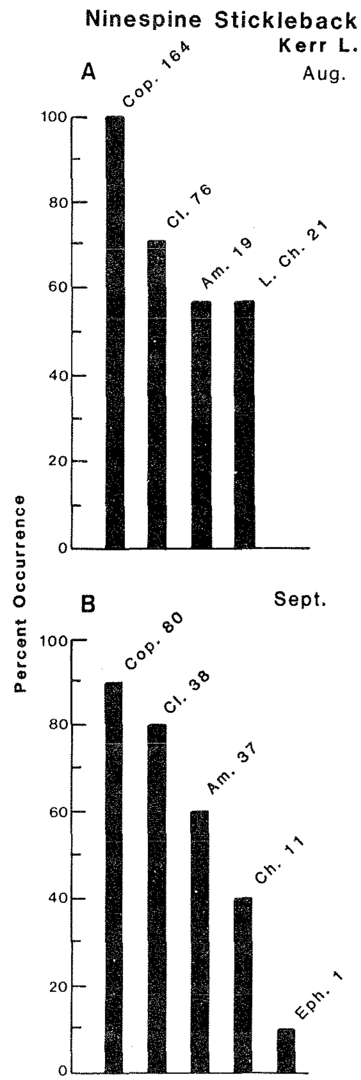


Fig. 28. Percentage of ninespine stickleback stomachs containing various food items. A: n = 5, $\bar{L}$ = 4.1; B: n = 10, $\bar{L}$ = 3.8; C: n = 5, $\bar{L}$ = 3.0.

Fig. 29. Percentage of ninespined stickleback stomachs containing various food items. A: n = 7, $\bar{L}$ = 3.5; B: n = 10, $\bar{L}$ = 4.2.

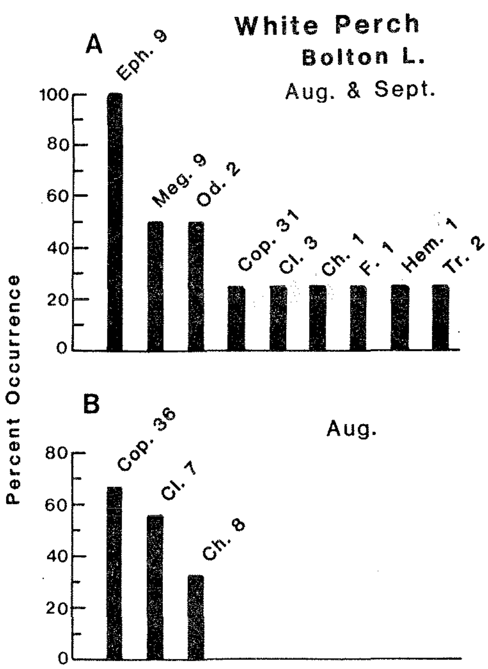


Fig. 30. Percentage of white perch stomachs containing various food items. A: perch >10 cm <15 cm (n = 4, $\bar{L}$ = 14.4); B: perch < 5 cm (n = 9, $\bar{L}$ = 2.0).

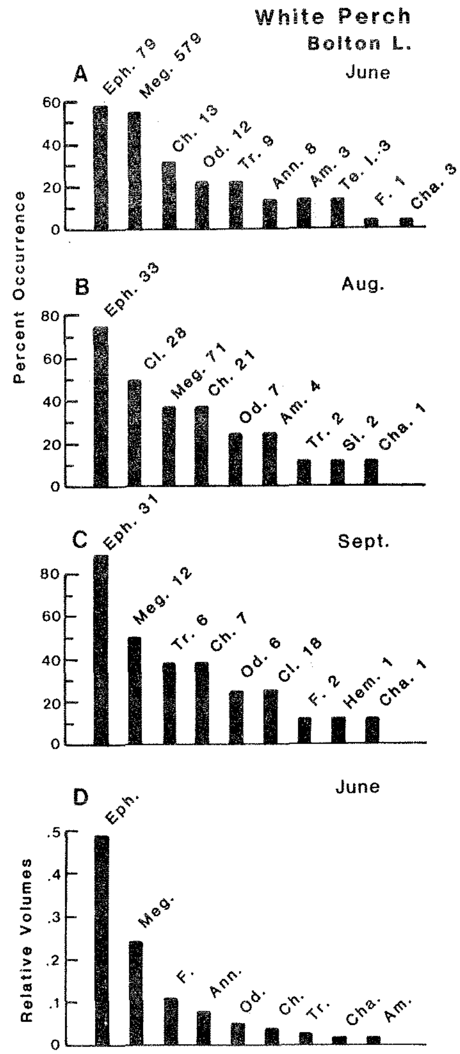


Fig. 31. A–C: Percentage of white perch stomachs containing various food items.

D: Relative volumetric importance of various food items in white perch diets. A: n = 22, $\bar{L}$ = 20.1; B: n = 8, $\bar{L}$ = 19.8, C: n = 8, $\bar{L}$ = 19.2; D: n = 12.

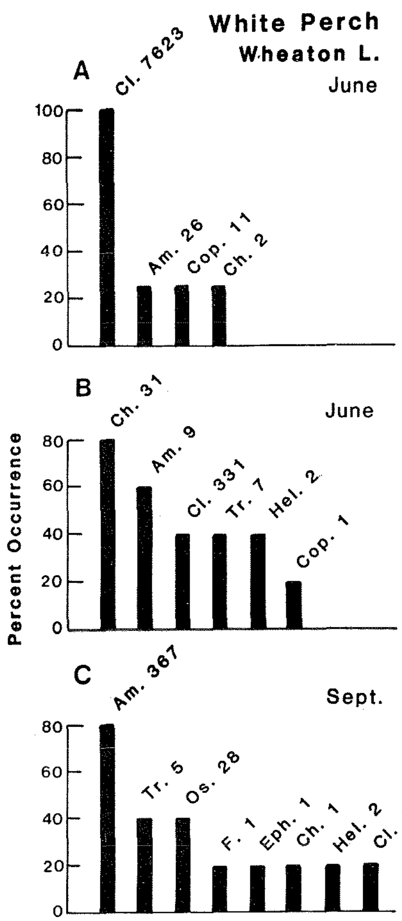


Fig. 32. Percentage of white perch stomachs containing various food items. A, B: perch >10 < 15 cm; C: perch > 5 < 10 cm. A: n = 5, $\bar{L}$ = 12.1; B: n = 5, $\bar{L}$ = 13.5; C: n = 4, $\bar{L}$ = 6.1.

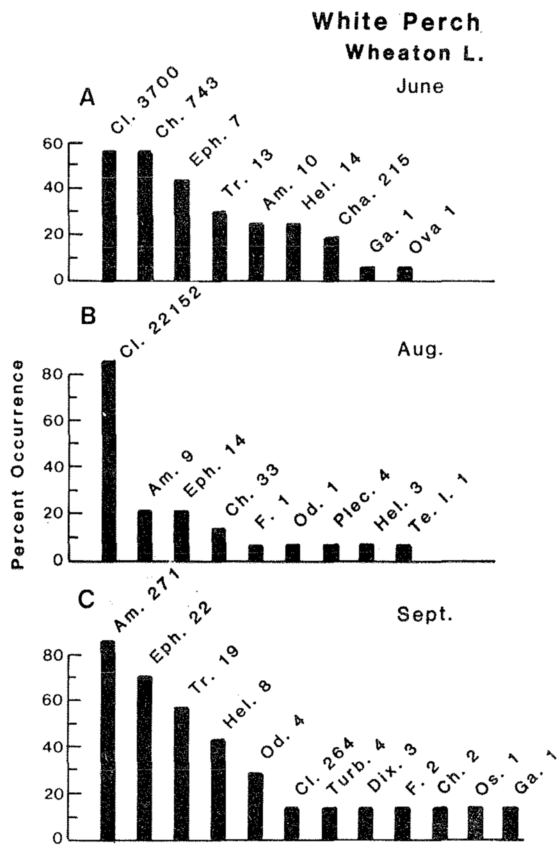


Fig. 33. Percentage of white perch stomachs containing various food items. A: n = 16, $\bar{L}$ = 18.9; B: n = 14, $\bar{L}$ = 21.1; C: n = 7, $\bar{L}$ = 19.4.

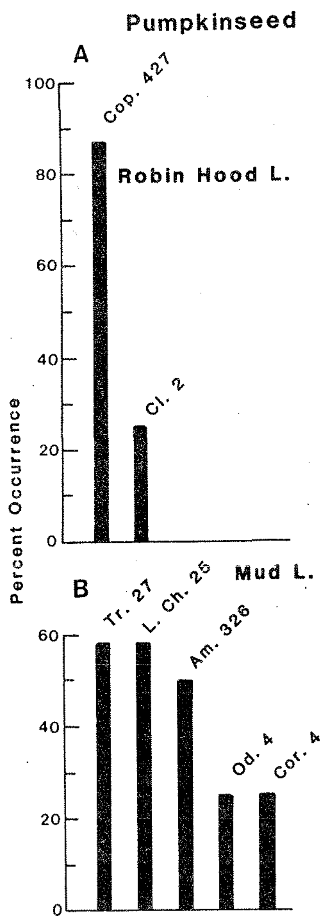


Fig. 34. Percentage of pumpkinseed stomachs containing various food items. A: n = 8, $\bar{L}$ = 1.7; B: n = 12, $\bar{L}$ = 9.7.

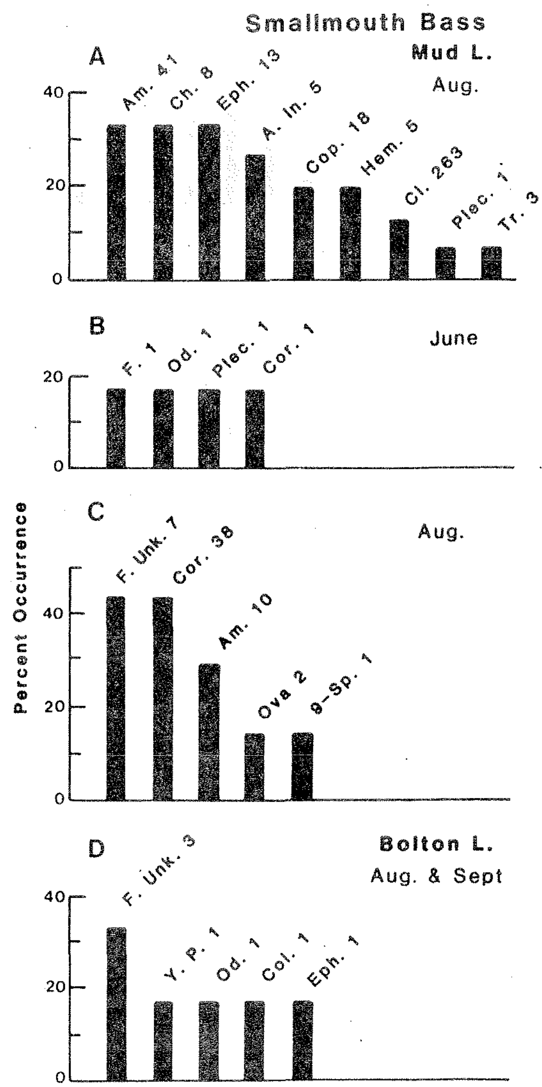


Fig. 35. Percentage of smallmouth bass stomachs containing various food items. A: n = 15, $\bar{L}$ = 5.3; B: n = 6, $\bar{L}$ = 34.5; C: n = 7, $\bar{L}$ = 29.2; D: n = 6, $\bar{L}$ = 18.7.

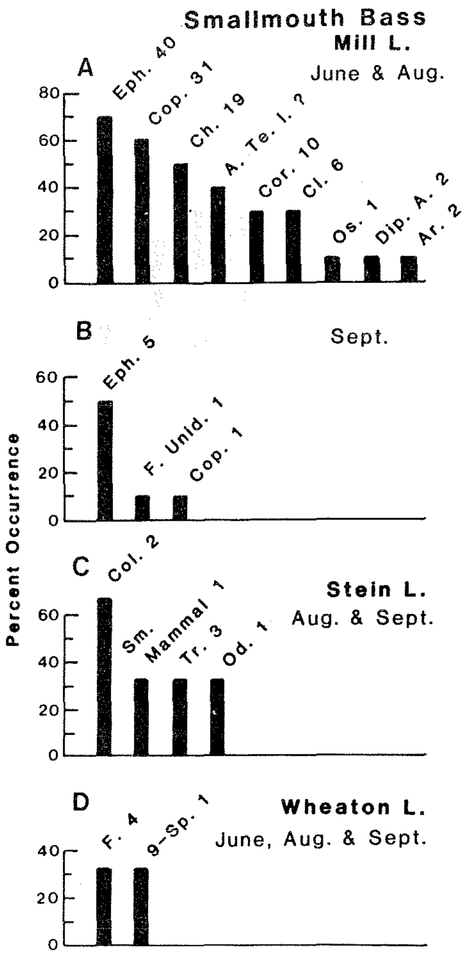


Fig. 36. Percentage of smallmouth bass stomachs containing various food items. A: n = 10, $\bar{L}$ = 4.6; B: n = 10, $\bar{L}$ = 6.5; C: n = 3, $\bar{L}$ = 23.5, D: n = 3, L = 34.1.

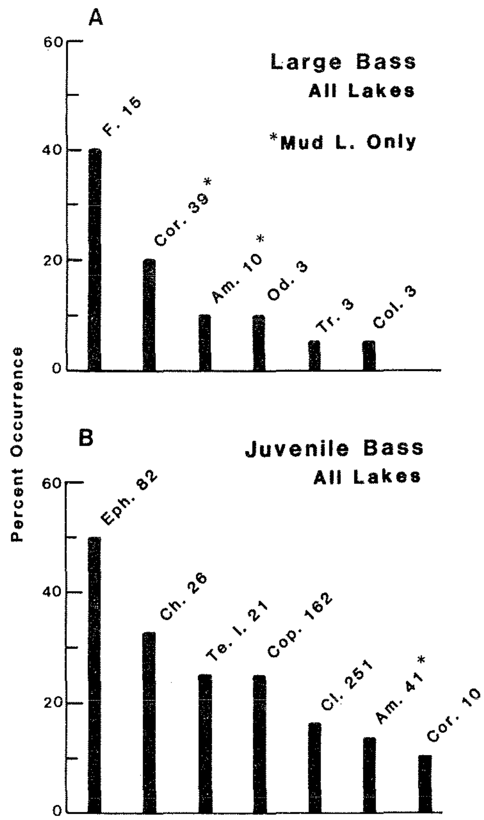


Fig. 37. Percentage of smallmouth bass stomachs containing various food items. A: n = 20 ($\bar{L}$ > 20); B: n = 36 ($\bar{L}$ < 10).

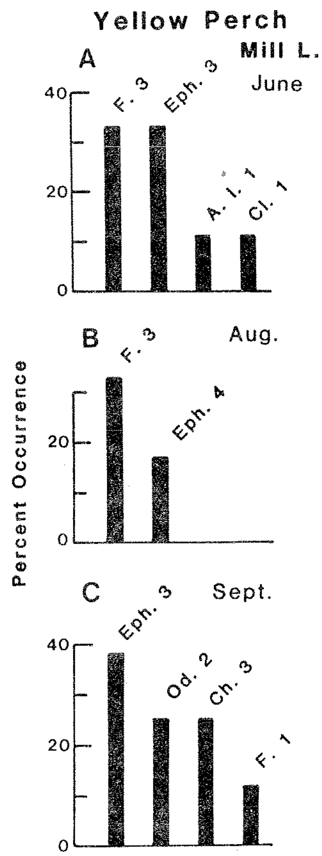


Fig. 38. Percentage of yellow perch (>15 cm) stomachs containing various food items. A: n = 9, $\bar{L}$ = 24.1; B: n = 6, $\bar{L}$ = 21.0; C: n = 7, $\bar{L}$ = 20.7.

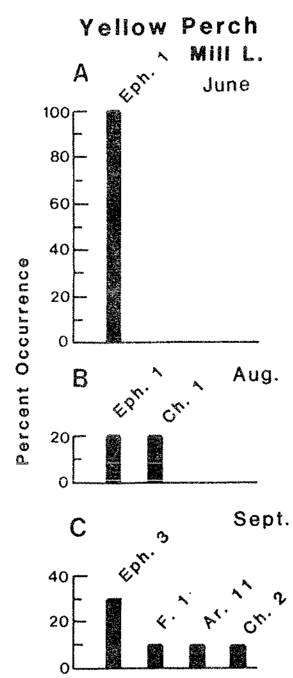


Fig. 39. Percentage of yellow perch (> 10 < 15 cm) stomachs containing various food items. A: n = 1, $\bar{L}$ = 10.1; B = n = 5, $\bar{L}$ = 11.1; C: n = 10, $\bar{L}$ = 11.3.

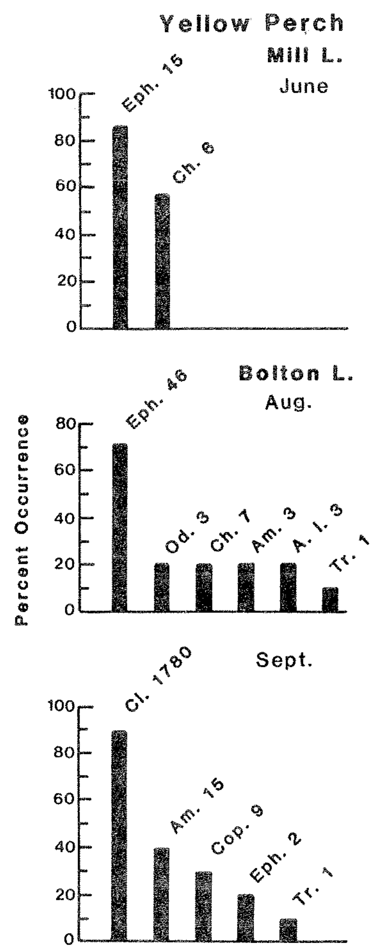


Fig. 40. Percentage of yellow perch (>5 < 10 cm) stomachs containing various food items. A: n = 7, $\bar{L}$ = 6.6; B: n = 10, $\bar{L}$ = 7.5; C: n = 10, $\bar{L}$ = 5.9.

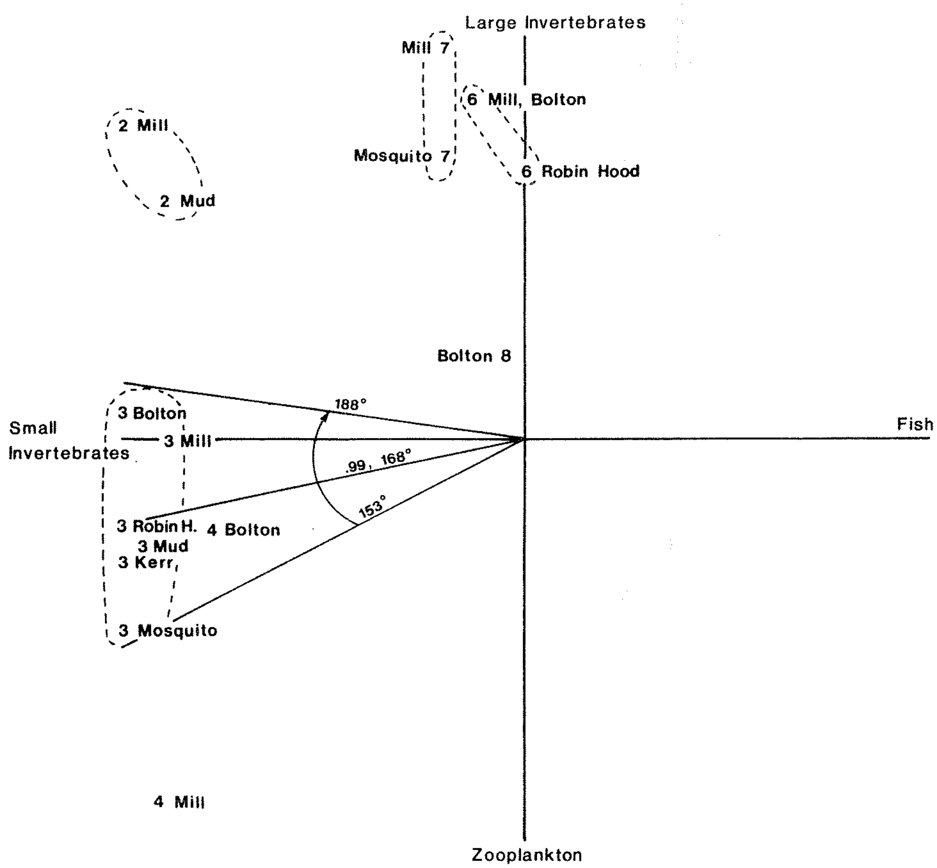


Fig. 41. Positions of various species on food habit coordinates as determined by the vectorial analysis described in the text. 2: adult brown bullhead; 3: adult white sucker; 4: juvenile white sucker; 6: adult fallfish; 7: adult lake chub; 8: adult common shiner.

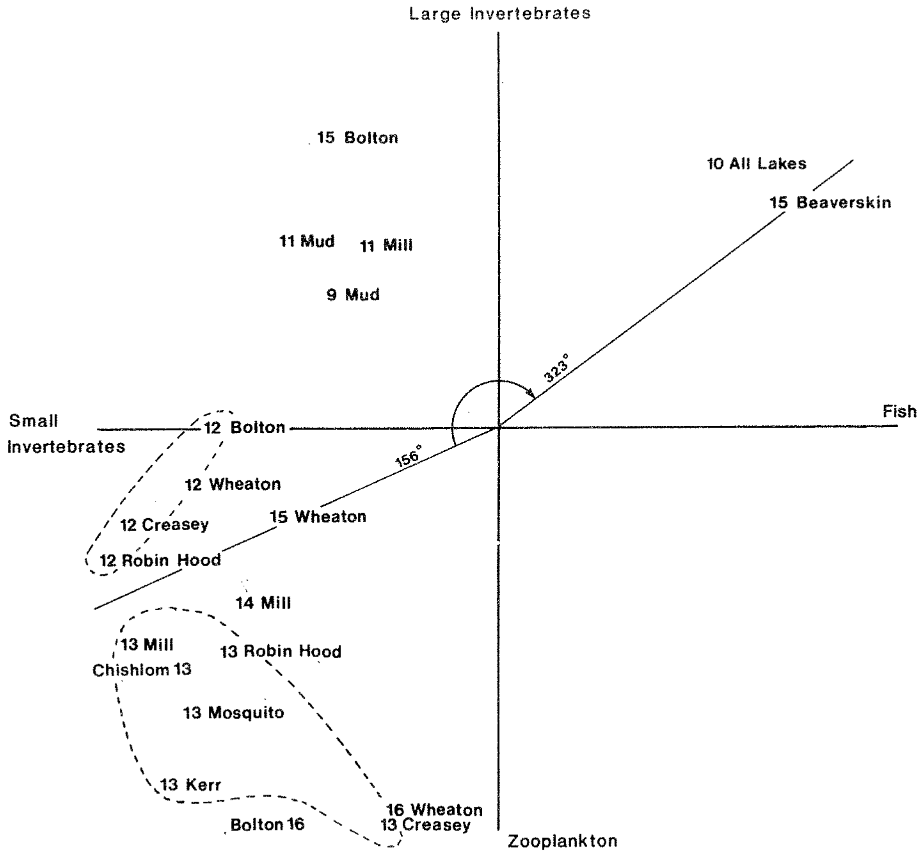


Fig. 42. Positions of various species on food habit coordinates as determined by the vectorial analysis described in the text. 9: adult golden shiner; 10: adult smallmouth bass; 11: juvenile smallmouth bass; 12: banded killifish; 13: ninespine stickleback; 14: threespine stickleback; 15: adult white perch; 16: juvenile white perch.

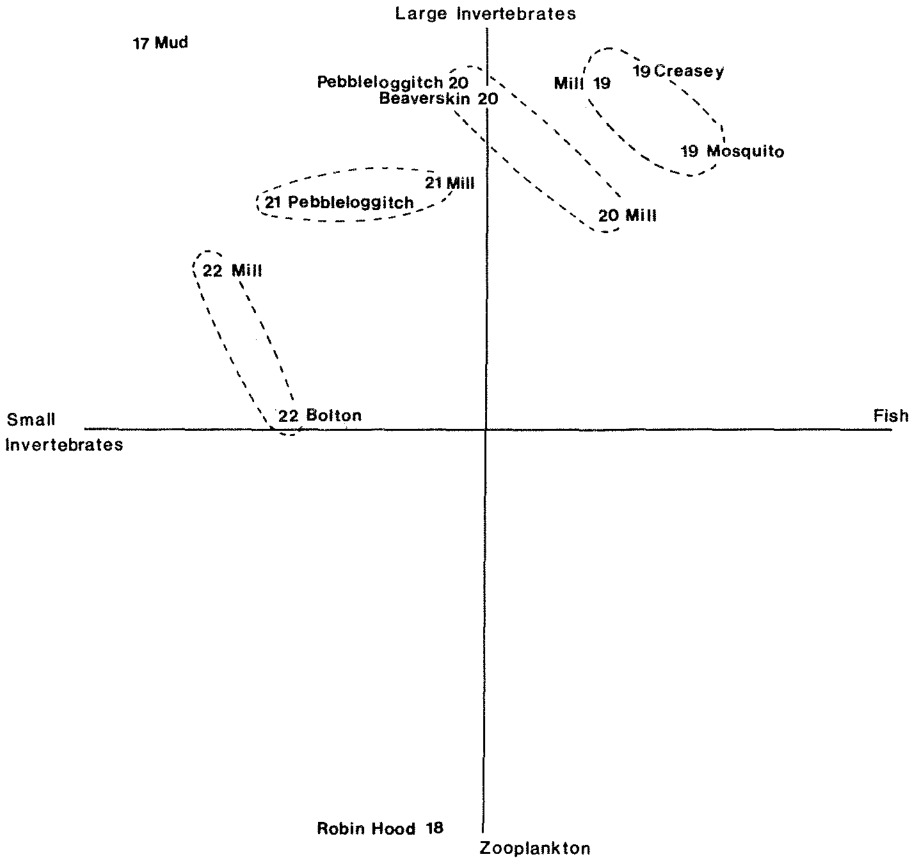


Fig. 43. Positions of various species on food habit coordinates as determined by the vectorial analysis described in the text. 17: mature pumpkinseed; 18: juvenile pumpkinseed; 19: mature brook trout; 20: mature yellow perch (> 15 cm); 21: > 10 < 15 cm yellow perch; 22. juvenile yellow perch (>5 < 10 cm).

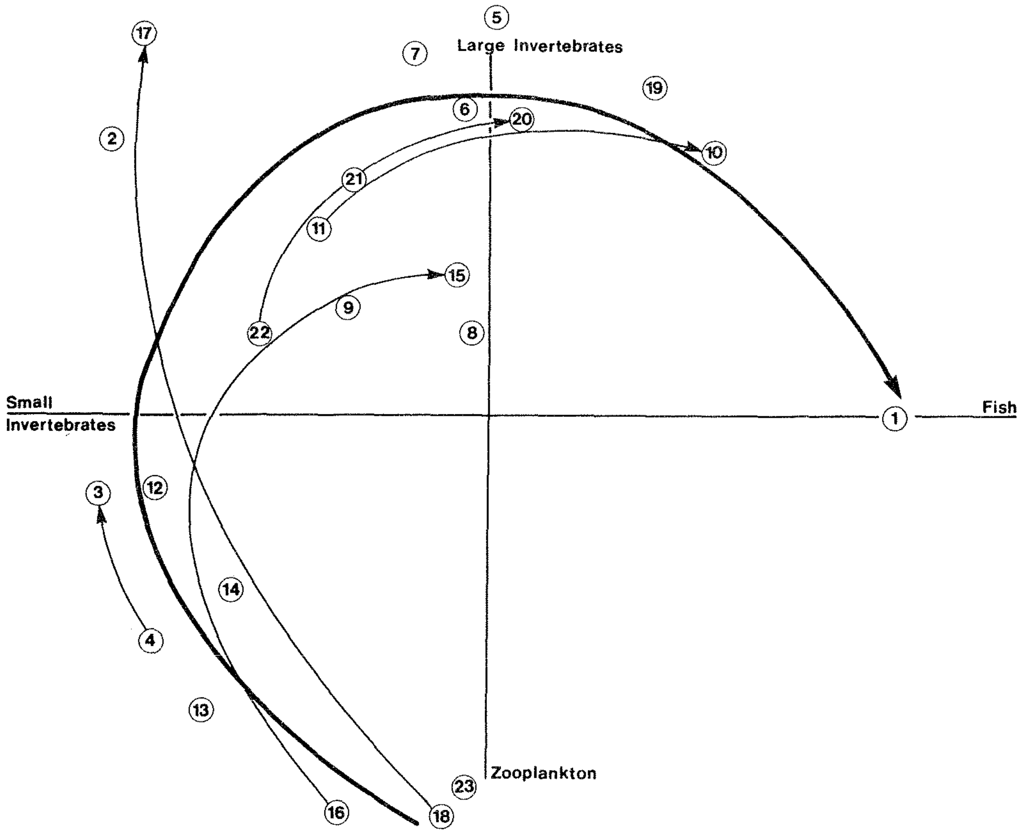


Fig. 44. Summary of the vectorial analysis of food habits for all fish species studied. The heavily lined vector summarizes the trends in the manner in which food habits change with increased fish size. Species lowest in the trophic order occupy positions furthest counter-clockwise, near the zooplankton axis; those at the highest trophic levels furthest clockwise, near the fish axis. 1: chain pickerel; 2: brown bullhead; 3, 4: white sucker; 5: pearl dace; 6: fallfish; 7: lake chub; 8: common shiner; 9: golden shiner; 10, 11: smallmouth bass; 12: banded killifish; 13: ninespine stickleback; 14: threespine stickleback; 15, 16: white perch; 17, 18: pumpkinseed; 19: brook trout; 20-22: yellow perch; 23. blacknose shiner.