The Utilization of the Benthic Invertebrate Resource Base by the Fish Population in Sunfish Lake, Waterloo, Ontario.

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ABSTRACT

The benthic invertebrate population and the fish population of Sunfish Lake, Waterloo, Ontario, were each sampled during the summer of 1980.

The seasonal dynamics of the benthic taxocenes and the size distributions of individuals caught are presented. The distribution of invertebrate numbers relative to site, to sampler and to the presence or absence of the macrophyte Chara shows a strong correlation between the benthic fauna and the qualitative abundance of Chara in a sample.

Data on the feeding of the fish population are based on stomach content analysis of fish caught during May and July nettings. The fish are divided into size groups to detect any major dietary shifts with age.

The composition of the fish diets indicates a very distinct numerical emphasis on Cladocera as a food (≈ 90% of the prey items taken), followed secondarily (≈9%) by chironomid larvae. When just the benthic component of the diet is considered, chironomids predominate (≈90%) followed by amphipods (5%) and a series of less frequent dietary items such as Odonata nymphs,

Ephemeroptera nymphs, Decapoda and Gastropoda. Larger bodied prey are absent from the diet. A correlation exists between the proportions of prey consumed and those available in the environment.

The fish species are divided as predominantly, facultatively or non- benthic feeders on the basis of the observed diets. The Yellow Perch (Perca flavescens) and the White Sucker (Catostomus commersonii) show notable differences from diets described in other studies. They retain the purely planktonic diet characteristic of the juvenile throughout the adult stage.

The diets of the Iowa Darter (Etheostoma exile) and the Pumpkinseed (Lepomis gibbosus) are considered relative to the abundances of their prey items in the environment. Feeding appears to be proportional to availability. Where this does not hold true, the benthic taxocenes involved suggest that prey items associated with dense Chara are inaccessible to fish and that the foraging is concentrated on open sediment. The open sediment is far less productive than the Chara is.

Tentative support is given to a Chara harvesting program undertaken by a local resident. This is based on an anticipated increase in food resource availability and predation protection for young fish associated with a sparser growth of Chara.

Several avenues for further exploration are suggested.

This study is the third part in a long-term study of the Biology of Sunfish Lake, by Queen's University. The phytoplankton and zooplankton populations were studied during 1979 (Hamilton 1980, Black 1980). The ultimate goal of the study is the development of a management program for the lake.

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and with a drafting pen.

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INTRODUCTION:

A study of the food chain in a freshwater system is one of the first and most important strides towards understanding the ecological relationships between the different species present. This study investigates the utilization of the benthic macroinvertebrates as a fish food in Sunfish Lake, Waterloo, Ontario.

The data are presented in six parts, each representing a somewhat different approach towards determining the nature and extent of the fish utilization of the benthic resource base. As such, each addresses a different question as outlined below.

1) What is the composition of the benthic macroinvertebrate population as a potential food resource, in terms of the taxocenes present, the size distribution of individuals within the taxocenes and seasonal changes in the abundances of each taxocene?

The seasonal dynamics of the major benthic invertebrate groups are examined in terms of the numerical abundances and relative bulks of each throughout the summer and fall. Changes in numerical abundance as the result of insect emergence or juvenile recruitment are noted as they pertain to the availability of prey items both in terms of prey size and in terms of prey presence or absence. Coupled with the data on invertebrate population dynamics are some conclusions regarding invertebrate distributions relating to the aquatic macrophyte, Chara.

2) What are the different size groups of the different fish species consuming during May and July and how does this compare to other published findings for the same species?

Fish feeding on the benthos is considered through analysis of the stomach contents of fish caught during May and July. Numerical and percent volume contributions of prey taxocenes to the different size classes of fish species are presented and comparisons with other published data regarding the diet of each species are made.

3) How does the diet of the total fish population correlate with benthic availability and are there any significantly over- or under-exploited taxocenes?

Considering the total fish catch, the relative numerical importance of of different prey items in the diet is compared to the relative numerical availability of the same prey items in the environment. Correlations and the presence or absence of potential prey items from the combined diet are tentatively interpreted in terms of prey accessibility and availability.

4) Which fish species are wholly or in part dependent on the benthos for their food?

The fish population is then divided into broad categories by each species' observed degree of dependance upon the benthos as a food resource.

5) Does closer examination of two benthic feeding fish groups show a correlation between proportionate consumption and environmental availability? Can this be related to a particular benthic habitat sampled?

Based on the division of the fish species into dietary groups, the Iowa Darter and the Pumpkinseed, both predominantly benthic feeders, are examined to determine if the benthic component of their diet is consumed in numbers proportionate to the relative abundances of those same invertebrates in the environment.

6) What, on the basis of this study, would be the

impact on fish feeding and benthic invertebrate population if the *Chara* were harvested in part?

The importance of the macrophyte, *Chara*, in terms of benthic productivity and as a habitat for fish-food organisms is interpreted in view of a harvesting program undertaken by a local resident.

Finally, a summary of the conclusions that can be drawn regarding the manner and extent of the fish utilization of benthic invertebrates is presented and suggestions are made concerning potentially fruitful avenues of future research.

This study is the third in a series of undergraduate theses aimed, ultimately, at forming a management program for Sunfish Lake. The algal composition and distribution and the zooplankton composition and distribution were examined by Hamilton (1980) and Black (1980) respectively.

LITERATURE REVIEW

The link between benthic invertebrates and fish feeding has been the subject of interest for centuries. The original research was, and still is, being done by anglers on preferred prey items of game fishes.

Work such as that of Carbyne and Applegate (1955), involved random sampling of the fish population and yielded qualitative information regarding the realized, as opposed to the preferred, diets of a particular fish population. This idea was then further expanded into systematic sampling with attention paid to quantifying the prey consumption. Several approaches have been taken. Amtar and Stewart (1972), studying the killifish, *Fundulus notatus*, Gerking (1962) and Pardue (1973), each studying the bluegill *Lepomis macrochirus* and Keast (1977b, 1978a) studying the Yellow Perch, *Perca flavescens*, and the Pumpkinseed *Lepomis gibbosus*, respectively, have considered the ecological relationships between a particular fish species and the benthic prey organisms in a single lake system. Work such as that of Brown (1977) on the Yellow Perch, *Perca flavescens*, considers plasticity in the feeding of a single fish species in populations with different competitive backgrounds and different benthic productivities.

The dietary habits of the fish population of a water body have been studied by Hartley (1948) (The Cam River, England) and others. Similar studies presented in the light of benthic prey availability and dynamics have been done by Keast (1965, 1977a) and Harker (1976) on Lake Opinicon, Ontario. The study of Harker (1976) is concerned with feeding relations in different habitats within the single lake. Those of Keast are concerned with a specific inshore assemblage.

This study is concerned with the fish fauna of Sunfish Lake which is small and, relatively speaking, uniform as a fish habitat (see Study Site).

Variation exists in the diets of fish species and interacting groups of species throughout their geographic range and between different lakes in similar parts of this range. Etnier (1971) considered sunfishes in three Minnesota lakes, Clady (1974) considered Yellow Perch, Smallmouth Bass, and Largemouth Bass in two Michigan Lakes. A considerable amount of dietary information on Canadian fish species has been consolidated by Scott and Crossman (1974). These geographic variations in diet make it very difficult to predict fish feeding in a lake on the basis of literature for other regions.

A second approach to the study of relationships between benthic prey organisms and fish feeding has emphasized the nature and dynamics of benthic populations relative to various environmental parameters, including fish predation. Brinkhurst (1974) maintains that for benthic communities, it is perhaps better to consider the standing crop of benthic invertebrates as the residue following fish predation, rather than as the resource potentially available as fish food. Several studies tend to confirm this. Ball and Hayne (1952) considered changes in benthic population composition and dynamics in a lake where the fish had been removed, and found greatly increased, sustainable population numbers. McLachlan (1969) considered the effects of aquatic macrophytes in increasing benthic invertebrate distributions in an African Lake and Barber and Kevern (1973) consider protection from fish predation to be a major factor in observed benthic invertebrate distributions. The present study of Sunfish Lake shows a correlation between benthic invertebrates and the aquatic macrophyte distribution and considers, in general terms, the accessibility of these prey items.

Benthic macroinvertebrate distributions are controlled by a variety of physical and biological parameters. Species specific studies such as those of Cooper (1965) on the amphipod Hyallela azteca and Lyman (1956) on Ephemeroptera nymphs serve to underline the specificity of these microhabitats. In order to gain relevant information about the composition of the benthic population it is necessary to identify all organisms to the level of Order and to maintain within this identification as high a degree of morphological similarity as possible. Species identifications, although they would provide considerably more habitat information, tend to assign individuals to microhabitats that the foraging fish can not distinguish. Keast and Webb (1966) have shown that fish predation is size (determined by the mouth aperture of the fish) specific and that idea guided the level of identification and the sampling procedures used in this study.

Keast,(1977a), has suggested, after intensive sampling, that an accurate picture of the feeding of a fish population can be determined on the basis of three fish collection dates chosen at the onset of growth and feeding during May, at the height of macrophyte growth during July and prior to overwintering in September.

The use of instantaneous sampling of food resource standing crops and fish stomachs does not consider growth rates and productivity of the resources

(Brinkhurst 1974) but it does provide information on relative abundances of different prey organisms. These can be correlated with changes in the relative abundances of prey organisms in a fish species diet (Keast 1965, Brown 1977, Harker 1976).

From these sorts of correlations, it is possible to broadly determine where, on a continuum between generalist (predation varies with numerical abundance) and specialist (a resource is limited and is consumed in similar numbers irrespective of fluctuations in its availability) strategies any particular species is feeding under the given circumstances (Brown, 1977). With the accumulation of a larger body of data regarding the range of dietary niches that a species can occupy it may be possible to make generalizations about the plasticity of individual species and their responses to different competetive situations.

THE STUDY SITE

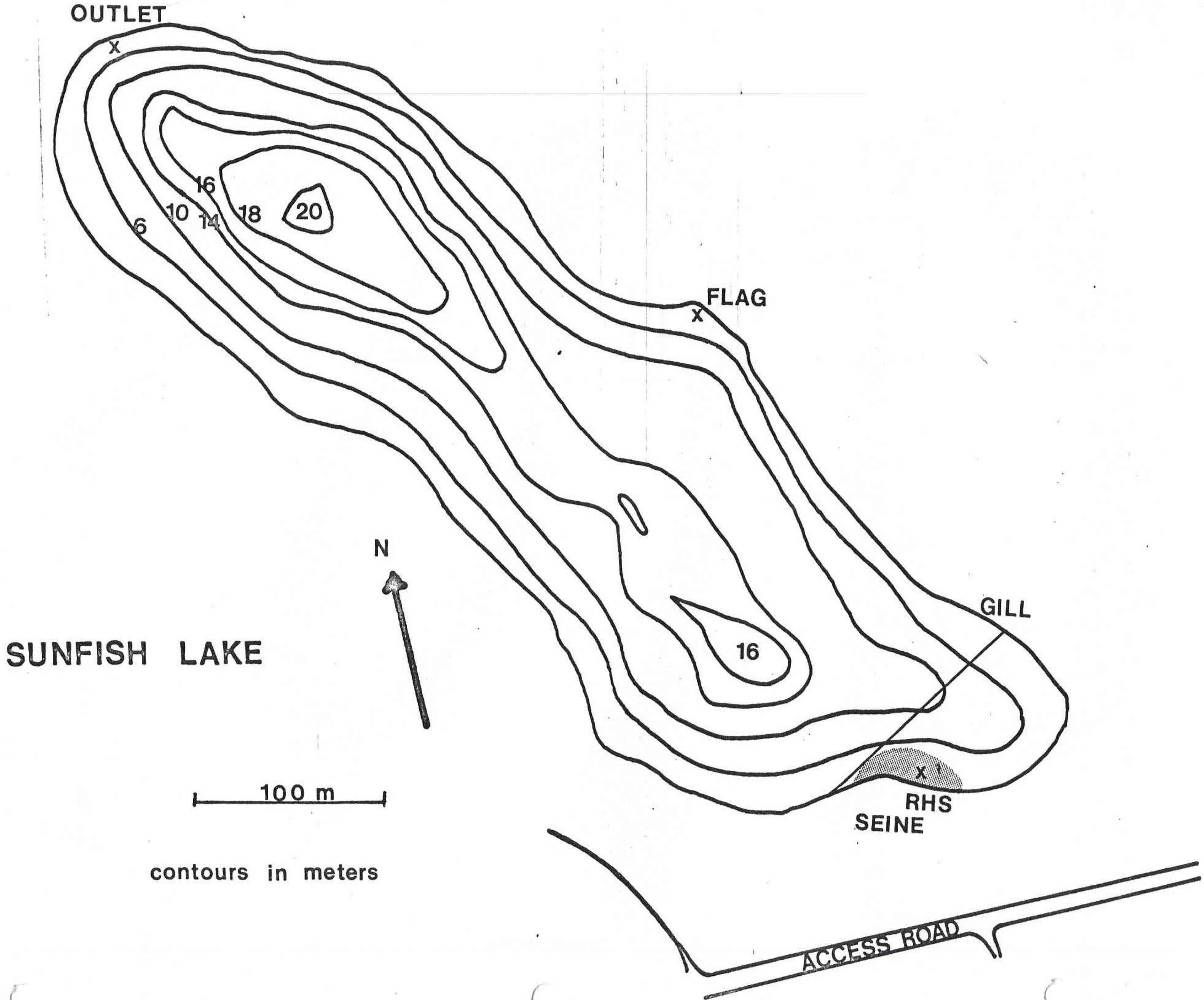
Sunfish Lake is a small (8.3 ha), relatively deep (20 m) kettle lake 8 km west of Waterloo, Ontario. It lies in one of the earliest deglaciated areas of Ontario and paleolimnological studies of the sediment stratigraphy have elucidated much of its history. Sreenivasa and Duthie (1973) state that Sunfish Lake became eutrophic approximately 850 years B.P., and that it became meromictic approximately 140 years B.P., when local land was cleared for agriculture. Ongoing research at Queen's University (Smol,MacIntosh) indicates that the meromixis may be more than 300 years old and that it may be more stable than Duthie and Carter (1970) indicated upon observing turnover once in eighteen months.

Sunfish Lake lies in privately owned land surrounded by cottages and permanent residences. Fishing pressure on the lake is minimal (pers.obs.) and a cottagers agreement prohibits the use of motorboats. An active Cottagers Association is concerned for the trophic status of the lake, in particular because the lake is soon to be incorporated within the limits of the city of Waterloo. This may involve construction and increased

Table: 1

Morphometric Data for Sunfish Lake
(from Duthie and Carter, 1973)

Surface Area	8.3 ha
Maximum Depth	20 m
Mean Depth	10.4 m
Maximum Length	577 m
Maximum Width	189 m


OUTLET
x
6
10
14
16
18
20
FLAG
x
16
GILL
x
RHS
SEINE
ACCESS ROAD
N
SUNFISH LAKE
100 m
contours in meters

human activity in the area.

The surrounding watertable lies close to the surface during the summer months, and many of the cottage lawns hold water for all or part of the summer. Considerable modification of the natural shoreline has occurred as the result of human disturbance. Retaining walls, docks, and loads of sand have all been used in attempts to stabilize and ameliorate the recreational appeal of the shoreline.

Morphometric data for the lake are shown in Table 1 . In the eastern end of the lake the littoral zone is at its most extensive with the two meter depth contour falling an average of 10 meters from the shoreline (pers. obs.). The remainder of the shoreline drops off more steeply and the two meter depth contour falls 4-5 meters from the shoreline. The littoral sediments are characterized by a layer of calcareous marl underlain by highly reduced organic ooze.

Chara is the only abundant macrophyte in the littoral zone. The small size of the lake and the limited extent of the littoral zone mean that there is relatively low diversity in available benthic and fish habitats. The sediments are reasonably uniform as described for each site and the major parameter controlling invertebrate distribution appeared, after initial sampling, to be the presence or absence of _Chara_.

The benthos was sampled at three sites chosen on the basis of more extensive May sampling. These sites are marked on the hydrographic map of Figure 1. The sites were labelled OUTLET, FLAG, and RHS (Right Hand Side) for convenient reference.

OUTLET:

The Ekman sampling area was characterized by a dense mat of _Chara_ which reached over 75 cm in height during the latter part of July. The pushnet site lay just within the bounds of the ouflow itself in a region of patchy _Chara_ growth reaching a maximum height of 40 cm. Flow in the Outlet was slow and intermittent during the summer months as the channel was clogged with shrubs and organic debris. Local residents cleared the channel in late August and lowered the overall water-level in the lake by 4 or 5 cm. The OUTLET site was the most productive of the three sites examined.

FLAG:

Both the Ekman and the Pushnet sampling sites consisted of dense mats of *Chara* with a maximum height of 30-40 cm. The underlying sediment was very soft and the two meter depth contour lay just three meters off the reinforced shoreline. Pushnet sampling was not possible in September because the site had been disturbed by the cottage owner dumping rockfill in the area.

RHS:

The RHS Pushnet site was the least productive site studied. The sediments were coarse grained marl and gastropod shells bearing small patches of *Chara* rarely exceeding 10 cm in height. The Ekman sites also had patchy *Chara* distributions although these reached 25 cm in height. More organic ooze was found in the sediment than at the Pushnet site but large numbers of gastropod shells were still present.

Fish Netting:

In May, the fish netting consisted of Seine netting three sites corresponding roughly to OUTLET, FLAG, and RHS. A transect as shown in Figure 1 was the site of the May Gill net sampling. July and September samplings were restricted to the eastern end of the lake because the dense *Chara* growth prevented effective seining and human activity made Gill netting unsafe at the other sites. No qualitative differences between sites were discerned during the May sampling so this restriction was not considered critical.

SAMPLING PROCEDURES

Benthos:

The benthos was sampled on five different occassions, May 15-16, June 12-16, July 23-28, September 3-6, and November 24 of 1980. Extensive sampling by Drs. Brown and Keast and field assistants in May enabled the choice of three representative sites for sampling, OUTLET, FLAG, and RHS (see Figure 1).

Two methods of sampling were used. Samples from less than 1.5 m in depth in areas containing patches of Chara were obtained using a heavy framed Pushnet by the method of Keast (1965). The Pushnet has an 0.25 m wide cutting surface designed to remove the top few centimeters of the substrate into a fitted, 0.4 mm mesh size, collecting net. The method of sampling is very quick and efficient but proved ineffectual in the dense Chara because the restricted aperture of the frame could not accept the algal mat. A 1 meter grid of stakes was set out at each site at least 12 hours prior to sampling. These stakes were used as reference points to push the net through a horizontal distance of 1 meter. They also assured that evening samples were not disturbed in the process of collecting the morning samples. Eight

Pushnet samples were collected from each site on each sampling occasion. Four were collected between 0800 and 1000 hours and four were collected prior to 1700 hours the same day.

Where samples were taken from dense *Chara*, or where the water depth prohibited access by a person in chest waders, collections were made with a 6" by 6" Ekman dredge. Ten Ekman samples were collected from each site on each sampling occasion. Five were collected from between 1 and 1.5 meters in depth and five were taken between 2.5 and 3.5 meters in depth. All samples were collected at the same time in either the morning or the evening. Random Ekman sampling of depths greater than 3.5 meters on each sampling date did not yield any macroscopic benthic invertebrates after May, so no systematic sampling was undertaken at greater depths. Any fauna at greater depths were considered too diffuse to be of major importance to fish feeding.

Each benthic sample was transferred directly into either a plastic bucket or a plastic garbage bag and tagged with the site, sample, sampler, date, time of day, and a qualitative assessment of the amount of *Chara* in the sample. Immediate processing involved washing each sample through a series of nested screens (Keast

1965) of 5 mm,2 mm, 1 mm, and 0.4 mm mesh sizes respectively. Organisms were hand picked from each screen and transferred to 95% ethanol. Screening the samples serves to remove larger debris so that smaller organisms retained on the finer screens are not obscured by large grain size sediments. Unfortunately, the calcareous marl and the gastropod shells would not wash cleanly through the screens and, where sediments were retained on the screen, the smaller organisms are likely to be underrepresented in the samples. Alternative methods of collecting the benthic invertebrates such as saturated solutions of sucrose and agitation of the sample were tried but none approached the effectiveness of the method used. It must also be noted that many of the invertebrates are vermiform in outline and are capable of passing through the smallest screen during washing. The water used to wash the samples was drawn by bucket from the lake.

In order to remove organisms that were bound to, or clinging to, the surface of the *Chara*, all of the macrophyte from each sample was washed thoroughly by thrashing the *Chara* in a bucket of water and pouring the wash-water through the screens. Washing was repeated at least three times and, where the macrophyte was abundant, washing was done in subsamples. Regular checks of the accuracy of this method of collecting the epifauna indicated that it was as or more efficient than visual clearing of the plants.

Fish:

The fish population was sampled on May 14-15, July 24-25, and September 2-4 of 1980. Some of the limitations of the sampling sites have already been described (see Study Sites). Triplicate Seine net samples were collected morning and evening on each sampling occasion. The area covered was limited by the restricted littoral zone and the depths accessible in chest waders. The nylon Seine net was 15 meters in length and 2 meters in depth. The collection bag had a 5 mm mesh and was able to retain most young of the year. Records of the area seined were kept to facilitate interpretation of the catch in terms of the total fish population.

The Gill net was 100 meters in length and 2 meters in depth. It was composed of four equally long panels of 5, 4, 3, and 2 cm meshes. The net was set for two consecutive twenty-four hour periods and was cleared every six hours. Every twelve hours the orientation of the net was reversed to present a range of different mesh sizes to all habitats. The small littoral zone prevented the entire net from being set in a region of uniform depth so that, while both ends of the net were in two meters of water, the mid-section was set over fourteen meters of water (see Figure 1).

All fish caught were kept and preserved in 10% formalin. Larger fish were slit to allow rapid penetration of the formalin into the body cavity. Each fish was identified and its total length, wet weight, date and time of day caught,and net used recorded.

Species identifications were made using Scott and Crossman (1974). Total lengths, as opposed to the standard lengths used by some authors (Scott and Crossman 1974), were recorded for each fish. To standardize wet weight measurements all fish were soaked in water for at least 24 hours after removal from formalin and were externally patted dry using absorptive towelling prior to weighing. Preservation is known to affect weight so the weights are not directly comparable to fresh weights although the method of weighing is consistent. For Centrarchid and Percid fishes, scale samples were kept so that they would be available for future reference. For the purposes of this study it was not necessary to read scales and exactly age fish as body size is more important to prey selection than is absolute age (Keast 1965, Brown 1977).

Stomach contents of up to 25 fish of each species were analyzed from the May and July sample collections. The limit was imposed by time constraints. Often the numbers were less because the samples were not large enough to provide a sample size of 25 fish or because the stomachs were empty.

Analysis of the stomach contents followed the method used for the benthic samples with the addition of a few categories not applicable to the benthic samples. These included zooplankters, organisms of terrestrial origin such as insect adults. Several categories of detritus of animal, plant, or uncertain origin were created and assigned percent volume scores.

Secondary Processing:

Secondary processing of both the benthic and the stomach samples involved examination of each under 10x -40x magnification of a binocular microscope. Each organism was identified to Order using Merritt and Cummins (1978) and obvious morphological groups within Orders were distinguished. The prevalent groups were subsequently identified as Family, Genus or Species specific using more specialized references (see Bibliography: Identifications).

The length of each organism and total counts for each taxonomic category in each sample were recorded and later converted to numbers per meter squared. Using the method of Keast (1965) the organisms were spread to a uniform depth in a sample dish against a calibrated background and the percentage volume contributed by each taxonomic category was recorded. Periodic repetitions of sample analyses and comparison with the estimations of other researchers served to minimize any variation in this method of estimating bulk. For a discussion of the relative accuracy of this method of estimating bulk the reader is referred to Hyslop (1980).

To obtain an accurate picture of fish feeding patterns it is necessary to record the numbers of prey items, their individual sizes and some measure of their relative bulks. Any less detailed record omits potentially important information regarding the number of prey pursuits, size selectivity in feeding and the relative energy gains from different prey. Visual estimates of bulk are, in general, as accurate as volumetric displacements, are less time consuming, and are not as complicated by fluid retention in the organism (Hyslop, 1980).

Much of the subsetting and plotting analyses were done using the Queen's University Q'text floppy diskette programs.