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Foraging Factors Which Facilitate the Cohabitation of Yellow Perch (*Perca flavescens*) and the Golden Shiner (*Notemigonus crysoleucas*) in Lac Choiniere.

Allan R. Elliott

A Thesis

in

The Department

of

Biology

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ABSTRACT

FORAGING FACTORS WHICH FACILITATE THE COHABITATION OF YELLOW PERCH (PERCA FLAVESCENS) AND THE GOLDEN SHINER (NOTEMIGONUS CRYSOLEUCAS) IN LAC CHOINIERE

Allan Ross Elliott

The feeding preferences of golden shiners and yellow perch less than 13.0cm in a shallow Quebec reservoir, were compared using electivity and diet overlap information. Zooplankton was the major food item for both species. The principal difference in their pelagic foraging strategies was that, in August and September, golden shiners preferred Bosmina and yellow perch Daphnia .

Yellow perch were found to be more of a generalist forager, feeding on a range of zooplankton types, as well as incorporating more littoral prey in their diet than golden shiners which foraged primarily on smaller pelagic zooplankters.

Perch and shiners were not found to be segregated spatially in Lac Choiniere or geographically in Quebec suggesting these two species are common cohabitors with overlapping foraging ranges.

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INTRODUCTION

Coexistence has been a subject for study which has intrigued ecologists for some time. Niche and competition theories all have been developed through coexistance studies. Lack (1947) studied the co-occurrence patterns of the finches of the Galapagos islands which have proved invaluable in the expansion of the two previously mentioned ecological concepts. There have been many co-existence studies covering a wide variety of organisms (eg. Paine et al. 1963, Schoener 1968, Schmitt & Coyer 1983), all of which has contributed in some way to the understanding of ecological principlals. In most of these studies, especially in those of aquatic systems, food is believed to be the key limiting resource, and it is for fish populations the resource which molds community composition (Hanson & Leggett 1986, Crowder 1986).

Species that coexist in a given area do so by having sufficient differences in their usage of resources or by partitioning food eaten, space, or time (Schoener 1982). There are numerous examples in the literature of resources being partitioned in aquatic fish communities (eg. Werner & Hall 1979, Gascon & Leggett 1977, Keast & Webb 1966).

Resources can be partitioned among species on the basis of habitat preference or food specialization. Segregation by habitat is the most frequently used method for providing sufficient differences between species (Schoener 1974). In lake communities many fish species are present, and each can be found associated with a specific habitat. This habitat partitioning allows for the co-occurence of many fish species. For example, the bluegill sunfish Lepomis gibbosus and the pumpkinseed Lepomis macrochirus are residents of littoral habitats. Black bullhead Ictalurus melas are associated with benthic habitats and herrings Coregonus artedii with pelagic (Scott and Crossman 1979). As a consequence, direct competition for food resources is minimal when these species co-occur. Within these three habitats further subdivisions can be found. An example of this the the vegetated and non vegetated areas of a littoral habitat.

Food partitioning can occur among fish found in the same habitats. MacDonald & Green (1986) provide a good example of how five marine species of fish coexist through differences in their morphology. Demersal prey are the principal food items for all five species but because of their different morphologies,they have different prey preferences, thus partitioning their demersal prey.

Examples of apparently morphologically similar species modifying their diets allowing coexistence can be found when comparing allopatric and sympatric species. For example, Schmitt and Coyer (1983) found differences in diets of surfperch Embiotoca jacksoni with and without a congener. These differences could not be explained by variation in the resource base.

Coexistence can also be predator mediated. The presence of a predator may allow species to co-occur. This can be achieved through a number of ways:

1) The predator can keep the species A numbers in check enabling species B to exist, whereas, if the predator was not present, species A would competitively exclude species B. Lubchenco (1978) showed predator mediated coexistence in an intertidal community.

2) The predator can enforce habitat use. Mittelback (1986) illustrated that the presence of a predator can cause prey species to alter their habitat preference. Werner et al (1983) found that the presence of a predator caused small bluegill sunfish to feed in the vegetated habitats whereas without the predator would thus feed in the open water habitat.

3) The predator can lower the demand for resources, thus reducing competition and allow for coexistence. (Brooks & Dodson 1965, Caswell 1978).

Whether competition, predation, or some abiotic factor, such as temperature (Persson 1986), is the principal force molding community composition remains a controversial subject (Schoener 1974, 1983, Connell 1983, Persson 1986, Conner and Simberloff 1979). In most situations there is no single force which molds community composition, instead there is a combination of forces, all of which are important, and are intertwined producing different communities depending on various circumstances.

Keast & Webb (1966) investigated the feeding ecology of fishes of a small lake and found six basic morphologies among the fourteen cohabitating fish. Each one was adapted for a particular feeding strategy based on different foods and habitats. These different feeding stategies enabled many species to co-occur. Most species morphologies were flexible enough to permit foraging over a range of habitats. There were few species so specialized as to only forage over a narrow range of prey types. A similar study involving three fish species can be found in Werner(1986).

The type and quantity of food resource consumed by a predator is dependent on the preys' abundance, and exploited to various degrees depending on the following factors:

Morphology

Mobility is directly related to body design as various swimming modes are associated with specific body designs (Keast & Webb 1966). Rapidly moving and continuously swimming fish such as the northern pike Esox lucius and the alewife Alosa pseudoharengus have the fusiform body design (Keast & Webb 1966).

The gibbose body form is the other basic body shape and is associated with fish such as bluegill sunfish which spends time hovering, as the design offers stability (Keast & Webb 1966).

The swimming capabilities of a species of fish can limit the variety of food type consumed. For example, a slow moving bottom feeder is adapted for foraging in the sediment, and inept at feeding piscivorously.

Mouth design is another important parameter which can govern prey choice of a predator. Important factors such as mouth location, buccal volume (Drenner et al. 1978), and size and spacing of gillrakers (Drenner 1977) have been said to influence capturing efficiency and prey choice.

Behaviour

Foraging techniques are instrumental in determining how efficiently a predator can exploit food resources. O'Brien et al. (1988) outlined three search strategies planktivores use in foraging. First, the cruise strategy involves searching while constantly swimming. The second is the ambush strategy. This strategy has frequent stationary phases during which the predator waits for prospective prey which it ambushes. The third is the saltatory method. The predator moves in a stop and go manner stopping more frequently than in the cruise method but the period of pausing is less than in the ambush method.

Once the planktivore has located its prey it uses one of three basic feeding modes to trap its prey. These are the particulate, filter and gulping feeding modes. The particulate feeding mode involves the capture of individual zooplankters. The filter feeding mode has two varieties. First, the pump variety incorporates the use of the operculum to force water through the gillrakers which strain out and trap the zooplankton for ingestion. In the second of the two net varieties, the fish swims with a gaping mouth directing water and prey through gillrakers in order to capture prey (O'Brien 1979). The third basic mode involves undirected gulping of a volume of water into the buccal cavity and expelling it out through the gills and gillrakers.

Different feeding techniques can arise from differences in habitat selection, timing of feeding period, mode of feeding strategy, feeding solitarily or in schools. All are behavioral traits involving a morphological element.

Zooplankton are an important food resource during the larval and juvenile stages of a majority of fish species. Among species such as the alewife (Alosa pseudoharengus)(Jansen 1976) and bluegill sunfish (Lepomis gibbions) (Werner & Hall 1979), zooplankton constitute a significant portion of the diet even as adults.

The distribution of zooplankton in lakes is controlled by biotic and abiotic factors, resulting in heterogeneity in its distribution in the environment. This patchiness of zooplankton in the environment has been documented by Nie et al. (1980). This variablity makes determinations of densities difficult and dependent on sampling methods used. Heterogeneity of prey (Folt 1987) along with the morphological and behavioural characteristics of diffferent predators results in efficiency differences between predators foraging on zooplankton.

Obligate planktivores such as ciscoes (Coregonus artedii) are superbly developed for foraging on zooplankton. They have finely spaced gillrakers, and the body design of a continuously swimming highly maneouverable fish, according to criteria put forth by Keast and Webb (1966). These characteristics have equipped them well for a life of foraging on zooplankton. The alewife has similar features and also has the capablity of switching feeding modes from particulate feeding to filter feeding (Jansen 1976).

The bluegill sunfish represents a faculative planktivore, foraging on zooplankton, benthic animals and vegetation, and not relying on one particular food item. The abundances of the food sources is important in determining food preferences. Such predators are called opportunistic feeders.

Whether or not competition is occurring in the field between co-existing fish species is difficult to establish. The primary stumbling block is the difficulty of establishing the food resources as limiting, and that these resources are indeed competed for. Controlled experimentation must be undertaken to properly answer these questions (Connell 1983, Crowder 1986). Controlled experiments dealing with factors such as prey density (Folt 1987), piscivore density (Hall et al 1983), and species density (Hansen & Leggett 1986) have been performed to determine the presence or absence of interspecific competition. In many cases such controlled experiments are impractical to perform due to many uncontrollable abiotic and biotic factors such as enviromental disturbances, predatory and parasitic fauna to name a few. Evidence for species interacting during the procurement of food resources is usually based on comparisons of gut contents and habitat preferences. Foraging preferences are proposed for each species and overlap in these preferences provides circumstantial evidence for interspecific competition. This method does not conform to the strict methodology Connell(1980) outlined to determine if competition exists, but, according to Schoener (1974), patterns of habitat utilization among coexisting species on its own, can be used to suggest ideas and theories concerning competition and community structure. Diamond (1978) and Schoener (1974) suggest that similar resource use between co-occurring species by itself can be strong circumstantial evidence for the occurrence of competition. This point can be argued, but when the investigation of the foraging preferences of co-occurring species suggests differences, even if recources are not limiting, one can at least speculate that these differences can ease co-habitation by helping to segregate the species. In turn, if differences are not found then there is circumstantial evidence that interspecific competition may occur.

My study investigates the foraging strategies of co-dominant planktivores in a Québec reservoir. The specific objectives of this study are:

1) To determine the food resources used by golden shiners _Notemigonus crysoleucas_

2) To substantiate prey selection of yellow perch _Perca flavescens_ found by Chabot and Maly (1986).

3) To determine the distribution of perch and shiners in the water column of Choinière.

4) To establish foraging patterns for each species from information collected regarding their spatial preference, prey preference, and diet overlap. Comparing these patterns could unveil features which would ease co-habitation in a competitive situation.

Yellow Perch

Yellow perch can be found in all of North America's five major drainage basins (Scott & Crossman 1979). They are not closely associated with a specific habitat (Engel & Magnuson 1976) and are flexible in their choice of habitat. Habitats range from cool and warm lakes or ponds to slow moving rivers and include both littoral and pelagic areas (Scott & Crossman 1979, Sandheinrich & Hubert 1984).

Adults and young are gregarious, often moving about in a loose aggregation of 50-200 individuals (Scott & Crossman 1979). The schools can be segregated by size (Hasler & Bardach 1949) and sex (Jorgensen 1983). They can be found throughout the water column but primarily occupy the mid to bottom regions of shallow lakes (Keast & Webb 1966).

Yellow perch are opportunistic predators feeding on a multitude of food sources (Sandheinrich & Hubert 1984). Food of the young consists of cladocerans, ostracods and chironomid larvae and shifts to feeding on Odonata nymphs (40%) Ephemeroptera (30%) and fish fry (30%) near the end of the first year. Fish over 150mm feed primarily on decapods (70%) and small fish (75%) (Keast & Webb 1966). Chikova (1969) found perch to continually feed on zooplankton until they were 18.0cm in length and the widest range of food items was found in fish between 10-18cm. Perhaps variations in perch diet are due to their being opportunistic feeders, and the variability in diet is due to the various abundances of food groups among habitats.

The diet characteristics of yellow perch (1-1.5 years) in Lac Choinière are described by Chabot (1983) who found that large prey species such as <u>Leptodora</u>

and Epischura lacustris were generally preferred, with extreme variability among individual perch in numbers and types of prey consumed. Daphnids became a preferred food item when they became abundant.

Perch feed actively in the morning and at dusk (Thorpe 1977, Keast & Webb 1968, Scott & Crossman 1979). They tend to patrol for individual prey (Keast & Webb 1966). These single prey are not held and swallowed en masse but ingested individually (Hall et al 1979).

Golden Shiner

Golden Shiners commonly occur in upper regions of lakes, ponds and slow moving rivers throughout eastern North America (Scott & Crossman 1979, Hall et al 1979, Keast & Webb 1966). They can be found in the littoral and limnetic zones (Hall et al. 1979). Adults are brassy colored, and range in size from 76mm to 175mm. The young are silvery and have a conspicuous lateral band (Scott & Crossman 1979). Both young and adults have a body design that fits the criteria for a highly maneouverable fish (Keast & Webb 1966). The mouth is small and dorso-terminal. The protrusible premaxilla and extensible mandible form a scoop-like structure (Keast & Webb 1966). Keast & Webb (1966) suggest that golden shiners exploit the surface waters for their food as a result of their mouths being dorso-terminal. However Paszkowski (1984) did not find the golden shiner to be particularly effective as a surface water feeder.

Plankton constitutes the bulk of a golden shiner's diet (Hall et al 1979). Keast & Webb (1966) classified golden shiners as specialized planktivores, since zooplankton constitutes 20-90% of their total gut contents, flying insects 20%, and chironomid pupae between 10 - 30%. Occasionally they have been found to utilize benthic prey as their major food source (Gascon & Leggett 1977). There has been limited research on the feeding behaviour of shiners.

Shiners capture prey by continuously swimming and, when a prey item is located, they tilt their body upwards towards the prey and inhale it into the buccal cavity, after which they resume swimming (Hall et al. 1979, personal observation). They can store up to 50 prey in their buccal cavity before ingestion (Hall et al. 1979). During the day, they congregate in schools and forage very little. Golden shiners feed primarily at dusk and dawn, at which time their schools dissipate (Hall et al. 1979).

MATERIALS AND METHODS

Study Site

The Choinière reservoir was chosen as the study site for two reasons. Chabot (1983) investigated the diet of yellow perch in Choinière and found a co-dominant fish species which might influence the diet of perch. The unknown species was the golden shiner. The other reason was our in depth knowledge of the biotic and abiotic characteristics of Choinière accumulated over the last five years by researchers of our laboratory. In 1977 two dams were constructed, altering the North Yamaska river. The Choinière reservoir resulted, with a surface area of 4.4 km2, an average depth of 4-5 meters and a maximum depth of 15 meters. It is situated 65 kilometers east of Montreal near Granby, Québec. (42' 24"N, 72' 33"W) The Yamaska river and the Choinière reservoir serves as the drainage basin for approximately 136.72 km2 (Lemoyne 1979). Some of the physical and chemical characteristics can be found in Appendix A.

Most of the drainage basin is farmland, resulting in high nutrient loading for the lake. Sewage from the municipality of Waterloo also drains into the lake (Belanger 1981). This nutrient rich water is exploited by a wide variety of algal populations, causing the turbidity to be high (Appendix A). Bacillariophyceae, and Cryptophyceae are the dominant algae in spring; by summer the Cyanophyceae predominate, followed by Pyrophyceae in the fall (Belanger 1981). Macrophytes contribute little to the total autotrophic community.

The zooplankton community varies through the seasons. Table 1 lists the species found, along with their relative abundances through the summer months derived from past and ongoing zooplankton studies. The species were identified using keys in Edmondson (1959) and Pennak (1978).

Table 1 PLANKTON SPECIES OF CHOINIÈRE RESERVOIR

PLANKTON SPECIES	Relative Abundance
CLADOCERA	
LEPTODORIDAE	
Leptodora kindtii (Focke)	+
SIDIDAE	
Diaphanosoma leuchtenbergianum (Fischer)	++++
DAPHIDAE	
Daphnia galeata mendotae (Birge)	++
Daphnia retrocurva (Forbes)	+++
Ceriodaphnia reticulata (Jurine)	+
BOSMINIDAE	
Bosmina longirostris (Muller)	+++
CHYDORIDAE	
Eurycercus lamellatus (Muller)	+
Alona costata (Sars)	+
COPEDODA	
TEMORIDAE	
Epischura lacustris (Forbes)	++
DIAPTOMIDAE	
Diaptomus minutus (Lilljeborg)	++++
Diaptomus birgei (Marsh)	++
CYCLOPIDAE	
Mesocyclops edax (Fischer)	++++
Cyclops vernalis (Norman & Scott)	+++

Legend

++++	abundant throughout summer season
+++	abundant during specific periods but found throughout summer
++	abundant during specific period and rare other periods
+	rare throughout summer season

Table 2 FISH SPECIES OF THE CHOINIÈRE RESERVOIR

Plankton Feeders
- _Perca flavescens_ (Mitchell)* Yellow perch
- _Notemigonus crysoleucas_ (Mitchell)* Golden shiner
- _Lepomis gibbosus_ (Linnaeus) Bluegill sunfish
- _Notropis atherinoides_ (Rafinesque) Emerald shiner

Piscivores
- _Esox niger_ (Lesueur)* Chain pickerel
- _Esox lucius_ (Linnaeus) Northern pike
- _Micropterus dolomieui_ (Lacepede) Smallmouth bass
- _Perca flavescens_ (Mitchell)* Yellow perch

Bottom Feeder
- _Catostomus commersoni_ (Lacepede)* White sucker
- _Ictalurus nebulosus_ (Lesueur)* Brown bullhead

* signifies abundant species

Lists of the fish species inhabiting Choinière can be found in table 2. These species were identified using Scott and Crossman (1979).

Further information concerning Lac Choinière can be found in Chabot (1983) and Raess (1982).

Field Sampling Methods

Monofilament gill nets (2m x 20m) with mesh sizes ranging between 1.5cm and 2.5cm were used to acquire representative samples of yellow perch and golden shiners. Three nets were positioned, perpendicular to the shore in the pelagic zone, so as to sample throughout the 6 meter water column. The first net sampled the upper 2 meters, the second the mid 2-4 meters and the third the bottom 4-6 meters. The nets were checked and reset every four hours over a 24 hour period. Sampling in this manner was carried out during the following dates: July 22-23, Aug. 22-23, September 28-29, 1983, and June 22-23, 1984.

The procedure for each four-hour sampling period involved measuring all yellow perch and golden shiners caught at each depth. Up to ten yellow perch with a fork length less than 13.0cm and ten shiners of all sizes were sacrificed by cervical dislocation and immediately preserved in a formalydehyde solution. The nets were then reset immediately.

Perch less than 13.0cm, and all shiners were preserved as results from past researchers (Chabot 1983, Hall et al. 1979) and preliminary experiments in Choinière suggest that perch less than 13.0cm and shiners of all ages feed primarily on zooplankton. It is these fish which are the co-dominant planktivores of the lake. Perch larger than 13.0cm feed on large macroinvertebrates and small fish which are not used by golden shiners.

The available zooplankton was then sampled at each of the three depths using a 30 liter Patalas Shindler trap usually within 10 meters of where the nets were set to capture fish samples providing estimates of zooplankton densities in the immediate vicinity of the fish samples. At no time was the plankton sampled more than 100 meters from the nets. For each four hour period three 30 liter samples were taken, and samples were immediately preserved with 10% formaldehyde. Water temperatures and oxygen concentrations were also measured using a YSI oxygen and temperature meter at each depth and sampling time.

Treatment of Samples

The preserved fish were brought back to the laboratory for gut analysis. Three fish, when quanities permitted, were arbitrarily selected of each species at each depth and time for gut analysis. The stomach and intestine of each fish were excised and the contents placed in a slide chamber for the enumeration and measuring of prey. The total alimentary canal was analysed because shiners have no true stomachs (Bond 1979). Analyzed guts of yellow perch included the true stomach as well as the intestine. A Wild M40 inverted microscope equipped with an Hitachi video camera and monitor was used to view and facilitate the measurement, by measuring the image, of plankton found in gut and water samples.

Each prey item was identified, counted and measured. The presence or absence of sediment was noted. The prey items were classified into the following categories.

Macroinvertebrates
- Chironomid larvae
- Adult Diptera

Microinvertebrates
- *Diaphanosoma*
- *Daphnia*
- *Leptodora*
- *Bosmina*
- Calanoid Copepods
- Cyclopoid Copepods

The available plankton were classified, enumerated and measured in a similar manner.

The length of ingested and available prey items were measured directly from the video monitor. These lengths were used in the following formulas taken from Downing (1984) to provide biomass approximations. Weights are expressed as milligrams of dry weight.

Taxon	Formula	Range in mm
Daphnia	$\ln W = 1.4711 + 2.8445 \ln L$	.5 - 2.0
Diaphanosoma	$\ln W = 1.2894 + 3.3030 \ln L$	.4 - 1.20
Bosmina	$\ln W = 2.7116 + 2.5572 \ln L$	.28 - .54
Calanoid	$\ln W = 1.2431 + 2.2634 \ln L$	.30 - 1.85
Cyclopoid	$\ln W = 1.9434 + 3.5990 \ln L$	.40 - 1.20
Leptodora	Table (Cummins et al 1969)	

The total body lengths of Leptodora, Bosmina and Diaphanosoma were measured. Daphnia were measured in the same manner excluding the spine. Metasomal lengths of calanoid copepods were measured. Cyclopoid copepods were measured excluding the furcal rami.

The total body lengths of chironomid larvae were measured and their biomass approximated from estimates of sample length-dry weight relationships established from larvae in Choinière. These length-dry weight relationships were derived from measured chironomid larvae from Choiniere which were dried and later weighed.

Treatment of Data

Electivity indices are a measure of the utilization or selectivity by a predator for a prey type in relation to the availability of the prey type in the environment. I chose to use the Chesson preference index (Manly 1974;

Chesson 1978, 1981) to analyze data. This index is similar to Ivlev's (1961) foraging ratio, E = (Ri-Ni/Ri+Ni), where Ri represents the ingested proportion of prey species and Ni the proportion found in the environment, but modified so the sums of all the ratios for the predator equals one:

Chesson Preference Index (alpha i)

$$= \sum_{j=1}^{m} \frac{R_i/N_i}{R_j/N_j} \qquad i = 1,\ldots m$$

Manly(1974)
Chesson(1978)

The advantage of using the Chesson index is that the index is unaffected by relative abundances of prey, thereby allowing for meaningful between sample comparisons. (Lechowicz 1981).

Preference alpha values were calculated for each prey item. The ingested proportion (Ri) of a prey item equals the proportional occurrence in the total gut contents it represented. The available proportions (Ni) for the prey groups were determined from analysis of Schindler samples. The mean number per liter at those depths where fish were caught were averaged and expressed as a proportion of the available zooplankton. For example at 0330 no fish were caught in the 4-6m gill net. Available proportions for 0330 are only computed using information from Shindler traps taken at 0-2 and 2-4 depths to increase the chance that the available plankton were encountered by the fish in question. It is important to note that, with few exceptions, Chabot and Maly (1986) found zooplankton in Lac Choinière to be uniformly distributed among times of day and depth. The (Ni) and (Ri) values were substituted in the Chesson formulae producing (alpha) values for each prey item found in each fish. Fish with fewer than 50 prey individuals in the gut were not included in analysis since assumably, they were not actively feeding.

Chesson preference alpha values vary between 0 and 1 with 0 indicating avoidance and 1 preference. When alpha equals the inverse of the total number of prey groups the prey is neither preferred nor avoided but preyed upon non selectively. For example in a situation where there are 5 prey groups, an alpha value for a particular prey type which equals the inverse of five (0.20), would suggest that the predator was feeding nonselectively on that prey item. Fish from various depths were grouped, as insufficient numbers of fish were caught at many of the depths, making diet comparisons of fish from different depths difficult. For illustrative purposes the preference indexes were transformed to electivity values. The difference between the two indices is in their range of values Chesson developed the following formula for transformation:

Chesson Electivity Index (E')

$$= \frac{m\alpha_i - 1}{(m-1)\alpha_i + 1}, \quad i = 1 \ldots m$$

Chesson (1981)

M is the number of prey types and alpha is the preference value for that particular prey item. Values of E' range between -1 and +1. Avoidance of a prey species by a predator is suggested when E' values approach -1. When a positive value results the predator was feeding selectively on that prey item. The predator is feeding proportionally to the prey's abundance in the environment if E' values range close to 0.

Every yellow perch and golden shiner of a given time, depth, and month has six electivity values corresponding with the six prey groups. These individual electivities were plotted to show feeding preferences and individual variation of each fish species.

For each fish species, grouped prey electivities were established for each month by taking the mean of all electivities for each prey type for a given month. The same groupings were done with the respective preference alpha values. Any statistical comparisons were made using the corresponding Chesson preference alpha value instead of the E' value on the grouped data. To compare feeding preferences of perch and shiners Mann Whitney U tests were performed to compare alpha values. Schmitt & Coyer (1983) and Chesson (1983) both suggested that alpha values be used for statistical analysis instead of electivity values since the statistical properties of E' are not available. The Kruskal Wallis test was used to establish whether perch and shiners differed significantly in their prey selection over the four months. Comparing all the alpha preference values over the four months, a ranking for each is made. This test compares the totals of the ranks for each month, and determines if there are significant differences among months. To locate where the differences lay, a nonparametric Tukey-type multiple comparison test with unequal sample sizes, was used (Zar 1984). The grouped data provides additional information on trends and differences regarding foraging preferences of perch and shiner populations in Choiniere at four different times through the summer months.

Although the Chesson index provides information regarding the food types preferred by each species of fish, the degree of similarity in their choice of prey is not evident. The degree of similarity in resource used by shiners and perch can be determined from diet overlap indices. Niche overlap indices have been developed to indicate foraging overlap (Horn 1966, Levins 1968, Schoener 1970). Hurlbert (1978) defined diet overlap as follows:

> "It is the degree in which frequency of interspecific encounter is higher or lower than it would be if each species utilized each resource state in proportion to its abundance."

The diet overlap index of Hurlbert (1978) was used to determine the degree perch and shiners overlap in prey use. L values were calculated for each time period of every month. Analysis of the index will show the extent of diet overlap and how it varies over 24 hours and between months suggesting times when competition for food resources are maximal. This revised diet overlap equation differs from other overlap equations for it incorporates available prey.

Diet overlap (L) was calculated for each time period and expressed as a histogram. The degree of overlap is a function of how rare the common food resource is for both species. For example, if a prey type constitutes 90% of the diet of two predators, and it represents only 10% of the available plankton, a high L value results. Both species are intensely feeding on a resource which is rare.

$$L = (A/XY) / (xi\ yi\ /ai)$$

A = total available of all prey types (100%)

X = total amount of all prey consumed by species X (100%)

Y = total amount of all prey consumed by species Y (100%)

xi = mean volume percentage of prey in diet of predatorX

yi = mean volume percentage of prey in diet of species Y

ai = availability of prey expressed as percent volume

The percentage of the total numbers or occurrence is important in characterizing diets, yet it offers little information for measuring overlap. The percentage of total numbers could be used for overlap indices if the prey items are of a similar size, as they result in being a proportional measure of diet. The prey items involved in this study have widely varing sizes, which makes the use of occurrence percentages less reliable than the volume percentages for calculating diet overlap. The ingested prey used for the niche formula is expressed as the proportion of total biomass found in the gut, and similarly for the available prey, as a proportion of the available biomass found in the environment. The average percentage that each food category contributed to the total volume of food in each stomach is represented by xi and yi. The available proportion (ai) is also expressed in these terms. The value of A/XY is basically a constant (.01).

L approaches 0, when no resources are shared between species. Values of 1 indicate that the species are utilizing resources according to abundance. (opportunistic feeding). Overlapping resource use between species is evident when values are greater than 1.

Selectivity and overlap results were both taken into consideration when formulating foraging preferences of the co-habitating species in Lac Choinière.

Additional Methods

If a fish forages over a wide range of habitats, for example the pelagic and littoral zones, it would have at its disposal a greater variety of prey from which to choose as compared to a fish which only feeds in one of the zones. The ranges of foraging for perch and shiners were determined by the percent of fish which had ingested littoral and pelagic prey. Littoral prey included aquatic insects, littoral cladocerans such as Alona costata , and chironomid larvae. Chironomid larvae were not considered a pelagic prey item as they were never present in any water samples taken in the pelagic areas. The Friedman X test was used to test for significant differences in foraging ranges between perch and shiners.

The geographical and spatial overlap of the two predator species was determined. The extent of co-occurrence of yellow perch and golden shiners was assessed by examining files provided by The Fish and Game Ministry in Sherbrooke, Québec of 49 lakes in south western Québec. A correlation for dichotomus nominal scale data was used to determine the degree of association between perch and shiners.

The relative proportion and spatial distribution of perch and shiners in Lac Choinière was determined from the frequency of each in the various gill nets used during the sampling periods. A Chi square analysis was done to indicate if species caught were dependent on depth.

RESULTS

Individual Indices

The cyclopoids, *Mesocyclops edax* and *Cyclops vernalis* both range in size between 0.80mm and 1.8mm (Edmondson 1959). Perch and shiners tend not to utilize these cyclopoids (fig.1a) even when they constitute the bulk of the zooplankton community, as in July when their density was 52.3 per liter, which represented 70% of the total amount of zooplankton (fig. 2). Several golden shiners and perch ate cyclopoids but generally cyclopoids were an avoided food source throughout the summer season. The E' values of figure 1 are based upon numerical densities.

Calanoids represented a substantial portion of the available plankton throughtout the summer months (fig.2). Yellow perch and golden shiners clearly avoid calanoid copepods (Fig. 1b). This prey group is comprised of *Diaptomus minutus* , *Diaptomus birgi* and *Epischura lacustris* , however the latter 2 species represented less than 5% of the prey total items in this group. Perch and shiners differ little in their selectivity of calanoids throughout the sampling periods and months. Golden shiners show little individual variation in their selection of calanoids; perch do, to some extent, particularly in June.

Daphnia galeata mendotae and *Daphnia retrocurva*

Figure 1a-f Patterns of resource use for individual yellow perch and golden shiners illustrated as electivities. Each dot represents the E' value of an individual fish for that prey type. The X axis represents the six sampling times over a 24-hour sampling period.

Fig.**a**

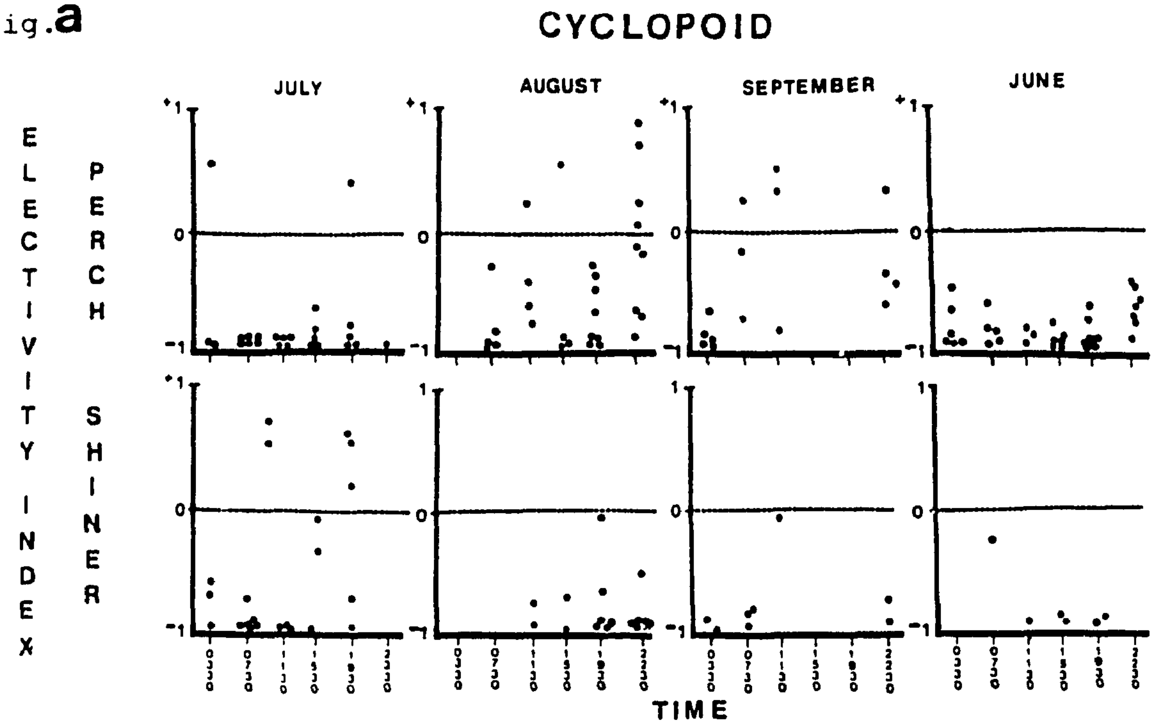

CYCLOPOID
JULY
AUGUST
SEPTEMBER
JUNE
ELECTIVITY INDEX
PERCH
SHINER
+1
0
-1
0330
0730
1130
1530
1930
2330
TIME

Fig. **b**

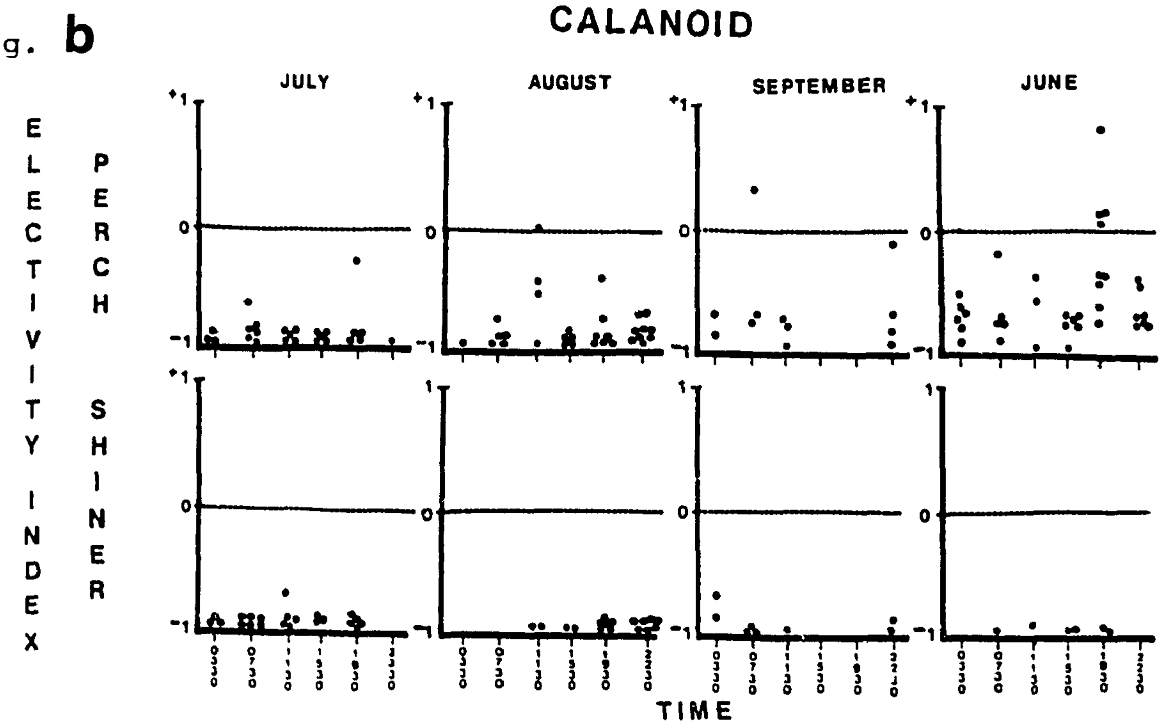

CALANOID
JULY
AUGUST
SEPTEMBER
JUNE
ELECTIVITY INDEX
PERCH
SHINER
+1
0
-1
0330
0730
1130
1530
1930
2330
TIME

Fig. c

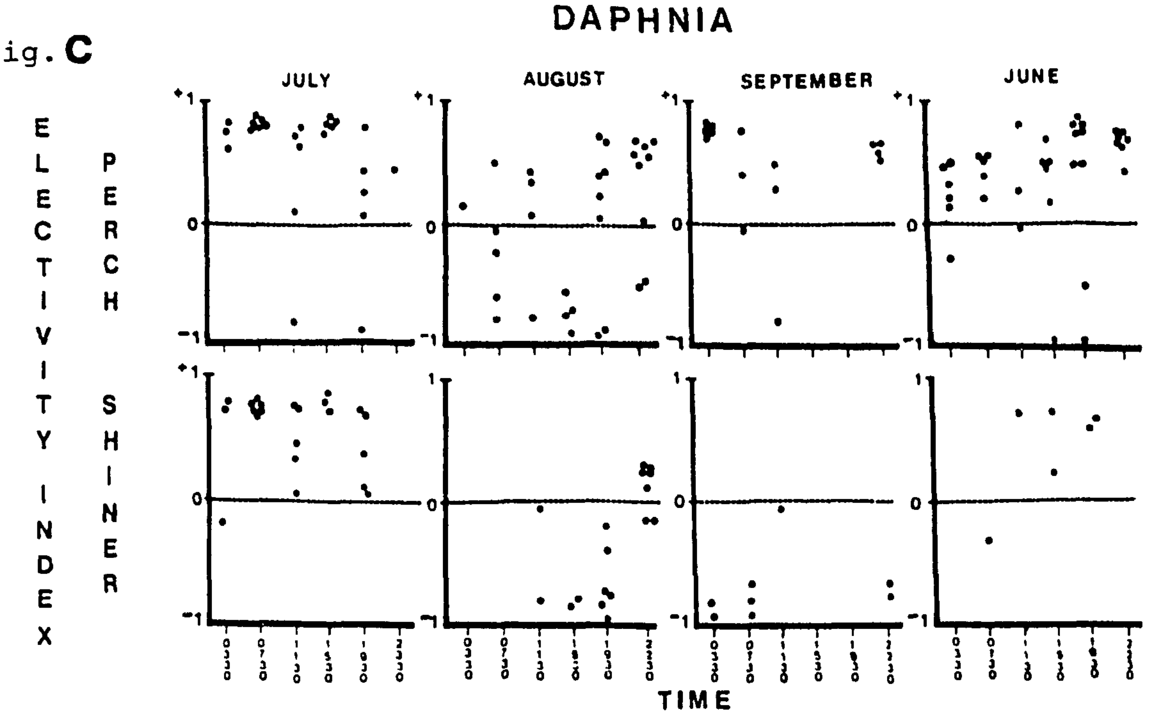

DAPHNIA
JULY
AUGUST
SEPTEMBER
JUNE
ELECTIVITY INDEX
PERCH
SHINER
+1
0
−1
0330
0730
1130
1530
1930
2330
TIME

Fig. d

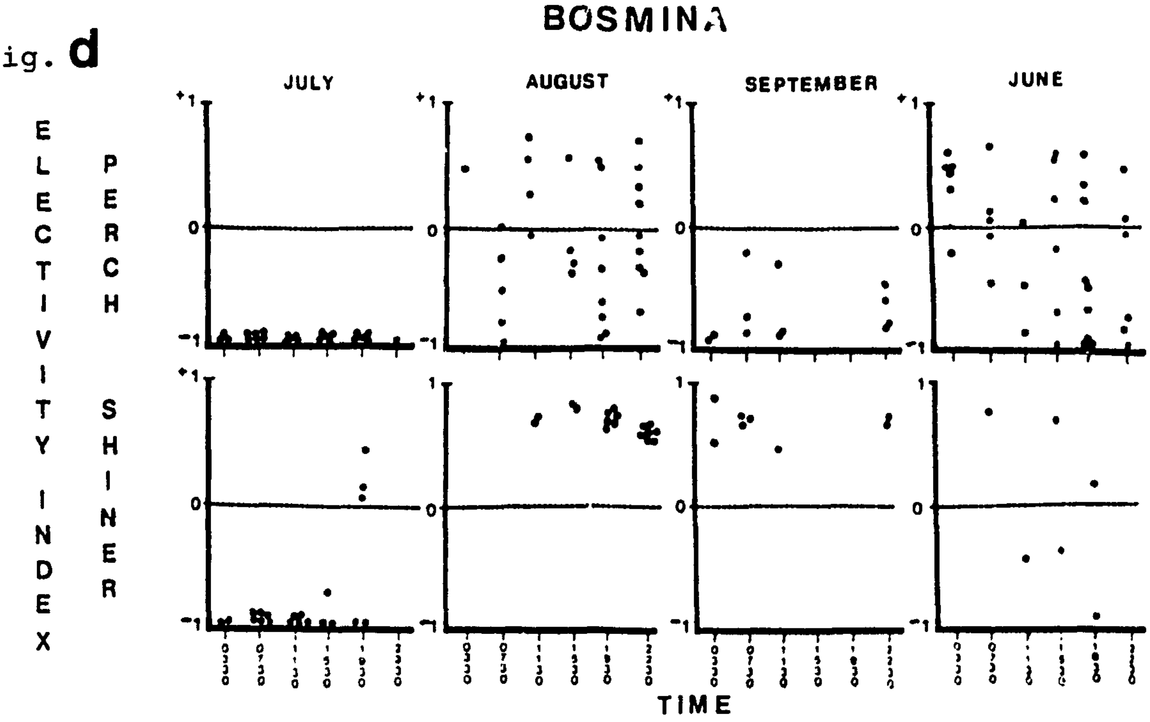
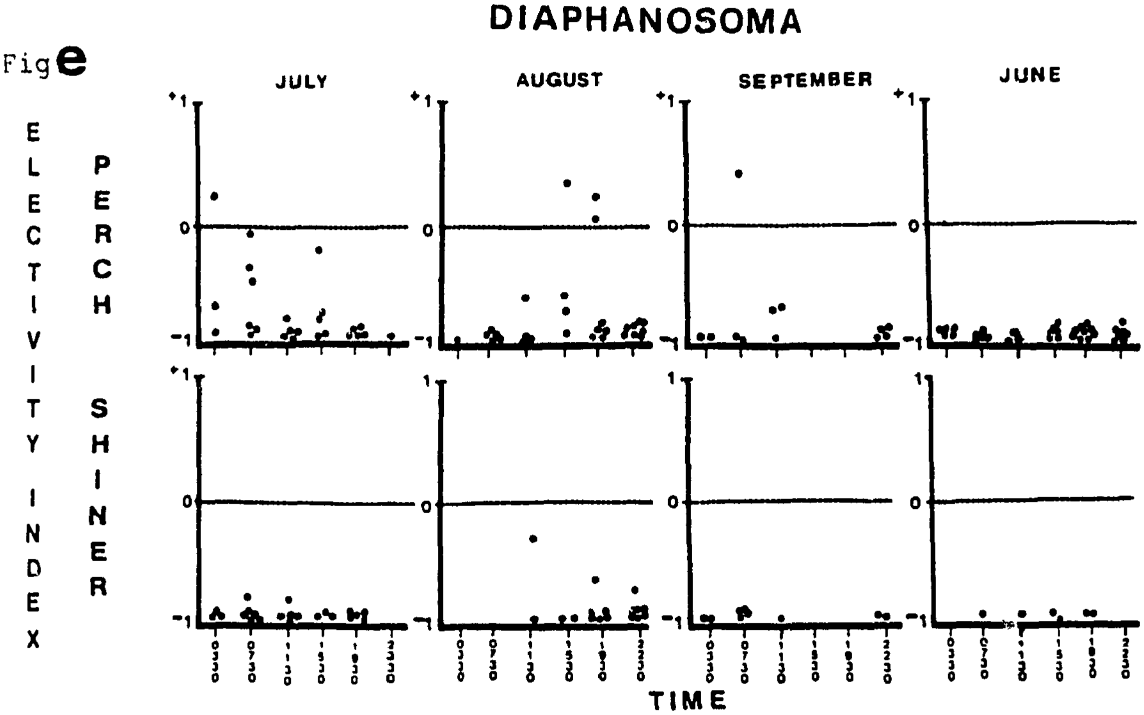
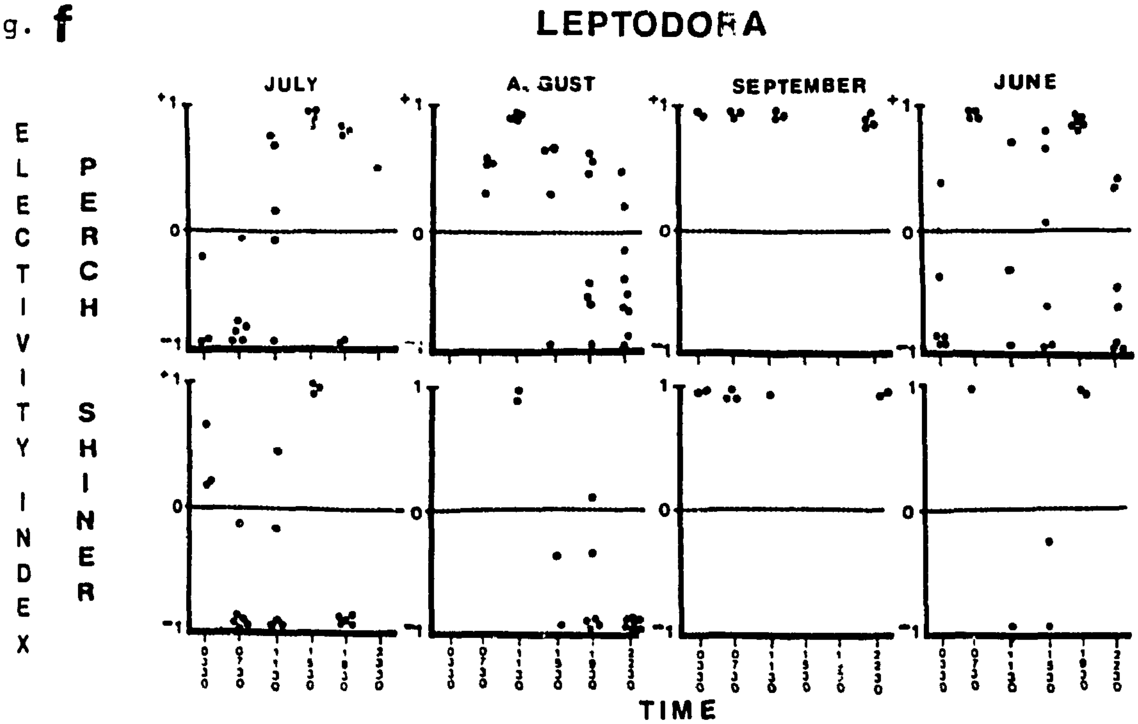

BOSMINA
JULY
AUGUST
SEPTEMBER
JUNE
ELECTIVITY INDEX
PERCH
SHINER
+1
0
−1
0330
0730
1130
1530
1930
2330
TIME

Fig **e**



DIAPHANOSOMA

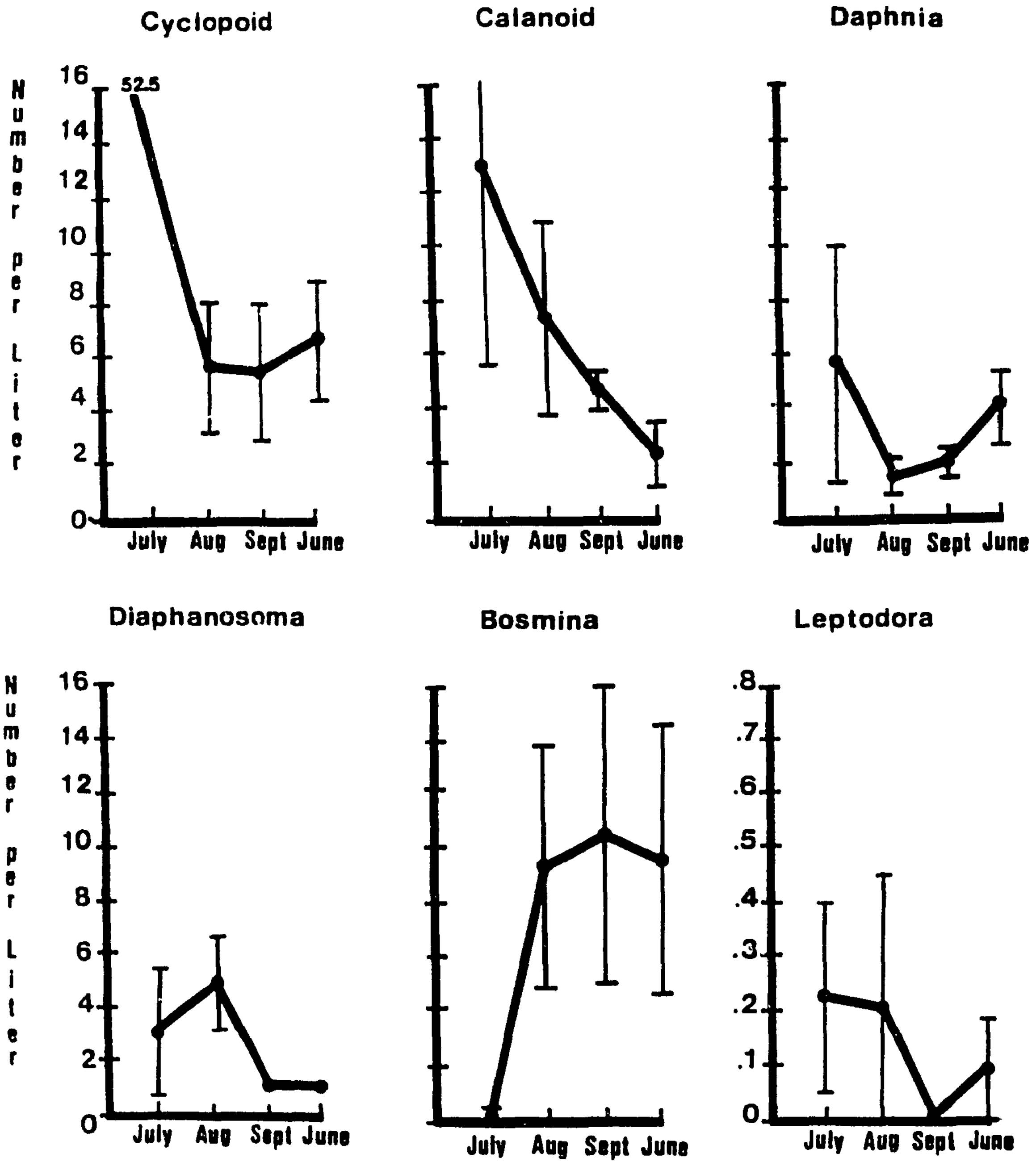
Fig. **f**



LEPTODORA

Figure 2 Density graphs of the available zooplankton in Lac Choinière.

Fig. 2 AVAILABLE ZOOPLANKTON



abundances were grouped to facilitate enumeration of gut contents. Daphnids never had a density greater than 5,8 per liter which constituted no more than 17% of the total zooplankton community (fig. 2), but were a generally preferred food source throughout the summer months. In July when the total available plankton was at its highest, both perch and shiners actively fed on daphnids, as is evident from their generally high positive electivities (fig. 1c). In August the electivities of shiners towards daphnids ranged between zero and -1, suggesting that they avoided daphnids and used alternate food sources. Perch showed a high degree of variation among times of day and among individuals. Daphnids remained a principal food source for a number of individuals. In September perch were positively selecting *Daphnia*, whereas shiners were avoiding them. Both perch and shiners were positively selecting *Daphnia* in the month of June.

Bosmina longirostris were very scarce in July when cyclopoids, *Daphnia*, and calanoids were at their maximum density (fig. 2). Perch and shiners varied slightly in their avoidance of *Bosmina* (fig. 1d). In the remaining months *Bosmina* numerically represented the most abundant zooplankton, having densities between 9.3 and 10.4 per liter or between 28 and 38% of the total zooplankton in Choinière (fig. 2). Reaction to this food item differed between fish species. Perch in August had a high degree of variability with the mean E' being near 0, suggesting no preference or avoidance. On the other hand, shiners showed a strong preference for Bosmina with little variation as indicated by the high positive electivities. In September, perch and shiners differed in their use of Bosmina . Perch avoided Bosmina , having high negative electivities and shiners preferred Bosmina , as illustrated by their high positive electivities (fig. 1d). Both perch and shiners exhibited a high level of individual variation in June. Some fish guts contained Bosmina exclusively while others contained none.

Diaphanosoma leuchtenbergianum reached their maximum numbers in August, where their density was 5.0 per liter, which represented 16% of the total zooplankton community (fig. 2). Diaphanosoma was rarely preferred by either yellow perch or golden shiners (fig. 1e). There was slightly more individual variation among perch than among golden shiners.

Leptodora kinitti represented a small fraction of the total zooplankton community (fig. 2). They may be patchy in their distribution for, in September, the sampling methods failed to capture a single Leptodora but there must have been some present as substantial numbers were found in the stomachs of fish. The degree of predation by individual perch and shiners varies as the variable electivity values suggest (fig. 1f). In September electivity values are equal to 1 because the Ni is zero producing E' values of 1.

These selectivity results suggest that certain prey species are selected more often than others and that there can be a high degree of individual variation in prey selection by both predatory species.

Grouped Indices

The monthly mean alpha preference values of perch and shiners were compared statistically to show similarities and or differences between their feeding preferences (table 3).

Month versus month

Golden shiners avoided cyclopoids throughout the four summer months (fig.3), with electivities ranging between -0.49 in July and -0.85 in June (table 3). The alpha values did not differ significantly (table 4) over the four months, suggesting that golden shiners consistently avoid cyclopoids. Alpha values for perch during the four months were also negative, with significant differences (P<.02) existing among all four months. The reason that July and June electivities looked similar but differed significantly was that two individual fish in July were responsible for the higher electivity value. If these two outlyers are removed from averaging, the electivity becomes -0.9635 instead of -0.8386 (table 3).

Calanoids were avoided by perch throught all four

Table 3 Average Electivity Values

		July	August	Sept.	June
Cyclopoid	Y	-.8386 (25)	-.3855 (30)	-.2956 (12)	-.8242 (36)
	G	-.4924 (22)	-.8244 (17)	-.7597 (8)	-.8455 (6)
Daphnia	Y	+.5604 (25)	-.0334 (30)	+.5756 (12)	+.4208 (36)
	G	+.5952 (22)	-.3261 (17)	-.5462 (8)	+.4867 (6)
Bosmina	Y	-.9961 (25)	-.1071 (30)	-.7245 (12)	-.1478 (36)
	G	-.7685 (22)	+.7540 (17)	+.7316 (8)	-.0322 (6)
Diaphanosoma	Y	-.7960 (25)	-.8321 (30)	-.6677 (12)	-.9945 (36)
	G	-.9970 (22)	-.9261 (17)	-.1.00 (8)	-.1.00 (6)
Calanoid	Y	-.9480 (25)	-.8521 (30)	-.6677 (12)	-.5400 (36)
	G	-.9512 (22)	-.9770 (17)	-.9215 (8)	-.9855 (6)
Leptodora	Y	-.0196 (25)	+.1453 (30)	+ 1.00* (12)	+.1578 (36)
	G	-.3948 (22)	-.6548 (17)	+ 1.00* (8)	+.0114 (6)

Y Yellow Perch
G Golden Shiner
* unrealistic
() number

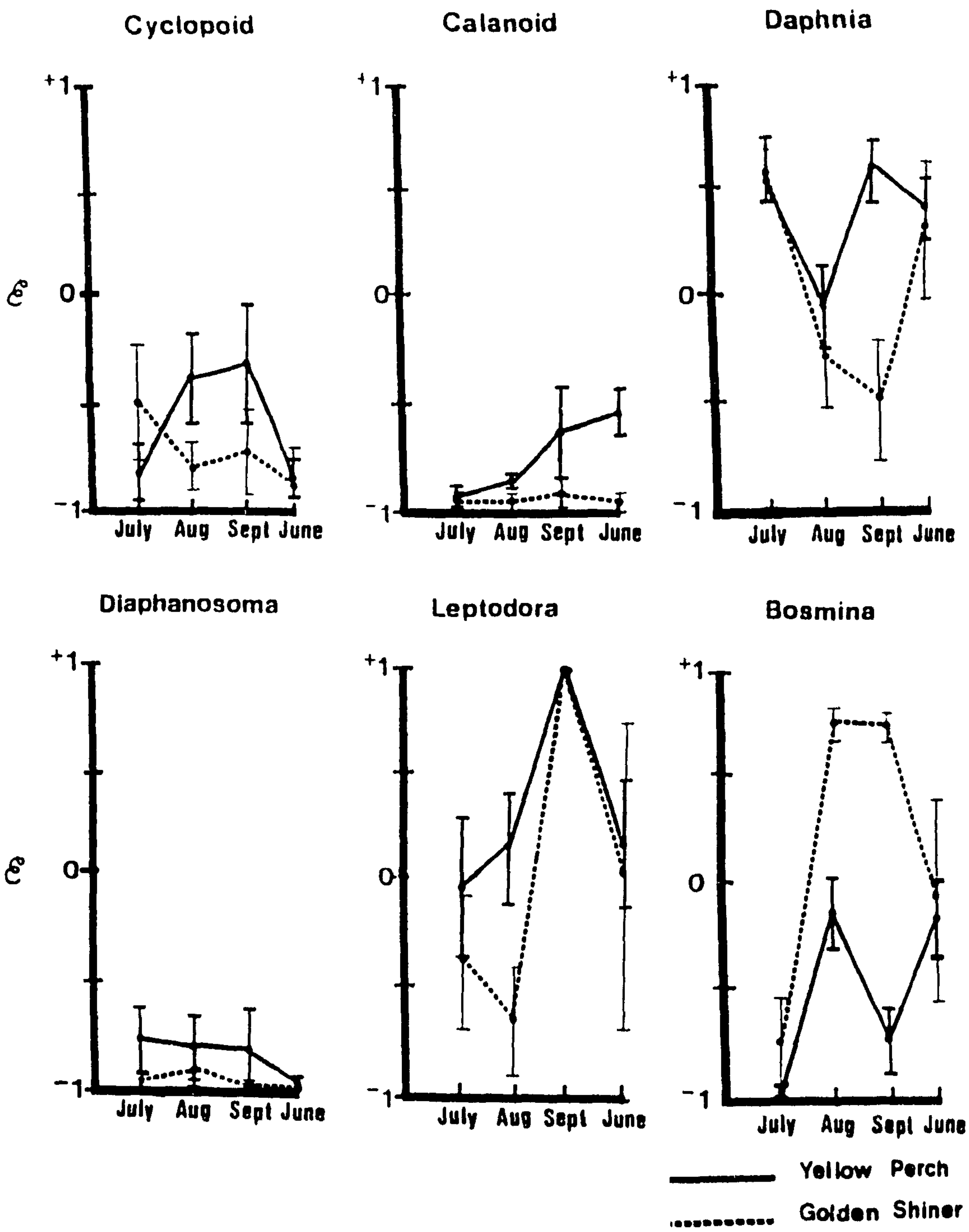
Table 4 Probabilities of differences existing between months in the selection by Yellow Perch and Golden Shiners for the various types of zooplankton using Kruskal Wallis test

Species	H Values	Probability	Where Differences Lie
		Yellow Perch	
Cyclopoid	28.83	$P < .001$ *	differences lie between all months
Daphnia	15.54	$.001 < P < .005$	differences lie between all months except July and September
Bosmina	43.14	$P < .001$	only July differs from all other months
Diaphanosoma	5.02	$P > .05$	NS
Calanoid	31.61	$P < .001$	each month is significantly different
Leptodora	18.68	$P < .001$	differences lie between all months except between August and July
		Golden Shiners	
Cyclopoid	1.80	$P > .05$	NS
Daphnia	27.54	$P < .001$	no significant differences between June and July and August and September. All others differ significantly.
Bosmina	39.72	$P < .001$	July-August, July-September only have significant differences
Diaphanosoma	3.65	$P > .05$	NS
Calanoid	4.43	$P > .05$	NS
Leptodora	15.35	$.001 < P < .005$	September-July, September-August only have significant differences

NS - no significant differences
* - Tukey non parametric multiple comparison test was used to locate differences ($\alpha < .05$)

Figure 3 Graphs of the monthly electivities of yellow perch and golden shiners. The electivities value are on the Y axis.

Fig. 3 MEAN MONTHLY ELECTIVITIES



months but the alpha values differed significantly among months (table 4). Selection by golden shiners for calanoids remained negative with no significant differences between months.

Daphnia exhibited similar density fluctuations to cyclopoids and calanoids (fig. 2). High densities in July and June corresponded with positive monthly electivities for golden shiners (fig. 3). These alpha values differed significantly from alpha values in August and September, suggesting that Daphnia were displaced as the major source of food. Daphnia was an important food source for yellow perch in all months. Daphnia were fed upon non selectively in August; in July and September they were positively selected. No significant differences between the Chesson preference indexes (alpha) of July and September were found but differences were found when all other months were compared (table 4).

Except for July, Bosmina was the most abundant prey item in Lac Choinière (fig. 2). Perch negatively selected for Bosmina ; this pattern did not change over the sampling periods. Significant differences in the Chesson preference alpha values were only found when July values were compared with these of other months. Perch did not differ in their selection of Bosmina in the remaining three months. Golden shiners significantly differed in their selection for Bosmina throughout the four months. In August and September shiners had high electivity values but in July and June they were more negative, particularly in July. The alpha preference values for July differed significantly from those in September and August. The use of Bosmina as a food source was much lower in July and June than in August and September.

Diaphanosoma remained an avoided prey item, with no statistical differences in alpha among months for both fish species. The mean E' for perch, as illustrated in fig. 3, over the four month period was -0.82 and for shiners it was -0.98 (table 3).

Leptodora kinitti was scarce and variable in distribution. There were significant differences among mean monthly perch preference alpha values when comparisons were made with September values (table 4). The September value is misleading as I failed to capture any Leptodora in the water column. Such a situation leads to exaggerated alpha and electivity values of 1. Electivity values(E') for the other three months suggest that perch slightly select for Leptodora as the average E' was .1075. Golden shiners did not differ significantly in their selection of Leptodora when the month of September was excluded. The E' value for the three months averaged -.3460 (table 3).

Yellow perch versus golden shiner

In July the only food source which was preyed upon differently by the two predators was the cyclopoids

Table 5 Probabilities of differences existing between Yellow Perch and Golden Shiners in their selection of prey using the Mann Whitney U tests

	July			August		
	U_1	U_2	P	U_1	U_2	P
Cyclopoid	400	149.5	*$P < .02$	166	344	$.05 < P < .10$
Daphnia	264	286	$P > .10$	166	344	$.05 < P < .10$
Bosmina	338	212	$P > .1$	488	22	*$P < .001$
Diaphanosoma	130.5	419.5	$.05 < P < .10$	213	297	$.05 < P < .10$
Calanoid	352	198	$P > .10$	168	342	$.05 < P < .10$
Leptodora	193	357	$P > .10$	131	379	*$.001 < P < .01$
	N_1 25			N_1 25		
	N_2 22			N_2 22		

*Meets the 95% confidence level

Table 5 (cont'd)

	September			June		
	U_1	U_2	P	U_1	U_2	P
Cyclopoid	16	80	$*.01 < P < .02$	94.5	121.5	$P > .20$
Daphnia	3	93	$*P < .001$	137	79	$P > .20$
Bosmina	96	0	$*P < .001$	121	95	$P > .20$
Diaphanosoma	36	60	$P > .20$	93	123	$P > .20$
Calanoid	18.5	77.5	$*.02 < P < .05$	9	207	$*P < .001$
Leptodora	131	379	$P > .20$	108	108	$P > .20$
	N_1 12 N_2 8			N_1 36 N_2 6		

*Meets the 95% confidence level

(table 5). Both fish species had few cyclopoids in their guts. Golden shiners had a mean E' value of -0.45 while perch E' values were -0.80 suggesting that golden shiners avoid cyclopoids to a lesser degree (table 3). This point is evident in figure 3 which shows the mean monthly E' value for shiners to be higher than for perch in July. Both primarily fed on Daphnia , with cyclopoids and Leptodora representing a small portion of their diets.

In August, Bosmina and Leptodora are utilized in different ways by perch and shiners. Shiners showed a strong preference for Bosmina (E'=+.75) while perch were non-selective (E'= -.10) in their choice of Bosmina as a food source. Leptodora represented a substantial portion of the diet of perch yet little of the golden shiners'. The diet of shiners consisted almost exclusively of Bosmina , perch did not feed specifically on any one food item but Leptodora and Daphnia were the most preyed upon items. Statistical comparisons between preference alpha values of perch and shiners showed significant differences for both prey types (table 5).

Except for the case of Leptodora and Diaphanosoma in September, perch and shiners differed significantly in their selection of prey. The primary difference lies in their selection of Daphnia and Bosmina : perch preferred Daphnia and shiners preferred Bosmina .

In June few significant differences were found in the feeding preferences of perch and shiners. The only difference was in the degree of negative selectivity of calanoids, particularly by shiners. Daphnia constituted the bulk of the diet for both fish in this month, but some Leptodora and Bosmina were also eaten.

Diet Overlap

In July the high diet overlap (L) values (fig. 4), suggest that perch and shiners were both utilizing the rarer food items. These high values were found in four of the five time periods where perch and shiners were found. In August and June the L were close to 1. The two species were sharing the abundant food items and avoiding the rarer ones. September L values suggest that perch and shiners were not sharing the same resources since L values close to 0 suggest that interspecific encounter as a result of the pursuit of prey is rare, as the fish are feeding on different food items.

Bar graphs (figs. 5+6) were constructed from available and ingested plankton data to determine the prey types which were involved in reducing or enhancing diet overlap.

Daphnia represented a small proportion of the available plankton biomass yet a substantial proportion of the diet of perch and shiners, resulting in high L values for July. In August Bosmina displaced Daphnia as the shiners' most important food source, comprising 80% of

Figure 4 Histogram of diet overlap between yellow perch and golden shiners

Fig. 4 **DIET OVERLAP**

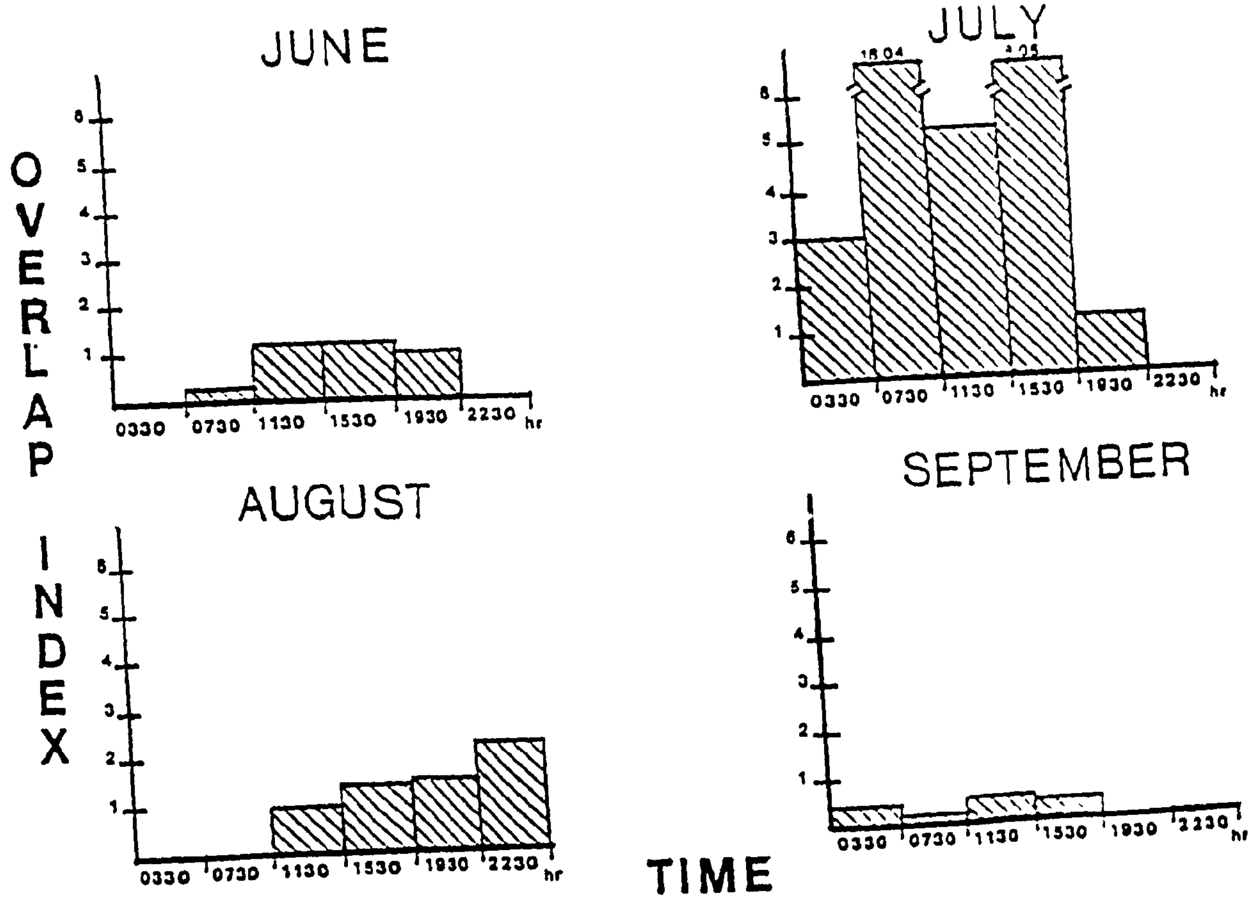


Figure 5 Occurrence bar graphs of analyzed zooplankton available and in the guts of yellow perch and golden shiners

Fig. 5 Frequency Histograms of Analyzed Zooplankton

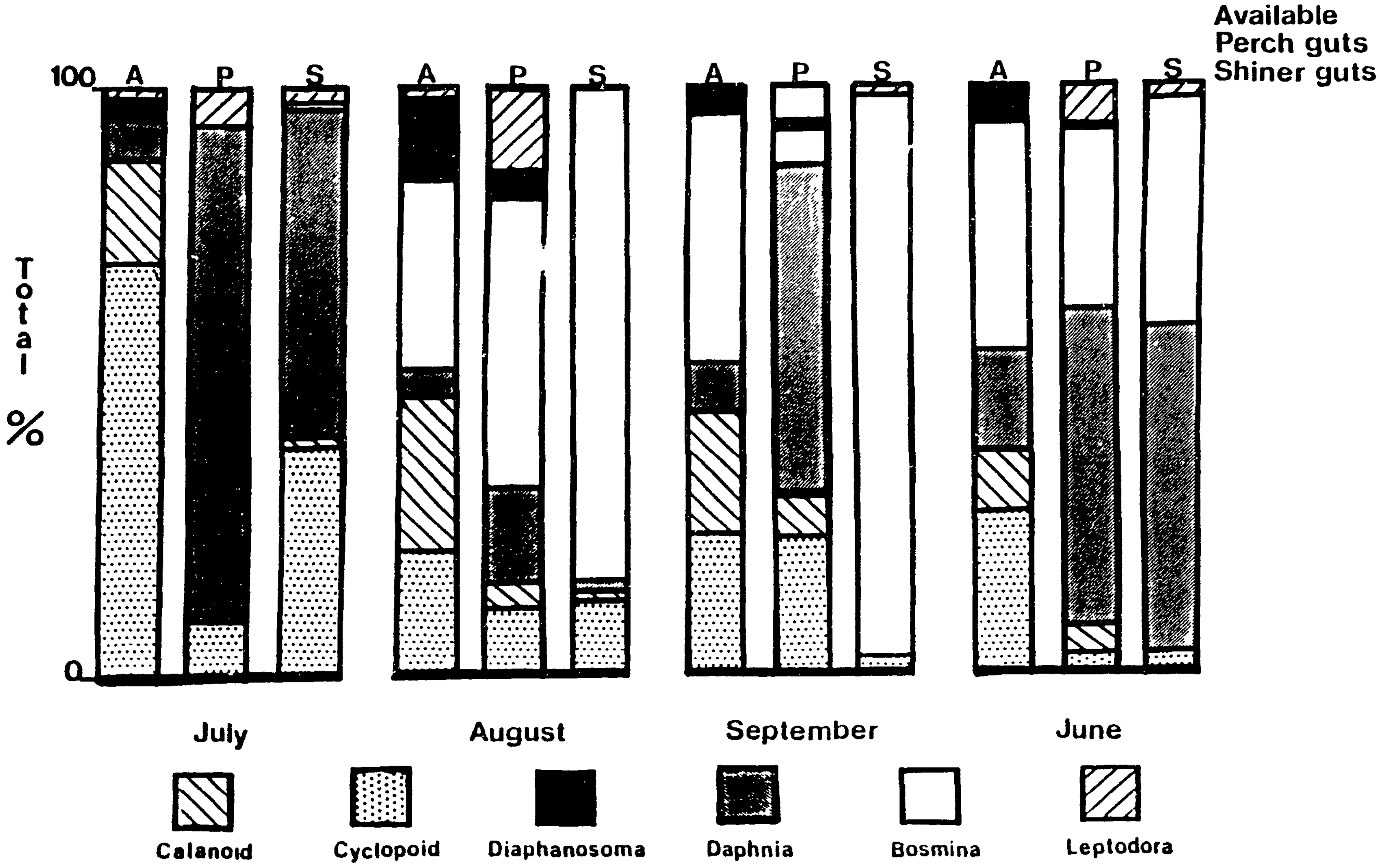
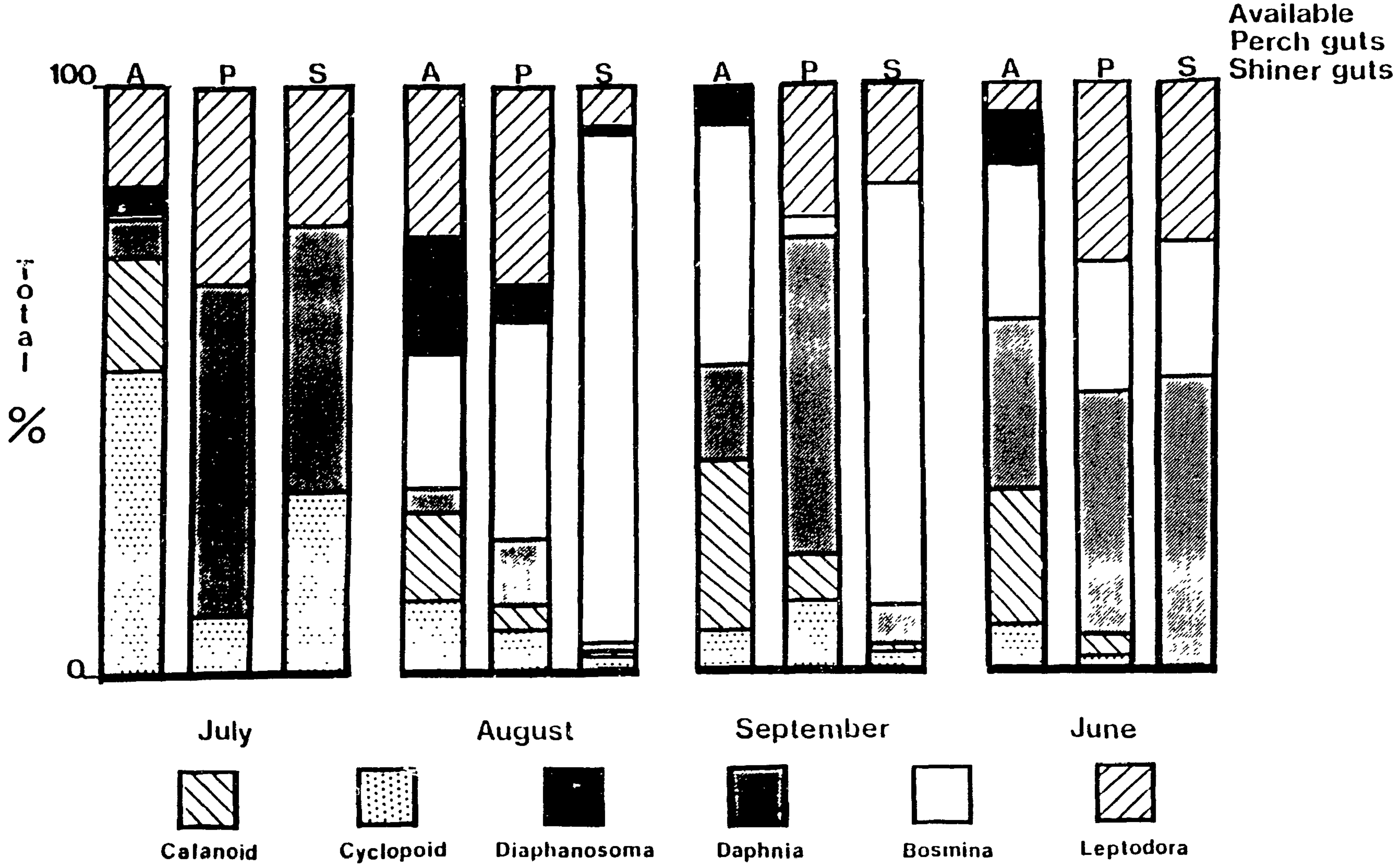


Figure 6 Biomass bar graphs of analyzed zooplankton available and in the guts of yellow perch and golden shiner

Fig. 6 Biomass Histograms of Analyzed Zooplankton



their total diet. Perch were exploiting Bosmina to a lesser degree, and feeding on an array of food types with none constituting more than 20% of the total diet. Such feeding strategies accounted for L values of 1 indicating that the two predators were not converging on any particular prey item.

In September perch fed heavily on Daphnia , which represented 65% of their diet yet only 10% of the available plankton biomass. Golden shiners did not change their diet between August and September. Little sharing of resources occurred, thus L values were below 1. The bar graphs for June suggest that perch and shiners foraged on similar items in the same proportion as they occured in the environment. Comparing biomass bar graphs (fig. 6) with the numbers bar graphs (fig. 5) leads to the same conclusions about the foraging behavior of the two species, that Leptodora is of greater importance in the diet of perch and shiners when biomass is considered (figs. 5+6).

Using the electivity (E') data (table 3), a ranking of each prey species could be made. Table 6 compares the feeding preference rank and the body length order of available zooplankton attained from appendix B. A prey rank of 1 is for the most preferred item and 6 the least. In such cases where feeding electivities for two prey types differed by less than 0.1, they were said to have been preyed upon equally and half values were assigned,

Table 6 Feeding preference versus body length order of prey items

July	Bosmina	Cyclopoid	Calanoid	Daphnia	Diaphanosoma	Leptodora
YP	5 1/2	3 1/2	5 1/2	1	3 1/2	2
GS	4	2	5 1/2	1	5 1/2	3
August	Bosmina	Cyclopoid	Calanoid	Daphnia	Diaphanosoma	Leptodora
YP	3	4	6	2	5	1
GS	1	4	5 1/2	2	5 1/2	3
Sept.	Bosmina	Cyclopoid	Calanoid	Daphnia	Diaphanosoma	Leptodora
YP	4 1/2	3	4 1/2	1 1/2	6	1 1/2
GS	1	4 1/2	4 1/2	3	6	2
June	Cyclopoid	Bosmina	Daphnia	Calanoid	Diaphanosoma	Leptodora
YP	5	3	1	4	6	2
GS	4	2 1/2	1	5 1/2	5 1/2	2 1/2

Smallest body length ——→ Largest body length
(determined from Appendix E)

YP Yellow Perch
GS Golden Shiner

and in the case of three items, the three rankings were added and divided by three. The order of prey according to size, remained constant through July, August and September, with *Bosmina* being the smallest and *Leptodora* the largest. For both fish species, *Leptodora* was always highly preferred. Even though *Diaphanosoma* ranks as the second largest prey item it ranks low in prey choice. This trend was found in all four months.

In three of the four months *Daphnia* was the third largest prey and was a highly preferred prey. Calanoids contributed little to the food of perch and shiners. Cyclopoids, the second smallest prey, were generally eaten by perch and golden shiners, except in July when their density was extremely high. The smallest prey was *Bosmina* , which golden shiners chose as their primary food in August and September.

Alternate Food Sources

Although zooplankton supplied the bulk of the food material in the digestive tract of yellow perch and golden shiners examined, other foodstuffs were found in both fish species. Alternate food sources included adult diptera, chironomid larvae and sediment, all of which are associated with feeding in littoral and benthic habitats.

Both species are capable of utilizing chironomid larvae as a food source, but yellow perch tended to exploit them to a greater degree than golden shiners throughout the sampling period (table 7).

Flying insects, although found at times in a substantial portion of yellow perch and golden shiner guts (table 7), constituted little of the total diet. When found there was rarely more than one adult dipteran found in any single fish of either species although one golden shiner had 19 in its gut. The flying insects consumed belonged to the dipteran family Chironomidae. The adults can range in size between 1 and 13mm. Their small size and scarcity in the diet suggests that they play a minor role in the nutrition of perch and golden shiners in Lac Choiniere.

Table (7) shows that a substantially higher percentage of golden shiners contained sediment than did yellow perch through the four months. Perch show a higher affinity for chironomid larvae than shiners through the same four months.

Table 7 SUPPLEMENTAL FOOD SOURCES

CHIRONOMID LARVAE

	JULY	AUGUST	SEPT.	JUNE
PERCH	4.2	6.0	6.9	0.9
SHINER	0.0	8.8	0.5	0.0

Expressed as a percentage
of the total biomass chironomid
larvae represent

ADULT DIPTERA

	JULY	AUGUST	SEPT	JUNE
PERCH	10.3	6.9	24.7	0.0
SHINER	31.2	7.4	9.4	0.0

Percentage of analyzed
fish containing adult
diptera

SEDIMENT

	JULY	AUGUST	SEPT.	JUNE
PERCH	1.7	2.0	5.0	0.0
SHINER	26.7	18.4	11.5	27.0

Percentage of analyzed
fish containing sediment

The fish samples were collected in the pelagic zone. Fish containing littoral prey such as chironomid larvae, adult diptera and littoral plankton as well as pelagic plankton must have foraged in two different habitats. Comparisons were made between the percentage of perch and shiners having both littoral and pelagic prey types in their guts (table 8). Perch foraged over both littoral and pelagic habitats to a significantly greater extent than shiners over the four months.

Table 8 Comparing the Percentage of Yellow Perch and Golden Shiners Containing both Pelagic and Littoral Prey

	June	July	August	September
Yellow Perch	44.2% (43)	32.1% (28)	48.9% (45)	15.8% (19)
Golden Shiner	33.0% (9)	24.0% (25)	8.3% (24)	0% (8)

$X^2 = 22.0$

$P < .001$

( ) number of fish analyzed

$\overset{o}{o\;o}$ percent Yellow Perch containing both Littoral and Pelagic Prey is greater than for Golden Shiners over the four month period

Geographical and Spatial Distribution of the Two Predators

A 2x2 contingency table (table 9) was constructed from information from appendix B to determine the degree of association between perch and shiners. The test produces a Yule coefficient of association expressed as a correlation coefficient (rn). A value of +1 indicates the two species are found exclusively together. A -1 value means that they are never found co-existing. The rn value of 0.1837 indicates that there was no significant positive or negative association. Perch were not exclusively inhabiting lakes which contain shiners and vice versa. However the data do suggest that perch and shiners are commonly found together since they co-occur in 55 percent of all lakes studied (appendix B).

Yellow perch and golden shiners are spatially distributed throughout the water column in Lac Choinière (table 10). The Chi test indicates that the species were caught independently of depth. There were no significant differences in depth distribution for each species.

Table 9 2 x 2 Contingency table correlating Occurrence patterns

		YELLOW PERCH		
		Present	Absent	Total
GOLDEN SHINERS	Present	27	1	28
	Absent	19	2	21
	Total	46	3	49

rn = .1837

Table 10 Spatial Distribution of Fish Caught

	Depth Zone Netted (meters)			
	0-2	2-4	4-6	Total
Yellow Perch	326	323	106	755
Golden Shiners	167	134	47	348

$$X^2 = 0.529$$

$$X^2_{0.05,\,1} = 3.841$$

$$0.500 > P > 0.25$$

Therefore, do not reject the null hypothesis

Table 11 Frequency of Perch and Shiners Found in Gill Nets

Number of Nets		
total set	90	
without fish	32	
subtotal	58	
with perch & shiners	37	(62.7%)
perch	19	(32.2%)
shiners	2	(3.5%)

The occurrence of both species in a single gill net was found in 62.7% of the cases, perch alone 32.2% and in only 3.2% of the nets were shiners by themselves (Table 11).

DISCUSSION

Distribution of Yellow Perch and Golden Shiners

The geographic range of both species was found to overlap in south eastern Québec for 55 percent of all lakes studied contained both species. There was no positive or negative association between the two species. Hall et al. (1979), Keast & Webb (1966) and Gascon & Leggett (1977) are a few researchers who found both species co-existing along with other planktivores in other lakes. Discussions with researchers at the Ontario Ecology and Ethology Colloquium (1985) confirm that both species commonly inhabit the same lakes, and divers have frequently seen both species swimming together. In Lac Choinère both species were found. Neither species was associated with a specific depth (table 10), but generally the greatest yields were from the upper 4 meters as 86 percent of all the fish caught for both species were in the nets occupying the upper four meters These results support literature findings regarding golden shiners (Hall et al. 1979, Keast & Webb 1966). Zaret & Sufferin (1976) also found golden shiners to occupy the upper stratas of lakes, while perch are suggested to have a wide vertical range (Engel 1976). In 62.7 percent of the nets containing fish, representatives of both species were caught substantiating the fact that both species can be found intermingling, hence there is no evidence for severe spatial segregation of the two species in lac Choinière.

Perch were found to forage in both littoral and pelagic habitats more so than shiners which preferred pelagic prey. This contradicts results of Gascon & Leggett (1979) who found shiners to be primarily a littoral species and yellow perch to be a more pelagic species. I failed to show that perch and shiners are either spatially segregated, or partition their resources on the basis of habitat preference.

Prey Selection of the Golden Shiners in Lac Choinière

Although chironomid larvae, adult dipterans and sediment were found in the guts of shiners, zooplankton was their major food source. Chironomid larvae never exceeded 8.8 percent of the total food biomass (table 7). My results substantiate the claims made by Hall et al. (1979), Keast and Webb (1966), and Scott & Crossman (1979) that zooplankton is the major food resource for golden shiners. These studies indicate that *Daphnia* is the principal zooplankton species consumed. Along with daphnids I found *Leptodora* and especially *Bosmina* to be important dietary items (figs.1,5 and 6). Hatch (1987) found larval golden shiners of about 6.5 mm in length to exclusively feed on *Bosmina* , which remain a principle food item even for fish over 14mm, despite the increase in mouth gape and swimming abilities of the larval fish. My results showed that golden shiners even up to 130mm could still feed exclusively on *Bosmina* . *Diaphanosoma* , cyclopoids and calanoids were avoided except in July when cyclopoids represented 75% of the available zooplankton and 30 percent of the total diet biomass. There was individual variability in the number and the prey species chosen (figs. 1a - 1f). It was found the golden shiners vary their diets throughout the summer months (fig. 3). In July and June *Daphnia* were the most abundant cladocerans (fig. 2), and also the most consumed prey item (figs.5 and 6). When *Bosmina* became the dominant cladoceran, in August and September, golden shiners switched from feeding primarily on *Daphnia* to feeding almost exclusively on *Bosmina* (figs.3,5 and 6).

Prey Selection of Yellow Perch in Lac Choinière

Zooplankton represent the bulk of the diet of yellow perch less than 13.0 cm, since the second most abundant food item was chironomid larvae, which averaged 4.5 percent of the total food biomass consumed. Perch less than 13.0 cm were in most cases less than two years in age. Age determination was calculated by the scale method which involves counting the growth rings of individual scales. Chabot and Maly (1986) also found that perch less than 1 1/2 years old ate considerable quantitites of zooplankton. *Daphnia* , *Bosmina* and *Leptodora* constituted the majority of zooplankton eaten during the summer months. Perch varied the proportion of prey types consumed during the summer months. In June they preyed upon *Leptodora* , *Daphnia* , and *Bosmina* equally. *Leptodora* and *Daphnia* represented 80% of the total diet in July and in August *Leptodora* and *Bosmina* were preferred. Chabot & Maly (1986) found *Daphnia* and large calanoid species to be preferred by yellow perch. In both studies the smaller calanoid, *Diaptomus minutus* was found not to be eaten by perch. The discrepancy in feeding preference of perch on large calanoids probably resulted from lower abundance of the larger *Epischura lacustris* and *Diaptomus birgi* making these large prey types a scarce food source. In both studies yellow perch were found to prefer the larger individuals. In summary *Leptodora* and *Daphnia* were found in both studies to be an important food item of yellow perch yet calanoids were not found in my study to be as important as suggested by Chabot and Maly (1986).

Yellow perch showed individual variability in their selection of most prey types (Fig. 1a - 1f). Calanoids and *Diaphanosoma* were the prey types which showed the least variability in their negative selection by perch.

Perch not only foraged in the pelagic zone of Lac Choinière, but also frequented the littoral zone as chironomid larvae and adult diptera which are associated with littoral areas were found in their guts (table 7).

Comparison of the Foraging Behavior of Yellow Perch and Golden Shiners

Plankton represents the major food item of both golden shiners and yellow perch less than 13.0 cm. In July and June there was little difference in the zooplankton selected by yellow perch and golden shiners. The largest prey item was not necessarily the number one prey choice of either fish, especially for golden shiners. Other factors such as density, visibility, and movement of the prey must therefore be taken into consideration. Comparing the lenghts of zooplankton found in the enviroment and guts, yellow perch took the largest individuals from all prey groups in 80% of the cases. For example in July, the mean size of cyclopoids in the enviroment was 6.09 while the mean lenght found in perch was 7.15. Golden shiners selected the largest individuals in only 63% of the cases (appendix C). The major difference in the feeding preferences of yellow perch and golden shiner was in their selection of Daphnia and Bosmina during August and September. Golden shiner selected the small, more abundant, Bosmina while yellow perch fed primarily on Daphnia . Raess and Maly (1986) did not find yellow perch to decrease the population of Bosmina to the same extent as the Daphnia population in enclosure experiments suggesting that Daphnia are preferred over Bosmina . Golden shiners can better utilize Bosmina due to their different feeding behaviour and morphology. Golden shiner while continuously swimming can capture many individual prey and hold many of them in their buccal cavity before swallowing. Yellow perch on the other hand have a stop and start feeding mode to capture individual prey, and must swallow each individually, making feeding totally on small prey such as Bosmina less economical. Golden shiners are also more manoeuverable than yellow perch. The spacing between gillrakers of a 9.8cm perch averages 0.07cm while in a 10.8cm golden shiner the spacing is only 0.03 cm, suggesting that shiners are better able to retain smaller items than perch. All of the above comparisons suggest that golden shiners can be more efficient at using smaller sized zooplankton.

Yellow perch and golden shiners were found to overlap in their choice of dietary items in all months except September, when shiners were feeding primarily on Bosmina and perch on the other prey types suggesting no direct competition for food resources. During the other three months perch and shiners were overlapping in their selection of prey types. The diet overlap values for August and June suggested that both species were feeding on the same prey types, but because the prey is abundant, competition for them is probably slight. In July, the two predatory species are feeding on relatively rare prey items which would suggest that the possibility for competition is at its' greatest. It is important to point out, however, that there is no evidence that food resources were ever limiting, thus it cannot be stated that competition occured. We did find that there was a switching of prey choice of the predators through the summer months, particularly by golden shiners, suggesting that there could be some interaction between the two species for the procurement of food resources. This was evident in August but particularily so in September. The different prey preferences as a result of this switching could help to segregate the species which would prove beneficial in a situation where food resources are limiting.

Yellow perch were found to be more generalist feeders, feeding on a wider range of zooplankton, and stomach analysis suggests that they use littoral prey as a food source more often than golden shiners.

In a potential competitive situation, the factor which may allow for the co-existence yellow perch and golden shiners is golden shiners' ability to switch feeding preferences, to feed exclusively on smaller prey items such as Bosmina and leave the remaining larger items for yellow perch, thus reducing competition for food resources.

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Appendix 1 Chemical and Physical Characteristics of Lac Choinière

Surface Area (Max.)	*	4.4	km
Mean Depth	*	6	M
Maximum Depth	*	15.2	M
Drainage Basin	**	136.8	km
Phosphorus input	**	5040.3	kg/year

Epilimnetic Temperatures (in C)	7/07/83	24 C
	20/07/83	24 C
	4/10/83	17 C
	18/05/84	14 C
	25/07/84	23 C

Epilimnetic O Conc. (in ppm)	7/07/83	6.0 ppm
	20/07/83	6.6 ppm
	4/10/83	9.5 ppm
	18/05/84	10.0 ppm
	25/07/81	10.0 ppm

* from Belanger 1981

** from Lemoyne 1979

Appendix B The Presence of Yellow Perch and Golden Shiners in 49 Eastern Township Lakes

Lake	Yellow Perch	Golden Shiners	Lake	Yellow Perch	Golden Shiners
Argent	*	*	Lovering	*	*
Arnold	*	-	Lyster	*	*
Aylmer	*	-	Magog	*	*
Baldwin	*	-	Massawippi	*	*
Barbotte	*	*	McKenzie	*	-
Barbue	*	-	Megantic	*	*
Becancour	*	-	Memphrémagog	*	*
Bisby	-	-	Mont Joie	*	-
Bissonette	*	-	Nicolet	*	-
Boivin	*	*	Orford	*	-
Bolduc	*	-	Parker	*	*
Bonne Allée	*	-	Petit lac trois	*	*
Bowker	*	*	Roxton	*	*
Brome	*	*	St. Francois	*	-
Brompton	*	*	Selby	*	*
Choinière	*	*	Silver	*	-
Davignon	*	*	Slater	*	*
Lac à la truite	*	-	Spooner	-	*
Lac à le truite	*	*	Stukely	*	*
Lac de l'est	*	*	Trois lacs les Orford	*	*
Lac des Iles	*	-	Wallace	*	*
Lac trois	*	*	Waterloo	*	-
Libby	*	*	William	*	-
Lindra	-	-	Windsor	*	*
Louise	*	-			

* present
- absent

Appendix C Length range of zooplankton found in the environment and in the guts of fish

	Cyclopoid	Calanoid	Daphnia	Diaphanosoma	Leptodora	Bosmina
July Available	0.66 ± 0.12 (450)	0.69 ± 0.03 (502)	0.81 ± 0.05 (360)	0.89 ± 0.07 (316)	2.02 ± 0.43 (12)	0.48 ± 0.04 (29)
Perch Gut	7.44 ± 0.12 (249)	0.82 ± 0.20 (32)	0.88 ± 0.08 (675)	0.84 ± 0.08 (84)	8.54 ± 0.37 (75)	0.45 ± 0.08 (4)
Shiner Gut	0 08 ± 0.09 (175)	0.78 ± 0.14 (9)	.88 ± 0.05 (327)	+	+	0.43 ± 0.08 (17)
August Available	0.08 ± 0.08 (320)	0.85 ± 0.03 (453)	0.76 ± 0.03 (280)	0.82 ± 0.10 (311)	3.02 (26)	0.41 ± 0.02 (368)
Perch Gut	0.59 ± 0.06 (415)	1.08 ± 0.14 (117)	0.87 ± 0.04 (121)	0.84 ± 0.24 (31)	3.82 (242)	0.49 ± 0.02 (740)
Shiner Gut	0.53 ± 0.04 (81)	–	0.78 ± 0.03 (50)	–	3.92 (14)	0.46 ± 0.03 (559)
September Available	0.39 ± 0.04 (486)	0.87 ± 0.02 (528)	0 71 ± 0.08 (243)	0,87 ± 0,08 (158)	–	0.35 ± 0.03 (402)
Perch Gut	0.59 ± 0.05 (274)	1.16 ± 0.08 (30)	0.81 ± 0.04 (37)	0.90 ± 0.01 (36)	5.[illegible] ± 0.72 (49)	0.45 ± 0.05 (180)
Shiner Gut	0 05 ± 0.05 (18)	+	+	–	5.88 ± 0.22 (11)	0.35 ± 0.02 (245)
June Available	0 36 ± 0 04 (444)	0.78 ± 0 05 (188)	0.76 ± 0.08 (219)	0.85 - 0.08 (111)	+	0.40 - 0 05 (447)
Perch Gut	0 88 ± .09 (228)	1.01 ± 0 08 (134)	0.87 ± .08 (148)	+	4 58 ± 0.73 (209)	0.59 ± 0.05 (842)
Shiner Gut	0 50 ± 0.10 (83)	+	0.74 ± 0.08 (144)	–	5.69 ± 1.38 (4)	0.52 ± 0.07 (178)

+ Insufficient numbers

– none found