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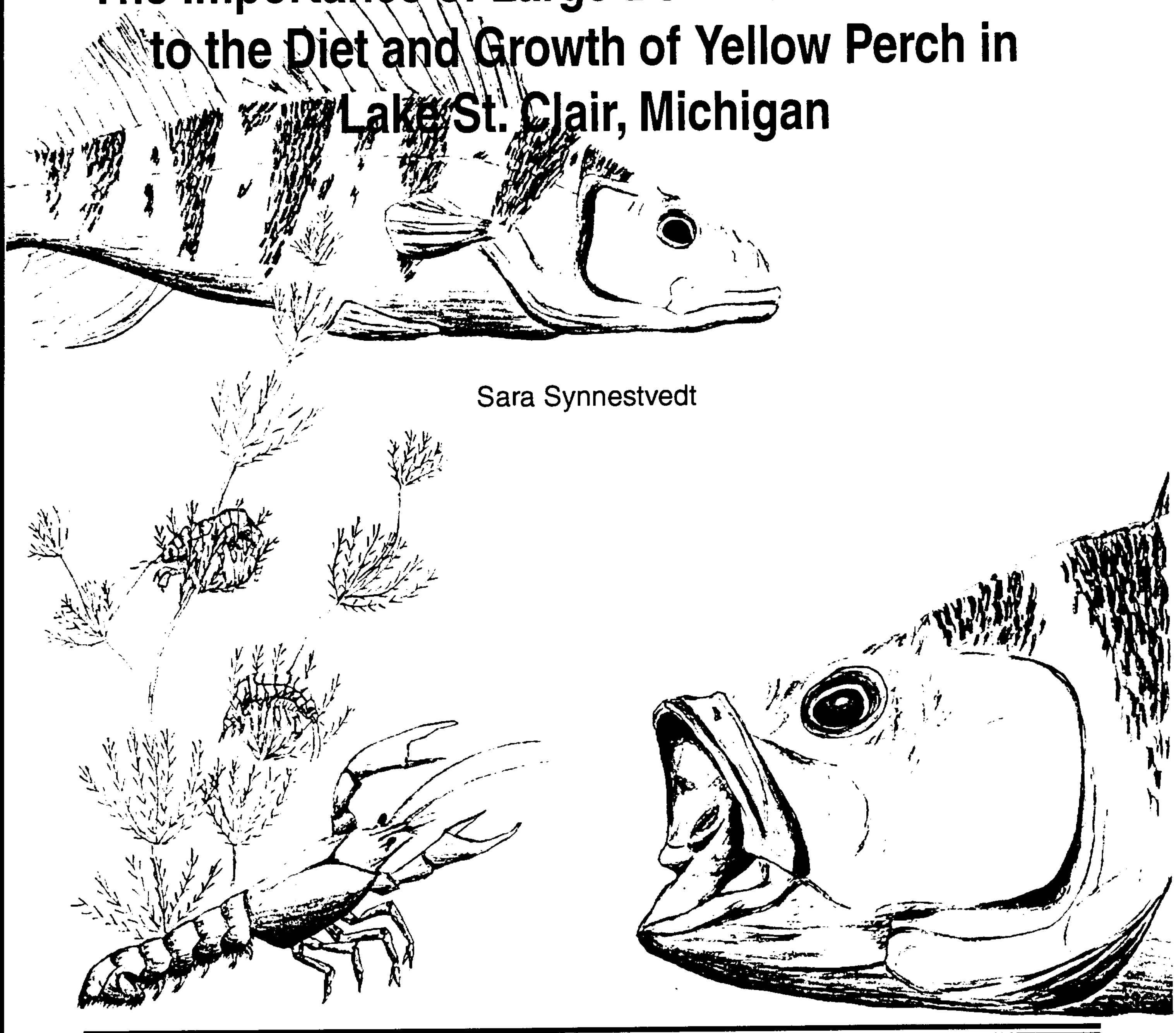

Sara Synnestvedt

FISHERIES DIVISION
RESEARCH REPORT

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
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THE IMPORTANCE OF LARGE BENTHIC INVERTEBRATES TO THE DIET AND GROWTH OF YELLOW PERCH IN LAKE ST. CLAIR, MICHIGAN

Sara Synnestvedt

A thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science

Department of Biology

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the requirements for the Master degree

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Date: May 1, 1996

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Date: May 2, 1996

"O Lord, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches. So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts. There go the ships: there is that leviathan, whom thou hast made to play therein. These wait all upon thee; that thou mayest give them their meat in due season. Thou sendest forth thy spirit, they are created: and thou renewest the face of the earth.

Psalm 104: Verses 24-27, 30

For Mom and Dad

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I wish to thank my advisor, Dr. Herb Lenon, for his kind assistance and willingness to discuss my concerns at any time throughout this project. Many thanks to my other commitee members: Dr. John Scheide for taking on this project at such short notice and Mr. Robert Haas of the Department of Natural Resources who I am indebted to for his considerable knowledge of yellow perch research and help in tackling the computer. I also want to thank Dr. Ray Hampton, a committee member who passed away before this was published. He would do anything to help a student and always made me smile. Thanks also to employees of the Great Lakes Fisheries Research Station in Mount Clemens: Ken Koster for technical help and welcome company in the lab; Mike Thomas, Jack Hodge and Larry Shubel without whose assistance I could not have obtained my samples; and Bonnie Menovske who was always on top of things and helped keep the checks in the mail. I greatly value assistance with the necessary dirty work in the laboratory from Scott Scholton and Matt Dare. Finally, I thank Don Bonnette for his caring support, and from whose example I learned about strength and persistance. Funding from the Department of Natural Resources and Central Michigan University was greatly appreciated.

ABSTRACT

THE IMPORTANCE OF LARGE BENTHIC INVERTEBRATES TO THE DIET AND GROWTH OF YELLOW PERCH IN LAKE ST. CLAIR, MICHIGAN

by Sara Synnestvedt

Yellow perch (*Perca flavescens*) were collected monthly from Lake St. Clair from May-October, 1993 using a bottom trawl. Data on wet weight, length, age, redworm infestation, somatic tissue dry weight, somatic tissue water content and stomach contents were obtained. Consumption rates were calculated using a bioenergetics model and an algorithm. Wet weights were above the Michigan averages from August-October and growth was much better than perch in Saginaw Bay, Lake Huron , western Lake Erie and some populations in central Lake Erie. Young-of-the-year yellow perch switched to benthic invertebrates in August. Older fish ingested invertebrates, primarily amphipods and *Hexagenia* sp., in late spring and summer and switched to *Orconectes propinquus* and fish in the fall. Age 1-2 perch ingested *Bythotrephes cederstroemii* in September. Age 2-4 perch were much above maintenance rations from July-October. The diet of large invertebrates, especially amphipods and *Hexagenia* sp., is believed to be the reason for good growth.

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INTRODUCTION

Various studies have been conducted to determine food preferences and growth of yellow perch (*Perca flavescens*). Keast (1977) found that yellow perch in Lake Opinicon, Ontario, go through three feeding phases: first eating mainly cladocerans, then insect larvae, and finally fish. The existence of ample prey in each of these three size strata appears essential for good growth, leading to a balanced population. Hayward and Margraf (1987) studied yellow perch populations in the central and western basins of Lake Erie. Food limitations in the western basin appeared related to a reduced size structure of benthic prey due to eutrophication. In the central basin, large benthic prey were available. Consumption rates were higher and growth of 1-, 2-, and 3-year old fish were clearly higher in the central basin. In the western basin, a decline in food consumption rates was seen with increasing yellow perch size, apparently leading to stunting and population degradation.

Haas and Schaeffer (1992) found a lack of large benthic organisms (particularly the large mayfly naiad *Hexagenia* sp.) in the forage base of Saginaw Bay, Lake Huron and this was implicated as a possible factor in the poor growth of the yellow perch in this location. It appeared that yellow perch in that study could not maintain a positive energy balance on a diet of zooplankton and small benthic prey such as chironomids.

A decline in *Hexagenia* sp. occurred in Oneida Lake (Clady and Hutchinson, 1976). However, despite a 10-fold decline in biomass of *Hexagenia* after 1959, frequency of occurrence in yellow perch stomachs decreased only 3- or 4-fold through 1964, indicating strong selection by perch. Changes in the diet reflected changes in the benthos. As *Hexagenia* eventually disappeared, it was replaced by chironomids, amphipods, isopods, trichopterans and zooplankton in the diet. A slight, but significant, decrease in the growth of older perch was witnessed which could have resulted from the loss of *Hexagenia*.

Fish growth is a function of protein and lipid accumulation and gonad synthesis in a tradeoff with energy losses due to spawning, over-wintering and parasitism (Salz, 1989). If a fish does not take in enough calories (with the majority ingested during the summer) to provide for metabolism, gamete production and spawning in addition to growth, growth will suffer. Furthermore, it appears that the relative cost of reproduction increases with age (Diana, 1995). Therefore, if an older fish is forced to rely on zooplankton and small invertebrates for food as in Saginaw Bay (Haas and Schaeffer, 1992) and increasingly needs more calories to reproduce as it ages, this fish may undergo energy depletion with stunted growth as a result.

Lake St. Clair appears to have a strong population of yellow perch but these fish have not been formally studied in recent times. Approximately 4 million people live within a one hour drive of Lake St. Clair and almost 22% of all Michigan Great Lakes sport fishing effort was spent on Lake St. Clair (Jamsen, 1985). This lake is also undergoing changes in species composition with the addition of the non-indigenous zebra mussel (*Dreissena polymorpha*), tubenose goby (*Proterorhinus marmoratus*), round goby (*Neogobius melanostomus*) and white perch (*Morone americana*). However, many of the benthic invertebrate populations (with the exception of large unionid clams) have remained stable with an abundance of *Hexagenia*, amphipods and crayfish. Griffiths (1992) reported that zebra mussels may benefit some macroinvertebrates such as worms by increasing the organic content of sediments by the deposition of feces and pseudofeces. In addition, the altered habitat in Lake St. Clair, (clearer water and increased patches of macrophytes), as a result of zebra mussel colonization most likely accounts for increased abundance of amphipods and snails.

It seems likely that the presence of large benthic invertebrates has been the main reason for the apparently high growth-rates of yellow perch in Lake St. Clair. Consumption rates are expected to be high. Therefore, the objectives of the present study are:

1) to provide baseline data on yellow perch growth and diet which may be a useful reference with which to compare future populations of perch as Lake St. Clair invariably undergoes change.
2) to qualify and quantify prey types and to determine the contribution of each prey type to the yellow perch diet.
3) to calculate daily food consumption rates.
4) to calculate water content of somatic tissue to be used as an indication of fat content.

SITE DESCRIPTION

Lake St. Clair is a large, shallow body of water in the Laurentian Great Lakes system (Figure 1). It receives 97% of its water input from Lake Huron via the St. Clair River (Bolsenga and Herdendorf , 1993) and is connected to Lake Erie by the Detroit River. It is bordered by the Detroit, Michigan metropolitan area to the west and by the province of Ontario, Canada to the east and south. Bolsenga and Herdendorf (1993) described the lake's characteristics. Mean depth is 3 m, maximum natural depth is 6.4 m and the shipping channel is dredged to 8 m. Water temperatures peak in August to about 24°C on the eastern side and are lower by 2-4°C on the western side due to the influence of Lake Huron. There is usually 100% ice cover in January and February. Due to its shallow depth, Lake St. Clair does not thermally stratify during the summer. Sediments are silt, clay and fine sand.

Lake St. Clair is shallow and has a short residence time of about seven days (Bolsenga and Herdendorf, 1993). In the current study, perch were collected from Anchor Bay. This northern portion of the lake is heavily influenced by the flow from the St. Clair River. The great volumes of water it receives from Lake Huron via the St. Clair River allow the northern portion of the lake to remain meso-oligotrophic despite its shallow depth.

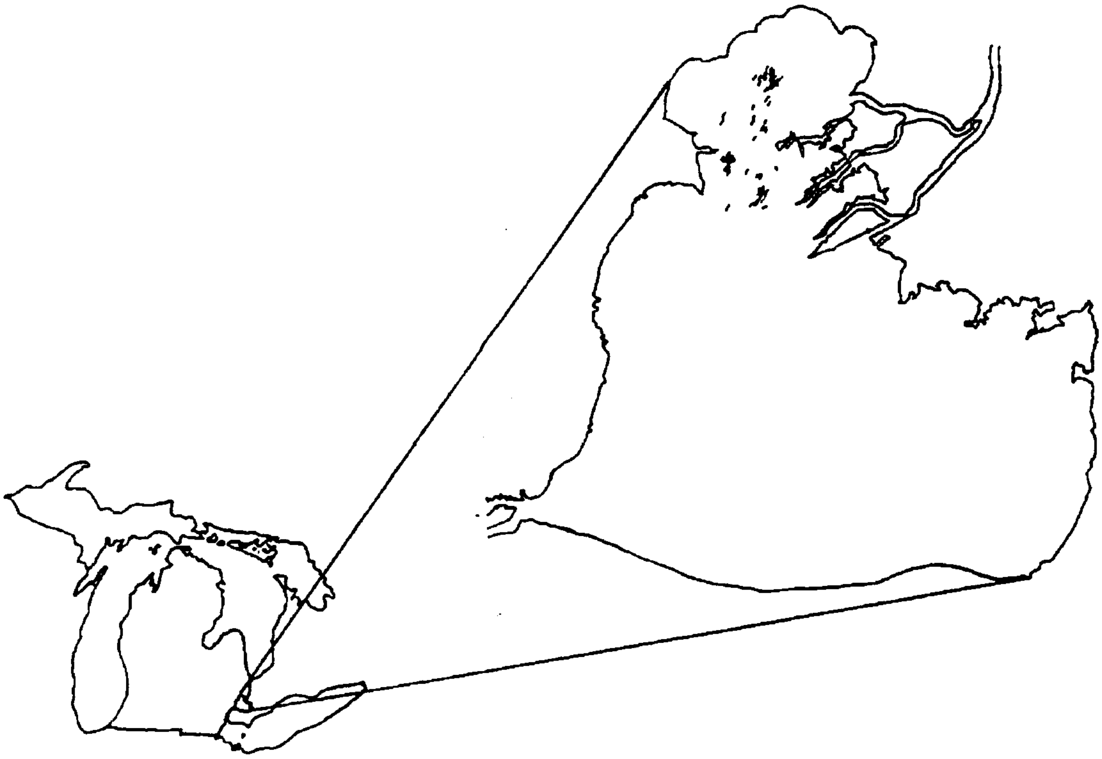

Figure 1. Map of Lake St. Clair. Tick marks in the northern portion (Anchor Bay) represent trawling sites, 1993.

METHODS

Field Sampling

Yellow perch were collected from the northwest portion of Anchor Bay using a bottom trawl monthly from May-October, 1993 from the research vessel "Channel Cat" in cooperation with the Michigan Department of Natural Resources (MDNR) (Figure 1). Sampling dates fell near the second week of each month. Trawling equipment was made up of a 10.66 m headrope otter trawl towed with a single warp and a 45.7 m bridle. Tows were conducted with the trawl on the lake bottom for 10-15 min at an approximate speed of 2 knots.

The efficiency of yellow perch using this otter trawl in Lake St. Clair was estimated in 1989 to be at 42% (Haas and Schaeffer, 1992).

Each month, a modified diel sampling procedure was used to obtain yellow perch. Approximately 52 adult fish and 10 young-of-the-year fish (if available) were collected over two days from trawls at 1500 hrs, 1800 hrs and 2100 hrs on the first day and at 0600 hrs, 0900 hrs, and 1200 hrs on the second day. Occasionally multiple tows were needed during the three hour time period to catch the preferred sample size of 52 adult fish.

Yellow perch were removed from the trawl at random. However, notably large perch were always included, although at no more than three per sample. These fish were placed in tubs of ice-water to stop digestion, then removed and frozen with liquid nitrogen and placed in a cooler until they could be moved to a freezer unit in the laboratory on land.

Laboratory Procedures

In the laboratory, fish to be processed were thawed and blotted to remove excess water. They were then measured, weighed and scale samples were removed from below the lateral line near the tip of the pectoral fin. Yellow perch were slit from anus to gills, sexed, and the viscera, including the stomach and gonads, was removed. This allowed somatic tissue weight (fish weight minus viscera) to be measured. The full stomach was weighed. Stomach contents were extracted, weighed and placed in vials containing 70% ethanol or 5% buffered formalin if the stomach contained fish. The empty stomach and viscera excluding the stomach were weighed separately. Body cavities and viscera were examined for infestation by the redworm parasite *Eustrongylides tubifex*.

After processing, the viscera were wrapped in weighing paper and put into a plastic bag with the respective somatic portion of the fish and refrozen.

All yellow perch and their viscera were dried separately in aluminum tins or boats for 48 hrs in a drying oven at 90°C. Percent water of the somatic tissue was calculated by the formula:

$$\% \text{ water} = (\text{somatic wet weight} - \text{somatic dry weight}/\text{somatic wet weight}) \times 100$$

The above somatic wet and dry weights were both measured after re-thawing following placement in the freezer after initial processing. Percent water content can be used as an indication of fat content. Elliott (1976) found that as food ration size increased, protein and fat increased and percent water content decreased. Energy density was calculated from somatic percent water using the regression statistics from Craig (1977).

Fish were aged from scale impressions magnified at 42X. Aging techniques were verified by an experienced Michigan Department of Natural Resources technician.

Growth was defined in the following manner: as an increase in total length, an increase in wet weight, and an increase in somatic tissue dry weight.

Daily food consumption rates were calculated in two ways : from the algorithim of Elliott and Persson (1978) and using the computer bioenergetics model by Hewett and Johnson (1992). For the Elliott and Persson method, median wet food weights of fish for each 3 hr trawl period and temperatures recorded at the times of the trawls were entered into the algorithm. It was assumed that fish did not feed from the period between 2100 hrs and 0600 hrs. Rates of gastric evacuation were estimated from a regression of evacuation rates and temperatures given for the Eurasian perch (*Perca fluviatilis*) in Persson (1979). Due to small sample sizes for fish of other ages, only consumption rates for age 2 fish were calculated with the Elliott and Persson method. Using the bioenergetics model, required inputs are temperature, perch caloric density, prey caloric value, diet proportions and perch wet weights. The temperature entered in the model for each month was a mean of six temperature readings taken over the sampling period each month (Table 1).

Table 1. Temperatures used in the bioenergetics model. These data are means of readings taken over the 2-day trawling period at a depth of one meter for each month. The day of year is the Julian date of the first day of trawling.

Day of Year	Temperature (°C)
122	10.00
150	12.83
178	16.67
213	22.20
241	19.75
269	12.00

Perch caloric densities were obtained in the method used above by Craig (1977) to estimate caloric value by dry weight. Percent water data (Appendices 1-3) were then used to calculate energy density by wet weight (Table 2) as this was required in the bioenergetics model. Diet proportions were calculated as the proportion of the total dry weight of diet items occurring in approximately 10% or more stomachs for each age class. For forage fish which were unidentifiable, dry weights were estimated to be the mean dry weight of the identified fish for each age and month. Weighted means of wet weights and caloric values of each forage fish species were used to calculate a mean wet weight and caloric value of total fish eaten at each age and month.

Table 2. Energy density values used in the bioenergetics model from yellow perch in Lake St. Clair, 1993.

	May	Jun	Jul	Aug	Sep	Oct
Age	cal/g wet weight	cal/g wet weight	cal/g wet weight	cal/g wet weight	cal/g wet weight	cal/g wet weight
1	———	1055.9	1057.7	1155.2	1297.8	1200.2
2	1091.4	1159.5	1233.1	1302.3	1361.7	1278.1
3	1153.1	1232.9	1316.3	1375.1	1335.3	1317.4
4	1168.2	1281.6	1367.9	1387.7	1449.1	1354.8

Prey wet and dry weights for diet items other than oligochetes were estimated in the following way:

1) a subsample of each major prey type (occurring in approximately 10% or more stomachs) from the preserved stomach samples for each month was weighed wet and then dried at approximately 70°C for 24 hrs. Only intact items that appeared undigested were used.

2) Most wet and dry weights were corrected for preservative effects using correction factors from Howmiller (1972) for invertebrate weights. Fish wet weights were corrected for preservative effects using correction factors from Haas (unpublished data) for wet weights and it was assumed that this correction factor was the same as for dry weights. Mollusk weights were not corrected for preservative effects because correction factors were unavailable.

3) Because many of the forage fish in the stomachs were unidentifiable, their weights were estimated by using the means of the identified fish that were weighed in the laboratory and caloric values were estimated by taking a weighted average of the caloric values of the known fish.

Although this is a somewhat imprecise way to measure wet and dry weights of prey items, comparisons with weights in another study (Meyer, 1989) showed that these estimates were reasonable.

For oligochaetes, the mean individual dry weight was calculated using median lengths of oligochaetes from stomach samples and the length-weight relation from Nalepa and Quigley (1980). Corrections were not made for preservative effects as this information was unavailable. Caloric values of all prey items except unidentifiable fish were obtained from the literature or unpublished data (Table 3). For fish which were unidentifiable, caloric values were estimated by taking the mean of the values for identified fish for each age and month.

The caloric value of the diet of the perch was calculated by taking the mean numbers for each prey item in the stomachs and multiplying this by the corrected weight of an individual organism. This figure was then multiplied by the caloric value of the item per gram (Table 3) using dry weights for invertebrates and wet weights for fish because most caloric values for fish are given for wet weights. Finally, a correction factor of 0.058 for fish and 0.158 (mean of values given in Brett and Groves, 1979) for invertebrates was applied for the portion that is excreted.

Consumption Modeling

The computer bioenergetics model provided the user with many options to model consumption rates and maintenance rations. In this study, each bioenergetics "run" was performed for each age group separately and the growing season was broken up into a section (cohort) for each month. The model fit a "P-value" (proportion of maximum consumption) to each cohort. The model was also run with cohorts grouped in the following way: for age 1 and age 4 perch, with one cohort, two cohorts for age 3 fish, and three cohorts for age 2 perch. Maintenance rations were estimated by performing runs (six cohorts for age 2 - 3 perch, five cohorts for age 4 perch and four cohorts for age 1 perch) which simulated the growth of perch for one day each month.

Statistical Analysis

Student t-tests were performed to determine differences in mean lengths, wet weights, somatic tissue dry weights, somatic tissue water content and parasitic redworm (*Eustrongylides tubifex*) occurrence between male and female fish of each age group for each month.

Data were initially checked with a Levene test for homogeneity of variance and the appropriate t-test conducted depending on whether the variances were equal or not.

Table 3. Caloric values of diet items used in the bioenergetics model and in calculations of caloric intake during the growing season of yellow perch from Lake St. Clair, 1993.

Diet Item	cal/g dry weight	Source	cal/g wet weight	Source
Amphipod	4002	Cummins and Wuycheck (1971)	934	Cummins and Wuycheck (1971)
Isopod	4082	Johnson and Brinkhurst (1971) (mean of Asellus racovitzai)	816	used cal/g dry wt. figure from left and subtracted an estimated 80% as suggested by Hewett and Johnson (1992)
Hexagenia sp.	4885	Cummins and Wuycheck (1971) (used Ephemeridae value)	733	Cummins and Wuycheck (1971) (from % water data)
Chironomid larvae	5424	Cummins and Wuycheck (1971)	656	Cummins and Wuycheck (1971)
Chironomid pupae	5424	Cummins and Wuycheck (1971)	656	Cummins and Wuycheck (1971)
Tricoptera	4999	Cummins and Wuycheck (1971)	1000	used cal/g dry wt. figure from left and subtracted an estimated 80% as suggested by Hewett and Johnson (1992)
Orconectes	2950	mean of King and Ball (1967) and Kelso (1973) in Rabeni (1992)	707.115	used cal/g dry wt. figure from left and subtracted 76.03% as suggested by Jim Breck (unpublished data)
Gastropoda	2024	Cummins and Wuycheck (1971)	430	Cummins and Wuycheck (1971)
Pelecypoda	1070	Johnson and Brinkhurst (1971) (mean of sphaerid clams)	214	used cal/g dry wt. figure from left and subtracted 80% as suggested by Hewett and Johnson (1992)
Oligochaeta	5575	Cummins and Wuycheck (1971)	1115	used cal/g dry wt. figure from left and subtracted 80% as suggested by Hewett and Johnson (1992)
B. cederstromii	5241	Cummins and Wuycheck (1971) ("cladocera" value)	629	used cal/g dry wt. figure from left and subtracted 88% as suggested by other authors in Hewett and Johnson (1992)
Hirudinea	5443	Cummins and Wuycheck (1971)	1089	used cal/g dry wt. figure from left and subtracted 88% as suggested by other authors in Hewett and Johnson (1992)
Mysids			1030	Rudstam (1989) in Hewett and Johnson (1992)
Lepidoptera	4000	Assumed		
Corixidae	3000	Assumed		
Sculpin			1372	Rottiers and Tucker (1982) (slimy sculpin value)
Alewife			1495	Rottiers and Tucker (1982)
Rockbass			1362	used yellow perch value from Hurley, 1986 in Haas and Schaeffer (1992)
Bluntnose Minnow			1191	used emerald shiner value from Kelso (1972) in Haas and Schaeffer (1992)
Logperch			510	Mark Kershner, unpubl. data
Johnny Darter			510	Assumed to be same as logperch
Tubenose Goby			1372	Assumed to be same as sculpin
Troutperch			766	Mark Kershner, unpubl. data
Brook Stickleback			600	Assumed

To measure changes in length, wet weight, somatic tissue dry weight, and somatic tissue water content over the growing season for each age group, a Levene test for homogeneity of variance was conducted. If variances were not significantly different, a One-Way ANOVA was performed. If variances were significantly different, a Kruskal-Wallis non parametric One-Way ANOVA was utilized. The test used is indicated in parentheses in the Results section. Differences were considered significant when $p \leq 0.05$.

RESULTS

Growth as Measured by Length

The seasonal changes in length for yellow perch are listed in Appendices 1, 2 and 4. Maximum growth for age 0 and age 1 perch with sexes pooled occurred between July and September (Figure 2). The mean length of age 0 and age 1 fish from September to October remained relatively stable. For all months when it was possible to test (September for age 0 fish and July, September and October for age 1 fish) there was no significant difference in length between males and females, although males were greater in length in all cases. There was a significant increase in length during the growing season for age 0 fish (Kruskal-Wallis One-Way ANOVA). Age 1 fish had a significant increase in length between July and August and August and September (One-Way ANOVA).

For female perch of ages 2 - 4 , the greatest change in length occurred from July - August (Figure 3). Sample sizes for age 5 females were too small after June to be included. Between September and October, age 3 and age 4 female lengths leveled off.

Females of ages 2-5 always had greater mean total lengths than males of the same ages although this was not always significant. Age 2 females were significantly longer than age 2 males from May - October. Age 3 females were significantly longer than age 3 males in July, August and October. It is possible that for May, June and September, sample sizes were not large enough to illustrate a difference between age 3 males and females. Age 4 females were significantly longer than age 4 males in May - August and October. Only two age 4 males were captured in September so it was not possible to test this month. Age 5 females were significantly longer than age 5 males for the two months in which sample sizes were large enough to test: May and June.

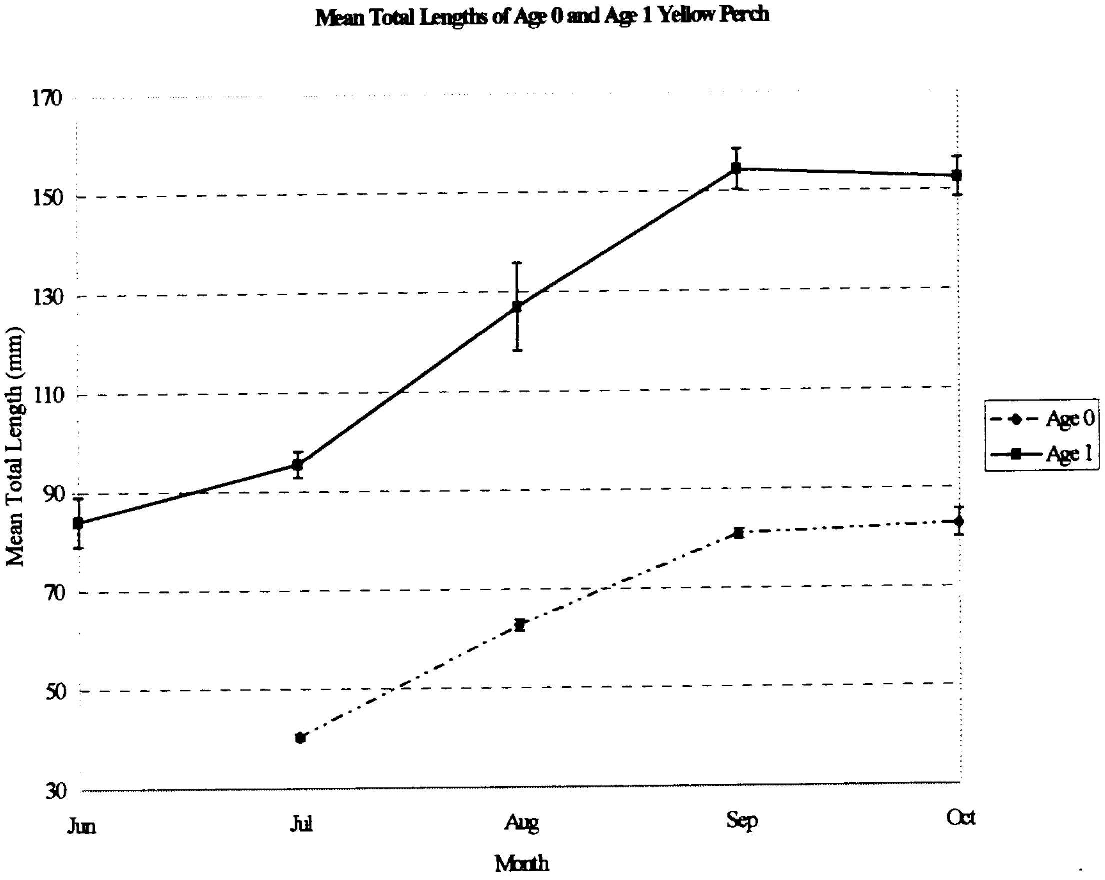

Figure 2. Seasonal change in mean length (with standard error bars) of age 0 and age 1 yellow perch from Lake St. Clair, 1993. Sexes were pooled due to small sample sizes and/or difficulty in sexing.

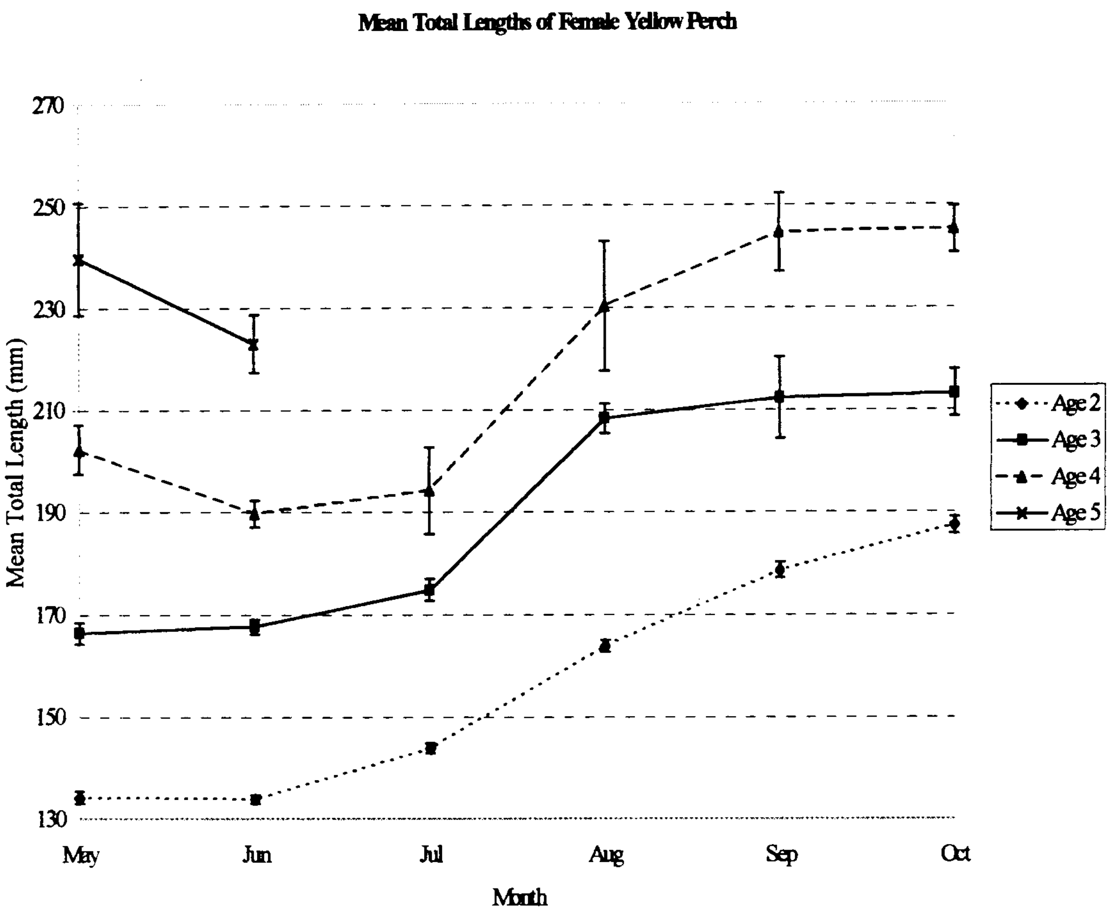

Figure 3. Seasonal changes in length (with standard error bars) of female yellow perch from Lake St. Clair, 1993.

Age 2 females experienced a significant change in length over the growing season (Kruskal-Wallis One-Way ANOVA). Age 3 females grew significantly over the growing season (Kruskal-Wallis One-Way ANOVA). Increase in length from June through August was significant for age 4 females (One-Way ANOVA).

Similar to the females, the period of the greatest increase in length for male perch occurred between July and August and substantial change in length did not occur until July for age 3 and age 4 males (Figure 4).

Mean length decreased slightly for age 3 males between September and October. Length data for age 5 males after June and for age 4 males in September was unavailable due to small sample sizes. Age 2 males increased significantly in length over the growing season (Kruskal-Wallis One-Way ANOVA). Age 3 and age 4 males grew significantly between July and August (One-Way ANOVA).

Fish older than five years of age were not sampled frequently and therefore are not included in the figures. However, it is important to know whether the perch are reaching older ages and if they are still growing. Four age 9 females were sampled in May and had a mean total length of 298.3 mm with 95% confidence limits of 23.6 mm. The oldest fish sampled was an 11 year-old female which was 335 mm in October. When compared to younger females (Figure 3), it appears that the perch are able to reach old age while continuing to grow in substantial amounts.

The growth of Lake St. Clair yellow perch were compared to Michigan averages from Laarman and Schneider (1985). For the months of June and July, Lake St. Clair perch from one to four years of age were 10 mm under the state average. During August-September, Lake St. Clair perch of these same ages were 13 mm above the Michigan average.

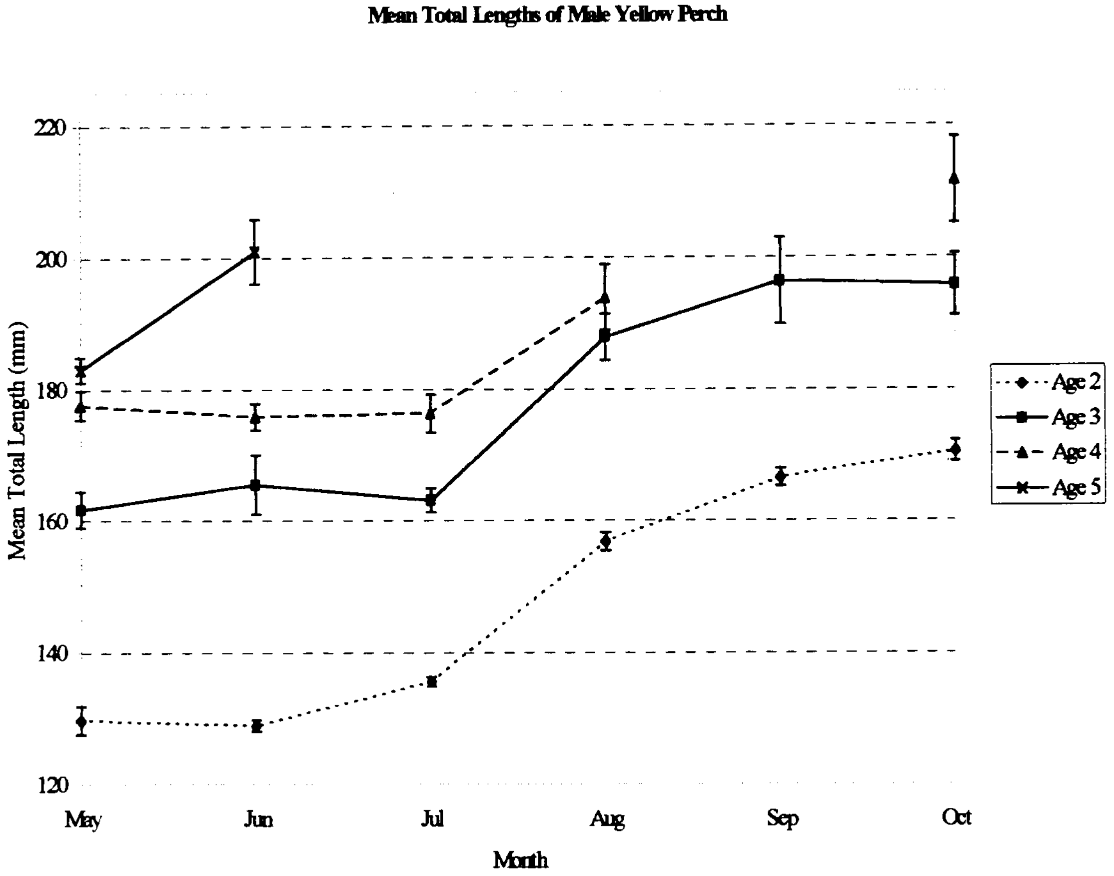

Figure 4. Seasonal change in mean length (with standard error bars) of male yellow perch from Lake St. Clair, 1993.

The October value for Lake St. Clair perch of ages 0-4 was 13 mm above the state average for the months October-December. No sampling was performed after October in Lake St. Clair so only October data were available with which to compare to the Michigan average of October-December.

Growth as Measured by Weight

A listing of wet weights for each age group by month and sex is given in Appendices 1, 2 and 4. Lake St. Clair perch weights are given along with perch from a study conducted in Inner Saginaw Bay from 1986 - 1988 (Haas and Schaeffer, 1992) with the Saginaw Bay perch as an example of a perch population which was growing poorly. Sexes were pooled for age 0 and age 1 perch due to small sample sizes and/or difficulty in distinguishing between sexes. Age 0 Lake St. Clair perch weights increased slowly but steadily over the growing season surpassing those of Saginaw Bay (Figure 5). Age 1 perch from Lake St. Clair were also smaller than age 1 perch from Saginaw Bay during June and July but then dramatically increased in weight from July through September.

For the months in which Lake St. Clair perch could be tested, September for age 0 perch and July, September and October for age 1 perch, there was no significant difference in mean weight between males and females. However, males were generally heavier than females. Age 0 and age 1 perch with sexes pooled grew significantly heavier over the growing season (Kruskal-Wallis One-Way ANOVA). Females of ages 2-5 always had a greater mean wet weight than males although this was not always a significant difference. Both age 2 male and female perch from Lake St. Clair increased greatly in weight from June through October with female weights growing almost linearly during this period (Figure 6). Age 2 females from Lake St. Clair were significantly larger than age 2 males for each month sampled.

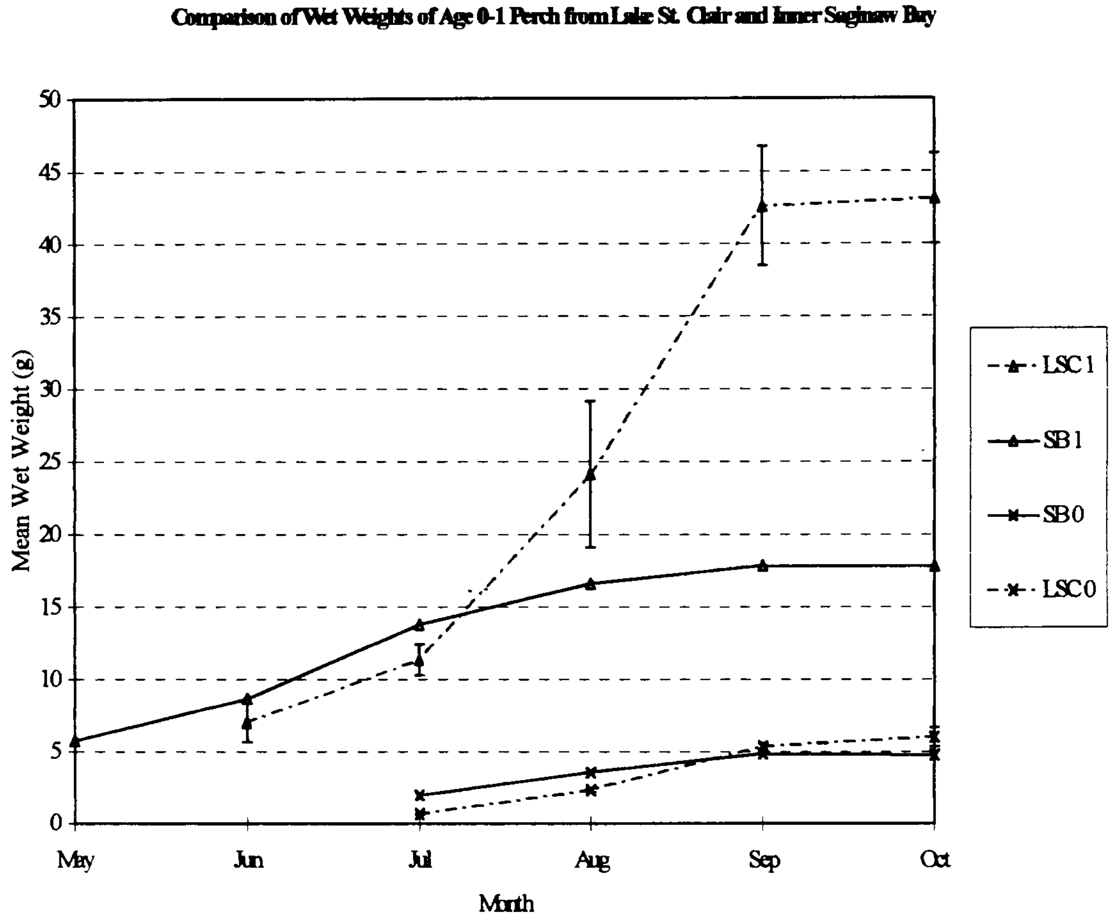

Figure 5. Seasonal change in mean wet weights for age 0 and age 1 yellow perch from Lake St. Clair, 1993 (with standard error bars) and Inner Saginaw Bay, 1986 - 1988. Saginaw Bay data from Haas and Schaeffer (1992). Sexes were pooled.

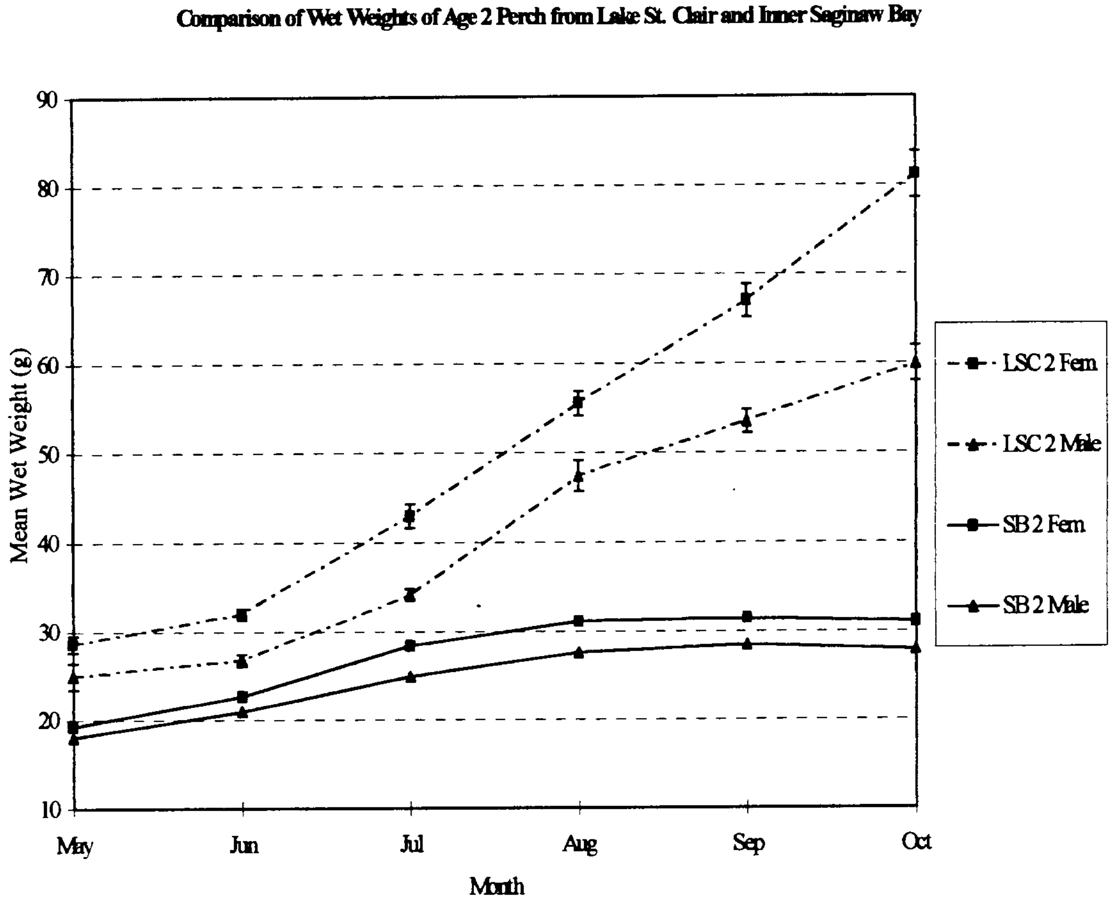

Figure 6. Seasonal change in mean wet weights for age 2 yellow perch from Lake St. Clair, 1993 (with standard error bars) and Inner Saginaw Bay, 1986 - 1988. Saginaw Bay data from Haas and Schaeffer (1992).

Age 2 males and females had a significant increase in wet weight over the growing season (Kruskal-Wallis One-Way ANOVA).

Age 3 females from Lake St. Clair were significantly heavier than age 3 males during the May, July and August sampling dates (Figure 7). There were large confidence intervals most likely due to smaller sample sizes for these two groups during June, September and October. It seems likely that if sample sizes were larger, females would have been shown to be larger than males for these months also. Greatest weight gain occurred between July and September for both sexes and there was a slight decrease in mean weight for females from September to October. Age 3 perch from Lake St. Clair were much heavier than perch from Inner Saginaw Bay. Age 3 females increased significantly in wet weight over the growing season (Kruskal-Wallis One-Way ANOVA). For age 3 males, gain in wet weight was significant between July and August (One-Way ANOVA).

Age 4 females from Lake St. Clair were significantly heavier than age 4 males from May - July and October. In September there were not enough males to perform a statistical test (Figure 8). Greatest weight gain for age 4 females occurred between July and September with a slight loss in mean weight from September to October. Age 4 males gained weight in an almost linear fashion from July through October. Age 4 perch from Lake St. Clair were much heavier than age 4 perch from Saginaw Bay, especially after the month of July. Age 4 males increased significantly in wet weight between July and August while age 4 females increased significantly between July and September (One-Way ANOVA).

Although fish weights are commonly measured "wet", dry weight is a better measure of fish growth because it removes the influence of water which may change seasonally. In addition, the viscera, particularly the gonads, may influence the weight of fish at any given time. Therefore, the weight of dried somatic tissue provides a better picture of body growth.

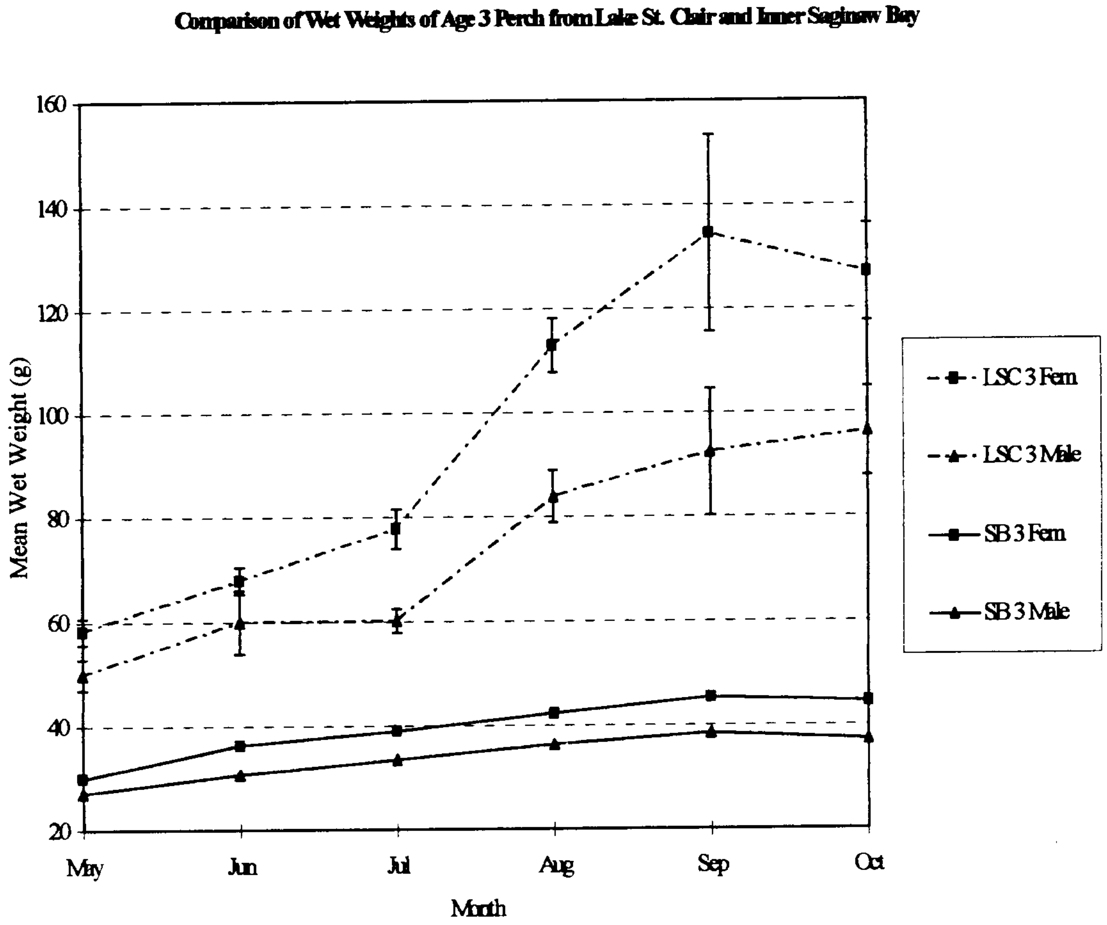

Figure 7. Seasonal change in mean wet weights for age 3 yellow perch from Lake St. Clair, 1993 (with standard error bars) and Inner Saginaw Bay, 1986 - 1988. Saginaw Bay data from Haas and Schaeffer (1992).

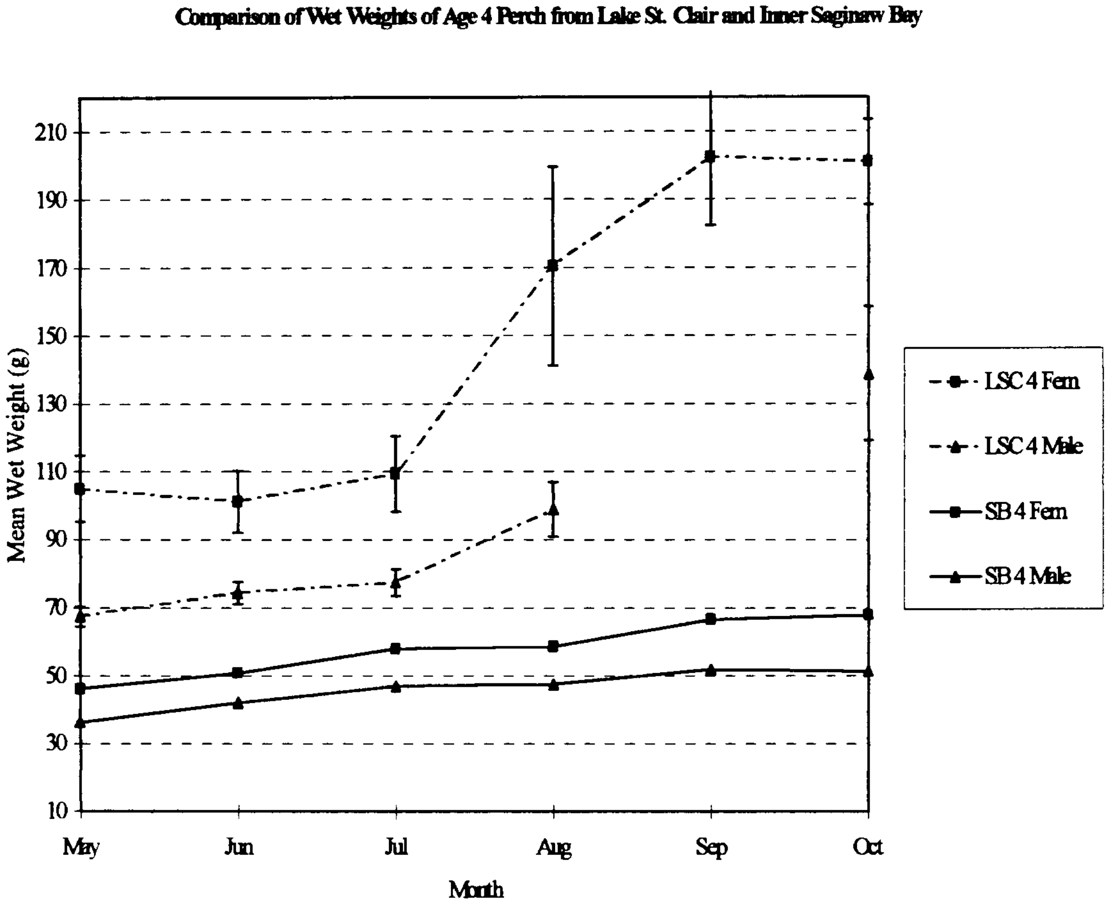

Figure 8. Seasonal change in mean wet weights for age 4 yellow perch from Lake St. Clair, 1993 (with standard error bars) and Inner Saginaw Bay, 1986 - 1988. Saginaw Bay data from Haas and Schaeffer (1992).

Appendices 1-3 list somatic dry weights for each age and sex by month. Most growth occurred in the period between July and September. Growth for age 2 and age 4 males was significant over the growing season (Kruskal-Wallis One-Way ANOVA) (Figure 9). For age 3 males, somatic dry weights became significantly greater in August. Age 5 males were significantly heavier in June than May (t-test for unequal variances). Somatic tissue dry weights changed significantly over the growing season for age 2 females and for age 3 females (Kruskal-Wallis One-Way ANOVA) (Figure 10). For age 4 females, August weights were significantly larger than May weights and September and October weights were significantly heavier than July weights (ANOVA) (Figure 10). Somatic dry weights for age 5 females were greater in June than May but differences were not significant (t-test with equal variances) (Figure 10). Age 0 and age 1 perch also exhibited a significant change in dry weight of somatic tissue over the growing season (Kruskal-Wallis One-Way ANOVA) (Figure 11).

Females of ages 2-5 had greater mean somatic dry weights than males for all months but this was not always significant. Age 2 females were significantly heavier than age 2 males from May-October. Age 3 females had a significantly greater somatic dry weight than age 3 males in July and August. Age 4 females were significantly heavier than age 4 males in May, June, July and October. September weights for age 4 fish could not be compared due to only capturing two males. Age 5 females were significantly heavier than age 5 males in May and June, the only two months when adequate numbers of perch of this age were captured. Age 0 and age 1 females had lower somatic dry weights than males but this was never significant.

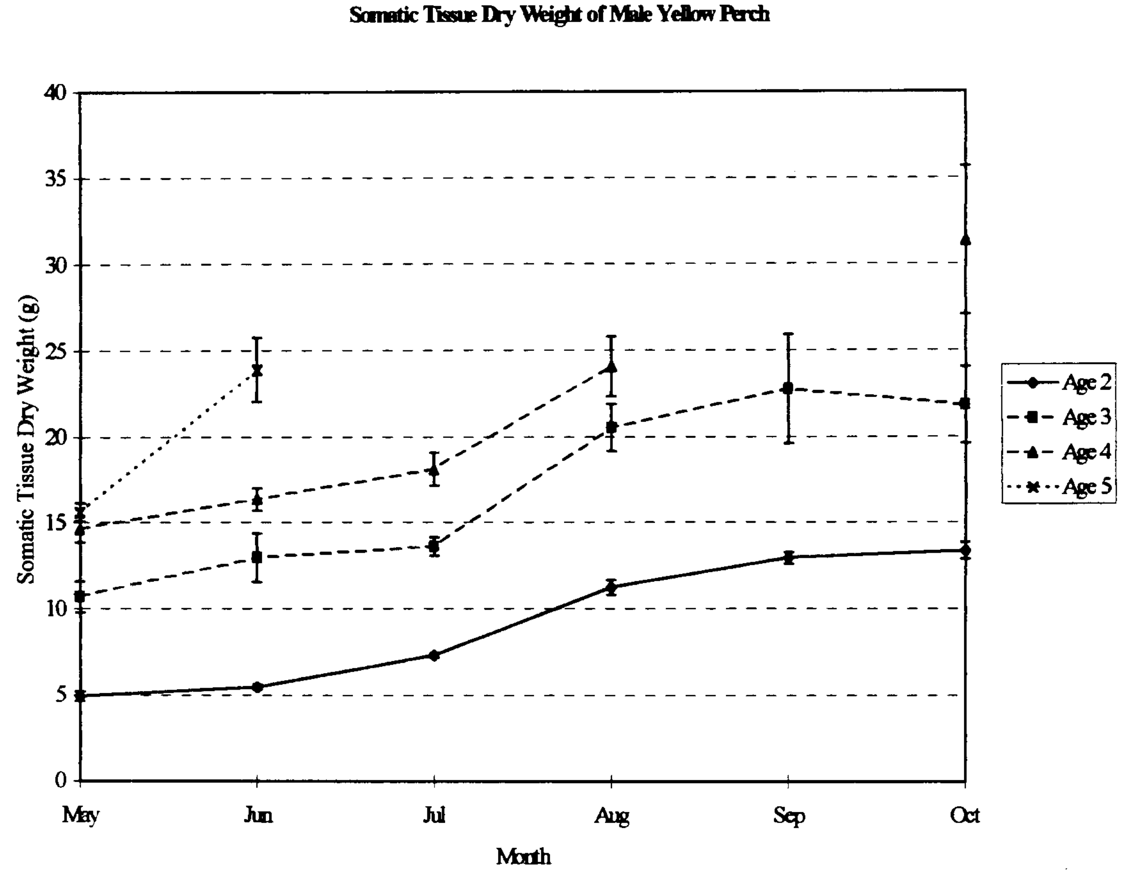

Figure 9. Seasonal changes in dry weight of somatic tissue (with standard error bars) of male yellow perch from Lake St. Clair, 1993. Data for age 5 fish were only available for May and June.

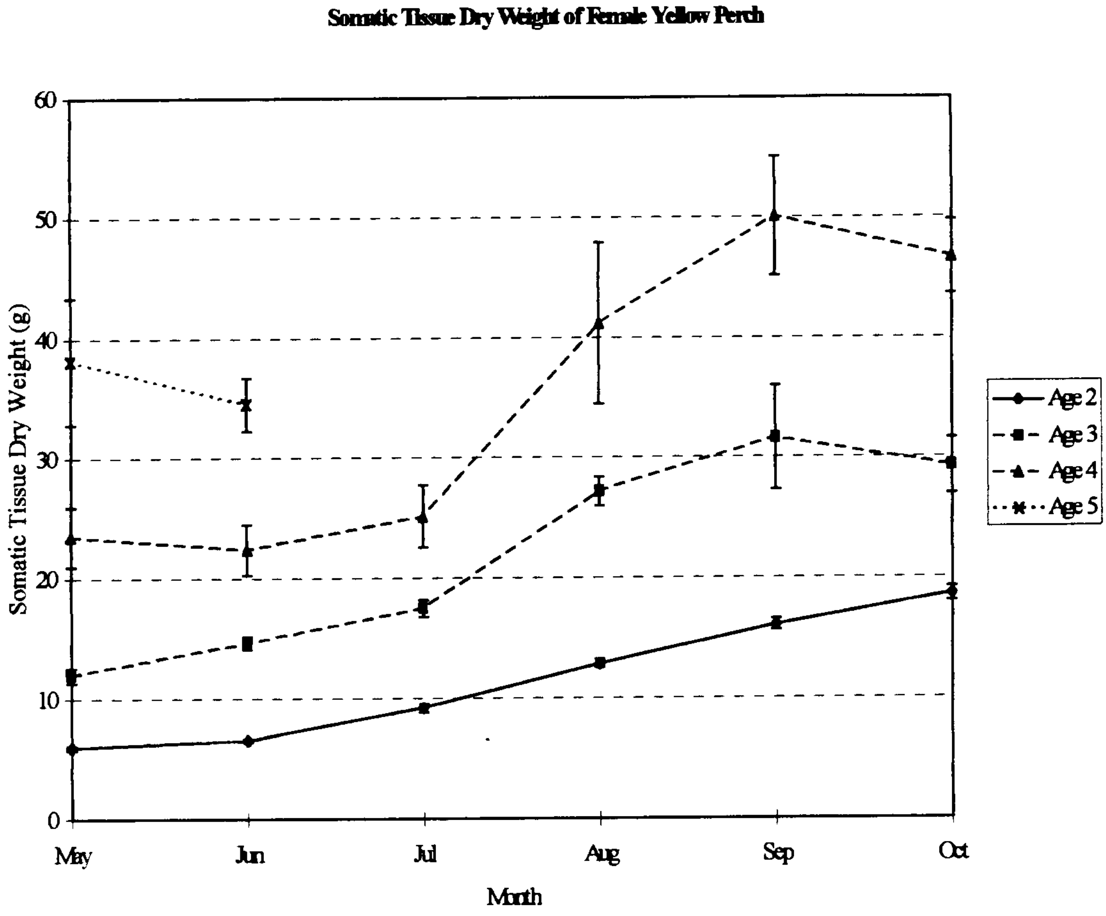

Figure 10. Seasonal changes in dry weight of somatic tissue (with standard error bars) of female yellow perch from Lake St. Clair, 1993. Data for age 5 fish were only available for May and June.

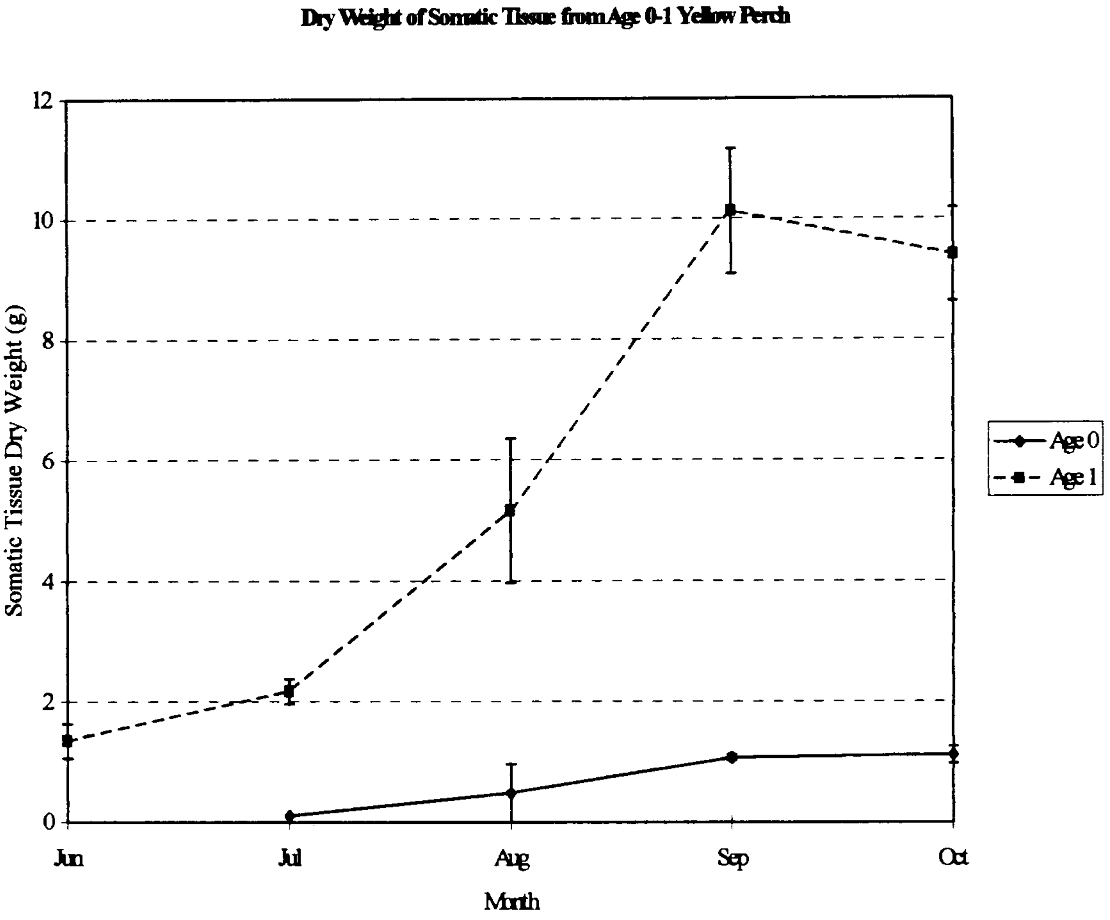

Figure 11. Seasonal changes in dry weight of somatic tissue (with standard error bars) of ages 0-1 yellow perch from Lake St. Clair, 1993. Sexes were pooled.

Somatic Tissue Water Content

Somatic tissue percent water content generally decreased during the summer and then rose from September to October although young-of-the-year perch did not follow this pattern (Figure 12). Age 0 and age 1 perch had a significant change in water content over their growing season (Kruskal-Wallis One-Way ANOVA) (Figure 12).

Somatic water content for age 2-4 males is given in Appendix 2. From May-August, age 2 males had a significant decrease in somatic percent water with each month until September (Figure 13). Water content in October was significantly higher than September (One-Way ANOVA). Age 3 males also had a significant change in percent water (Kruskal-Wallis One-Way ANOVA) and somatic water decreased significantly for age 4 males with each month from May-July (One-Way ANOVA) (Figure 13).

Somatic water content for female perch of ages 2-4 is given in Appendix 2. Water content for age 2 females decreased significantly each month from May-September and increased significantly from September-October (One-Way ANOVA) (Figure 14). A decrease in water content for age 3 females was significant between May and July (One-Way ANOVA) and for age 4 females, somatic water content in May was significantly different from the months July-October (One-Way ANOVA)(Figure 14). Although there was a decrease from June-September, confidence limits were very large and there was no significant difference. In general, for both males and females, the older the fish the lower the somatic water content.

For the most part, there was no significant difference in the somatic tissue water content of males and females. Age 2 males had a significantly higher somatic water content than age 2 females in May and age 1 males had a significantly lower somatic water content than age 1 females in September.

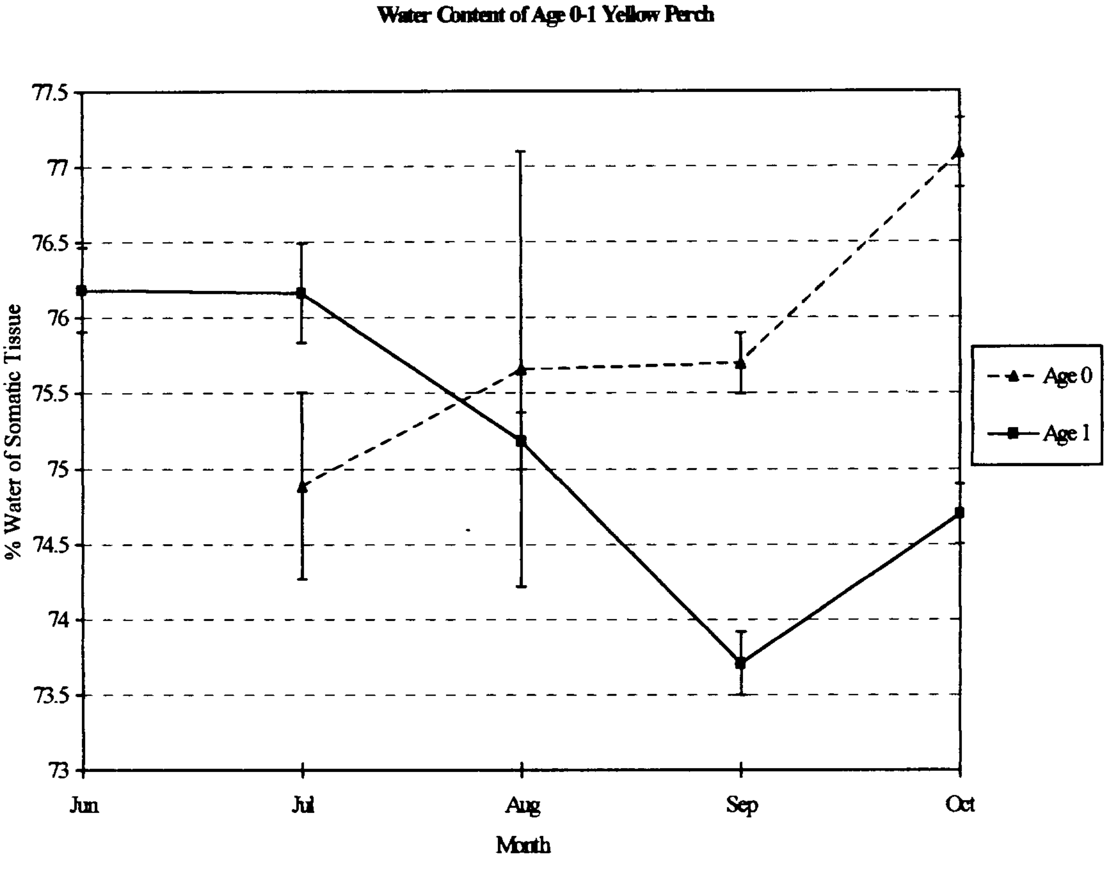

Figure 12. Seasonal changes in somatic water content (with standard error bars) of age 0-1 yellow perch from Lake St. Clair, 1993. Sexes were pooled.

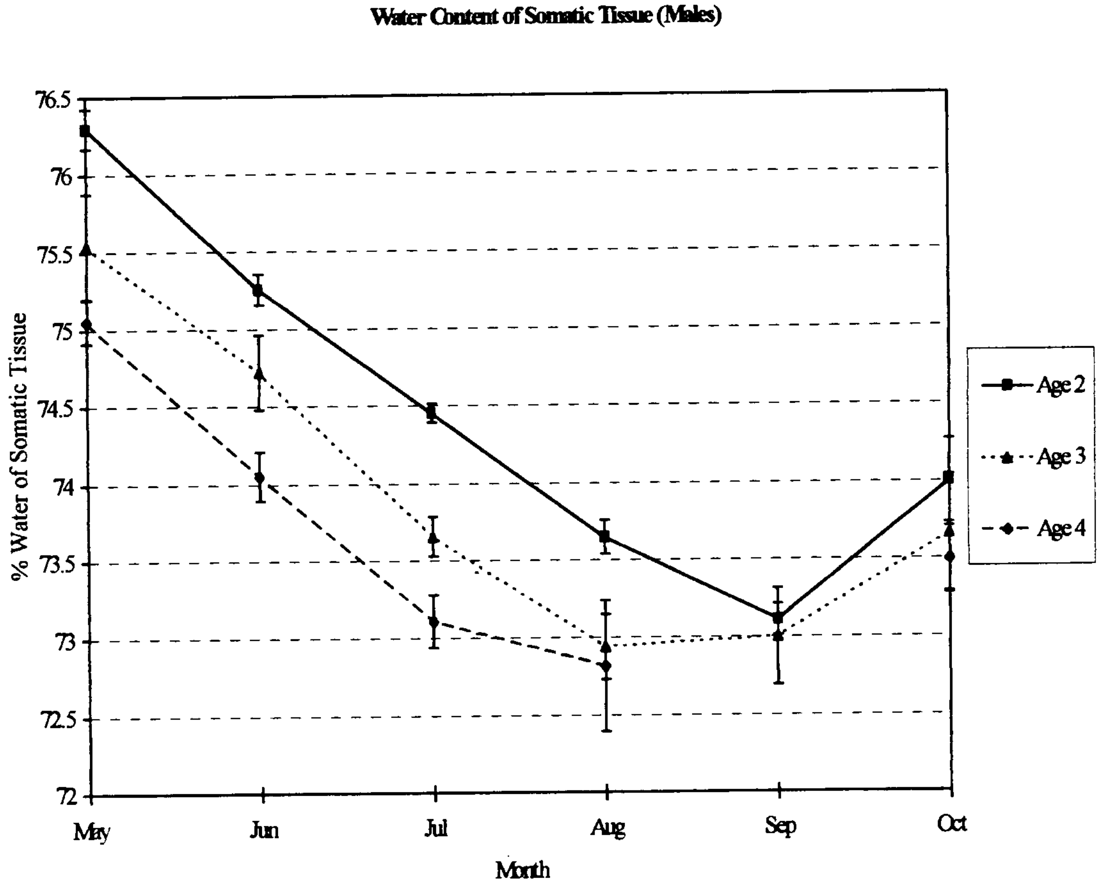

Figure 13. Seasonal changes in somatic water content (with standard error bars) of male yellow perch from Lake St. Clair, 1993. Data for age 4 males in September was unavailable.

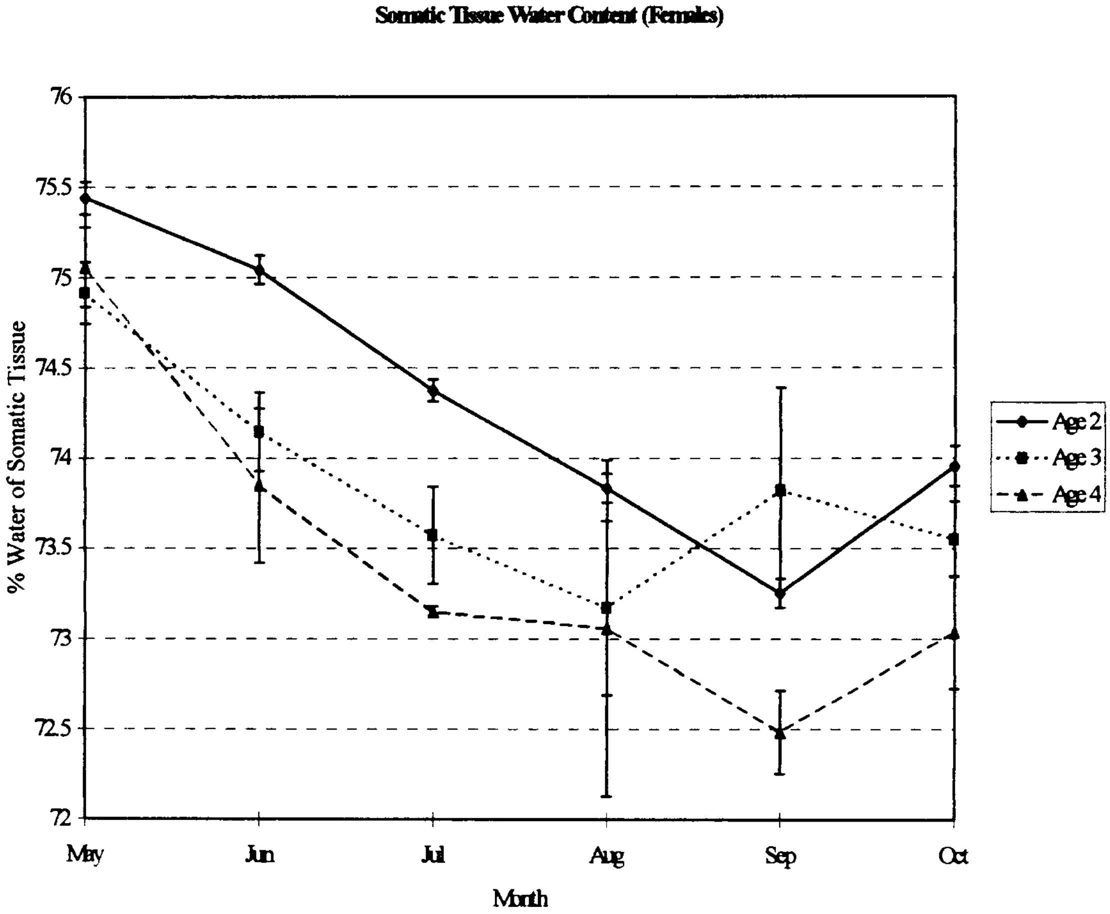

Figure 14. Seasonal changes in somatic water content (with standard error bars) of female yellow perch from Lake St. Clair, 1993.

Parasitic Redworm Occurrence

There were no significant differences in mean numbers of the parasitic redworm (*Eustrongylides tubifex*) between the sexes for any age group at any month. Rarely was more than one redworm found in the mesentaries of a yellow perch (upon cursory examination) that did have an infestation and infestation rates were mostly low (Table 4).

Table 4. Percent of yellow perch from Lake St. Clair, 1993, which contained the parasitic redworm, *Eustrongylides tubifex*.

	Month					
Age	May	Jun	Jul	Aug	Sep	Oct
0	—	—	0	0	0	0
1	—	0	36.4	0	11.1	0
2	3.0	1.2	27.0	2.1	0.8	1.1
3	7.3	0	0	7.7	0	5.3
4	12.8	0	6.7	9.1	0	5.6
5	23.1	0	—	—	—	—

Diet Composition by Mean Numbers of Food Items

Yellow perch of all ages had a varied diet which changed with the seasons (Appendix 5). Occasionally some of the stomachs examined contained unidentifiable tissue chunks as the only diet item or were empty. These were not included in the figures below but are noted in the text. For age 0 fish, the diet was predominantly zooplankton in July while age 1 fish declined zooplankton and foraged on benthic invertebrates (Figure 15). One age 1 fish had unidentifiable tissue in its stomach.

The number of zooplankton eaten by age 0 perch decreased greatly in August and amphipods became the predominant item for both age 0 and age 1 fish (Figure 16). Forage fish was eaten by one young-of-the-year perch. One age 0 stomach was empty and one age 0 stomach contained unidentifiable tissue.

July Diet of Yellow Perch of Ages 0-1

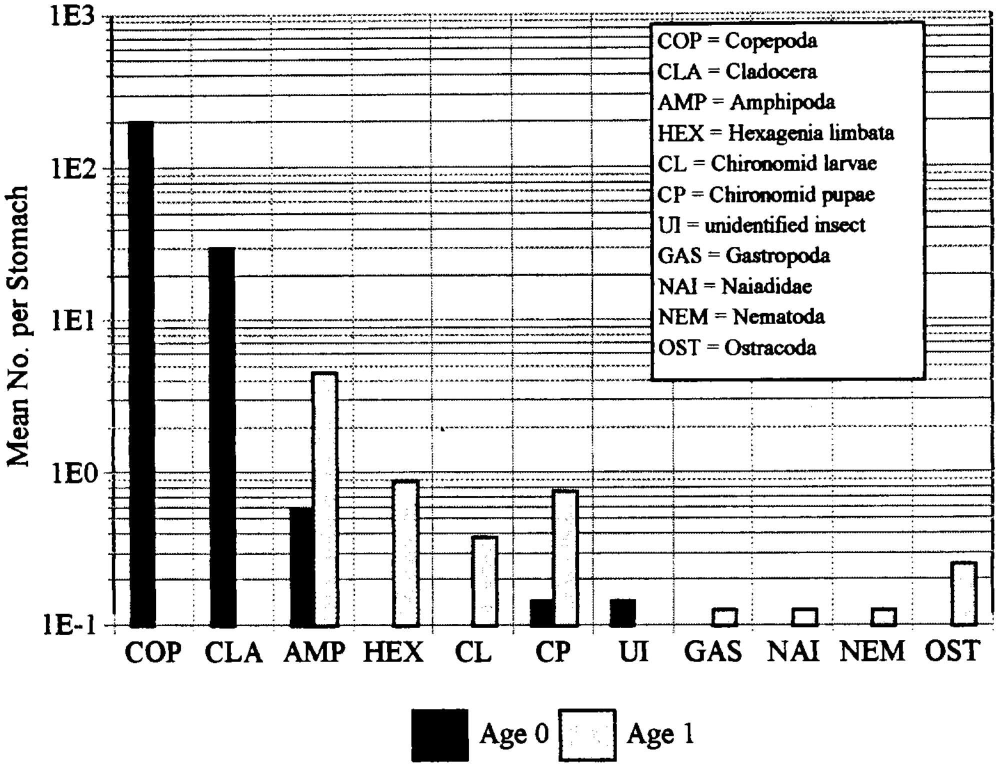

Figure 15. Mean numbers of organisms per stomach. Note that the Y-axis scale is logarithmic and sexes are pooled. For age 0 fish, n = 14 and for age 1 perch, n = 8.

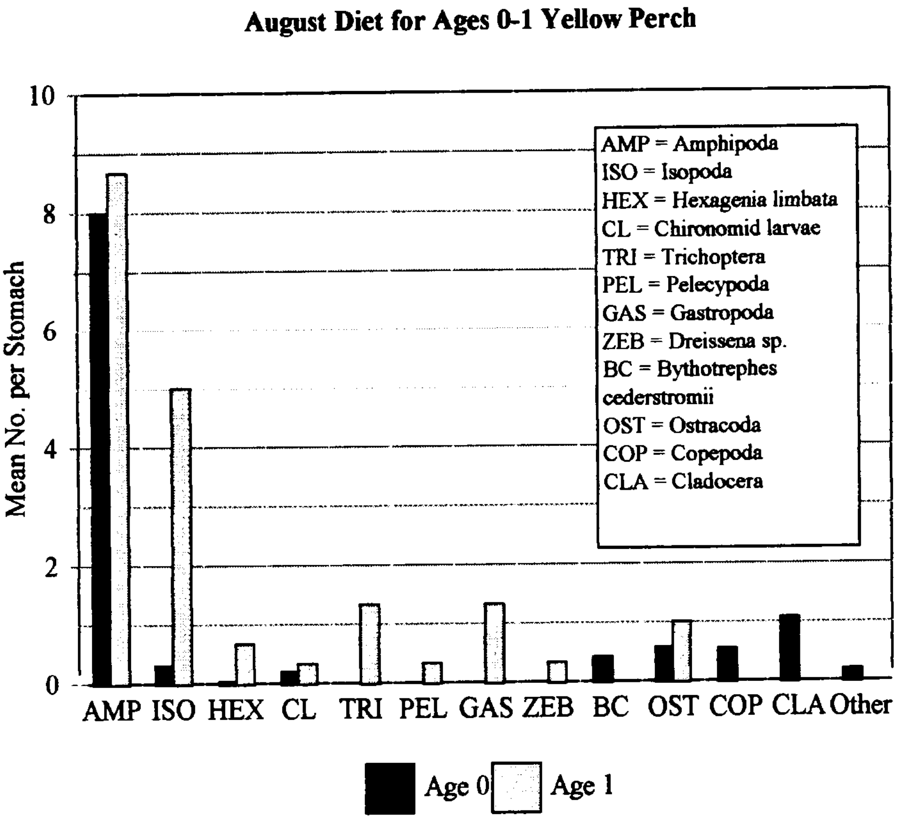

Figure 16. Mean number of organisms per stomach with sexes pooled. The category "Other" represents items which were found in less than ten percent of all stomachs of age 1 fish and includes forage fish, chironomid pupae, Trichoptera, unidentified insects and Hirudinea. For age 0 fish, n = 39 and for age 1 fish, n = 3.

Bythotrephes cederstromii were consumed heavily in September by age 1 fish (Figure 17). The number of amphipods and *Hexagenia* was similar to the month of August for both age 0 and age 1 perch. Seven age 0 and one age 1 perch contained empty stomachs. Unrecognizable tissue pieces were seen in three age 0 and four age 1 perch. During October, age 0 perch again consumed similar amounts of amphipods as the previous two months and an increased number of Trichoptera (Figure 18). A seasonal supply of Corixidae was also taken advantage of. Age 1 perch fed readily on gastropods, *Orconectes*, and fish (Figure 18). One age 0 stomach was empty. Unidentifiable tissue was encountered in one age 0 and four age 1 fish.

For older fish, two to five years of age, the May diet consisted mostly of amphipods and isopods with a mean of almost 60 amphipods per stomach of age 5 fish (Figure 19).

in their stomachs. Three 2 year-olds and one 4 year-old had empty stomachs and seven fish in the age 2-5 year classes contained unidentifiable tissue in their stomachs. In June, the diet for ages 2-5 fish was similar with *Hexagenia* found in greater numbers in age 5 fish (Figure 20). There were no empty stomachs but 20 held unrecognizable tissue in these age groups.

In July, the number of amphipods per stomach dropped (Figure 21). Sample sizes for age 5 fish in July , August, September and October were small and these fish are not shown in figures. No stomachs were empty for ages 2-4 but four stomachs in these age classes held unidentifiable tissue. In August, age 3 fish consumed mostly gastropods and amphipods. Age 2 and age 4 fish ate much fewer gastropods. Forage fish were seen more frequently in the stomachs (Figure 22). One age 2 fish had an empty stomach and 34 fish of the ages 2-4 contained unidentifiable tissue.

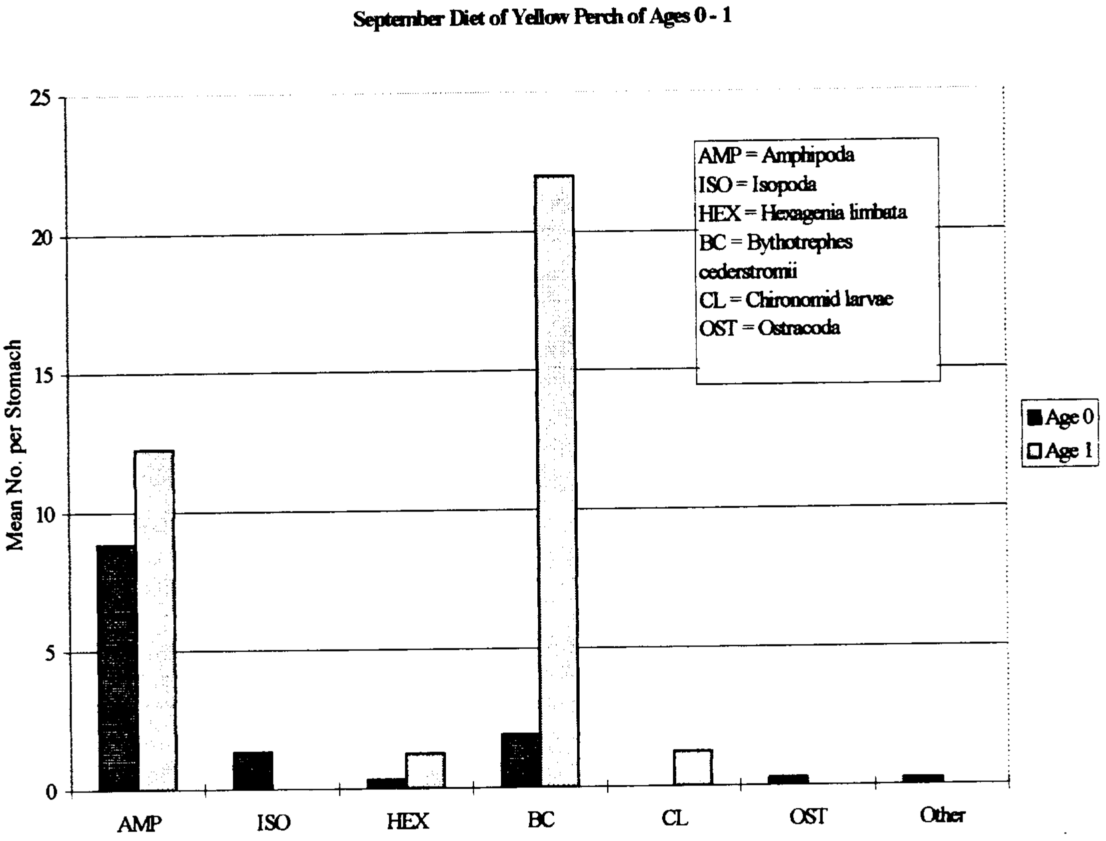

Figure 17. Mean number of organisms per stomach. The category "Other" indicates items which were found in less than ten percent of age 0 fish and includes chironomid larvae, Trichoptera, unidentified insects, Hirudinea and Copepoda. For age 0 perch, n = 42 and for age 1 perch, n = 4.

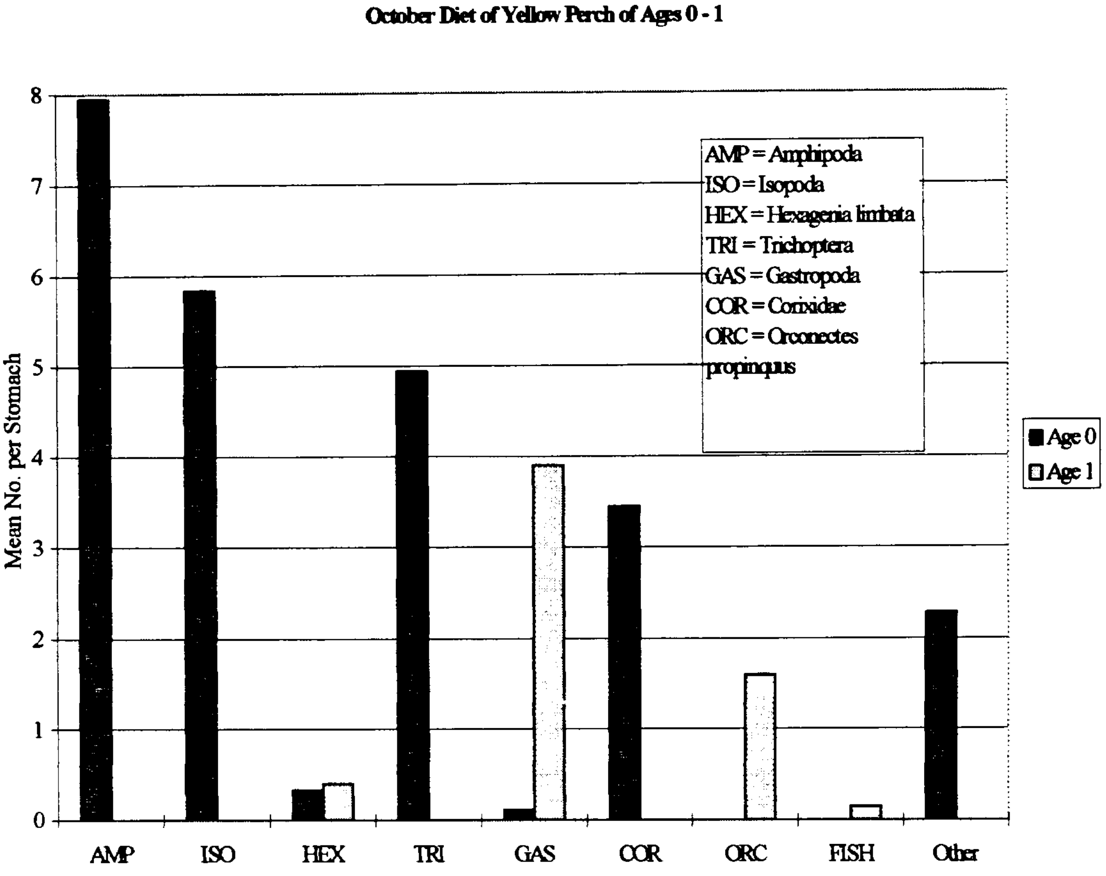

Figure 18. Mean number of organisms per stomach. The category "Other" represents items with were found in less than ten percent of all age 0 stomachs and includes *Bythotrephes cederstromii*, chironomid larvae and fish. For age 0 perch, n = 18 and for age 1 perch, n = 10.

May Diet of Yellow Perch of Ages 2-5

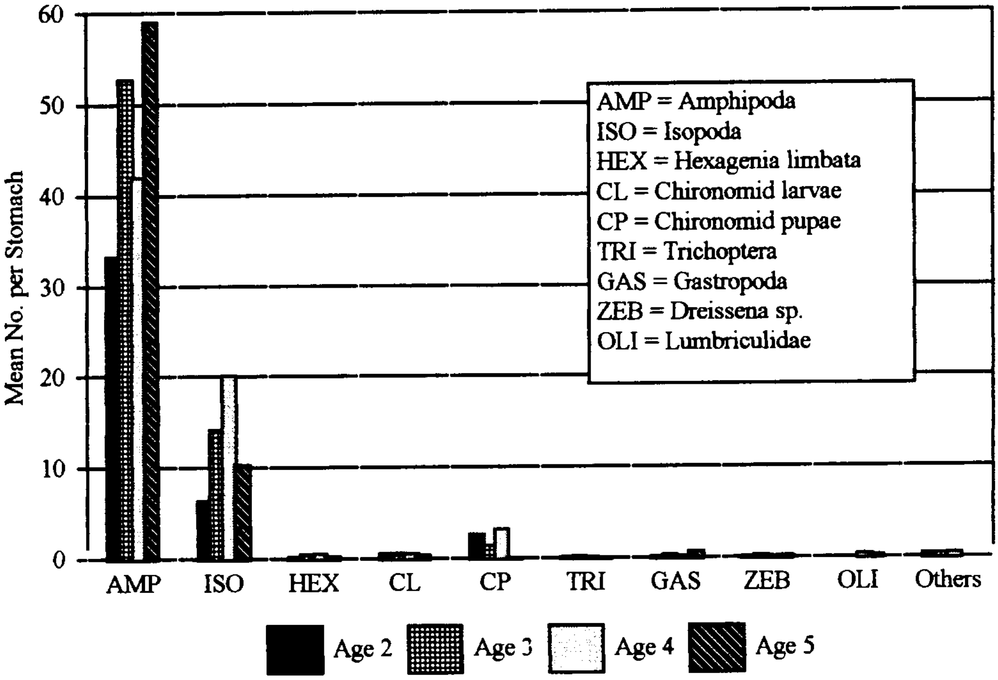

Figure 19. Mean number of organisms per stomach. Sexes were pooled. The category "Other" indicates items which were found in less than ten percent of all stomachs for each year class. For age 2 fish, "Other" = Cladocera, *Bythotrephes cederstromii*, Ostracoda, unidentified mayfly naiads, Pelecypoda, unidentified insects, Hirudinea, fish, Lumbriculidae, Copepoda and *Mysis* sp. For age 3 fish, "Other" = Lumbriculidae, *Mysis* sp., Ostracoda, *Dannella*, unidentified mayfly naiads, Pelecypoda, unidentified insects and Hirudinea. For age 4 fish, "Other" = Nematoda, *Mysis* sp., *Orconectes*, fish, Pelecypoda and Hirudinea. For the age 2 year class, n = 157, for age 3 fish, n = 40, for age 4 fish, n = 36 and for age 5 perch, n = 10.

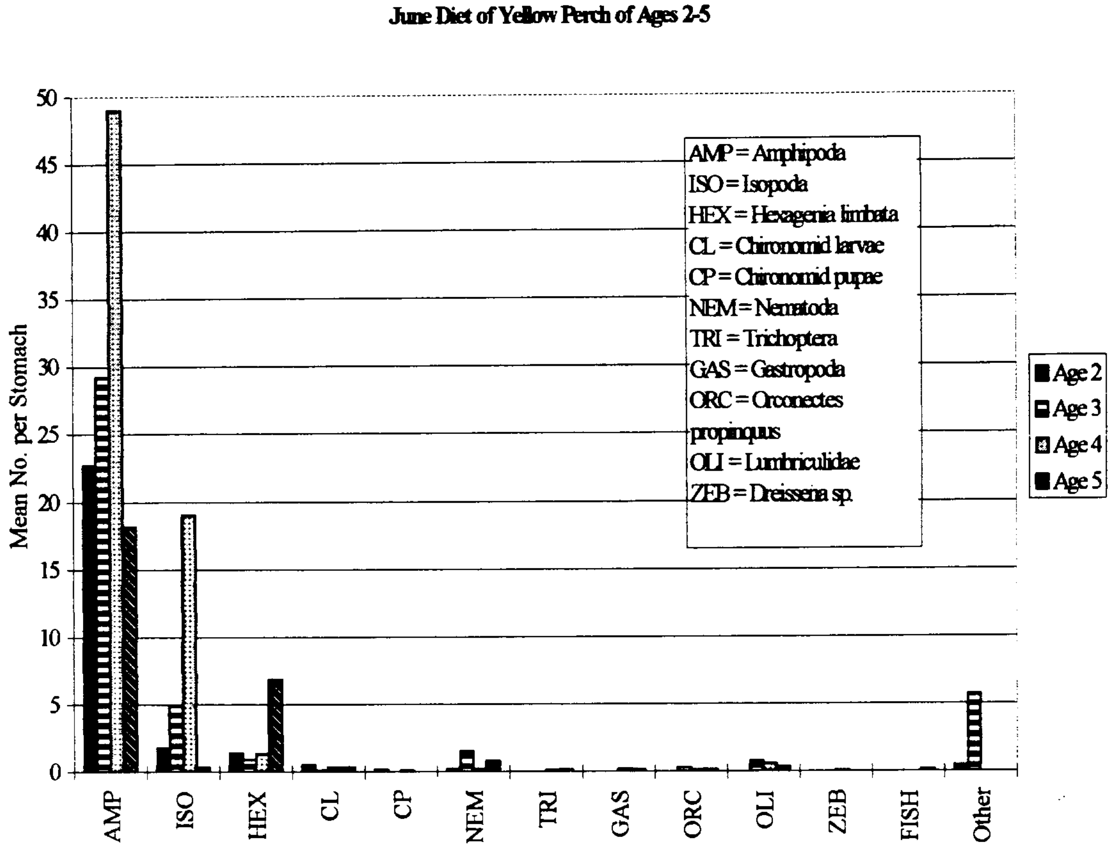

Figure 20. Mean number of organisms per stomach. Sexes were pooled. The category "Other" represents items found in less than ten percent of all stomach in each age-class. For age 2 fish (n = 176), "Other" = *Mysis* sp., Ostracoda, *Orconectes* sp., Trichoptera, Pelecypoda, Gastropoda, Hirudinea, *Dreissena* sp. and Lumbriculidae. For age 3 fish (n = 18), "Other" = unidentified eggs, chironomid pupae, fish and *Dreissena* sp. For age 4 perch, n = 17 and for age 5 fish, n = 6.

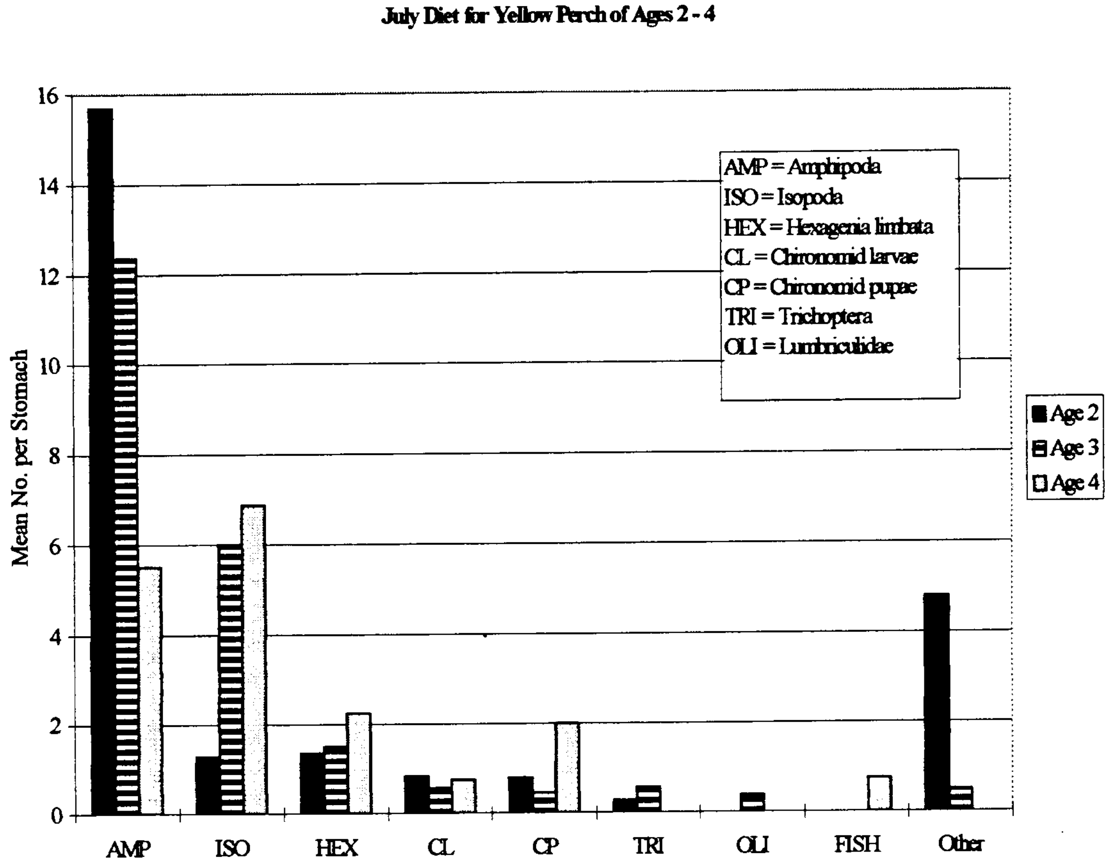

Figure 21. Mean number of organisms per stomach. Sexes were pooled. The category "Other" represents items which were found in less than ten percent of all stomachs for each age class. For age 2 fish (N = 159), "Other" = lepidopteran larvae, Pelecypoda, Gastropoda, unidentified insects, Hirudinea, fish, *Dreissena* sp., Lumbriculidae, Nematoda, *Mysis* sp., Coleoptera, Ostracoda, unidentified eggs, *Caenis* sp. and unidentified mayfly naiads. For age 3 perch (n = 16), "Other" = lepidopteran larvae and Pelecypoda. For age 4 fish, n = 8.

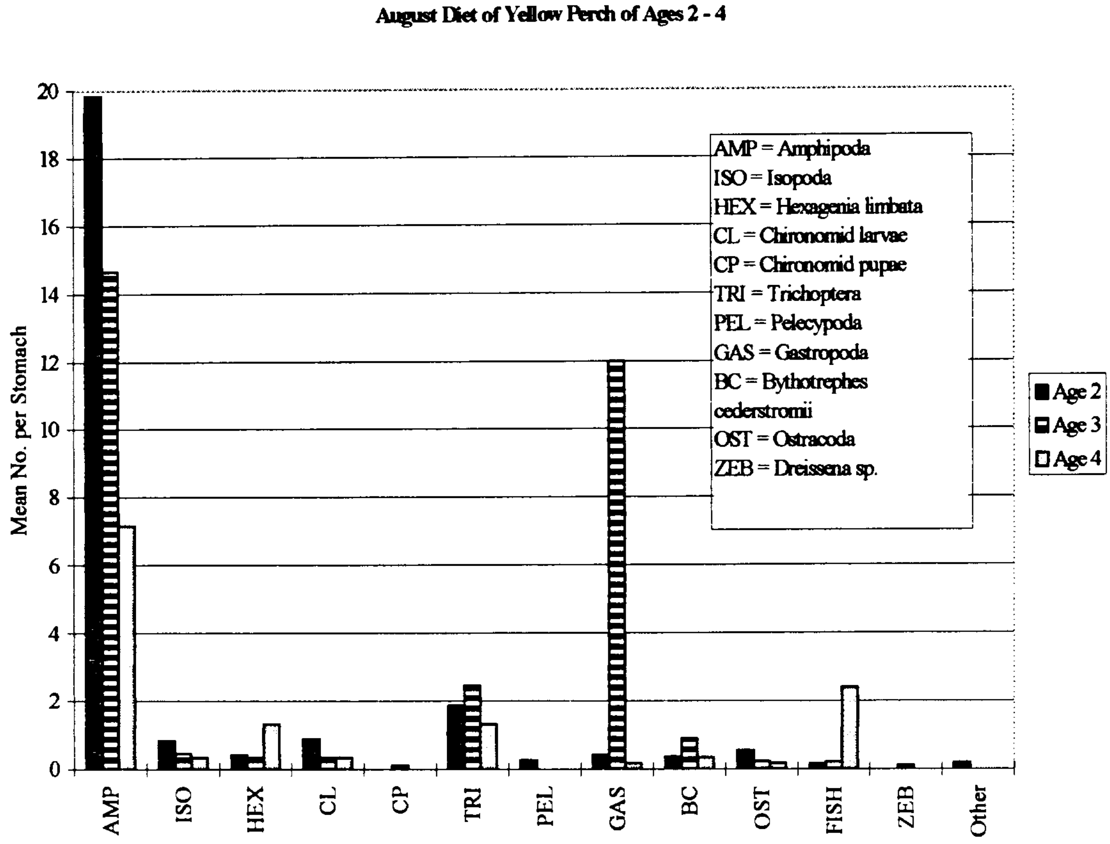

Figure 22. Mean number of organisms per stomach. Sexes were pooled. The category "Other" represents items found in less than ten percent of all stomachs for each age class. For age 2 fish (n = 167), "Other" = chironomid pupae, unidentified insects, Hirudinea, Nematoda, *Mysis* sp., Cladocera, *Dreissena* sp. and *Orconectes* sp. For age 3 fish, n = 9 and for age 4 perch n = 6.

In September, *Bythotrephes cederstromii* were found in good numbers in age 2 fish but were not eaten as readily by age 3 fish. The crayfish *Orconectes* became more numerous (Figure 23). Six 2- and 3- year olds had empty stomachs and 19 others in these age classes contained unidentifiable tissue. The only 4 year olds (n = 3) contained this unidentifiable tissue and, therefore, are not included in the figure. In October, total numbers of items in the stomachs for fish of ages 2-4 decreased tremendously. However, the items which were consumed were generally larger, mainly *Orconectes* and fish (Figure 24). One 2 year old had an empty stomach and 42 stomachs of ages 2-4 fish held unidentifiable tissue contents.

Diet Composition by Weight

Analysis of the diet by weight of the food items gives a better indication of the contribution of a particular diet item. For age 0 perch, amphipods made up the greatest proportion of the diet by weight in September (Figure 25). During October, the main diet item by weight was the mayfly naiad *Hexagenia limbata*. It should be noted that even though ostracods were found in 11.9% of age 0 fish they were not included in Figure 25 because weight data was unavailable. Error is assumed to be small due to ostracods' small size. Only data for September and October are given, as weights for certain diet items in July and August were not available.

The diet of age 1 perch is illustrated in Figure 26. Seasonal changes are apparent. As the amount of *Hexagenia* in the diet decreased, the weight of amphipods increased but both were dominant in the diet. When these two items decreased in the stomachs in October, the dominant item by weight became the crayfish *Orconectes propinquus*.

There was an obvious seasonal pattern to the diet of age 2 perch. During May, June and July the dominant food items by dry weight were the large, benthic invertebrates amphipods, isopods and *Hexagenia limbata*. In August, age 2 yellow perch switched to fish and for the rest of the growing season fish, mollusks and crayfish made up the largest part of the diet (Figure 27).

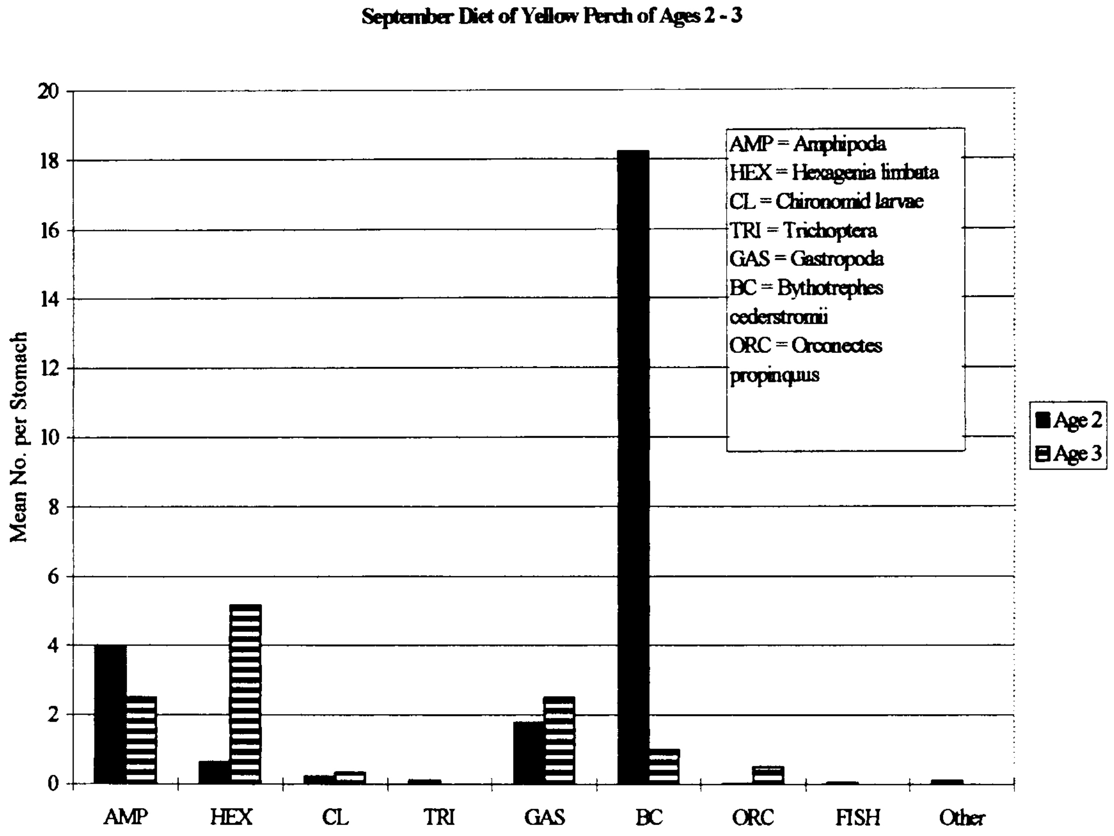

Figure 23. Mean number of organisms per stomach. Sexes were pooled. The category "Other" represents items found in less than ten percent of all stomachs of age 2 fish. For age 2 perch (n = 93), "Others" = Isopoda, Pelecypoda, chironomid pupae and Hirudinea. For age 3 perch, n = 6.

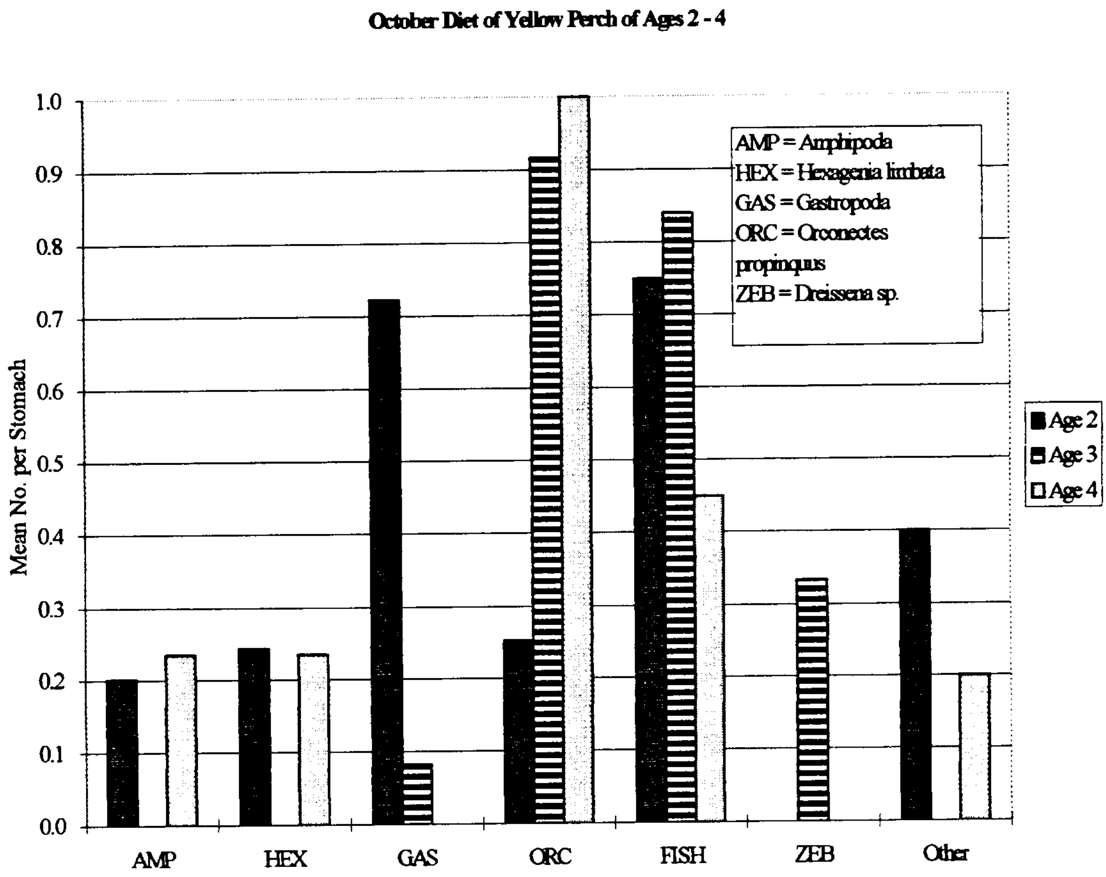

Figure 24. Mean number of organisms per stomach. Sexes were pooled. The category "Other" represents items which were found in less than ten Percent of all stomachs for each age class. For age 2 fish (n = 119), "Others" = Trichoptera, Dreissena sp., Nematoda, Ostracoda, Corixidae and Isopoda. For age 4 fish (n = 17), "Other" = Ostracoda and Isopoda. For age 3 perch, n = 12.

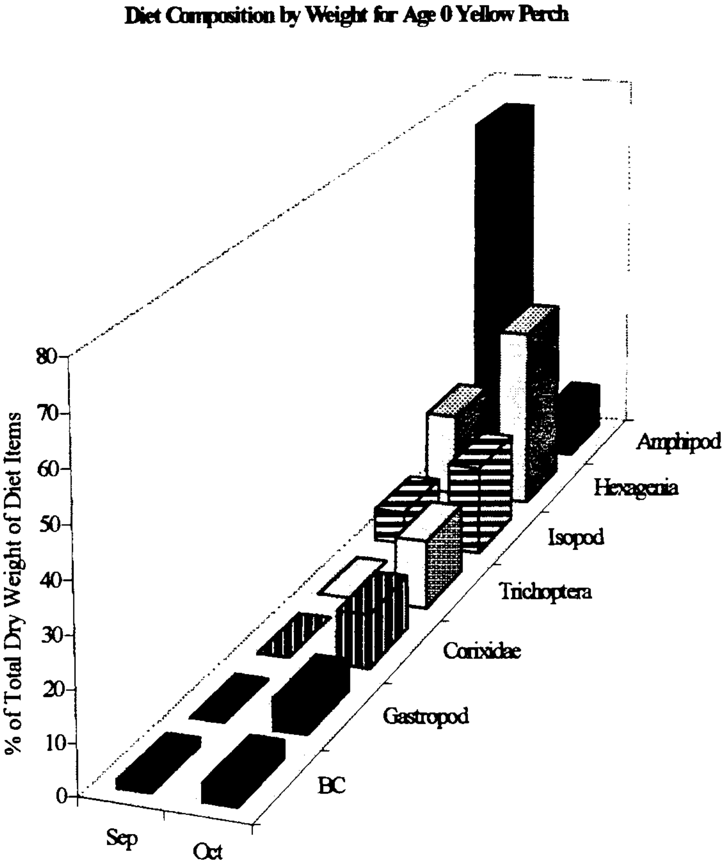

Figure 25. Diet as a percent of total dry weight of all food items. Sexes were pooled. "BC" stands for *Bythotrephes cederstromii*. Only diet items found in approximately 10% or more stomachs were included.

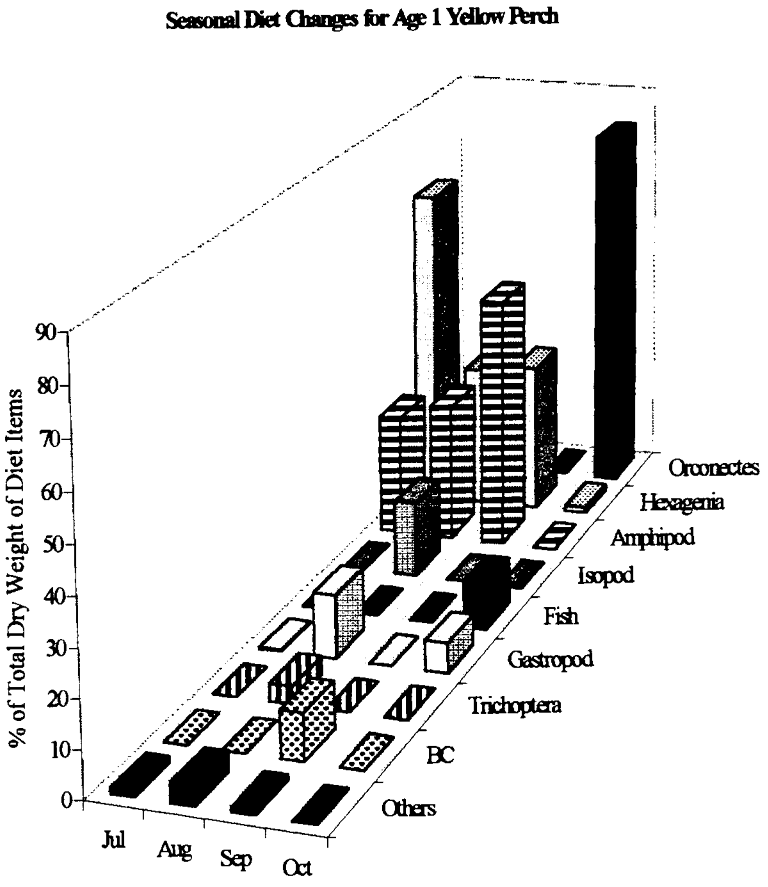

Figure 26. Diet as a percent of total dry weight of food items. Only diet items found in approximately 10% or more stomachs were included. Sexes were pooled. The category "Others" represents chironomid larvae, chironomid pupae, *Dreissena* sp. and other Pelecypoda.

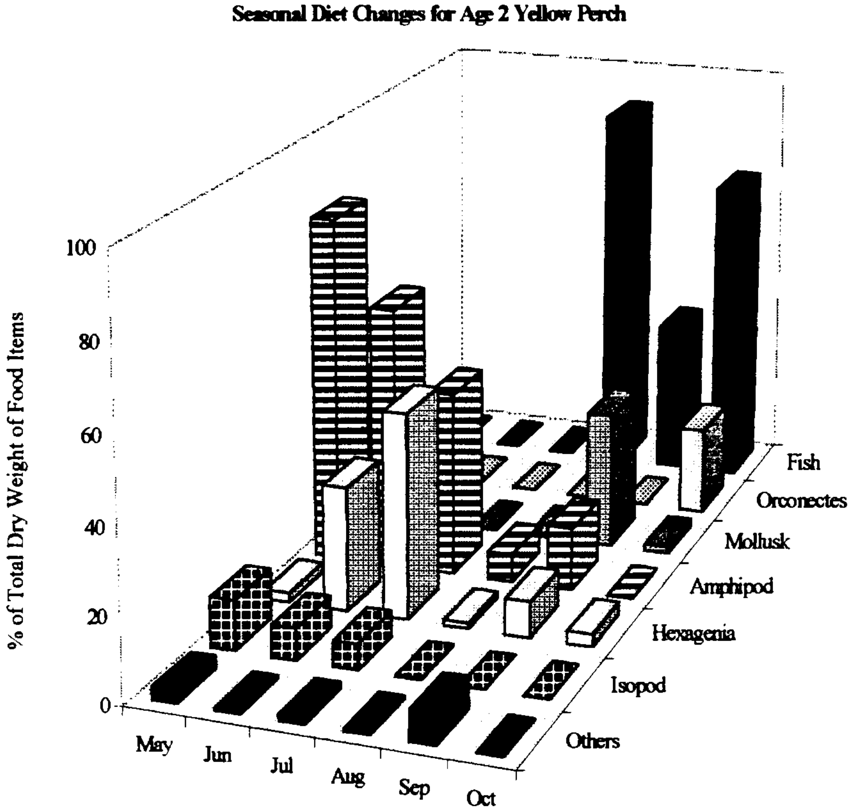

Figure 27. Diet as a percentage of the total dry weight of food items. Sexes were pooled. The category "Others" represents chironomid larvae, chironomid pupae, Trichoptera and *Bythotrephes cederstromii*. Only items found in approximately 10% or more stomachs were included.

It should be noted that even though unidentified Nematoda were in over 10% of all age 2 stomachs (13.9%) in June, they were not included in Figure 27 due to their minute size which made weight data unavailable. This is also the case for ostracods in August (found in 26.3% of age 2 stomachs). Any errors in the total make-up of the diet by weight were considered small due to these organisms' diminutive sizes.

The diet of age 3 and age 4 fish by weight was very similar to that of age 2 fish. During May, June and July amphipods, isopods and *Hexagenia limbata* were dominant items by weight although for age 3 perch, forage fish were also numerous in June (Figures 28 and 29). During the months of August - October, gastropods, the crayfish *Orconectes propinquus* and fish were the most important items for age 3 perch. For age 4 fish, *Orconectes propinquus* and fish were the outstanding diet items in August and October. Unidentified Nematoda were not included in Figure 28 in June even though these were identified in 22.2% of age 3 stomachs because weight data was unavailable. Unidentified Nematoda were not reported in Figure 29 in June nor Ostracoda in August (identified in 17.6% and 16.7% of age 4 stomachs) due to unavailable weight data. Any misrepresentation this caused was considered small due to their minute sizes.

Diet Composition by Caloric Value

An analysis of diet by caloric value is the most meaningful of all types of diet analyses if true caloric measurements of the food items are obtained. However, most studies including the present one, rely on general caloric values from the literature. Therefore, to understand which food items contribute most substantially to the diet, weight of the food items and caloric value should be considered. During September and October, almost 80% of the caloric intake of age 0 perch was obtained by feeding on amphipods and *Hexagenia limbata* (Figure 30). Although ostracods were found in 11.9% of stomachs in September they are not included in Figure 30. Any error this might cause is considered small due to the minute size of the ostracods.

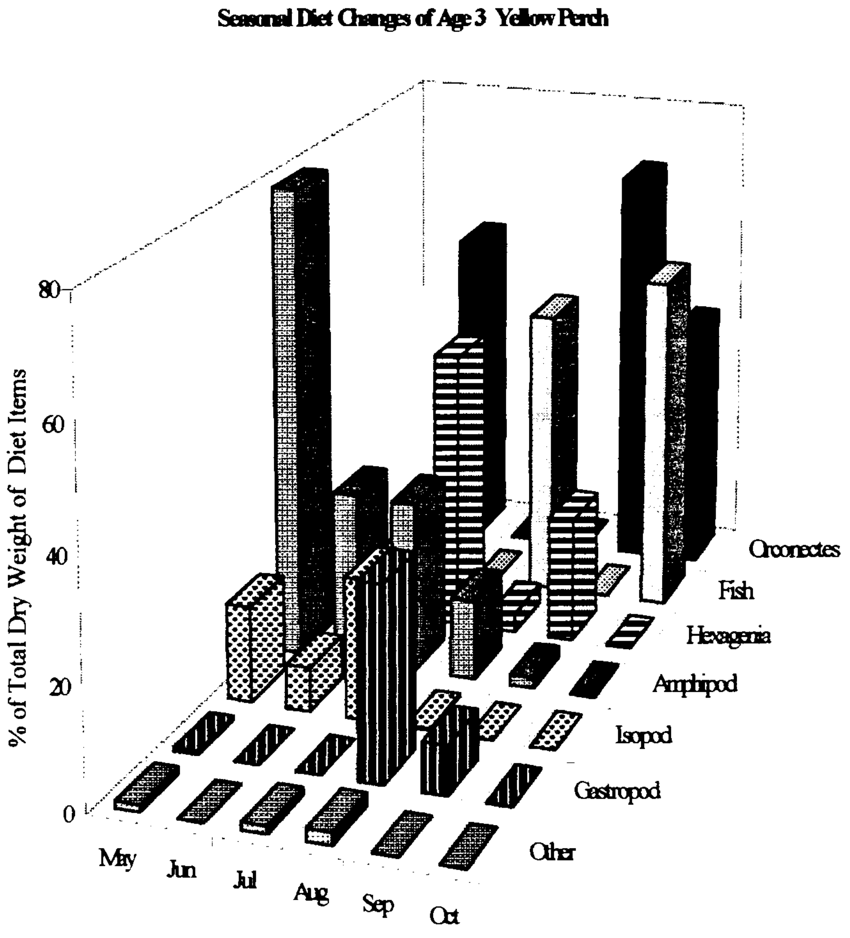

Figure 28. Diet as a percentage of the total dry weight of food items. Sexes were pooled. Only items found in approximately 10% or more stomachs were included. The category "Other" represents *Dreissena* sp., Lumbriculidae and *Bythotrephes cederstromii*.

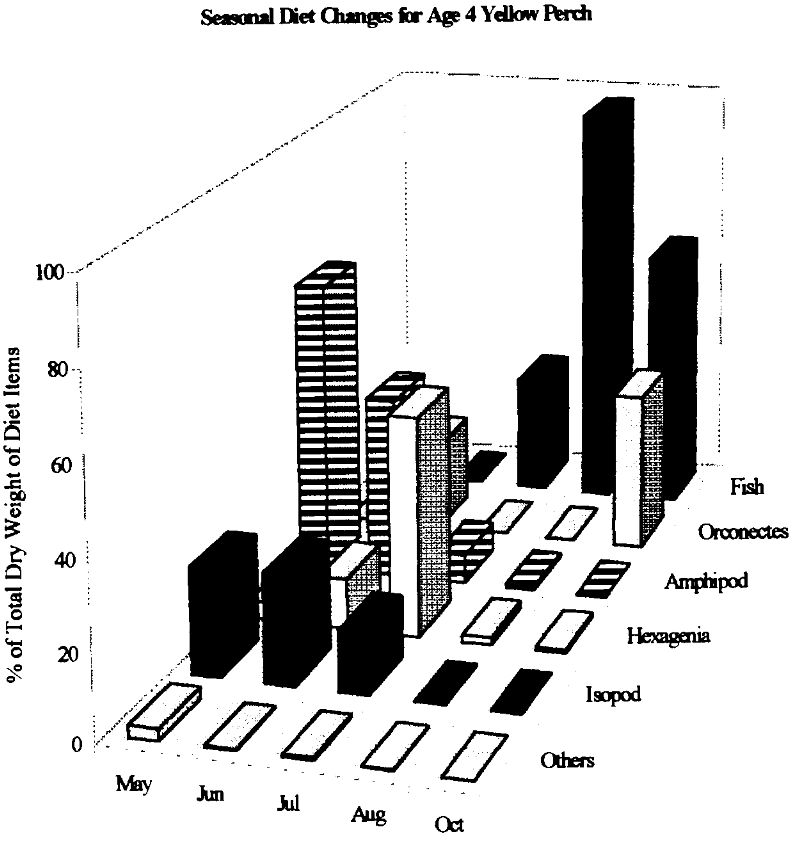

Figure 29. Diet as a percentage of the total dry weight of food items. Sexes were pooled. Only items found in approximately 10% or more stomachs were included. The category "Others" includes chironomid larvae, chironomid pupae, Trichoptera, Gastropoda, Bythotrephes cederstromii, Dreissena sp. and Lumbriculidae. September data was not included due to small sample sizes.

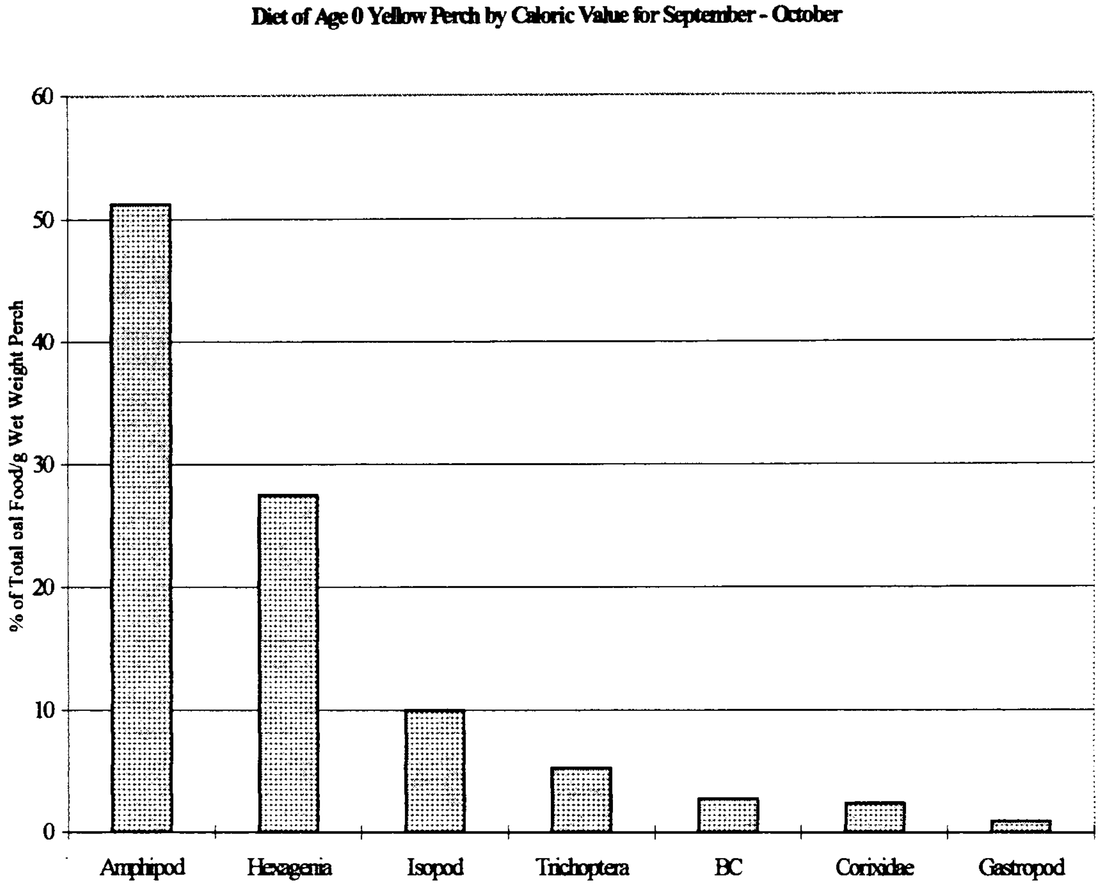

Figure 30. Diet composition according to the caloric value of prey items. Sexes were pooled. Only items that were found in approximately 10% or more perch stomachs were included.

From July-October, over 70% of all calories ingested by age 1 perch were supplied by *Orconectes propinquus* and *Hexagenia limbata* (Figure 31).

Amphipods and fish contributed greatly to the diet of age 2 yellow perch (Figure 32). *Hexagenia limbata* also made up a substantial portion of the total caloric intake. It must be noted that although Nematoda and Ostracoda occurred in over 10% of the stomachs (13.9% and 26.3% in June and August, respectively), they were not included in Figure 32 due to unavailable weight data. Any misrepresentation this poses is considered small due to the small size and numbers of these organisms.

For age 3 yellow perch, amphipods, *Orconectes propinquus* and fish all contributed about equally to the caloric intake from May - October, almost 70% of the total amount of calories (Figure 33). Hexagenia limbata made up about 16% of all calories. It must be noted that the June data in Figure 33 does not include Nematoda even though they were identified in 22.2% of age 3 stomachs because weight data were unavailable. Any error this might pose was considered small as these organisms were minute and not found in large numbers.

For age 4 perch, forage fish constituted about 45% of the total caloric intake from May - August and October (Figure 34). September data were unavailable due to small sample sizes. Amphipods, *Hexagenia limbata* and isopods together made up about 46% of the total calories ingested. Although Nematoda and Ostracoda were found in the stomachs in greater than 10% of the stomachs (17.6% in June and 16.7% in August, respectively), they were not included in Figure 34 due to unavailable weight data. Any misrepresentation this may have caused was considered small due to these organisms' minute sizes and small numbers.

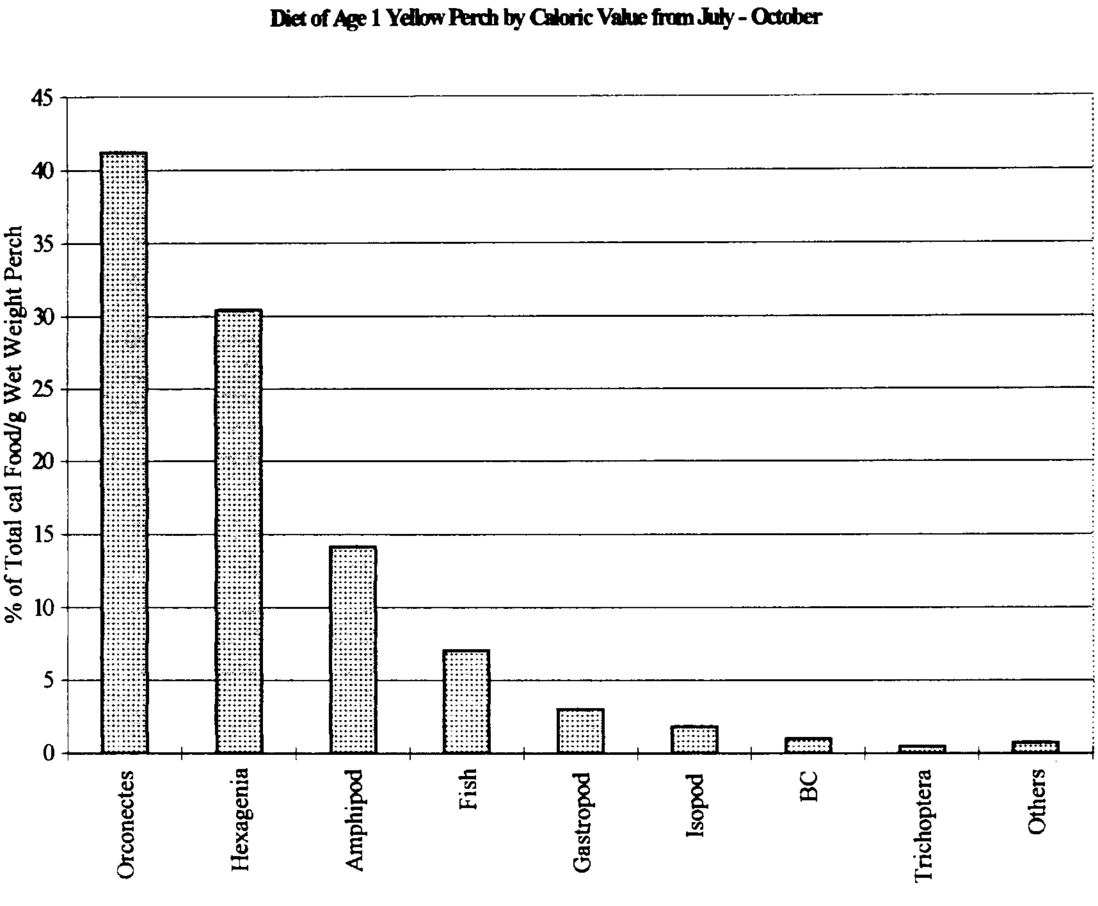

Figure 31. Diet composition according to caloric value of prey items. Sexes were pooled. Only items which occurred in approximately 10% or more perch stomachs were included. The category "Others" represents chironomid larvae, chironomid pupae, *Dreissena* sp. and other Pelecypoda.

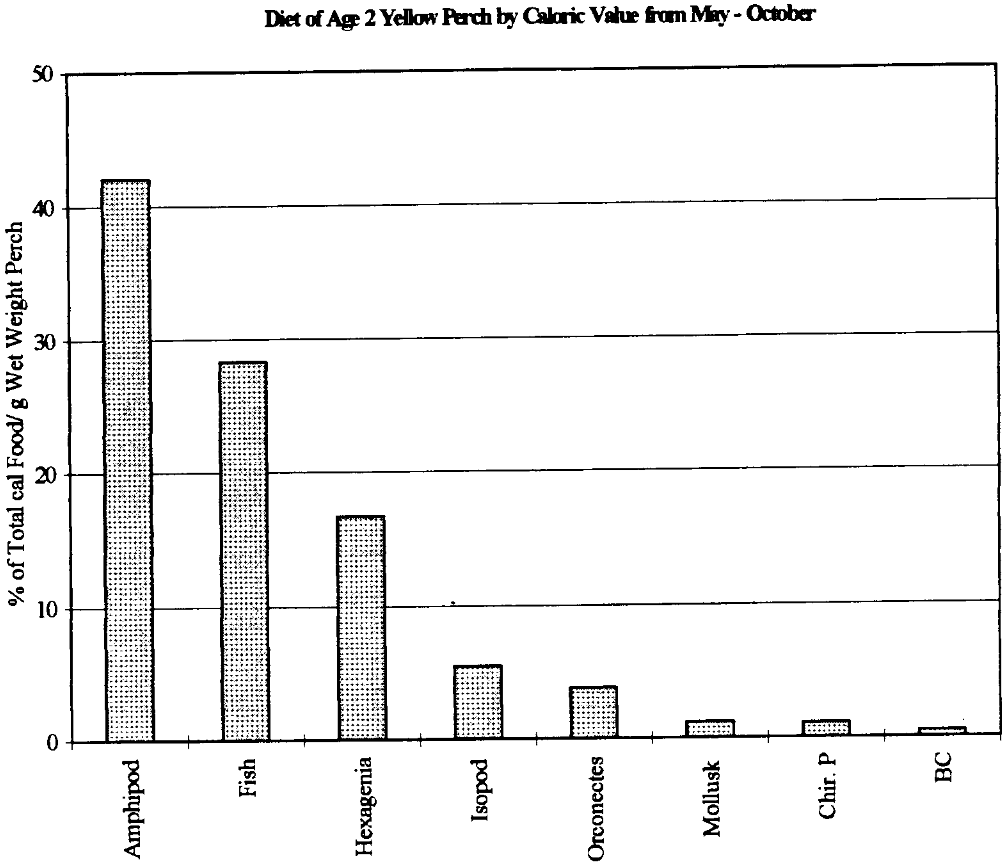

Figure 32. Diet composition according to caloric value of prey items. Sexes were pooled. Only items which occurred in approximately 10% or more perch stomachs were included.

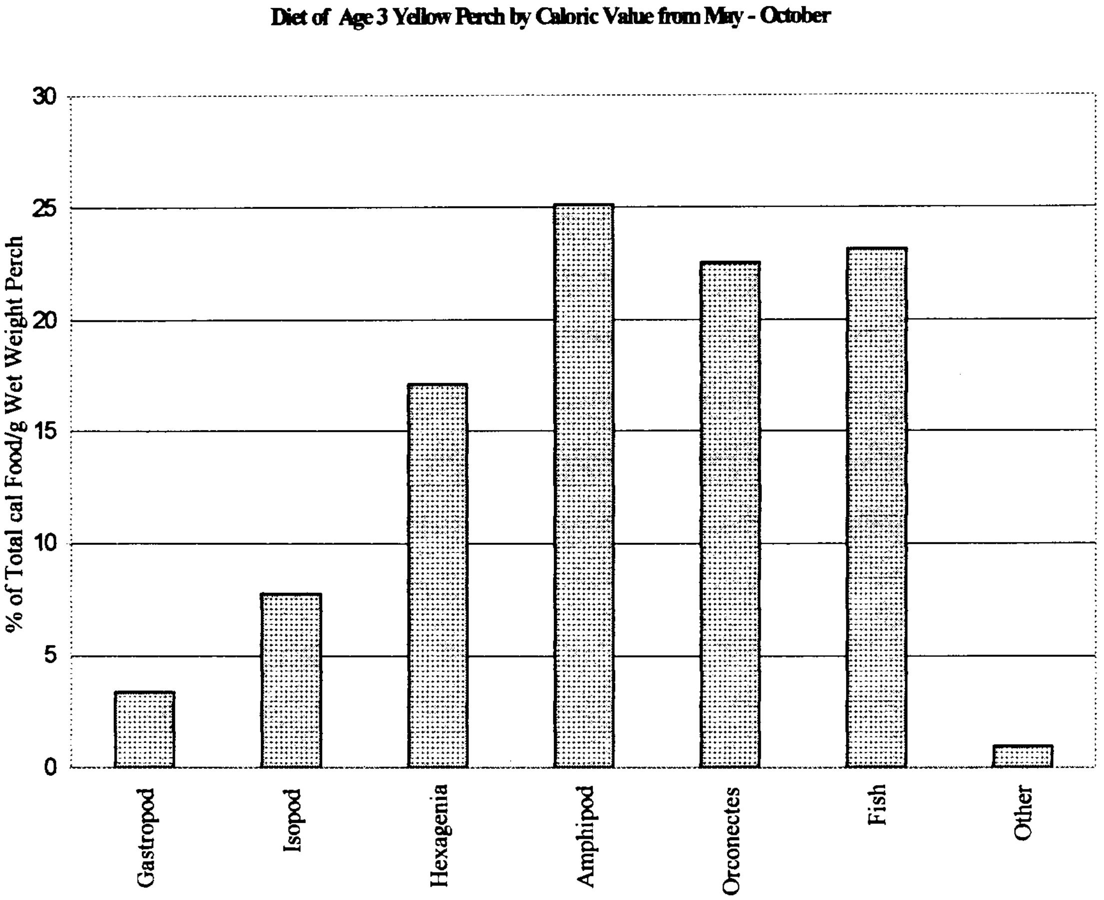

Figure 33. Diet composition according to caloric value of prey items. Sexes were pooled. Only items which occurred in approximately 10% or more perch stomachs were included. The category "Other" includes chironomid larvae, chironomid pupae, Trichoptera, Lumbriculidae and *Bythotrephes cederstromii*.

Diet of Age 4 Yellow Perch by Caloric Value from May - October

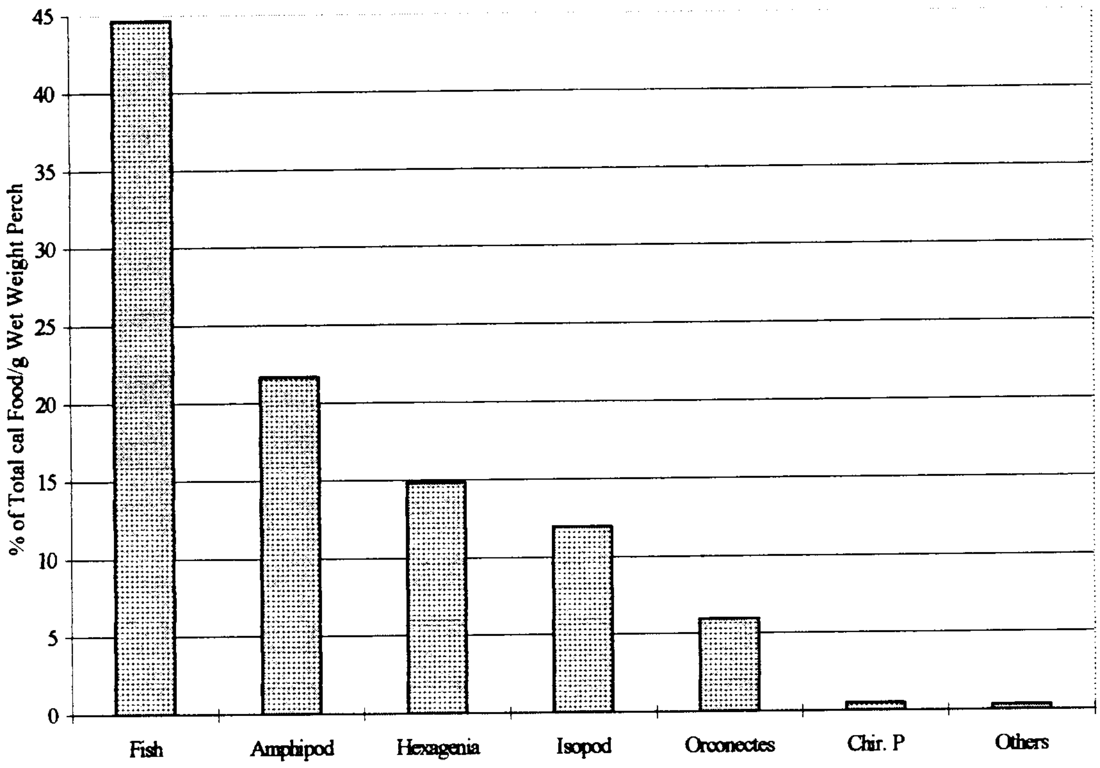

Figure 34. Diet composition according to caloric value of prey items. Sexes were pooled. Only items which occurred in approximately 10% or more perch stomachs were included. The category "Others" includes chironomid larvae, Trichoptera, Lumbriculidae, *Bythotrephes cederstromii* and Gastropoda.

Daily Consumption Rate and Maintenance Rations

Daily consumption rate and maintenance rations were calculated for age 1-4 perch using the bioenergetics model (Hewett and Johnson, 1992) and, for age 2 fish, consumption was also calculated with the algorithm from Elliott and Persson (Elliot and Persson, 1978). When the bioenergetics model was run with cohorts grouped together so that various months were pooled, it produced a rounded curve of consumption but was quite different than when each month of data was run separately at which point there were great variations in the consumption curve. This could be due to several factors. The model is designed to average the variation in prey availability so this may illustrate that there is not a constant p-value (proportion of the maximum consumption) for the season but rather that variation in prey type or availability causes the p-value to change. In addition, if sample sizes for age 1, age 3 and age 4 fish had been greater there may have been less variability in the p-value as it is partly based on the weight of the fish. With age 2 fish, for which sample sizes were greater and there was less variation in individual fish weights, there was less variability in the p-value between months.

Consumption was calculated with four cohorts for age 1 fish (Figure 35). The second cohort had a p-value greater than one which implies that in August, age 1 perch were feeding at greater than the normal maximum rate. During September and October, age 1 fish were feeding at or below maintenance ration. It should be noted that when the "run" was performed for the year as a whole and the p-value was averaged, age 1 perch fed well above maintenance ration.

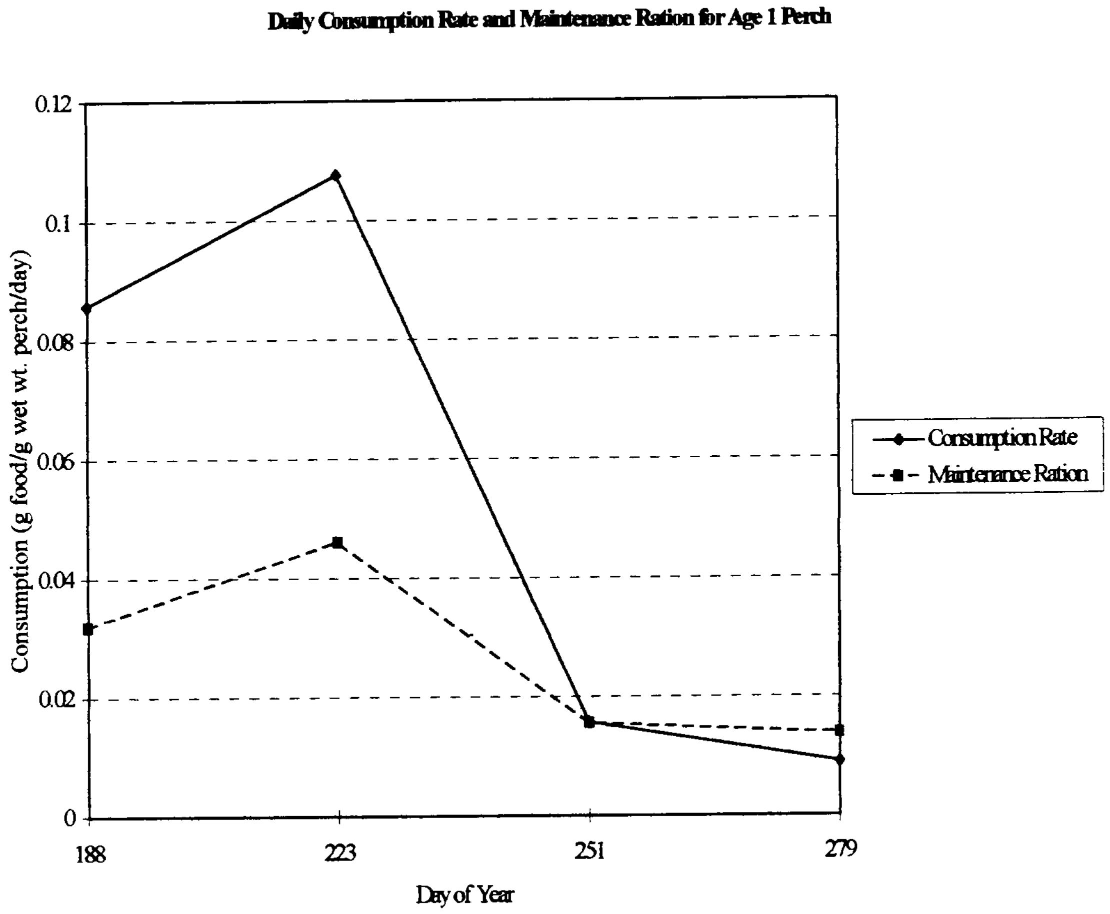

Figure 35. Daily consumption rate and maintenance ration as calculated by the bioenergetics model (Hewett and Johnson, 1992). Sexes were pooled.

Consumption rates calculated for age 2 fish with 5 cohorts with the bioenergetics model were consistently higher than those using the Elliott and Persson algorithm for age 2 fish with the exception of the month of June (Figure 36). With the bioenergetics model, consumption was much higher than maintenance ration for all months. Consumption was still higher than maintenance ration by the Elliott and Persson method, with the exception of May, but was generally lower than that estimated by the bioenergetics model.

For age 3 perch, consumption rates were always higher than maintenance ration for the growing season and peaked in July (Figure 37). Consumption rates for age 4 perch were below maintenance ration in May (Figure 38) and were at their peak in August which had a p-value of nearly one (perch feeding at maximum rates) when modeled with 4 cohorts.

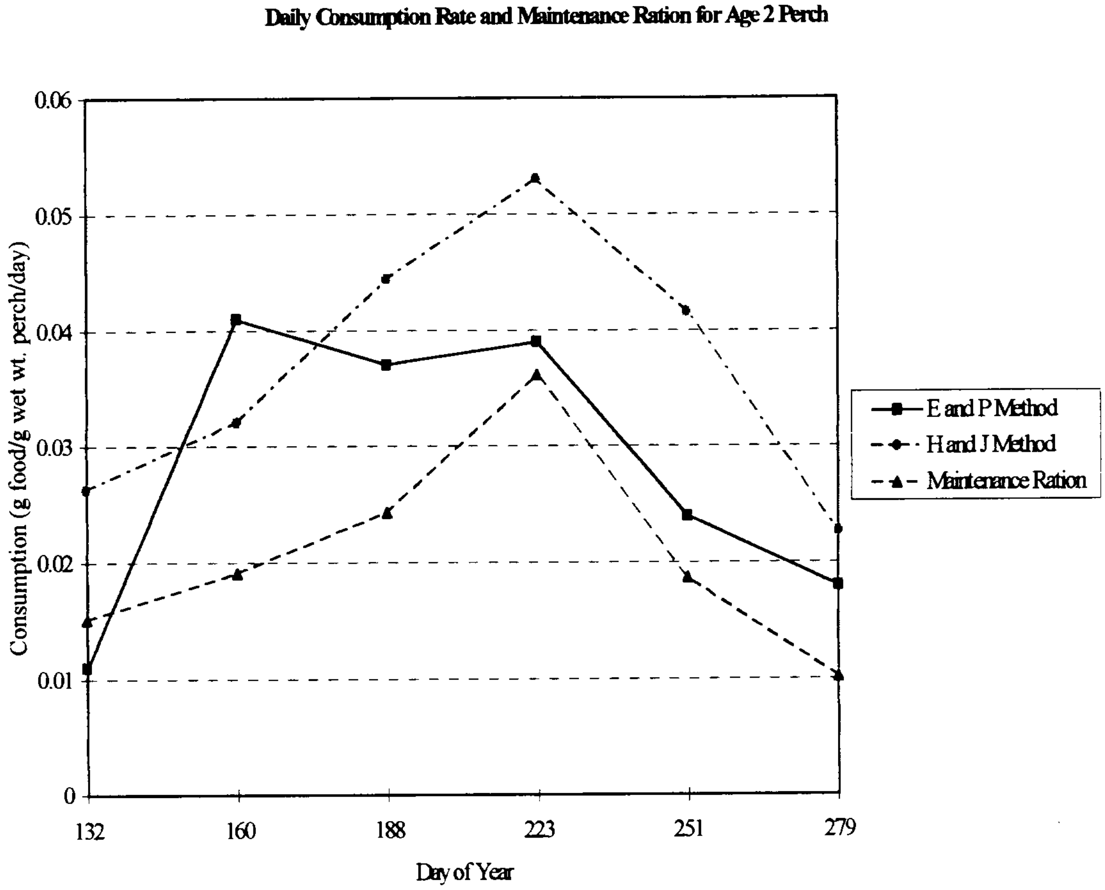

Figure 36. Consumption rates as calculated with the bioenergetics model from Hewett and Johnson (1992) and the method of Elliott and Persson (1978) and maintence ration from the bioenergetics model. Sexes were pooled.

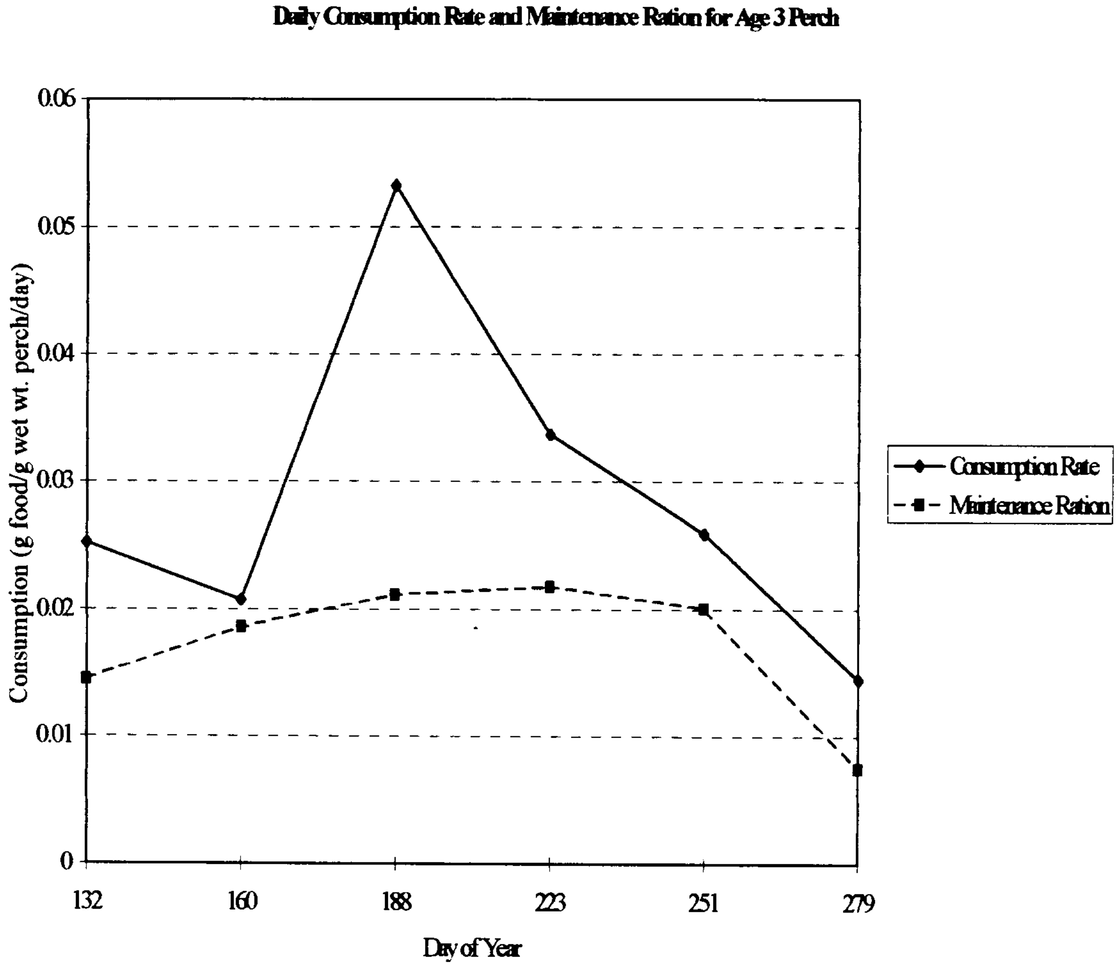

Figure 37. Consumption rates and maintenance rations as calculated by the bioenergetics model of Hewett and Johnson (1992). Sexes were pooled.

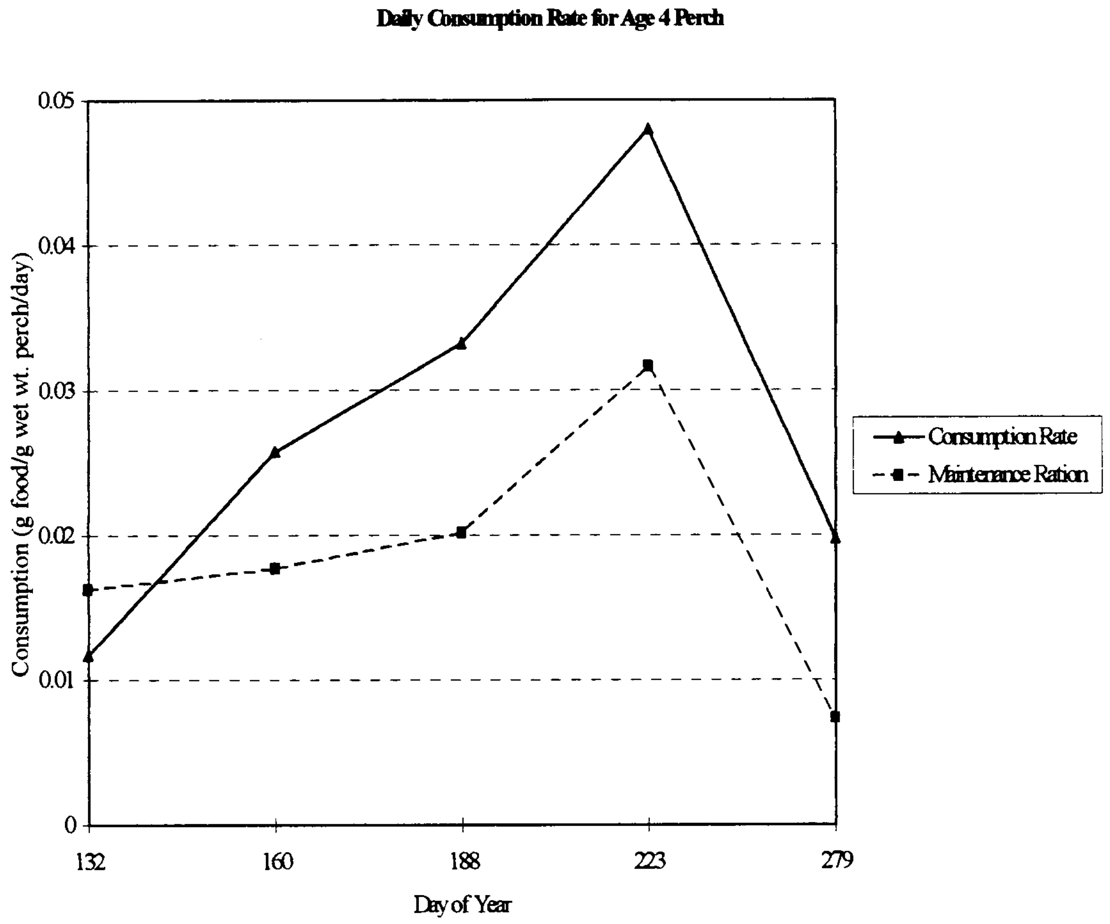

Figure 38. Consumption rates and maintenance ration as calculated by the bioenergetics model of Hewett and Johnson (1992). Sexes were pooled.

DISCUSSION

Lake St. Clair yellow perch appear to have a favorable environment compared to their counterparts in Saginaw Bay, Lake Huron and western Lake Erie. Lake Erie's western basin has been subjected to cultural eutrophication in the past from massive inputs of nutrients. This nutrient loading increased oxygen demand and led to the demise of the large mayfly *Hexagenia* and other organisms intolerant of low-oxygen conditions. The benthic community was soon dominated by more tolerant invertebrates such as chironomids and small oligochaetes. Although the nutrient loading did not appear to directly affect the yellow perch population, a decline in growth rates was reported, beginning around 1970 (Hayward and Margraf, 1987). It appeared that yellow perch were not able to adapt to this new forage base and relied on the remnants of the previous (*Hexagenia*-dominated) benthic community. Consumption rates were low and stunting occurred (Hayward and Margraf, 1987). In the less eutrophic central basin of Lake Erie in which larger prey items were still available, the perch grew better and had higher consumption rates. Although an expanding white perch (*Morone americana*) population probably exacerbated the problem by competing for food, yellow perch growth had been in a decline well before their arrival (Hayward and Margraf, 1987).

Similarly, in Saginaw Bay after 1950, *Hexagenia* declined and the benthic community became dominated by smaller tubificid oligochaetes and Chironomidae (Reynoldson *et al.*, 1989). Diana and Salz (1990) believed that because commercial catch rates were considerably high, limited growth was more likely a product of low food availability than high perch densities. Haas and Schaefer (1992) reported severe energy depletion of yellow perch most likely due to a lack of large benthic prey.

Large invertebrates seem to play a great role in the growth of yellow perch. In Lake St. Clair, older perch relied on invertebrates during spring and much of the summer. The most dramatic change in growth of any age occurred with age 1 fish from July-September with a nearly five-fold increase in dry somatic weight. During this time, perch fed mainly on amphipods and *Hexagenia* sp. For this reason these organisms appear to be extremely important. In October, when these two organisms were not eaten, perhaps due to less availability, and *Orconectes* sp. was the main diet item, growth was not as rapid. However, lower water temperatures or energy utilized for gonad maturation may have had an effect on growth at that time of year.

For ages 2-4 fish , *Hexagenia* sp. made up the bulk of the diet by weight in July and appeared to initiate the large increase in growth seen from July-September. Fish only appeared in substantial amounts in the diet from August-October. Indeed, the older the perch, the greater percentage of its caloric intake was from forage fish. Consequently, this is an important food resource for them. Indeed, Ridgway and Chapleau (1994) believed that the lack of fish prey for older yellow perch in a monospecific lake helped contribute to their stunted state. Despite the importance of fish in the diet of older yellow perch, young-of-the-year forage fish in Lake St. Clair are not readily available until late summer, thus large benthic invertebrates are necessary in early and mid-summer to allow adults to gain weight lost over the winter and from spawning.

Yellow perch in Lake St. Clair are opportunistic feeders. In September, age 1 fish ingested a mean of 22 *Bythotrephes* sp. and age 2 perch contained a mean of 18 per stomach. It is suspected that larger invertebrates were not as plentiful at this time and, despite its small size and spines, *Bythotrephes* sp. was a readily available food source. In southern Lake Michigan, *Bythotrephes* sp. occurred in 95% of stomachs of yellow perch 80-179 mm total length collected on 7 August (Baker *et al.*, 1992).

Although they were not a major food item, *Mysis* sp. were part of the diet of ages 2-4 perch in May and age 2 perch in June. This organism is normally found in deep, oligotrophic lakes and its presence may attest that Lake St. Clair, especially Anchor Bay, receives considerable influence from Lake Huron, regarding water temperatures and input of drift organisms. Conversely, it is possible that the presence of *Mysis* sp. in the diet may indicate the movement of yellow perch between Lake St. Clair and the St. Clair River or Lake Huron.

Zooplankton populations in Lake St. Clair have always been relatively low (Robert C. Haas, Michigan Department of Natural Resources, personal communication). Although age 0 perch fed mostly on zooplankton in July, the diet in August was dominated by amphipods. Whether this is due to a decrease in the zooplankton available or to the fish being large enough to consume larger invertebrates is not known. Wu and Culver (1994) noted a midsummer decline of *Daphnia g. mendotae* in Lake Erie due to low edible phytoplankton resources and increased consumption by young-of-the-year yellow perch.

Wahl *et al.* (1993) noted that in late June and mid-July when age 0 yellow perch were between 24-31 mm standard length, they acheived a degree of visual resolution nearly equal to that of an adult. This was reflected in the diet which showed a wider range of food types. It was theorized, however, that age 0 fish spend more time than adults searching for food. Young-of-the-year yellow perch in western Lake Erie switched from feeding on zooplankton to benthic prey after a mid-summer decline of zooplankton (Wu and Culver, 1992). In this study, age 0 fish did not have as great an increase in growth as age 1 fish which may be due to this observed shift in diet. Feeding on amphipods may require a period of learning to capture and handle this larger organism. Ney and Smith, Jr., (1975) noted that growth for age 0 perch between 1 July and 20 August was faster when zooplankton was the major food item than when amphipod or insect larvae were the main diet items. In enclosure experiments, Post and McQueen (1994) found that zooplankton alone was sufficient enough to produce growth rates in young-of-the-year yellow perch higher than that seen in many North American lakes. They believed that the frequently observed diet shift in age 0 yellow perch to larger benthos was not necessary to sustain high growth rates.

In September, *Bythotrephes* was readily fed upon by age 1 and age 2 perch, but only infrequently seen in age 0 stomachs. Barnhisel (1991) noted that age 0 yellow perch 50-60 mm in length developed an aversion to *Bythotrephes* after attempts to ingest it. Yellow perch were 62 mm in September in the present study and perhaps the scarcity of *Bythotrephes* ingested is evidence of this aversion.

Activity level may affect fish growth. The amount of energy expended during activity is generally considered equal to that deposited as growth (Boisclair and Leggett, 1989). If food availability or quality is low, a fish may spend so much time searching that growth efficiency is altered. In Lake St. Clair, larger invertebrates such as *Hexagenia*, trichopterans, amphipods, and isopods are available for much of the growing season. It is presumed that this would allow for much reduced searching times as opposed to the situation in Saginaw Bay, Lake Huron where large invertebrates, especially *Hexagenia*, are greatly reduced in number or extirpated.

Growth is also affected by water temperatures. Bronte *et al.* (1993) found that water temperatures (mean surface temperature of 18.2°C over a 16-year study) in Chequamegon Bay, Lake Superior were low enough to restrict the assimilation of energy necessary for growth, reproduction and maintenance with possible high mortality of maturing fish as a result. In addition, these authors postulated that this increase in mortality with increasing biomass of yellow perch and higher mortalities of larger year-classes may be influenced by intraspecific competition for food. Kitchell *et al.* (1977) stated that the optimal temperature for consumption is 23°C for older fish. In the current study in Lake St. Clair, although temperatures were only measured once per month, they did not approach the optimum temperature until August and in mid-July were only 16.7°C. Presumably enough food was available to maintain good growth.

Energetics modeling showed that for most of the summer, ages 1-4 yellow perch were feeding well above maintenance ration. Age 4 fish were below maintenance ration in May and age 3 perch were very close to maintenance rations in June. LeCren (1951) noted that mature Eurasian perch (*Perca fluviatilis*) do not begin to grow in length until after spawning and when relative condition is near 90-95%. Although the present study did not check for maturity of the perch, it is possible that overwintering and spawning resulted in a lag time while the perch gained weight to make up for energy lost. Because change in weight is a primary component of the bioenergetics model, a slow increase in weight will be illustrated in the model output as low consumption rates. It is also possible that diet affected consumption rates. During these months, amphipods and crayfish were the main items eaten. At times when *Hexagenia* and fish were the dominant items of the diet, consumption rates were high.

Age 1 perch consumed slightly above maintenance ration in September and October. It is possible that this age group was too small to readily eat forage fish and larger crayfish present at this time. There were also less large invertebrates in the stomachs in September suggesting their unavailability. Age 1 fish readily consumed the zooplankter *Bythotrephes* during September so it appeared that they took advantage of this ready food source, despite its small size, perhaps to compensate for the decreased numbers of large invertebrates such as amphipods or *Hexagenia* available for consumption in these months.

Consumption rates for age 2 perch were also calculated using the Elliot and Persson algorithm. Except for the month of June when the values closely matched those calculated with the bioenergetics model, the Elliot and Persson method yielded lower values. However, it did give the same general pattern of consumption rates, peaking in June rather than August which occurred with the bioenergetics model.

There were some difficulties in diet analysis. Large worms in the family Lumbriculidae were frequently found in ages 3-4 stomachs in late spring but it was difficult to analyze their contribution to the diet because they easily fragmented in the stomach, making them difficult to count. Although Nalepa and Quigley (1980) provided a formula with which to calculate dry weight based on worm length, it was difficult to obtain a true measure of a lumbriculid which had been partially digested and placed in preservative. Therefore, it is felt that lumbriculid worms may be a more substantial dietary item in late spring than the figures show.

Yellow perch ages 1-4 generally showed a decrease in somatic percent water with age, indicating a higher fat content. It would be beneficial to obtain this data on perch older than age 4 since Craig *et al.* (1989) found that goldeye (*Hiodon alosoides*) exhibited a progressive decline in soma fat as they age.

Salz (1989) noted that the dry weight, length and somatic percent water of yellow perch in Saginaw Bay, Lake Huron showed only slight changes from August to October, suggesting that after August, accumulated energy was utilized mostly for metabolism and reproduction. Little was available for somatic tissue growth. Saginaw Bay perch are a population which exhibits poor growth. However, in Lake St. Clair, perch older than age 0 also showed a similar increase in somatic water content and very little increase in length or somatic tissue dry weight from September to October despite their better growth overall. Hayes and Taylor (1994) showed that both sexes of mature yellow perch began gonad development in September and showed concurrent declines in fat and energy content of somatic tissues. LeCren (1951) noted that the development of testes and ovaries in Eurasian perch (*Perca fluviatilis*) is made partly by maintaining a total body weight for length higher than normal and partly at the expense of the condition of the rest of the fish. It appears then, that whether there be a poor-growing population such as that from Saginaw Bay or a faster-growing population from Lake St. Clair, each has only a short period during late spring to mid-summer to add to the somatic tissue. After this, most of the energy will go to metabolism and reproduction. This is why the presence of high-quality food is so important. Large benthic invertebrates, particularly *Hexagenia*, are especially suited to this need at least until summer when forage fish of the appropriate size are more available. In this study, amphipods were very important in May. The crayfish *Orconectes* also contributed much to the diet, primarily in October.

Somatic water content in age 0 perch followed a different pattern from the older fish from July through October with an increase during that time representing a decrease in lipid content. This appears to be related to the concern noted above that perhaps the change in food type from zooplankton to benthic invertebrates is difficult and requires a period of learning. In addition, whereas 2- to 5-year old perch relied heavily on fish in October and one-year olds on *Orconectes propinquus*, age 0 fish were probably too small to utilize these and somatic water content increased further. If data on energy density of age 0 perch prey had been available it would have been beneficial to run the bioenergetics model with this age group to see if the model gave an indication that age 0 perch were feeding near maintenance ration.

Cysts of the redworm parasite *Eustrongylides tubifex* are formed mainly in the mesenteries but also in the liver, gonads and body wall of yellow perch (Crites, 1979). Salz (1989) noted that visceral percent water was consistently greater in perch with redworm than in those without suggesting that redworm may utilize much of its hosts lipid reserves. Crites (1979) indicated that the higher the number of *E. tubifex* present within an age class, the less the yellow perch weighed. Yellow perch in Lake St. Clair generally had a low incidence of this nematode. Although it seems that lower redworm occurrence is a less important element than diet quality with regards to growth, it could be another factor for better growth in Lake St. Clair yellow perch than in perch from Saginaw Bay where, for example, redworm occurs in greater numbers.

Competition with other fish species for food can affect growth. The exotic white perch (*Morone americana*) began to proliferate in Lake Erie in the 1970's (Parrish and Margraf, 1990). This species ate substantial amounts of benthic organisms and, unlike yellow perch, it maintained high consumption rates on zooplankton when benthos was sparse (Parrish and Margraf, 1990). Hayward and Margraf (1987) suggested that this added predation on the already depleted benthic invertebrate forage base exacerbated the slow growth of yellow perch. White perch have been found in Lake St. Clair since the mid-1980's (Robert C. Haas, Michigan Department of Natural Resources, personal communication) but were only sporadically caught in trawls for this study and are most likely not a great source of competition.

The exotic ruffe (*Gymnocephalus cernuus*) is cause for concern in Lake Superior and Lake Huron where it is now located. Ruffe have a similar optimum growth temperature as yellow perch and, in a tributary to Lake Superior, yellow perch and small forage fish declined sharply as ruffe numbers increased (Edsall *et al.*, 1993). Ogle *et al.* (1995) noted that young-of-the-year ruffe fed mostly on cladocerans, copepods and midge larvae. Adult ruffe 12 cm and larger ate mostly midges, *Hexagenia* sp. and trichopterans. These diet items are among those that yellow perch prefer. In addition, the highly sensitive lateral-line canals in ruffe fry allow night-feeding (Collette *et al.*, 1977). Ruffe have not been seen in Lake St. Clair at this time and, therefore, present no source of competition. However, the situation should be monitored for its presence.

The exotic species of greatest concern now are most likely the tubenose goby (*Proterorhinus marmoratus*) and round goby (*Neogobius melanostomus*). These two species were introduced into the St. Clair River system between 1986 and 1988 and have become established in Lake St. Clair. Gobies in Lake St. Clair have a similar diet to yellow perch. Tubenose gobies feed upon amphipods, isopods and ostracods. Zebra mussels, sphaerid clams, snails, amphipods, chironomids, caddisfly larvae and *Hexagenia* sp. naiads were found in round gobies (Muzzall *et al.* 1995). A study on competitive interactions between yellow perch and the gobiids in Lake St. Clair would be beneficial.

Yellow perch in Lake St. Clair have a relatively short period of growth from July to September but are above the Michigan averages for growth from August-October and have much higher growth rates than comparable populations in Saginaw Bay, Lake Huron , western Lake Erie and some populations of central Lake Erie (Haas and Schaeffer, 1992; Hayward and Margraf, 1987). In general, the majority of the diet in spring and summer consisted of amphipods and *Hexagenia*, even for older perch. Larger perch were not able to utilize forage fish until September and relied on large invertebrates in the spring when energy is needed to replenish reserves depleted from spawning. The importance of large benthic invertebrates, particularly *Hexagenia*, can not be denied and efforts to maintain the high water quality of Lake St. Clair must be continued.

From this study, food habit data on yellow perch in Lake St. Clair are known. Qualitative and quantitative studies of the benthos and zooplankton would be helpful at this time. Age 0 yellow perch exhibited lower growth rates than ages 1-4 fish. It would be worthwhile to know whether phytoplankton levels have been reduced by zebra mussels (*Dreissena polymorpha*), thus affecting zooplankton, to the point that growth of age 0 yellow perch is affected.

Yellow perch in Lake St. Clair are growing well and have a high-quality diet at this time. However, the lake's proximity to a large metropolitan complex and recent introductions of exotic species that are not well understood, warrants continued research on Lake St. Clair to maintain favorable conditions for this valuable species.

APPENDICES

Appendix 1. Lengths, wet weights, somatic tissue dry weights and somatic tissue water content of female yellow perch of ages 2-5 from Lake St. Clair, 1993. Numbers in parentheses represent ninety-five percent confidence intervals.

Age and Month	Total Length (mm)	Wet Weight (g)	Somatic Dry Weight (g)	Somatic % Water
Age 2				
May	134.2 (2.3)	28.60 (1.82)	5.98303 (0.43323)	75.4410 (0.1708)
Jun	133.9 (1.7)	31.98 (1.25)	6.58304 (0.27244)	75.0433 (0.1509)
Jul	143.9 (1.9)	42.92 (2.59)	9.22350 (0.60604)	74.3768 (0.1224)
Aug	163.9 (2.3)	55.54 (2.72)	12.8711 (0.6873)	73.8324 (0.1639)
Sep	178.7 (2.8)	67.05 (3.66)	16.0895 (0.9136)	73.2521 (0.1623)
Oct	187.5 (3.2)	81.21 (5.07)	18.6000 (1.1784)	73.9555 (0.2095)
Age 3				
May	166.5 (4.2)	58.31 (4.94)	11.98249 (1.19738)	74.9171 (0.3304)
Jun	167.7 (3.0)	68.02 (4.98)	14.60011 (1.05769)	74.1454 (0.4395)
Jul	174.9 (4.3)	77.78 (7.41)	17.46892 (1.34958)	73.5724 (0.5303)
Aug	208.3 (5.7)	112.99 (10.13)	27.1745 (2.4077)	73.1693 (0.9331)
Sep	212.3 (15.7)	134.41 (36.93)	31.6602 (8.4866)	73.8196 (1.1166)
Oct	213.2 (9.0)	126.94 (18.36)	29.2564 (4.5389)	73.5496 (0.4076)
Age 4				
May	202.3 (9.4)	104.93 (19.09)	23.46891 (4.84637)	75.0594 (0.4381)
Jun	189.8 (5.0)	101.18 (17.77)	22.34582 (4.17559)	73.8474 (0.8510)
Jul	194.3 (16.6)	109.44 (21.71)	25.12296 (5.06972)	73.1466 (0.0682)
Aug	230.3 (24.8)	170.42 (57.22)	41.1634 (13.1383)	73.0571 (1.8182)
Sep	244.7 (15.0)	202.42 (39.11)	50.0774 (9.7023)	72.4828 (0.4586)
Oct	245.3 (8.8)	200.88 (24.46)	46.6709 (5.9336)	73.0351 (0.5988)
Age 5				
May	239.8 (21.7)	175.56 (47.12)	38.16988 (10.32711)	75.3583 (0.6634)
Jun	223.0 (11.1)	153.52 (18.31)	34.49980 (4.38541)	74.3364 (2.4445)

Appendix 2. Lengths, wet weights, somatic tissue dry weights and somatic tissue water content of male yellow perch of ages 2-5 from Lake St. Clair, 1993. Numbers in parentheses represent ninety-five percent confidence intervals.

Age and Month	Total Length (mm)	Wet Weight (g)	Somatic Dry Wt. (g)	Somatic % Water
<u>Age 2</u>				
May	129.7 (4.1)	24.93 (2.88)	4.94249 (0.55559)	76.2978 (0.2458)
Jun	128.9 (1.8)	26.74 (1.34)	5.47503 (0.29667)	75.2577 (0.1981)
Jul	135.6 (1.5)	34.06 (1.21)	7.30001 (0.28772)	74.4544 (0.1248)
Aug	156.2 (2.9)	47.39 (3.39)	11.2189 (0.8281)	73.6464 (0.2114)
Sep	166.5 (2.5)	53.48 (2.58)	12.9283 (0.6624)	73.1131 (0.1912)
Oct	170.5 (3.2)	59.93 (3.88)	13.3572 (0.9576)	74.0012 (0.5319)
<u>Age 3</u>				
May	161.7 (5.2)	50.00 (5.80)	10.67902 (1.78150)	75.5416 (0.6602)
Jun	165.5 (8.9)	60.02 (11.89)	12.96963 (2.76788)	74.7221 (0.4784)
Jul	163.1 (3.6)	60.20 (4.45)	13.59555 (1.03791)	73.6561 (0.2492)
Aug	187.9 (6.9)	83.88 (9.71)	20.5191 (2.6720)	72.9401 (0.4134)
Sep	196.4 (12.7)	92.40 (24.03)	22.7535 (6.1733)	73.0028 (0.6018)
Oct	195.8 (9.3)	96.33 (16.90)	21.8050 (4.3532)	73.6611 (0.7416)
<u>Age 4</u>				
May	177.6 (4.4)	70.69 (3.67)	14.61997 (1.49119)	75.0536 (0.2726)
Jun	175.8 (3.9)	74.41 (6.15)	16.33762 (1.28645)	74.0526 (0.3148)
Jul	176.3 (5.7)	77.45 (7.85)	18.10339 (1.92384)	73.1079 (0.3429)
Aug	193.9 (9.8)	98.90 (15.66)	24.0788 (3.3708)	72.8179 (0.8289)
Sep	---------	119.64 (1.99)	---------	---------
Oct	211.6 (12.6)	138.72 (38.76)	31.3849 (8.4074)	73.4955 (0.4160)
<u>Age 5</u>				
May	183.0 (3.7)	70.69 (3.67)	15.59412 (1.02507)	74.6781 (0.4838)
Jun	201.0 (9.6)	105.75 (15.81)	23.88283 (3.67421)	73.6120 (0.4549)

Appendix 3. Somatic tissue dry weight and somatic tissue water content of male and female yellow perch of ages 0 - 1 from Lake St. Clair, 1993. Numbers in parentheses represent ninety-five percent confidence intervals.

Age and Month	Somatic Tissue Dry Weight (g)		
Age 0	Male	Female	Sexes Pooled
Jul	--------	--------	0.1055 (0.0096)
Aug	--------	--------	0.4834 (0.0619)
Sep	1.2546 (0.1672)	1.1610 (0.1610)	1.0774 (0.0879)
Oct	1.4408 (0.4070)	--------	1.1209 (0.2681)
Age 1			
Jun	--------	--------	1.3438 (0.5491)
Jul	2.4944 (0.5479)	1.9510 (0.5853)	2.1738 (0.4054)
Aug	--------	--------	5.1664 (2.3242)
Sep	11.7339 (2.2612)	8.1249 (2.7073)	10.1299 (2.0460)
Oct	9.7719 (1.6540)	8.9851(2.7335)	9.4048 (1.5054)
		Somatic Tissue Water Content (%)	
Age 0			
Jul	--------	---------	74.89 (1.21)
Aug	--------	75.76 (1.18)	75.66 (2.82)
Sep	74.80 (0.95)	75.66 (0.54)	75.70 (0.39)
Oct	76.99 (0.59)	--------	77.09 (0.44)
Age 1			
Jun	--------	76.24 (0.86)	76.19 (0.55)
Jul	75.82 (1.07)	76.53 (0.90)	76.16 (0.65)
Aug	--------	--------	75.18 (0.36)
Sep	73.28 (0.33)	74.24 (0.39)	73.71 (0.41)
Oct	74.43 (0.29)	75.02 (0.72)	74.70 (0.38)

Appendix 4. Lengths and wet weights male and female yellow perch of ages 0 - 1 from Lake St. Clair, 1993. Numbers in parentheses represent ninety-five percent confidence intervals.

Age and Month	Total Length (mm)			Wet Weight (g)		
	Male	Female	Sexes Pooled	Male	Female	Sexes Pooled
Age 0						
Jul	--------	---------	40.3 (1.2)	---------	---------	0.645 (0.057)
Aug	--------	---------	62.7 (2.2)	---------	---------	2.32 (0.24)
Sep	84.7 (3.9)	82.7 (3.4)	81.0 (1.9)	6.18 (0.81)	5.73 (0.72)	5.35 (0.40)
Oct	--------	---------	82.9 (5.6)	7.62 (1.77)	9.25 (4.48)	6.00 (1.30)
Age 1						
Jun	--------	---------	84.1 (9.9)	---------	---------	7.01 (2.63)
Jul	100.0 (6.8)	92.2 (6.8)	95.5 (5.1)	12.57 (3.20)	10.16 (2.62)	11.36 (2.10)
Aug	--------	--------	127.0 (17.4)	---------	---------	24.11 (9.87)
Sep	159.6 (8.5)	148.0 (13.4)	154.4 (8.1)	48.59 (9.11)	35.11 (10.90)	42.60 (8.02)
Oct	155.3 (7.7)	149.3 (14.4)	152.5 (7.7)	44.64 (6.67)	41.41 (11.14)	43.13 (6.12)

Appendix 5. List of fauna found in stomachs from yellow perch from Lake St. Clair, 1993.

- **ARTHROPODA**
  - MOLLUSCA
    - **Gastropoda**
      - Ancylidae
      - Hydrobiidae
        - *Amnicola* sp.
      - Physidae
      - Planorbidae
      - Pleuroceridae
        - *Elimia* sp.
      - Valvatidae
        - *Valvata* sp.
    - **Pelecypoda**
      - Dreissenidae
        - *Dreissena* sp.
      - Sphaeriidae
        - *Pisidium* sp.
        - *Sphaerium* sp.
  - NEMATODA
  - ANNELIDA
    - **Hirudinea**
    - **Oligochaeta**
      - Lumbriculidae
      - Naiadidae
  - CRUSTACEA
    - **Amphipoda**
    - **Cladocera**
      - Cercopagidae
        - *Bythotrephes cederstromii*
      - Bosminidae
      - Chydoridae
      - Daphnidae
      - Sididae
    - **Copepoda**
    - **Decapoda**
      - Cambaridae
        - *Orconectes propinquus*
    - **Isopoda**
      - Asellidae
        - *Caecidotea* sp.
        - *Lirceus* sp.
    - **Mysidacea**
      - Mysidae
        - *Mysis* sp.
    - **Ostracoda**
    - **Insecta**
      - Coleoptera
      - Diptera
        - Chironomidae
      - Ephemeroptera
        - *Hexagenia limbata*
        - *Dannella* sp.
        - *Caenis* sp.
        - *Brachycercus* sp.
        - Unidentified mayfly
      - Hemiptera
        - Corixidae
      - Lepidoptera
        - *Acentria* sp
      - Odonata
        - Coenagrionidae
        - Macromiidae
          - *Macromia* sp.
      - Trichoptera
        - Leptoceridae
          - *Oecetis* spp.
          - *Ceraclea* sp.
          - *Setodes* sp.
          - *Triaenodes* sp.
          - *Mystacides* sp.
          - *Nectopsyche* sp.
        - Polycentropodidae
          - *Polycentropus* sp.
        - Molannidae
          - *Molanna* sp.
        - Hydropsychidae
- **CHORDATA**
  - **Osteichthyes**
    - *Ambloplites rupestris*
    - *Cottus* sp.
    - *Culaea inconstans*
    - *Etheostoma nigrum*
    - *Percina caprodes*
    - *Percopsis omiscomaycus*
    - *Pimephales notatus*
    - *Proterorhinus marmoratus*
    - Unidentified fish

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