Diet and feeding strategies of redbreast sunfish (*Lepomis auritus*) and bluegill sunfish (*Lepomis macrochirus*) in two suburban lakes.

by

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Abstract

Diet and feeding strategies of redbreast sunfish (*Lepomis auritus*) and bluegill sunfish (*Lepomis macrochirus*) in two suburban lakes**.**

by

Linda Anne Lalicata

Adviser: Dr. Joseph Rachlin

This is a study of the feeding habits of two species of sunfish, *Lepomis auritus* (Linnaeus, 1758), redbreast sunfish, and *Lepomis macrochirus* Rafinesque, 1819, bluegill sunfish, co-occurring in two suburban lakes with different degrees of shoreline development. Since it has been well-documented that other animal species change their dietary habits during or just prior to breeding season, it seemed sensible to determine if sunfish also exhibited this behavior. The two study lakes are close in proximity in Putnam County, New York. Lake Mahopac is a more urbanized setting, close to road traffic, surrounded by homes, and has little to no vegetation due to the introduction of grass carp. Long Pond is in a more pristine setting with one side being entirely wooded. It is not close to any main roads and there are few houses on the perimeter. The vegetation is for the most part undisturbed except for a small amount removed from its beach areas. Despite the lack of vegetation, Lake Mahopac still has as much species diversity as Long Pond. Unfortunately the bluegill population in Lake Mahopac has suffered from the lack of weed beds, which are necessary for successful breeding, which has resulted in a steady decline in numbers.

The redbreast sunfish population in Long Pond is very small, most likely due to the fact that redbreast sunfish prefer moving water and Long Pond is relatively stagnant.

Breeding season usually starts in May and ends in August; the exact time changes from year to year based upon weather conditions. Female bluegills from Lake Mahopac exhibited a dietary shift in which they fed opportunistically during the pre-breeding season (when water temperature is below 20° C), but shifted to that of a specialist during the breeding period (when water temperature is between 20° C to 28°C) and post-breeding (when water temperature once again begins to cool). When water temperature falls below 20° C in the fall, sunfish move to deeper waters until the following spring when the water once again warms up and they move to the shoreline to breed. There is some dietary overlap between the species, especially between females during pre-breeding, as well as between male and female redbreast sunfish from Lake Mahopac and male and female bluegills from Long Pond, indicating that if food sources become scarce they could develop both interspecific competition between females and intraspecific competition between the sexes in each lake.

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Introduction

The females of a variety of species change dietary preference prior to and during breeding (Young, 1989; Durstche, 1991; Rubenstein and Mikelski, 2003; Velara et al., 2005; Markovich et al., 2007). This change may be due to an increased need for certain nutrients to prepare for the costly demands of breeding (Rubenstein and Mikelski, 2003). Mammals have delayed reproduction if an adequate supply of nutritious food is unavailable (Temple, 2004).

Lack of sufficient nutrient supplies may influence fecundity in certain fish species, resulting in a greater interval between spawning periods (Ali and Wootton, 1999). Pre-spawning gonadal development of fish greatly depletes their protein and lipid stores (Huss, 1995). Proper gonadal development can only occur with correct nutritional intake (Shan, 1985).

The focus of this thesis was to study the dietary preferences of fish by season, specifically pre-breeding, breeding, and post-breeding times, as well as by gender. It is well-known that there are feeding preferences between genders in humans (Cline et al., 1998; Turrell, 1998). The dietary differences between the men and women of the Hadza people of Tanzania were studied by Berbesque and Marlowe (2009). The Hadza are hunter-gatherers whose diets have not changed much since Paleolithic times. They eat food items that are widely available, such as baobab (a type of fruit), honey, berries, game, and tubers. Berbesque and Marlowe (2009) found that although there were similarities in food choices among genders, women ranked berries higher than meat, whereas men ranked meat higher than berries. Erlinge (1981) in studying *Mustela ermine* Linnaeus, 1758 (ermine), found that males have a preference for large voles, whereas combinations of large and small voles are optimal prey items for females. Stellar sea lion females have significantly different diets from males, consuming more salmon; males eat more pollock, flatfish, and rockfish than females (Trites and Calkins, 2008). McKormick (1998) studied dietary shifts in the red moki *Cheilodactylus spectabilis* Hutton, 1872 (Cheilodactylidae) and found no differences in dietary trends between males and females; however, other studies have shown difference in diet composition. A study on neotropical pipefish by Garcia, et al. (2005) showed that female pipefish have a more diverse diet based upon prey richness and prey size range compared to male pipefish. The diets of female and male *Lepomis auritus* (Linnaeus, 1758), redbreast sunfish (Figure 1) and *Lepomis macrochirus* Rafinesque, 1819, bluegill sunfish (Figure 2) were compared in this study to see if gender-associated dietary preference was also present in sunfish.

Figure 1: Redbreast sunfish (*Lepomis auritus*)
DEC.NY.GOV

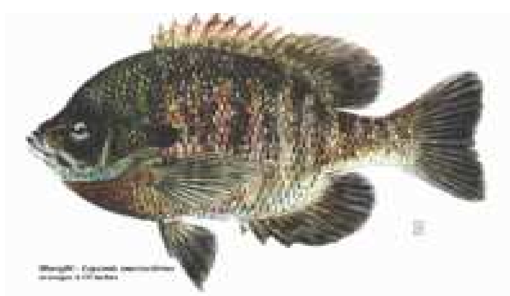


Figure 2: Bluegill sunfish (*Lepomis macrochirus*)
DEC.NY.GOV

Redbreast sunfish (commonly known as “redbreasts”) and bluegill sunfish (commonly known as “bluegills”) are members of the family Centrarchidae, order Perciformes. The redbreast’s native range is eastern United States and Canada, but they can also be found in western states. They inhabit lakes, ponds, and, most frequently, slow-moving streams (Steiner, 1997). They average in size from 15.2 - 20.3 centimeters (6 - 8 inches). They have been known to grow larger, attaining lengths of about 30.48 centimeters (12 inches). Their body is compressed and very deep. They have a very long, thin, dark blue earflap which is one of the main identifying features. The operculum is also dark blue. They have short, rounded pectoral fins, a dorsal fin of ten spines, a forked caudal fin, and three anal fin spines. The back ranges in color from olive to dark brown with the lower sides gray to green. Turquoise bands radiate from the back of the head (Werner, 2004). Sexual dimorphism centers on coloration differences (Kodrick-Brown, 1998), with males displaying a bright orange to red breast that is more deeply-hued during spawning than females, which have a less colorful pale orange or yellow breast. Sexual maturity occurs at about two to three years of age for males and three to four years for females.

Spawning season is from May through August when temperatures range from 20° C to 28° C (68° F to 82° F). Nests are similar in construction to other sunfish (Figure 3) with redbreasts known to use abandoned nest sites. The males of several species of sunfish have been documented as using nesting sites sequentially (Thorpe, 1988). The nest is constructed in the typical centrarchid manner; using the tail, the male fans out the benthic substrate (typically gravel or sand) (Avila, 1976; Stegemann, 1990). Substrate particle size is approximately 0.51 – 16.0 millimeters in diameter (Helfrich et al., 1991). Nests are approximately 30.48 centimeters in diameter. Females lay between 1000 and 10,000 eggs per season, depending upon their age and size (Stegemann, 1990). Males entice females to their nest where the female will lay a portion of her eggs. Females typically lay eggs in more than one nest, such that nests often contain eggs from two to six females (Hill and Cichra, 2005). After fertilizing the eggs, males may guard the nest for three or more weeks (Stegemann, 1990).

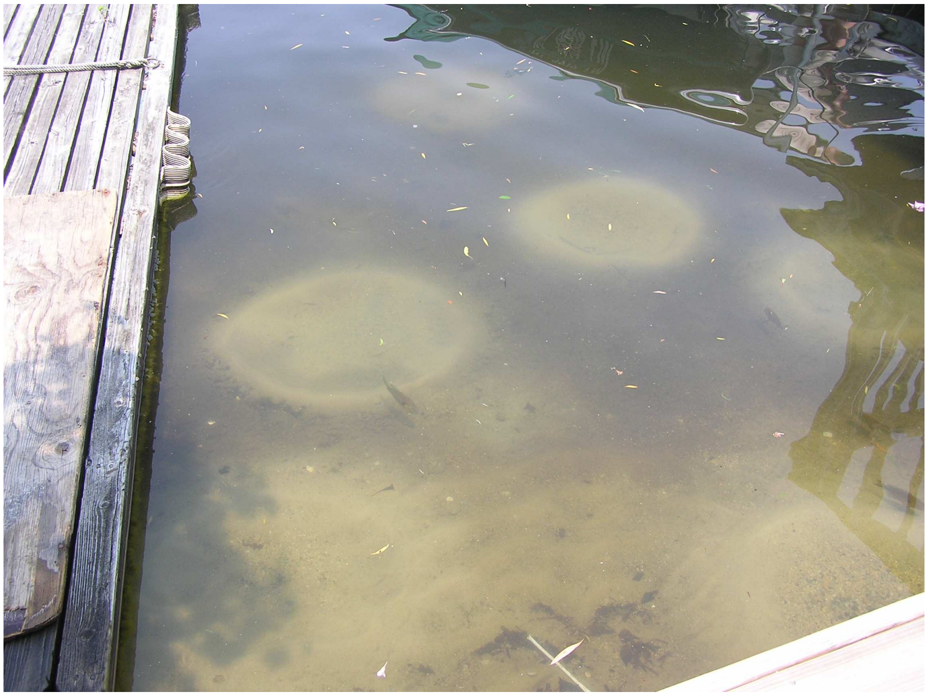


Figure 3: Redbreast sunfish (*Lepomis auritus*) nesting site, Lake Mahopac

Figure 4: Bluegill sunfish (*Lepomis macrochirus*) nesting site and collection site A, Long Pond

The diet of redbreasts is varied and includes snails, clams, crustaceans, aquatic and terrestrial insects, insect larvae, and small fish (Stegemann 1990). It is unclear whether there is a difference between male prey item preferences compared to female and if there is a difference in the quantity or quality of prey items in pre-spawning compared to breeding and post- spawning females and males.

Bluegills are native to the eastern United States, southeastern Canada, and northeastern Mexico (Stuber et al., 1982). They inhabit lakes, ponds, reservoirs, and slow-moving streams. They prefer still waters with abundant vegetation where they can hide and feed; they avoid direct sunlight (ODWC, 2010). Young fish will frequent the shoreline throughout the day, whereas adults prefer deeper waters during the day coming in to feed in the shallows during early morning and evening hours (Whitmore, et al., 1960; ODWC, 2010). They range in size from about 15 to 20 centimeters but can reach 25 centimeters (DEC 2011). They have a lifespan of four to six years but can live around 10 years in captivity (Parr, 2002). Like redbreasts, their bodies are deep and deeply-compressed with a short head and small mouth. Their dorsal fin is continuous with firm spines making up the front of the fin and soft spines in the rear. There is a dark spot on the soft rear portion of the dorsal fin, which is a distinguishing characteristic. Although not as colorful as other sunfish, their bodies are primarily olive green with yellow undertones in the belly. They have an iridescent bluish tinge on their cheeks and operculum, hence the name “bluegill.” There are faint vertical stripes on the sides of the body (Parr, 2002).

The bluegill diet is similar to that of the redbreasts; it has been documented that they forage on zooplankton (Mittelbach, 1981), macroinvertebrates (Schramm & Jirka, 1989; Dewey et al., 1997; Olson, et al., 2003), as well as on small fish (Engel, 1988).

Spawning season is quite long for bluegill sunfish; they begin nesting in May, when temperatures reach approximately 19°C, and will continue until August (Steiner, 1997). Bluegill sunfish are colonial centrarchids and are synchronous breeders with distinct bouts of spawning. The number of spawning bouts ranges from five to eight (Cargnelli and Gross, 1996). Bluegill sunfish males may spend up to three weeks defending their nests (Stegemann, 1990) (Figure 4). Because of the length of time male bluegills spend at the nesting site, it is possible that they increase their dietary intake prior to spawning and may also ingest a different array of food items, including an increase in larval insects. It has been stated that males will cannibalize eggs within their nest (DeWoody et al., 2001). Some of these eggs may be the result of nest piracy, but it is possible that some of the eggs ingested will have been sired by the guarding male (DeWoody et al., 2001).

Freshwater ecosystems such as those found in Lake Mahopac and Long Pond support a wide and diverse amount of biodiversity. Unfortunately, the balance is often thrown off due to urbanization which brings runoff, nitrification due to fertilizers, and introduction of non-native, invasive species (Molles, 1999). Over time, nutrient load may cause eutrophication of the system and loss of species (Tammi et al., 2003).

In 1994, 2,565 grass carp were introduced into Lake Mahopac as a biological control for Eurasian Milfoil, *Myriophyllum spicatum* L. Due to a miscalculation in the amount of fish needed to control the weed beds, almost complete eradication (86%) of aquatic vegetation resulted. By 1999 it was noted that there was a decline in largemouth bass populations of fish over 38 centimeters, although no one at that time was sure this could be attributed to the lack of vegetation (DEC, 2002). Another study published in 2004 (DEC 2004) stated that there has been a steady decline in total largemouth bass populations since the introduction of grass carp. In 1994 electrofishing catch rates per hour were 107.9, which dropped down to 24.9 in 2004. Smallmouth bass decreased slightly with electrofishing catches decreasing from 6.9 fish per hour to 5.8 fish per hour. Largemouth and smallmouth bass are popular sport fishes and Lake Mahopac has been a favorite lake for fishermen. Unfortunately it appears that these two fish species are being diminished and ultimately might be lost due to the change in their environment. No yellow perch or white perch (two other popular sport fish) were caught in 1999, indicating these animals may have become extinct in Lake Mahopac. This same study shows that bluegill sunfish may also have been affected by this lack of vegetation, with catch rates declining from 72 per hour down to 49. In response to questions regarding the grass carp and the state of Lake Mahopac, Ron Pierce, senior biologist for the DEC, provided data that was acquired prior to and for the years following the grass carp introduction. In 1994, catch rates per hour decreased from an average of 435 bluegills per hour compared to an average of only 210.7 in 1999. Redbreast sunfish numbers actually increased from 30 per hour to 62.7 per hour. Brown bullhead and yellow bullhead catfish have also increased in numbers since 1994. Redbreast sunfish appear to be not affected by the lack of vegetation and seem to be flourishing.

Largemouth bass are the primary predator of bluegill sunfish (Trebitz et al., 1997). Small and juvenile bluegills avoid predation by seeking out shelter in aquatic weed beds (Gotceitas, 1990).

Largemouth bass do forage on bluegill sunfish in vegetated areas but capture results are higher in open, shallow waters (Savino and Stein, 1989). The capture rate decreases as depth increases due to a reduction in light intensity (McMahon and Holanov, 1995). Because there is such a lack of vegetation in Lake Mahopac, it is possible that predation on the bluegills and their fry by largemouth bass may have increased in the shallows therefore further lowering the bluegill population.

In this study several questions are addressed:

1. Is there a difference in the diversity of macroinvertebrates in the two lakes?
2. Do the fish change their feeding habits during the pre-breeding, breeding, and post-breeding seasons?
3. Is there overlap in the diets of redbreasts and bluegills in Lake Mahopac?
4. Is there a difference in the diversity of the diets of redbreast and bluegill sunfish from Lake Mahopac?
5. Is there a difference between the feeding habits of male and female fish (both redbreast and bluegill sunfish)?
6. Is there a difference in morphology and feeding strategies between the bluegill populations from Lake Mahopac and Long Pond?
7. Is there a preference for certain prey items?

Collection Sites

Fish specimens and invertebrate were collected from two lakes in Putnam County: Lake Mahopac and Long Pond. Lake Mahopac (Figure 5) is a natural, freshwater lake approximately 80 kilometers from New York City. It has a circumference of 10.46 kilometers with a mean depth of 8.84 meters. The deepest section measures about 18.29 meters. There is an inlet on the northeast side of the lake and an outlet on the southwest side. Private homes and docking areas occupy most of the land encircling the lake shore. There are two restaurants located directly upon the shore edge of the water, as well as two marinas. There are three islands, (Canopus Island, Petra Island, and Fairy Island), located in the middle of the lake. Petra and Fairy both have permanent residences, whereas Canopus is for camping only; permanent structures are prohibited. Lake Mahopac was once heavily invaded with *Myriophyllum spicatum,* Eurasian milfoil, which became a large problem for boaters and swimmers. Eurasian milfoil is an aquatic plant that originated in Eurasia and was introduced in the early 1900's. It has a negative effect in the ecosystem because it crowds out native plants (USDA, 2010). A study done on Lake George, New York, found that since 1987, the spread of the plant has expanded in all directions leading to a decline in native species abundance as well as a decline in species richness (Boylen et al., 1999).

Two collection sites (Figures 5 and 6) were chosen because of the ideal conditions in which to place Hester-Dendy plates and to use an umbrella net. Other sites proved to not be suitable because after numerous tries, no fish were captured. One of these sites is located on the banks of Canopus Island. The benthic substrate is extremely rocky so fish cannot create nests and therefore do not congregate there in the summer months. Open-water fishing yielded no fish specimens—whether the method of collection was the umbrella net, minnow trap, or hook and line—despite numerous attempts over the years of study. Since much of the shoreline of Lake Mahopac is privately owned, other sites could not be accessed or were unsuitable.

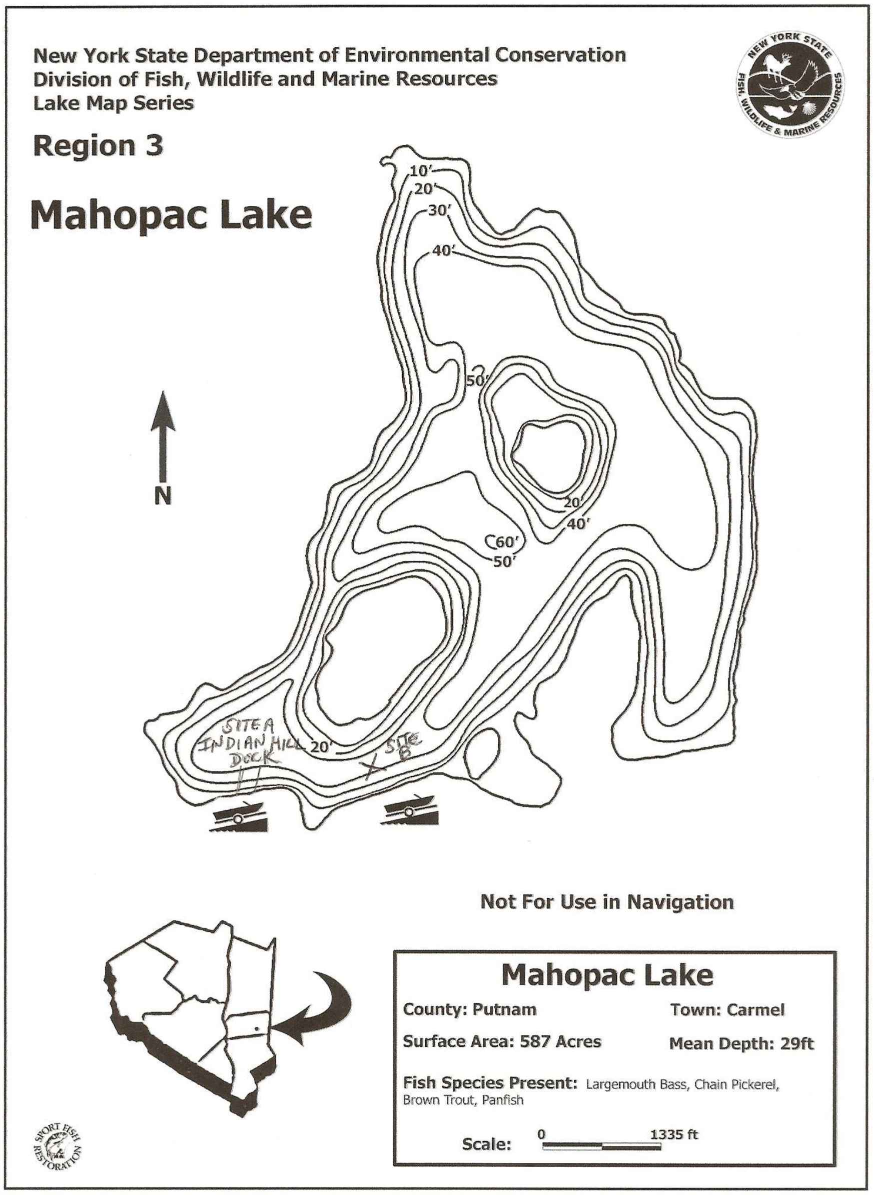


Figure 5: Lake Mahopac
Site A. 41°22'18.51"N 73°45'05.76"W
Site B. 41°22'21.16"N 73°44'55.43"W

Figure 6: Collection site A (41°22’18.51”N 73°45’05.76”W), Lake Mahopac

Long Pond (Figure 7) is a freshwater lake located approximately 8 kilometers from Lake Mahopac. It has an elevation of 60.35 meters. Private property lines much of the shoreline. There is a public park that consists of approximately 13 hectares. Eighteen acres have been developed for recreational use, including a developed beachfront. In 1922, the Girl Scouts of America built Rock Hill Camp on 81 hectares of land that border Long Pond. The site is still in use at the present time. Attempts were made to access the lake from this site, but safety issues made this an unsatisfactory collection area. The two sites that were chosen were ideal for different methods of sampling: the substrate is sandy so the fish are found in large populations due to it being an ideal nesting area (Figures 4 and 8). The dock area at collection site A (Figure 4) was suitable for use of the umbrella net, plankton net, and placement of the Hester-Dendy plates. Site B (Figure 8) was chosen because it was a more private spot where a minnow trap could be placed without disturbance from park visitors.

Figure 7: Map of Long Pond
Site A.   41°24’40.36”N 73°43’49.19”W
Site B.   41°24’40.36”N 73°43’52.02”W

Figure 8: Collection site B (41°24’40.36”N 73°43’52.02”W), Long Pond

Because there is such a difference in the ecosystems of the two lakes, it may affect the availability of prey items in the resource bases, therefore affecting the dietary choices of the two species of fish being studied. Insect larvae (such as chironomids) and crustaceans make up a large portion of the diets of both species of sunfish (Cooner and Bayne, 1982; Olson, et al., 2003) and their presence or lack there of may be affected by changes in the ecosystem.

Materials and Methods

To establish the food base in both lakes, invertebrates were collected using several methods. Three replicate Hester-Dendy plates (Hester and Dendy, 1962; Rachlin et al., 1987) were placed in fish collecting areas to assess prey item availability. Plates were used in Lake Mahopac in 2006 - 2008, whereas plates were only used in 2008 – 2009 in Long Pond since 2008 is the year when fish collecting began on this site. The plates were tied at one end with rope and secured to a dock at the Indian Hill property (Lake Mahopac) with wire to hold them below the surface. They were also placed on the bottom to capture benthic samples by attaching the rope to a cinder block in a depth of about 1.2 meters. The same technique was used at Long Pond for benthic samples but it was necessary to collect samples from the pelagic zone by attaching stiff wire to cinder blocks that raised the Hester-Dendy plates several centimeters from the bottom and about 12.7 centimeters from the surface. Although there are docks on Long Pond the collection sites are very public and it was necessary to put the plates in a protected area. It was important to sample from both benthic and pelagic regions of the lake to see what prey was available in the water column for the sunfish to forage upon. Uses of the above sampling methods were terminated because of the lack of specimens collected from Long Pond. It was decided that termination of these same collecting methods would be best for Lake Mahopac as well so as to try to keep the methods as even as possible for both lakes; any additional invertebrates added to the food bases after 2009 came from stomach contents.

It was intended that the plates would be placed into the lakes and removed at two-week intervals (first plate after two weeks, second plate after four, etc), but circumstances (lost plates, human error) sometimes prevented this from occurring. When the plates were removed they were scraped and rinsed into a pan of water to collect the invertebrates. The specimens were then put into 75% ethanol for preservation. They were later identified down to the lowest practical taxon (Appendix A). These data were used to create a food data base that was used for some statistical calculations. Other calculations were based upon stomach contents obtained from the sampled fish specimens. These contents were also separated out into the lowest possible taxon and preserved in alcohol (Appendix B). Plankton net trawls were used on both lakes; the net was thrown out into the water to approximately 3.1 meters and pulled back towards the dock areas; the volume of water sampled was 3.7×10^4 cm^3, which was determined by using the formula $V = \pi \times R^2 \times$ distance of the tow, with R = 6.35 cm and a net mesh of 80 µm. Plant samples were also taken from Long Pond since many invertebrates use weed beds for nesting and foraging. No plant samples were taken from Lake Mahopac since there are no existing weed beds available.

Parameters of the lakes' ecology, including temperature, pH, and dissolved oxygen have been obtained for several years (2008 – 2010) (Table 1). These data are used to determine the start of spawning season for the two sunfish of concern, which begins when the water temperature reaches approximately 20° C (68° F) (Stegemann 1990) and to assess if the oxygen and pH levels are within normal guidelines. Normal range for pH in a freshwater lake is 6.5 – 9.0 (Addy et al. 2004). Dissolved oxygen varies with temperature and can be influenced by additional factors such as inflow of ground water and decomposition of detritus (Addy and Green 1997). Low oxygen levels can affect reproductive success by damaging or killing embryos (Keickeis et al., 1996). Oxygen levels of 2 - 4 ppm stress fish populations, with fish kills resulting at levels below 2 ppm (Francis-Floyd, 1992). Long-term effects of low pH (<5.0) can include a decline or even loss of fish populations (Wright et al., 1976). The pH was measured using the LaMotte Precision pH monitoring kit. Oxygen levels were monitored using a Pinpoint

II oxygen monitor, testing at a depth of approximately six inches below the surface, where sunfish tend to forage.

Sunfish tend to stay mainly in the littoral zone (Robinson et al., 1996) therefore collection sites were close to the periphery of the lake. Fish were collected using an umbrella net and minnow trap at different times of the day and night, since redbreast sunfish are diurnal feeders (Johnson and Dropkin, 1995). The umbrella net allows the capture of several fish at one time making it an effective method. The fish trap was utilized where the use of an umbrella net was difficult to maneuver and therefore inefficient. Bait (bread, dog food, cat food, dried fish flakes) were placed inside the trap to lure fish. The trap was modified to better allow fish entry; flexible wire was used to hold the openings in place so the fish could swim in but not out. The trap was set in water depth of about one and a half feet and was removed at approximately fifteen minute intervals to collect the trapped fish; the trap was then put back into place. Water testing was conducted in the collection areas to assess the water parameters area and were found to remain constant at this depth where fish usually would forage (just below the surface in the littoral zone). Fish would enter the trap quickly, hence the fifteen-minute intervals. Although larger fish could not escape, it was discovered that smaller fish could swim out sideways. Ideally collection continued until at least ten fish were collected for that day but unfortunately some days yielded less to none of that number.

Collected fish were euthanized humanely using MS222 (tricaine methane sulphonate) to anaesthetize the fish before the addition of 10% formaldehyde. The fish remained in 10% formaldehyde for approximately one to two weeks according to standard museum protocol before transfer to 75% ethanol. The fish were then sexed, weighed, and measured before removal of the stomach. Stomachs were removed from the preserved fish by cutting from the anus to the start of the pectoral fin. Small cross cut incisions were made upwards of approximately one inch for easier removal. The alimentary canal is then detached from the body by cutting the large intestine and the esophagus. The stomach is identified and cut away from the alimentary canal at the sphincters. It is blotted dry with paper toweling and weighed to the nearest tenth of a gram. It is then opened by cutting lengthwise across the base. The two sides are spread apart to remove the stomach contents by carefully scraping the tissue using dissecting picks and flushing with water or alcohol. The stomach contents were then preserved in 75% alcohol until they could be analyzed. The stomach was re-weighed and its empty weight recorded.

Stomach contents were then separated into the taxa (Appendix B), and were placed in a Petri dish and examined under a dissecting microscope for enumeration. Many of the prey items were identified by body parts and not intact items. In this case the identifications were based upon wing venation, tarsal segments, and head capsules. In cases where individuals could not be reconstructed, the animals were counted based upon the head capsules. The individuals were then put into vials containing 75% alcohol. The data was then combined with the data collected from the Hester-Dendy plates, plankton net trawls, and plant samples and used to create tables reflecting the resource base for each lake.

Cumulative frequency curves were used to determine if an adequate number of fish specimens were collected for pre-breeding, breeding, and post-breeding time periods. Achievement of an asymptote indicates that enough specimens have been examined to ensure accurate characterization of their diet. In order to create these curves, prey items were grouped by order; prey invertebrates were identified to lowest practical taxon for additional statistical analysis (Ebert and Sulikowski, 2009; Hallet and Daley, 2010). The Shannon-Wiener Index of

Diversity (H' = $\sum p_i \ln p_i$) was used to measure biodiversity. A high index number indicates there is a great amount of biodiversity. The value of H' is based upon the number of categories, as well as the distribution of data (Zar, 1999). In this study the values range from approximately 0.400 to 2.000; the median is 1.200. The Pielou's evenness index (J'= H'/H'max) was calculated based upon the Shannon-Wiener index to indicate the evenness of the distribution of the organisms. The value of J' is between 0 and 1; if the value of J' is close to 1 it indicates that the distribution of abundance of organisms is approaching even. Shannon-Wiener diversity values were subjected to t-test analyses (Zar 1999). Comparisons were made between the different groups, such as pre-breeding female redbreast sunfish and pre-breeding male sunfish. This was also done to see if the diversity of organisms was different in the two lakes and if the diet of Lake Mahopac bluegill sunfish is different from the diet of Long Pond bluegill sunfish.

Niche breadth (NB) (Table 2) was calculated using Levins' relativised index $\{1/(R\sum p_i^2)\}$ (Levins, 1968), where p_i is the proportion of the ith item in the diet and R is the number of resource states available (Rachlin et al., 1989). Proportional similarity (PS) in feeding was calculated using Feinsinger's index PS = 1 – 0.5∑[pi – qi] (Feinsinger et al., 1981), where pi is the proportion of the ith item in the diet and q_i is the proportion of that item in the environment (Rachlin et al., 1989). The combination of the calculated values from the two indices gives us the following feeding habit definitions. If both NB and PS values are high (above 0.60), the species is viewed as a generalist and has a large feeding repertoire and is selecting its food in proportion to what is available in the food base. If both of the values are low (below 0.60), they are regarded as classic specialists with a narrow food range and not feeding proportionately from the available food base. If the NB is high and the PS is low, they are considered selectionists; its catalog of food items is as wide as that of a generalist but they are not feeding in proportion to what is available in the food base. When NB is low and PS is high, the species in question is considered to be an opportunist with a small feeding repertoire, but feeding in proportion to the items availability in the food base (Rachlin et al., 1989).

To assess which prey items the fish preferred, the electivity index (E*) of Vanderploeg and Scavia (1979a) was calculated and was based upon both the pooled stomach contents and data collected from Hester-Dendy plates, plankton net trawls, and plant samples (when available). Vanderploeg and Scavia (1979a) states that the indices W_i and E* can be used not only to assess prey size preference but also food preference, which is why it was chosen. The formula used is $E^* = \{W_i - (1/n) / (W_i + 1/n)\}$, where $W_i = (r_i/p_i) / \sum (r_i/p_i)$, n = the number of types of prey items, r_i = the proportion of the ith item in the diet of the species being studied, and p_i = the proportion of the ith item that is available in the food base. If the calculated E* values are positive, the food item is considered to be preferred; if the value is negative it is not preferred (Rachlin et al., 1987). This index was used to determine if the fish changed their diets depending upon the time period (pre-breeding, breeding, and post-breeding).

To look at comparisons of the feeding behavior of females and males depending upon pre-breeding, breeding, and post-breeding periods and also between the two species the Schoener % overlap index was used (Table 3). This index has the following form: $(\alpha_i = 100 (1 - 1/2\sum [p_{xi} - p_{yi}])$, where p_{xi} and p_{yi} are the proportions of the ith items in x and y (the two species that are being compared). A value higher than approximately 0.60 is considered to be biologically meaningful and would indicate possible competition between the groups in question (Zaret and Rand, 1971).

Results

Is there a difference in macroinvertebrate diversity between the two lakes?

The oxygen levels, pH, and phosphorus remained at normal levels for the most part throughout the collection season for both Lake Mahopac and Long Pond (Table 1). Any rises in pH and phosphorus is most likely due to lawn and garden fertilization of homes that are found on the periphery of the lake shore. At its highest point, the pH is still within the normal range 6.5 – 9.0) (Addy et al., 2004) for a freshwater lake. Phosphorus levels should not exceed 0.025 mg/l in freshwater lakes (NOAA/EPA, 1988); levels were frequently above this level in Lake Mahopac but never exceeded the maximum in Long Pond (Table 1). From this table we can determine that the pre-breeding season starts in May when water temperatures are approximately 16° C and usually lasts until temperatures reach 20°C, usually in June. When temperatures remain at 20°C and above, it is the breeding or spawning season, which continues until temperatures begin to cool down in August, signaling the start of post-breeding. It is also apparent from this table that there is little difference in the parameter values for both lakes during the same time periods. For example on July 28, 2008 the water temperature in Lake Mahopac was 27° C with a dissolved oxygen level of 7.7 ppm; Long Pond had a temperature reading of 28° C with the same dissolved oxygen level.

The two lakes have several differences in their composition, the most important being the lack of vegetation in Lake Mahopac compared to the large amount of aquatic weed beds found in Long Pond; the other important difference is the periphery of Lake Mahopac is much more suburbanized. Long Pond is more desolate with only a county park, a girl scout camp, and a few homes found on its shores. Because of these differences it was important to this study to compare them to see if the lack of vegetation in Lake Mahopac has had an adverse affect on the number of species in the fishes' dietary habitat. Macroinvertebrates were collected to estimate the resource base by using Hester-Dendy plates, plankton net trawls, plant samples (only from Long Pond), and the pooled stomach contents (Tables 4 and 5). Although sunfish tend to forage in the litterol zone, it is possible while constructing their nests in the benthic substrate they occasionally forage on benthic organisms, such as mollusks and annelids (Thorpe, 1988). Therefore it was important to sample the entire water column to determine what macroinvertebrates were available to the fish. Sunfish have been known to feed on benthos depending on the environment they inhabit (Werner et al., 1978). In order to collect benthic organisms Hester-Dendy plates were anchored to a brick to keep it from shifting from the collection site due to water current. The plates were allowed to sit on the bottoms of the lakes until they were removed at approximately two week intervals.

The Shannon-Wiener index of diversity was then calculated using the resource bases for both lakes to assess the amount of biodiversity (Table 6). A t-test based upon this index was calculated to see if the diversities of the macroinvertebrates in the two lakes were significantly different or the same. Species richness, total abundance, and evenness were also calculated for each lake (Table 6). The species richness values indicate how many different types of organisms are found within an ecosystem; the evenness values show whether the number of organisms is evenly distributed or if some species are more represented than others within the sample.

Lake Mahopac had a Shannon-Wiener divesity index value of 2.217, a species richness value of 44.0, and an evenness J-value of 0.586 (Table 6). The evenness value indicates that the organisms are not evenly distributed and there is a greater number of some species compared to others. Since Long Pond is a relatively undisturbed lake that is surrounded by woods, it would be expected that an even greater amount of biodiversity would be present when compared to a suburbanized lake such as Lake Mahopac. Long Pond has a Shannon-Wiener diversity index value of 1.942, a species richness value of 32.0, and a J-value of 0.560. Since the H’ value for Lake Mahopac is higher than the H’ value for Long Pond we can see that despite the lack of weed beds there is more macroinvertebrate diversity in Lake Mahopac as there is in the relatively undisturbed Long Pond. A t-test calculated from the two H’ values indicated that the diversities of the populations of the two lakes are significantly different with $P<0.05$, ($P=0.000$).

Do the fish change their feeding habits during the pre-breeding, breeding, and post-breeding seasons?

There were several questions that were addressed in this study regarding the feeding behavior of the two species of sunfish. The first was the question of whether or not there is a shift in diet during the pre-breeding, breeding, and post-breeding seasons for both redbreast sunfish and bluegill sunfish. Since producing offspring requires a large amount of energy, the females of some species will change their feeding habits, whether it is a change in diet (Young, 1989; Durstche, 1991; Rubenstein and Mikelski, 2003;Velara et al., 2005) or an increase in the amounts of food consumed to make up for the energy cost (Rubenstein and Mikelski, 2003). The Shannon-Wiener diversity index was used to calculate the amount of biodiversity there was in the diets and Pielou's evenness index (J'= H'/H'max) was calculated based upon the Shannon-Wiener index and indicates the evenness of the distribution of the organisms. Species richness signifies how many different organisms were found in the diets and total abundance shows how many individuals were consumed by the fish.

To determine if the populations in question are functioning as specialists, generalists, selectionists, or opportunists, both niche breadth and proportional similarity were calculated using Levins' relativised index $\{1/(R\sum pi^2)\}$ for NB and Feinsinger's index for PS, where $PS = 1 - 0.5\sum[pi - qi]$ (Table 2).

A total of 117 fish were collected from Lake Mahopac from 2007 to 2010 and a total of 62 fish were collected from Long Pond (Table 7); because there were not enough redbreast sunfish collected from Long Pond, they were not part of the study.

The cumulative frequency of prey item graphs were created by counting the number of prey items found in the stomachs from the earliest specimens (earliest meaning fish caught at the beginning of the collecting season) to specimens caught when temperatures were about ideal for breeding and nests were observed.

Pre-breeding redbreast sunfish females approached an asymptote at 15 fish, N=16 with a total of 20 prey items (Figure 9) and are opportunists with a NB = 0.05 and a PS = 0.82 (Table 2); they have a narrow feeding repertoire but feed proportionately to the prey items availability in the food base. Chironomids were the most common larvae found in their stomachs (Table 8), but it was not a preferred prey item (Table 9). Their preferred food items included several larval insects: two families of diptera (ceratopogonidae and empididae), the ephemeroptera of the family ephemerellidae, the coleoptera of the family dytiscidae, and two trichoptera families (hydropsychidae Curtis, 1835 and lepidostomatidae Ulmer, 1903) (Table 9). Other preferred prey items were the gastropod of the family planorbidae and eggs were also common and preferred, but from what animal they came from is unclear (Tables 8 and 9). Pre-breeding females have a diverse diet overall with a Shannon-Wiener diversity index = 1.396 with a species richness of 20.0 (Table 10), which was one of the highest numbers for any of the groups. They also consume large quantities of the food they choose to eat with a total abundance of 519 prey items. The diet is not evenly distributed amongst the prey they choose with an evenness value J' of 0.466 (Table 10).

During the breeding period, female redbreast sunfish remain opportunists having a very low NB value of 0.11 and a high PS value of 0.98 (Table 2). They reached an asymptote at 18 fish, N=22 (Figure 10). Chironomids are no longer the most abundant prey item and make up only 14% of their overall diet. Formicidae make up the majority of the pooled stomach contents at 35% and the cladocera of the family sididae makes up 27% (Table 11). Preference for certain food items has shifted slightly. Formicidae was a preferred food item but sididae was not (Table 12). No formicidae were captured using the invertebrate sampling methods used in this study but were often found in the stomachs of the two sunfish species because of swarms being trapped by the water. Besides formicidae, the isopod asellidae Latreille, 1802, sphaeriidae, the diptera of the family psychodidae, and the hemiptera of the family veliidae Amyot and Serville, 1843 are preferred (Table 12). They fed very proportionately from the food base with a PS value of 0.98 (Table 2) and they have a narrow feeding repertoire with a NB value of 0.11 (Table 2); they consume 14 different prey items but ingest less prey than pre-breeders with a total abundance of 223 (Table 13). The Shannon-Wiener index increases with an H’ value of 1.746 and a J’ value of 0.662 (Table 13) and since there is a decline in overall consumption with a total abundance of 223 (Table 13), it may indicate that females consume more prey prior to breeding and no longer need such large quantities after they have spawned. It is likely that some of the female fish sampled during the actual spawning period may have already deposited their eggs prior to capture and were exhibiting feeding behavior that was seen during the post-breeding period.

Post-breeding redbreast females approached an asymptote at 10 fish, N=11 (Figure 11) with species richness now down to four prey items with a total abundance of 46 (Table 14), a dramatic drop from the pre-breeding and breeding seasons. Formicidae makes up almost all of the diet at 91% of the overall intake (Table 15). The Shannon-Wiener index has a value of 0.386, a very low number with an evenness value of 0.278 (Table 14), indicating that the females did not choose equally from their food choices; preferred prey items were formicidae and heptageniidae, a family of the order ephemeroptera (Table 16). During this time period, they shift their feeding behavior to that of a specialist with a NB value of 0.03, which shows that they have a very narrow feeding repertoire, and a PS value of 0.57, which shows that they are not feeding proportionately from the resource base (Table 2).

Male redbreast sunfish are also opportunists and remain so during the pre-breeding, breeding, and post-breeding period with NB values all under 0.1 and PS values above 0.8 (Table 2). The cumulative frequency curve for pre-breeding redbreast males approached an asymptote at seven fish, N=8 (Figure 12) and had fairly diverse diets with an H' value of 1.208 with species richness of 12.0, a total abundance of 72, and a J'value of 0.486 (Table 10). Although chironomids made up 73% of the overall pre-breeding male redbreasts' diet (Table 17), it was not a preferred prey item; cambaridae Hobbs, 1942, a family of decapod, the diptera of the family dixidae, and heptogeniidae, a family of ephemeroptera, were favored items during the pre-season (Table 18).

There is a slight decline in the amount of food consumed during the actual breeding season with total abundance dropping to only 43 prey items; however, species richness is nearly the same with 11 different species consumed, and the Shannon-Wiener index increases with an H' value of 1.384 (Table 13). The evenness value is 0.577, which indicate that some prey items may be chosen more frequently than others (Table 13). Chironomids still make up the majority of the diet at 67% (Table 19), but the calculated E* values show that it still is not preferred. Only two items were sought out; these were the coleoptera of the family hydrophilidae Latreille, 1802 and undetermined ephemeroptera (Table 20). The cumulative frequency curve approached an asymptote at seven fish, N=8 (Figure 13).

When the males reach the post-breeding period, their overall consumption increases to 89 food items (Table 14); during the breeding season, males spend all of their time defending their nests and offspring, which would explain the low amount of food eaten during this period. After the fry have left the nest, the males are once again free to forage and will consume more food. They approached an asymptote at five fish, N=6 (Figure 14). The diversity of prey remains little changed with species richness = 10. The Shannon-Wiener diversity index value H' was 1.055 and the evenness value J' was 0.453 (Table 14). The relatively low evenness implies that the males are not choosing equally amongst its chosen diet choices, but rather choosing some more often. Formicidae make up majority of their diet at 69% (Table 21) and is favored according to the calculated E* values (Table 22). Sididae made up the next largest portion of the diet at 20% but was not favored. The only other items that had positive E* values were a spider and an undetermined gastropod.

Although there is a much smaller population of bluegill sunfish in Lake Mahopac compared to redbreast sunfish, enough specimens were captured to examine their feeding habits. The same time periods were observed as with the redbreast sunfish. Bluegill females are opportunists and remained so regardless of time period, with pre-breeding females having an NB value of 0.07 and a PS value of 0.85, breeding females a NB value of 0.04 and a PS value of 0.85, and post-breeding females having a NB value of 0.08 and a PS value of 0.73 (Table 2).

Pre-breeding females have a relatively diverse diet, consuming 12 different items; total abundance was 85 (Table 23) and the cumulative frequency curve approached an asymptote at four fish, N=5 (Figure 15). The Shannon-Wiener index value H' is 1.596 and the evenness value J' is 0.631 (Table 23). The most common prey item found in the stomachs were chironomids making up 60% of the diet (Table 24), but based upon the electivity index it was not a preferred item (Table 25). Their preferred dietary items were hydracarina, daphniidae Straus, 1820, sphaeriidae, scarabidae, and araneae (Table 25).

Bluegill females increase their intake of prey during the breeding period with total abundance of 240 macroinvertebrates with species richness of 11 (Table 26). The evenness is low with a value 0.311 indicating that they choose some items more often than others because the diet is not evenly distributed (Table 26). The Shannon-Wiener diversity index was calculated for females to be 0.746 (Table 26), which is considerably lower than the value of 1.596 that was seen during the pre-breeding period. An asymptote was reached on the cumulative frequency graph at 10 fish, N=12 (Figure 16). Sididae make up the majority of the breeding females diet at 83% of the stomach contents (Table 27) and was calculated to be a preferred prey item with a positive E* value (Table 28). All other macroinvertebrates were ingested in much smaller quantities. Other items that were preferred were hyallelidae and undetermined gastropods, as well as the plankton *Navicula* Bory.

The amount of food and diversity dropped dramatically during the post-breeding period with bluegill females choosing to feed on only four different species (Table 29) with hydracarina and formicidae making up majority of the diet at 44% and 33% respecitively (Table 30). Only hydracarina is favored as a food item (Table 31). Total abundance was a scant nine items (Table 29). The Shannon-Wiener diversity index was calculated for females to be 1.215 with an evenness value of 0.876 (Table 29). As with post-breeding redbreast sunfish females, the bluegill sunfish females no longer seek out large amounts of prey after they spawn, and feed quite modestly. The cumulative frequency curve reached an asymptote at five fish, N=7 (Figure 17).

Bluegill sunfish males from Lake Mahopac are opportunists and remain so from season to season. All had NB values below 0.20 and PS values greater than 0.60 (Table 2). Pre-breeding males had an evenness value of 0.888 (Table 23), which is quite high. They fed from their dietary repertoire quite uniformly (Table 32) consuming only chironomids and trichoptera of the family lepidostomatidae slightly more often than other organisms in their diet. They had a total abundance of 31 items chosen from 11 different species (Table 23). The cumulative frequency curve reached an asymptote at four fish, N=6 (Figure 18). The Shannon-Wiener index was calculated to be 2.128, which indicates that their diet is quite diverse (Table 23), although when compared to the availability of species found in the food base (Table 4), it is a relatively narrow diet. Their favorite food items are bivalves of the family unionidae Fleming, 1828, diptera of the family phoridae, and odonates of the family calopterygidae; all three had positive E* values (Table 33).

Breeding males have slightly less diversity in their diets choosing from amongst nine species (Table 26) with crustaceans (ostracods and anostraca) and gastropods of the family valvatidae being favored (Table 34). Another favorite food item is the diatom Navicula. *Navicula* was found in the stomach contents of many of the fish that were studied. Total abundance is misleading with a total of 454 (Table 26); 86% of that number is actually from anostraca Sars, 1867, also known as fairy shrimp (Table 35). Fairy shrimp can occur in large groups and when consumed it would most likely be in copious amounts. If this item was removed, the evenness would be much greater than the calculated 0.276 (Table 26). Males had a Shannon-Wiener diversity index of 0.606, which indicates lower diversity in their diet (Table 26). The cumulative frequency curve approached an asymptote at six fish, N=7 (Figure 19).

Post-breeding bluegill males, like the females, have a sharp decrease in prey selection as well as amounts consumed. The species richness drops down to six with total abundance only 13 (Table 29). The cumulative frequency curve approached an asymptote at five fish, N=6 (Figure 20). The Shannon-Wiener index was calculated to be 1.411 and the evenness increased to a J' value of 0.787 (Table 29). Once again the diversity is not really that wide when compared to the available species in the food base and would be considered narrow. Although majority of the dietary intake was made up of chironomids at 54% (Table 36) it was not calculated to be a preferred item having a negative value (Table 37). Two items that were favored were sididae and dixidae.

All Long Pond bluegill sunfish are opportunists with both males and females having PS values above 0.90 (Table 2); the NB values differ depending upon the gender and the time period but are all below 0.25.

Pre-breeding bluegill females had a Shannon-Wiener diversity index value of 1.943, which is relatively high and the evenness value of 0.884 shows that they feed almost equally from amongst the food items they forage on (Table 38). They have a narrow feeding repertoire with an NB value of 0.24 (Table 2). The cumulative frequency curve reached an asymptote at nine fish, N=13 (Figure 21). Of the nine different prey organisms found in the pre-breeding females' stomachs, five were found to be preferred with positive E* values for hydracarina, daphnia, undetermined diptera, odonates of the family aeshnidae, and cicadellidae (Table 39). Although chironomids made up 22% of the diet (Table 40), it did not prove to be a preferred item.

There is a very large increase in diversity in the breeding bluegill sunfish females with species richness of 18 different prey items in their dietary repertoire (Table 41). The calculated NB value is 0.08 with a PS value of 0.92 (Table 2). An asymptote was reached at 12 fish, N=14 (Figure 22). The Shannon-Wiener diversity index value was 1.279 with an evenness value of 0.442 (Table 41). During this time females are choosing certain prey items more frequently than others, specifically chironomids which make up 71% of the overall diet (Table 42). All the other prey items were fed upon almost equally. Although it would seem that chironomids would be a preferred prey item with so much of the diet coming from this particular larval diptera, when the electivity index was calculated chironomids had a negative value. However, breeding bluegill females do have quite a few favorite food items with isopods, ostracods, scarab beetles, undetermined diptera, undetermined odonates, heptageniidae, cicadellidae, and *Navicula* all having positive values (Table 43).

During the post-breeding period there is an increase in dietary richness with the females now feeding from 12 different items but a slight decrease in total abundance with 185 different specimens collected from the stomachs (Table 44). An asymptote was reached at four fish, N=8 (Figure 23). The Shannon-Wiener index value was 1.267 with an evenness value of 0.510 (Table 44). The low evenness can be attributed to the large amount of chironomids consumed (126 specimens). Chironomids are still the majority of the diet with 68% of the overall amount (Table 45). Post-breeding bluegill sunfish fed as classic opportunists with an NB value of 0.08 and a PS value of 0.95 (Table 2). Once again chironomids were not preferred when the electivity index was calculated. Sididae, ceratopogonidae, undetermined odonates, lepidostomatidae, and juncales all had positive E* values and were sought out prey items (Table 46).

Pre-breeding males forage on 11 different prey items (Table 38), which is the same species richness found in the diet of Lake Mahopac pre-breeding bluegill sunfish females but the total abundance of the prey is slightly higher with 58 individual items found in the stomachs. They had a calculated NB value of 0.22 and a PS value of 0.94 (Table 2). The various species are well-distributed in the diet with an evenness value of 0.821 (Table 38). Two families of diptera were consumed slightly more often with chironomids making up 28% of the diet and ceratopogonidae 24% (Table 47). The Shannon-Wiener diversity index is relatively high with a value of 1.969 and similar to the value calculated for pre-breeding bluegill sunfish females, which was 1.943 (Table 38). Of the five favored prey items, three were larval insects (ceratopogonidae, aeshnidae, and coenagrionidae); the remaining two items were valvatidae and daphniidae (Table 48). The cummulative frequency curve approached an asymptote at five fish, N=6 (Figure 24).

There is a slight decrease in species richness, dropping from 11 down to eight, during the actual breeding period, which was expected since males are now guarding their nests and offspring (Table 41). The cumulative frequency curve reached an asymptote at seven fish, N=9 (Figure 25). The Shannon-Wiener index value of 1.564 indicates this decline (Table 41). The evenness value was 0.752 (Table 41). There is a small decline in the actual amount of food consumed down from 58 organisms found in the stomachs to 47. Once again chironomids make up a large percentage of the overall diet at 34%; amphipods Order: Amphipoda Latreille, 1816 make up 36% and ostracods Class: Ostracoda Latreille, 1802, 13% (Table 49). Amphipods are favored but chironomids and ostracods are not, both having negative E* values (Table 50). Ceratopogonidae and scarab beetles were the only other preferred items. Breeding bluegill males had a NB value of 0.15 indicating that they do have a narrow feeding repertoire and feed very proportionately from the available resource base with a PS value of 0.91 (Table 2).

The post-breeding bluegill sunfish males are free to forage at this time and have more access to prey. The cumulative frequency curve reached an asymptote at five fish, N=7 (Figure 26). The species richness sharply increases up to seventeen and total abundance is up to 133; the Shannon-Wiener diversity index value is 1.678 with an evenness value of 0.592 (Table 44). The diversity in the diet has increased but they are now feeding less evenly from their food repertoire (Table 44). Chironomids remain a large part of the diet and are now 55% of the overall food intake. Ceratopogonidae make up the next largest percentage at 15% (Table 51). Both of these organisms are larval and have a large amount of body fat and therefore are quite caloric (Bernard and Allen, 1997). Perhaps because of the difficulty in obtaining prey during the breeding period when the males can spend weeks guarding nests males increase their foraging and seek out prey that will restore nutrients that may have been lacking in their diet. Although the chironomids make up large portion of the dietary intake, it was not a preferred item and had a negative value; the following invertebrates did have positive values and were preferred: sididae, coccinellidae Latreille, 1807, chaoboridae (a family of diptera), undetermined diptera, aeshnidae, and formicidae (Table 52).

Is there overlap in the diets of redbreasts and bluegills in Lake Mahopac?

The Schoener % overlap index was calculated for the six groups, pre-breeding, breeding, and post-breeding females and males to determine if there was diet overlap between the redbreast sunfish and bluegill sunfish in Lake Mahopac. Overlap between the two species would indicate possible competition for dietary resources.

Pre-breeding females of the two species had a Schoener index value of α_i=0.670; there was no indication of dietary overlap during the breeding period with a Schoener % overlap index value of =0.303 but there is overlap once again in the post-breeding period with α_i=0.643 (Table 3), indicating that there is a very small amount of overlap in the diets: hydracarina, daphniidae, amphipods, isopods, scarab beetles, chironomids, ceratopogonidae, formicidae, and *Navicula* were found in both diets.

During no time is there overlap between the diets of the males of the two species; the Schoener overlap index was calculated for the three periods and is as follows: pre-breeding α_i=0. 360, breeding α_i=0.112, and post-breeding α_i=0.499 (Table 3). Pre-breeding redbreast males preferred to consume decapods, dixidae larvae, and ephemeroptera larvae (Table 17), while pre-breeding bluegill males prefer unionidae, phoridae larvae, and calopterygidae larvae Table 33). Breeding redbreast males had only two preferred items, hydrophilidae larvae and an undetermined lepidoptera (Table 19), while breeding bluegill males preferred four, anostraca, ostrocoda, valvatidae, and navicula (Table 43). There are three preferred prey items that are ingested by post-breeding redbreast males, gastropods, formicidae, and one lone arachnid. Post-breeding bluegill males had two, sididae and dixidae larvae. At no time do they share any preferred prey items.

Few papers have been written specifically on competition between redbreast sunfish and bluegill sunfish, most focusing on foraging behaviors of bluegill sunfish, so it was impossible to compare these results with those of other researchers. Mittelbach stated in his 1981 paper on bluegills that foraging changes with size; as the fish become larger predation upon them decreases and they are able to move away from heavily vegetated areas to more open waters, therefore increasing their dietary repertoire.

Is there a difference in the diversity of the diets of redbreast and bluegill sunfish from Lake Mahopac?

To determine whether or not there was an equal amount of diversity in the diets of the two species, redbreast and bluegill sunfish, t-tests were calculated based upon the Shannon-Wiener index for each group (pre-breeding, breeding, and post-breeding males and females). Pre-breeding redbreast females from Lake Mahopac had a Shannon-Wiener diversity index of 1.396 with a species richness of 20.0 (Table 10), which was one of the highest richness numbers for any of the groups. They consumed large quantities of prey with a total abundance of 519 prey items. The diet is not evenly distributed; the calculated evenness value J' of 0.466 (Table 10) indicates that the fish are ingesting more types of prey than others. Bluegill females from the same lake during this time period had a Shannon-Wiener index value H'=1.596 and an evenness value J' = 0.631, which means that their diet is more evenly distributed than the redbreast females' diet (Table 23). Bluegill females did not consume as many different types of prey as the redbreasts with 12 different prey items with a total abundance was 85 (Table 23). To see whether or not the diets are significantly different in diversity a t-test was calculated; a result of $P<0.05$, ($P=0.00$), implies that the diets are not equal in diversity. Although many of the prey items they choose are the same, pre-breeding redbreast sunfish females have a more varied diet with 20 different organisms making up its diet compared to the 12 that were found in the pre-breeding bluegill sunfish females' stomachs.

During the breeding period the Shannon-Wiener index and the evenness value were a bit higher for redbreast females with H'=1.746 and a J'=0.662 respectively (Table 13). There was a decline in species richness and overall consumption with species richness of 14 and a total abundance of 223 (Table 13). Breeding bluegill females had a decline in diversity with the H'=0.746; the evenness was also lower with J'=0.311 (Table 26). Total abundance of prey increases with a total of 240 macroinvertebrates being removed from the stomachs; majority of this number comes from sididae, which made up 83% of the breeding bluegill females diet. Species richness had little change, down from 12 to 11. The calculated t-test yielded a result of $P<0.05$, ($P=0.00$), indicating that the diversities of the two diets are different with breeding redbreast females feeding on more insects than bluegill females from the same period, which tend to forage more on crustaceans (Tables 11 and 27).

Post-breeding redbreast females had a drop in both diversity and evenness values with H'= 0.386 and J'=0.278 (Table 14). Total abundance of prey consumed has also decreased with only 46 prey items removed from the stomachs. Species richness is down to only four different food items (Table 14). Bluegill females had an increase in both diversity and evenness values at this time with H'=1.215 and J'=0.876 (Table 29) but they also consumed only four diffent types of prey with a very low total abundance of nine. The result of the calculated t-test was $P<0.05$, ($P=0.00$); the diversity of the two diets is not the same.

The t-test result for comparison of dietary diversity between pre-breeding redbreast and bluegill males from Lake Mahopac was significant with $P<0.05$, ($P=0.00$), indicating that there is a difference in the diversities of the two diets. Redbreast sunfish and bluegill sunfish males had almost equal species richness in their diets with 12 prey items for redbreast sunfish (Table 10) and 11 for bluegill sunfish (Table 23) but only hydracarina, sididae, chironomids, and scarabs are seen in both diets; redbreast also consumed more food than bluegills with a total abundance of 72 (Table 10) compared to 31 (Table 23). Redbreast males had an H'=1.208 with a J'=0.486 (Table 10) compared to the bluegill males, which had an H' of 2.128 and a J'=0.888 (Table 23). It is apparent that at this time period there is more diversity in the diet of pre-breeding bluegill males with prey items in the diet being consumed more or less equally.

For breeding males the t-test also yielded a result of $P<0.05$, ($P=0.00$); there was no significant difference between the diversity of the diets of the post-breeding males with $P>0.05$, ($P=0.108$). Breeding redbreasts had an H' value of 1.384 and a J' value of 0.577 with species richness of 11 and total abundance of 44 (Table 13) compared to an H' value of 0.606 and a J' value of 0.276 with species richness of nine prey items and a total abundance of 454 individual macroinvertebrates for bluegill males (Table 26). Obviously there is much lower diversity in the bluegill males' diet and prey items are not being distributed evenly within their diet but they are consuming more prey during the breeding period. The low evenness value for breeding bluegill males is due to the fact that 86% of the overall food consumed is made up by chironomids. During the post-breeding time period redbreast males the H' value was 1.055 with a J' value of 0.453 (Table 14); bluegill males had an H' value was 1.411 with a J' value of 0.787 (Table 29). Total abundance of prey increases to 89 with species richness approximately the same with 10 different types of macroinvertebreates for redbreast males; bluegill males have a species richness of six different types of organisms and total abundance drops down to 13. The small amount of food that post-breeding bluegill males consumed is more or less evenly distributed in the diet, although chironomids do make up majority of their diet (Table 36).

Is there a difference in dietary overlap and diversity between male and female fish (both redbreast sunfish and bluegill sunfish) within each breeding period?

There was interest in finding out whether or not there is a difference in feeding behavior and food choice between the two genders since it is true of other species. It has already been established that animals other than fish will have differences in dietary preference based upon gender (Young, 1989; Durstche, 1991; Rubenstein and Mikelski, 2003; Velara et al., 2005). Other species of fish will shift their dietary habits due to age (Whiteley, 2006; Chan, 2007) and size classes (Graeb et al., 2006). There was no difference due to gender found by McCormick in his 1998 paper on *Cheilodactylus spectabilis* (red moki).

In a previous section it was shown that bluegill sunfish are opportunists regardless of the time period (pre-breeding, breeding, and post-breeding). Female redbreast sunfish are opportunists during the pre-breeding and breeding season but become specialists post-spawning; male redbreasts are consistently opportunistic feeders. Since there is little change in the way the fish forage for their food, is there overlap in their diets? To address this question, the Schoener % overlap index was calculated. To see if the diversity in the diets were equal, t-tests were calculated.

During the pre-breeding season, female redbreast sunfish consume large quantities of food when compared to the males of the species (519 vs. 72 prey items). When comparing their diets for overlap it was found that the Schoener index = 0.765 was very high (Table 3); this is biologically meaningful and indicates that if there was a decline in invertebrate population competition could possibly occur. Female redbreasts had a Shannon-Wiener H’ value of 1.396 and an evenness J’ value of 0.466; male redbreasts had an H’ value of 1.208 and a J’ value of 0.486. To see if the diversity of the two diets was the same or significantly different a t-test was calculated and it was found that there is a significant difference in the diversity of the two diets, with the result of the t-test $P<0.05$, ($P=0.023$).

Breeding redbreast sunfish apparently have little to no overlap in their diets as the pre-breeders do. The calculated Schoener index was 0.592 (Table 3). This number shows a decline in the similarity of the two diets; this may be due to the fact that males spend much of this time guarding their nests. Females are still consuming far more than the males (223 vs. 43 prey items). The Shannon-Wiener diversity index H' value for breeding redbreast females was 1.746 and the evenness J' value was 0.662 compared to male redbreasts, which had a calculated H' value of 1.384 with an evenness value of 0.577. The t-test yielded a result of $P<0.05$, ($P=0.00$), which indicates that the diversity of the diets of breeding redbreast females and males are significantly different.

When breeding season is over the redbreast females no longer consume such large quantities of prey. Males on the other hand have increased the amounts they ingest; after the fry have left the nest they are free to hunt for food. The overlap increases at this time with the Schoener % overlap = 0.835 (Table 3). The diversity of prey items decreases for post-breeding females with an H' value of 0.386 and J' value of 0.278. Diversity also decreases for males with an H' value of 1.055 and a J' value of 0.453. When the t-test was calculated on the H' values it was found that the diversity of the prey items is not equal in the two diets with a result of $P<0.05$, ($P=0.000$).

The opposite is true for the bluegills in Lake Mahopac. There is no overlap in the diets of the males and females at any time. During the pre-breeding period the Schoener index=0.570. When the fish are actually spawning, the Schoener index decreases to 0.491. When breeding time is over, there is virtually no overlap between the diets of the genders. The Schoener %

overlap index is exceptionally low with a value 0.111 (Table 3). The Shannon-Wiener diversity index was 1.569 with an evenness value of 0.631 for pre-breeding bluegill females; pre-breeding males had a higher H' value of 2.128 and a higher J' value of 0.888. The higher values for the males indicate that they have a more diverse diet that is more evenly distributed. To see if the diversities are equal for the pre-breeders a t-test was calculated with a result of $P<0.05$, ($P=0.029$). The diversity of prey items in the two diets was not equal.

Breeding bluegill females and males had low values for both the H' and J' values. For breeding females the H' value was 0.746 and for males it was 0.606; the J' value for the females was 0.311 and for males it was 0.276. When the t-test was calculated it was found that there was no significant difference in the diversity of prey items in the diets of the males and females during spawning, with $P>0.05$, ($P=0.088$).

Post-breeding females had an increase in dietary diversity with a Shannon-Wiener index value of 1.215 and an evenness value of 0.876. It increased for males as well with an H' value of 1.411 and a J' value of 0.787. Their dietary diversity was equal with the t-test result of $P>0.05$, ($P=0.458$).

The findings for the Long Pond bluegill population were quite interesting. In Lake Mahopac there was no overlap between the male and female bluegills at any time. The opposite is true for the Long Pond bluegills. During the pre-breeding the overlap was the lowest with a Schoener index value 0.673 (Table 3). However there is an increase when the fish begin to spawn with the Schoener % index value of 0.706 (Table 3). These numbers are high enough to be considered biologically meaningful as they are above the cut-off value of 0.6 and indicative of possible rivalry for food between the sexes. Since indices cannot be tested for statistical significance the value of 0.60 indicates there is "biologically meaningful" overlap (Zaret and

Rand 1971). The most dramatic overlap is post-breeding, with Schoener % overlap index value of 0.825 (Table 3).

As with the previous groups, a comparison between the Shannon-Wiener diversity index values was made for the males and females for each period (pre-breeding, breeding, and post-breeding); t-tests were calculated based on the H' values to see whether or not the diversity of prey items is equal for the males and females.

The values for the Shannon-Wiener diversity index and Pielou's evenness values were very similar for both the males and the females during the pre-breeding period for male and female bluegills. Pre-breeding bluegill females had an H' value of 1.943 and a J' value of 0.884; males had an H' value of 1.969 and a J' value of 0.821. The result of the t-test indicates there was no significant difference in the two dietary diversities with $P>0.05$, ($P=0.427$), during this time.

During breeding the diversity and evenness values drop for both males and females with H'=1.279 and J'=0.442 for females and H'=1.564 and J'=0.752 for males. Males have a higher diversity of prey in their diet and they are consumed more or less evenly. The result of the t-test was significant with $P<0.05$, ($P=0.044$) indicating the diversity of prey items is not equal in the two diets.

Post-breeding bluegill females have similar diversity and evenness values with an H' value of 1.267 and a J' value of 0.510; males had an H' value of 1.678 and a J' value of 0.592. Once again the diversities in prey items is different for males and females with a t-test result of $P<0.05$, ($P=0.005$), which is significant.

Is there a difference between the bluegill populations from Lake Mahopac and Long Pond?

In this study both populations fed as opportunists pre-breeding, breeding, and post-breeding but the Long Pond females had higher NB values compared to Lake Mahopac females during the pre-breeding period. Pre-breeding females from Long Pond had a NB value of 0.24 compared to 0.07 for the fish from Lake Mahopac (Table 2). Long Pond females apparently have a larger feeding repertoire than the females from Lake Mahopac and this may be due to the fact that they must share the resource base with redbreasts. During the breeding and post-breeding the NB and PS values are very similar (Table 2).

The average length of the bluegills in Long Pond is 9.2 centimeters and average mass is 29.8 grams; the Lake Mahopac population average length is 9.3 centimeters and average mass of 27.9 grams. T-tests were calculated based on the means of the length and mass of the two populations and there is no significant difference between the two populations with $P>0.05$. Length and mass are approximately the same for Lake Mahopac and Long Pond bluegills. Because these figures are very similar it is apparent that the lack of vegetation in Lake Mahopac does not seem to impede the growth of the bluegill sunfish as they mature. To determine if the diversity in the diets are different in the two populations, t-tests were calculated based on the Shannon index of diversity for six groups: pre-breeding females, pre-breeding males, breeding females, breeding males, post-breeding females, and post-breeding males.

The t-test result was $P<0.05$ for the pre-breeding females indicating that there is a difference in the diversity of prey items in the diets of the two populations. Female bluegills from Lake Mahopac consumed 12 different prey items and had an evenness of 0.631 (Table 23). Their preferred food items were hydracarina, daphnia, bivalves, and chironomids (Table 25). Pre-breeding females from Long Pond fed on nine different species with evenness of 0.884

(Table 38); they also prefer hydracarina, daphnia, and chironomids, as well as odonates and terrestrial insects that happen into the lake (Table 39).

The t-test result for pre-breeding males was significant with $P<0.05$, indicating that the diets are very different. Males from Lake Mahopac had a species richness of 11 with an evenness value of 0.888 (Table 23); results were similar for males from Long Pond whom also consumed 11 different prey items with an evenness value of 0.821 (Table 38). There was no similarity in their preferences for prey items.

Breeding females do not have the same diversity of prey items in their diets with $P<0.05$. Breeding males also have different diversities of prey items with $P<0.05$. Species richness is higher in the diets of Long Pond females with 18 different prey items (Table 26) compared to the 11 found in the stomachs of the Lake Mahopac breeding females (Table 41) but Lake Mahopac females consumed more prey with a total abundance of 240 (Table 26) compared to that of Long Pond females with 219 (Table 41).

There is no difference in the diversity of prey items in the diets of the two populations during post-breeding; the t-tests for both the post-breeding females and males from both lakes yielded results of $P>0.05$. Post-breeding bluegill sunfish of both genders from Lake Mahopac have very low diversity in their diets; females consume only four prey items and six for males compared to twelve for Long Pond females and seventeen for males. It is unclear why there would be such a discrepancy in the two populations during the post-breeding period because there is ample prey available as evidenced by Tables 4 and 5.

Is there a preference for certain prey items?

The relativised electivity index E*, based on Vanderploeg and Scavia (1979a, 1979b) was calculated to estimate if the fish have a preference or if they are feeding equally on all available prey items in the food base. To ensure that an appropriate food base was calculated, the data gathered from the traditional sampling methods as well as the pooled stomach contents was used for the indices (Rachlin et al., 1987).

Pre-breeding redbreast sunfish females gravitate towards larval insects. Species of trichoptera, diptera, ephemeroptera were all preferred, as were planorbidae and undetermined eggs (Table 9). Chironomids made up the majority of the diet (Table 8) but had a negative value when E* was calculated (Table 9). During the breeding period they forage for crustaceans, isopods being consumed preferentially, as well as sphaeridae, the diptera of the family psychomyiidae, and formicidae (Table 12). Since these organisms are available throughout all the periods it can be said that they shift their preference as they begin to spawn. After spawning occurs they no longer seek out crustaceans feeding entirely upon insects, adult and larvae, and in much smaller quantities (Table 15). At this point in time redbreast females have changed their dietary habits to that of a specialist. With only four prey items making up its feeding repertoire it can be said that their diet is very narrow; they also consume mostly formicidae with 91% of the diet being formed of this insect. Formicidae was found to be preferred, as was heptageniidae, a type of ephemeroptera (Table 16). This coincides with their low PS value of 0.57, with indicates that they are not feeding very proportionately from the resource base.

During pre-breeding males of the species consume several types of larval insects, with chironomids making up majority of the diet at 73% (Table 17); dixidae and ephemeropterans are preferred but the E* value for chironomids was negative (Table 18). The decapod of the family cambaridae was found to also be favored. During the actual breeding time they have few preferred items; the coleopteran of the family hydrophilidae and lepidoptera were the only organisms that had positive E* values (Table 19). Chironomids still make up the major part of the diet at 67% (Table 19). Crustaceans are not eaten in large quantities and this may be due to the fact that the males must stay on the nest to protect their offspring and any food that is eaten during that time is through serendipity. After spawning, males seek out more crustaceans; sididae make up 20% of the diet (Table 21) but is not a preferred food item (Table 22). Much of their diet at this time is based upon what falls into the water. More than half of the dietary intake is made up of formicidae at 69% (Table 21); a spider was found in one stomach, as well as an undetermined terrestrial hemiptera found in another. Other prey items include ostracods, gastropods, ephemeroptera, and *Navicula* none of which were consumed in great quantities (Table 21). The gastropod, spider, and formicidae all had positive E* values (Table 22) and so were considered preferred.

Bluegill sunfish from Lake Mahopac are opportunists and feed from a relatively narrow portion of the food base. Pre-breeding females preferred to eat crustaceans, hydracarina and daphnia specifically (Table 25). Chironomids made up 60% of their diet (Table 24) but were not favored. Bivalves, however, made up a very small percentage of the overall diet, only 2%, but in relation to its availability in the food base it is a preferred item (Table 25). They also prefer to consume terrestrial organisms when they are available; both scarab beetles and a spiders had positive E* values (Table 25). When breeding, the females shift to feed upon more cladocerans; 83% of the food intake was from sididae (Table 27). The only other food items that were considered to be preferred were amphipods, gastropods, and *Navicula* (Table 28). Chironomids were no longer sought out and dropped to only 1% of the diet (Table 27). After spawning, the females now have a very limited feeding repertoire. They only fed upon four different types of food, and only hydracarina are considered to be preferred (Table 31). Total abundance was very low; only nine items in total were found in the females' collective stomachs (Table 29).

Male bluegill sunfish also fed upon larval insects during the pre-breeding period but not in great numbers (Table 32). They fed very proportionately from the food base with a PS of 0.91 (Table 2). The largest portions of the diet came from the trichoptera of the family lepidostomatidae (26%) and chironomids (23%) (Table 32). Neither of these had positive E* values when the electivity index was calculated. Unionidae, phoridae, and calopterygidae were the only preferred items out of the 11 different prey items consumed. During the breeding period the diet does not change much in terms of diversity but more crustaceans are consumed during this time. A large amount of anastroca (fairy shrimp) was found in the males' stomachs, making up 86% of the diet (Table 35). Based on the relative electivity index it is preferred as well as ostracods and gastropods (Table 34). The diatom *Navicula* was also a prized food item and was the next most consumed item, although it only makes up 5% of the diet. As with the females, there was a decline in the number of different food items in the diet during the post-breeding period. The selected food items drop to only six (Table 29). Sididae and dixidae are the only preferred items (Table 37). Chironomids make up 54% of the diet but, based upon their numbers in the food base, they are not being heavily sought out and are just readily available, making them easy prey (Table 36). The amount of food consumed drops as with the females with total abundance only thirteen items (Table 29).

Although they are in an entirely different environment when compared to the Lake Mahopac bluegill sunfish, Long Pond bluegill sunfish do have similar diets. Pre-breeding females consume hydracarina, daphnia, chironomids, and ceratopogonidae just like their Lake

Mahopac counterparts (Table 40). They also consumed terrestrial insects that happened to fall into the lake, such as leafhoppers and adult diptera; Lake Mahopac females fed upon formicidae and one female consumed a spider. Chironomids and cladocerans made up the majority of their diet, 22% and 27% respectively (Table 40) but of the two only daphnia were preferred. Quite a few macroinvertebrates were found to be preferred, in fact five of the nine prey items: hydracarina, daphnia, undetermined diptera, aeshnidae, and cicadellidae (Table 39). The females' diet becomes much more diversified at breeding time, choosing from eighteen out of the thirty-two of the species available in the food base (Tables 5 and 43). They fed a bit less proportionately from the resources with species evenness only 0.442 (Table 42). Chironomids made up 71% of the overall diet (Table 42) but was not favored (Table 43). Other choice food items are isopods, ostracods, scarabs, undetermined diptera, undetermined odonates, heptageniidae, cicadellidae, and *Navicula* (Table 43). As the breeding season ends, we see little change in the diet for the females. They still choose chironomids as their most common prey, with 68% of the diet from the fly larvae (Table 45) but it still is not preferred (Table 46). They are still consuming crustaceans but only sididae is preferred (Table 46). Ceratopogonidae and trichoptera of the family lepidostomatidae are now sought out items, as are reed flowers.

Pre-breeding bluegill sunfish males from Long Pond fed very proportionally from the food base with a PS of 0.94 (Table 2). The majority of the diet comes from larval diptera, specifically chironimids and ceratopogonidae (Table 47). Their preferred food items are valvatidae, daphnia, ceratopogonidae, and odonates; chironomids did not have a positive E* value (Table 48). They have a relatively narrow feeding repertoire with 11 items, but it becomes even slimmer when they reach spawning time; the diversity drops to eight different species (Table 41). Amphipods and chironomids make up most of the diet but once again chironomids are not preferred. Besides amphipods, ground beetles and ceratopogonidae are favored. After spawning the males have a dramatic increase in their feeding diversity jumping up to 17 species (Table 44). Chironomids make up majority of the diet at 55% (Table 51), but still have negative E* values when the electivity index was calculated (Table 52). Prey items that did have positive E* values include sididae, the diptera of the family chaoboridae, undetermined diptera, aeshnidae, and terrestrial insects such as formicidae (ants) and coccinellidae (ladybird beetles or ladybugs.)

Discussion

Is there a difference in macroinvertebrate diversity between the two lakes?

Biodiversity was highest in Lake Mahopac. The lower total abundance of macroinvertebrates in Long Pond may be attributed to the fact that twice as many fish were sampled from Lake Mahopac where there were two species collected; only five redbreast sunfish were collected from Long Pond. If an equal amount of redbreast sunfish had been sampled, the abundance might have been as great as or greater than what was found in Lake Mahopac. More importantly is that the diversity seems to be greater in Lake Mahopac. The two lakes have different biogeographies. Lake Mahopac is found in a more surbanized setting with homes, two restaurants, and a highly trafficked road found on the periphery of the shores; motor boats are also allowed. Long Pond is relatively undistuburbed with only a few homes, a girlscout camp, and a small county park found on its shores. No motor boats are allowed on Long Pond and the roads that pass by it are not heavily trafficked. Lake Mahopac is almost completely devoid of aquatic vegetation and Long Pond has ample aquatic weed beds. It would stand to reason that Lake Mahopac would have less macroinvertebrate diversity than Long Pond given the several factors stated that could impact the water quality and biodiversity. This apparently is not the case.

The Hester-Dendy/plankton net/plant samples from Long Pond may not have had a great abundance of invertebrates but what was collected, when combined with the pooled stomach contents from the fish specimens, was enough to compare to Lake Mahopac. To compare the diversity of macroinvertebrates in the two lakes the Shannon-Wiener index of diversity H' was calculated for both Lake Mahopac and Long Pond; species richness and evenness were also calculated. The lack of vegetation due to the introduction of grass carp in Lake Mahopac evidently has not had a negative effect on invertebrate diversity since Lake Mahopac had a H' value of 2.217 compared to 1.942 from Long Pond. The difference between the macroinvertebrate diversity in the two lakes was significant with a t-test result of $P<0.05$. The J' values were not very different from each lake; Lake Mahopac had a J' value of 0.586 and Long Pond a J' value of 0.560. Data in tables 4 and 5 indicate that both lakes have a high number of chironomids. Lake Mahopac had over 36% of the total amount of macroinvertebrates collected coming from this family of diptera; 55% of the sampled macroinvertebrate population from Long Pond were chironomids. Chironomids are an important food source for both fish and aquatic birds (Shcherbina and Zelentsov, 2008) and their presence can be an indicator of water quality. Certain species are very tolerant of a wide range of quality conditions (Simpson and Bode, 1980). The species *Glyptotendipes lobiferus* indicates that there is the presence of large amounts of decomposable matter (Simpson and Bode, 1980). This organism was frequently found in both stomach contents (Appendix B) as well as from the samples from Hester-Dendy/plankton net (Appendix A) from Lake Mahopac and occasionally in samples from Long Pond. Lake Mahopac has a large amount of filamentous algae, which decomposes readily since they can be short-lived (Kiirikki and Lehvo, 1997) and decomposition of plant biomass can deplete oxygen levels in the water (Jewell, 1971) but Welch et al. found in their 1998 study that algae biomass did not have a negative effect on dissolved oxygen content and macroinvertebrate diversity. This appears to be the case with Lake Mahopac, which although it has a large biomass of filamentous algae it did not have an unusual decrease in dissolved oxygen levels (Table 1). *G. lobiferus* was not found in large numbers in Long Pond and large levels of algal biomass are not typical on this lake. The chironomid species *Ablabesmyia mallochi* was found regularly in both lakes; this chironomid is found in waters of various conditions (Simpson and Bode, 1980).

Cladocerans were found in much larger numbers in Lake Mahopac, specifically sididae. Daphnia were found in both lakes in almost equal numbers, but 348 sididae were obtained through invertebrate sampling methods and pooled stomach contents compared to a mere nine from Long Pond. Cladocerans are very sensitive to changes in water quality and are used to test for toxicity (Hickey, 1989; Cowgill and Milazzo, 1990; Bossuyt and Janssen, 2005; Meyer et al., 2009). Most times a species of daphnia (*Daphnia magna*) is used but a species of sididae (*Diaphanosoma brachyurum*) was used in a 2011 study by Mano et al. because they are frequently the dominant species in freshwater ponds and lakes. They found that *D. brachyurum* may be more sensitive to heavy metals than *Daphnia magna.* If this is the case, then it is possible that there may be contaminants in Long Pond that have not been discovered as of yet since the population of sididae is so small. This is definitely a finding that needs further study.

Another crustacean that appears to be absent from Long Pond is chirocephalidae, a family of anostraca; these organisms were found in large numbers in the stomachs of the fish from Lake Mahopac. Anostraca (fairy shrimp) have been used to test for the toxicity of chemicals (Moss, 2011). Pesticides have been found to cause high levels of mortality in some species of anostraca (Brausch et al., 2006). Because of the fear of disease caused by mosquitoes and ticks, insecticides are most likely sprayed in areas where groups of people frequent, specifically the beach at Sycamore Park and the girls scout camp. Runoff may cause these chemicals to enter the water therefore disrupting the ecosystem.

Whether sididae populations were larger in the past or if anostraca were ever present in Long Pond cannot be said for sure since no earlier study has been found on the flora and fauna of this lake. What can be stated is that this study found no evidence of anostraca and only a very small sample of sididae were obtained from invertebrate sampling methods and pooled stomach contents.

Do the fish change their feeding habits during the pre-breeding, breeding, and post-breeding seasons?

It was expected that there would be changes in feeding behavior based upon whether fish were in the pre-breeding, breeding, or post-breeding portions of the summer seasons. Other animals change their habits and food intake in preparation for breeding. Young found in his 1989 study of female crows that in order to prepare their bodies for egg laying and providing warmth and food to their offspring after they hatch, female crows increase their dietary intake. Iguanas use changes in food quality and water temperature to signal optimal breeding time (Rubenstein and Mikelski, 2003). Markovich et al. studied zebrafish in 2007 to see how diet can effect spawning success and found that the amount of viable offspring produced by the fish was dependent on the type of diet they were fed.

The cumulative frequency curves were not perfectly symmetrical due to several factors. When creating a cumulative frequency curve, food items that are found in the stomachs are tallied in a cumulative manner. In a hypothetical example, the first fish to be eviscerated has its stomach contents separated out into the lowest possible taxa which are then counted giving a total of four different prey items. The next fish yields five items, three of which were not found in the previous stomach. These new organisms are added to the first number of four making the cumulative frequency of prey items seven. This continues with the remainder of the fish in the group and the data is then used to create the curve. Many times there would be multiples of a particular items (see Appendix B) but in some instances odd prey items (for example a terrestrial beetle or spider) would be found in a fish's stomach that had to be added to the tally, which would create a crooked curve. If these items had not been counted the curves would probably have been much more uniform. Since it can be presumed that the fish consumed these items deliberately they could not be discounted. Another situation that led to imperfect curves were instances where stomachs were found empty; for example of the eleven post-breeding redbreast females were collected from Lake Mahopac, seven stomachs were empty so only a total of four types of prey items made up the curve (Figure 11). Female fish need recuperation time after spawning and it is not unusual to find empty stomachs during this time period (Nolli, 2011; Pitlow, 2012). Another factor that contributed to the appearance of the curves was the difficulty in collecting more specimens than were obtained, particularly bluegill of both genders and male redbreasts from Lake Mahopac. Despite many attempts over the course of three years (Appendix B), many times only redbreasts were captured and frequently they were female. As mentioned previously, sunfish males from both species guard their nests until the fry leave the nests (Stegemann, 1990). This decreases the number of males that will be attracted to bait and therefore in reach of capture. Other sites were sought but much of the periphery around Canopus Island (Figure 5) has either a sharp decline right off the shoreline or is very rocky, neither which situation lends itself to successful nest creation. Much of the main shoreline is privately owned, as is Fairy Island and Petra Island, so sites could not be obtained there. Although the curves are not perfectly formed, it is believed that the specimens that were captured yielded enough data to compare the two species of fish during the different time periods that were being studied (pre-breeding, breeding, and post-breeding).

Niche breadth (NB) and proportional similarity (PS) were calculated using the normalized version of the Levins index for NB and the Feinsinger proportional similarity in feeding index for PS for both genders of the two species of sunfish (redbreasts and bluegills from Lake Mahopac and bluegills from Long Pond) from both lakes for all three periods (Table 2). The results showed that both species of sunfish are opportunists and remain so throughout the summer months regardless of period except for post-breeding redbreast sunfish females, who became specialists after spawning. This is contrary to what other studies have shown. Paszkowski referred to bluegills as “dietary generalists” in her 1986 paper on foraging site use and competition between the bluegills and golden shiners. Rachlin et al. determined in 1989 that bluegill sunfish are classic specialists. The discrepencies that are seen here may be due to the differences in habitat or population density (Olson et al., 2003).

Is there overlap in the diets of redbreasts and bluegills in Lake Mahopac

Overlap is common between different species of sunfish (Werner and Hall, 1979; Osenberg et al., 1988; Huckins, 1997), and is often a product of habitat structure (Werner and Hall, 1977). Some species are more adaptable to different habitats than others and will abandon preferred habitats if the change will be more profitable (Werner and Hall, 1979). Bluegill sunfish normally forage in vegetated waters, but Werner et al. found in their 1981 study that bluegills can adapt to different habitats based on learning mechanisms and sampling. Lake Mahopac was devegetated due to the introduction of grass carp (*Ctenopharyngodon idella*) in 1994. As a result bluegill populations have declined. A study done by the DEC in 2003 found that catch rates went from 72 per hour in the 1990's to 49 per hour in 2003. Redbreasts have not been affected by the lack of vegetation and actually increased in the same time period. Although the populations are inequal, there is little overlap seen in the diets of the two fish. The Schoener % overlap index was calculated for comparison between pre-breeding, breeding, and post-breeding redbreasts and bluegills. The calculations were done seperately for each gender during these time periods. Only pre-breeding and post-breeding females had any overlap in their diets, with the Schoener % overlap 0.670 and 0.643 respectively. Males of the two species had no overlap in their diets at any time. Because many studies look at overlap in the general populations and do not separate them into time periods, the Schoener % index was also calculated for the two sampled populations from Lake Mahopac and still there was no overlap with a result of 0.278.

Bluegill diets include insect larvae (such as chironomids and trichoptera), crustaceans (such as amphipods and daphnia), as well as gastropods (Olson et al., 2003). These organisms were frequently found in the stomachs of the sampled bluegills from Lake Mahopac.

Chironomids were found in the female bluegill stomachs at all three time periods. During the pre-breeding period it is the major food item consumed with 60% of the overall diet being made up of this larval diptera. Sididae, a type of cladocera, was also frequently consumed by bluegills. It made up 83%t of the breeding bluegill females diet. Chironomids and sididae were found in the stomachs of male bluegills from all three time periods. Redbreast sunfish are primarily insectivores, occasionally consuming crustaceans and gastropods, as well as other food items (Cooner and Bayne, 1982). Pre-breeding redbreast sunfish had the most varied diet consuming 20 different types of prey. Chironomids were the most frequently found item and it made up 67% of the pre-breeding redbreast female diet. It was also found in the stomachs of breeding redbreast females but not in the post-breeding diet. During the post-breeding time consumption of food declined with total abundance of only 46 prey items, the majority of which came from formicidae.

Despite the lack of aquatic vegetation there is ample prey available (Appendix A) to sunfish and other species of fish that inhabit the lake and only a small amount of overlap was found in the diets of the two fish species studied.

Is there a difference in the diversity of the diets of redbreast and bluegill sunfish from Lake Mahopac?

There is a difference in the diversity of the diets of redbreast and bluegill sunfish from Lake Mahopac. The post-breeding males had no significant difference in the diversity of their diets. There were fluctuations in total abundance, species richness, and evenness of the distribution of the prey items in the diets of both males and females of both species. Neither female nor male redbreast and bluegill shared preferred prey items in their diets for any of the time periods.

There is a difference in the dietary diversities of the two species of sunfish from this lake; neither species has a more diverse diet than the other since the Shannon-Wiener index and evenness values had fluctuations. During the pre-breeding period, bluegill females had higher values for both H' and J' than redbreasts but during the breeding period redbreasts had the higher values. Both species had variations in the amount of dietary diversity and evenness; only post-breeding male redbreast and bluegill sunfish had the same diversity of food items in their diets.

Is there a difference between the feeding habits and species diversity in the diets of male and female fish (both redbreasts and bluegills)?

There was little change in the dietary habits of the redbreasts and bluegills of Lake Mahopac with only breeding redbreasts shifting from being opportunists to specialists in the post-breeding period. The majority of the diet during the time they feed as specialists came from swarming ants trapped by the water. Spawning is very costly in terms of energy losses (Milton et al., 1994; Berg et al., 1998); finding and consuming large quantities of an easily captured species during one's feeding would be advantageous and energy efficient.

Pre-breeding is an important time for females; producing offspring is very costly in terms of energy (Rubenstein and Mikelski, 2003) and dietary preferences can change for a variety of species (Young 1989, Durstche 1991, Rubenstein and Mikelksi 2003, Velara et al. 2005, Markovich et al. 2007). Dietary behavioral changes due to preparation for breeding occur with other species. Does it change with redbreast and bluegill sunfish and is there a difference between the dietary diversities of males and females at this time?

Pre-breeding redbreast females consumed a large amount of prey prior to spawing; 519 food items were removed from the sampled fish stomachs. The majority of this food came from chironomids and eggs from an undetermined species. Both of these items are high energy foods due to the amounts of protein and fat contained in both. The rest of the diet was made up of a variety of crustaceans, insects (both larval and adult), and algae (Table 8). There is quite a lot of overlap in the two diets. Males also consumed a variety of items, many of them also found in the females diet. However, the diversity of the prey items in the male redbreast diet is lower than diversity in the female redbreast diet.

Bluegill males and females from Lake Mahopac have no overlap in their diets at any time (pre-breeding, breeding, and post-breeding). Pre-breeding bluegill females have lower values for the Shannon-Wiener diversity index and evenness compared to males (Table 23), which contrasts with pre-breeding redbreasts from the same lake. Females consume a variety of crustaceans and insects but like pre-breeding female redbreasts consume the largest part of their diet from chironomids at 60% of the total amount consumed. Females may be increasing their consumption of high energy foods in preparation of spawning. Northern pike females cosume more energy than males throughout the year with ovary growth occurring during the winter months and testicular growth in late august; both females and males had decreased energy stores after spawning (Diana, 1983). Pacific saury increased their food intake during the summer months in order to prepare for spawning in sub-tropical waters during the winter months where there is less available food (Kurita, 2004). Production of eggs and somatic growth is directly linked to the amount of food consumed by the three-spined stickleback (*Gasterosteus aculeatus* L.) females (Wootton and Evans, 1976). Pre-breeding bluegill males did not consume any organism is such large numbers, although chironomids were the most frequently ingested prey, 23%. Chironomids were the most common macroinvertebrate sampled from Lake Mahopac based on both the Hester-Dendy/plankton net samples and pooled stomach contents (Table 4), it is a relatively easy prey to locate and capture. Since it is a high quality food it would be sought out by both males and females of the two species due to its abundance, although females consume chironimids in greater quantities.

During the breeding or spawning period the redbreasts have no actual overlap in their diets with the Schoener index value at 0.59. The diversity of prey items is not the same for males and females. The females have a higher diversity of macroinvertebrates than do the males and the prey items are more evenly distributed in their (Table 13). Females consume more crustaceans at this time compared to what they consumed pre-breeding; the males' diet does not change very much from the pre-breeding time to the actual breeding period with a combination of crustaceans and insects the main sources of food.

Breeding bluegills from Lake Mahopac have the same diversity of prey items in their diet and both had low Shannon-Wiener index and Pielou's evenness values (Table 26); diversity is also the same during the post-breeding period but H' and J' values both increase for both genders (Table 29). The greatest intake of food for both males and females is during the breeding period when total abundance is 240 for females and 454 for males. The number of prey items consumed by males and females is a bit misleading; most of that amount came from anostraca as 392 individuals were consumed by males and 200 sididae were consumed by females. Anostraca can be found in large groups making it easy for the fish to consume large amounts of them at one time. It is possible that the males would have access to these crustaceans even if they were guarding the nests. Anostraca frequent shallow bodies of water, including temporary pools (Dierckens et al., 1997), and are filter feeders foraging upon algae that is found in sediments on the bottom of lakes and ponds (Paggi, 1996).

Long Pond bluegill diets are opposite those from Lake Mahopac bluegills. There is an overlap in the diets of the males and females and it increases as summer moves towards fall. During the pre-breeding period it is lowest with a Schoener index value of 0.673; the value increases to 0.706 during spawning and it the highest post-spawning with a Schoener index value of 0.825 (Table 3). Since there is abundant prey available in Long Pond (Table 5) it cannot be said that the two species (redbreasts and bluegills) are actually competing for the prey available in the resource base but if conditions deteriorated and certain organisms that make up the bluegills' diet became scarce the males and females may be forced to compete for food. There is no significant difference in the diversity of prey items for males and females and both have similar H' and J' values (Table 38). During the pre-breeding period females consume mainly daphniidae and chironomids consuming 27% and 22% of these two food items respectively. Males also consume a fair amount of daphniidae at this time, although the majority of their diet came from larval diptera, chironomids and ceratopogonidae (Table 47).

During the breeding period the diversity of prey items is no longer the same for female and male bluegills from Long Pond. There is a drop in H' and J' values during this time for both but there is an increase in species richness for females. During the pre-breeding time they had nine different prey items in their diet, but during spawning it increases to 18. A large amount of their diet comes from chironomids at 71%; the rest of the prey consumed was made up of an array crustaceans, mollusks, insects, and plant items. Males also seem to favor chironomids with 68% of their diet based on this food type. As with Lake Mahopac, chironomids are in large supply as is evidenced by the resource base that was calculated from the combined Hester-Dendy/plankton net/plant samples and pooled stomach contents from Long Pond (Table 5).

The diversity of prey items at Long Pond is equal for post-breeding male and female bluegills. Males consumed a greater variety of prey items with species richness increasing to 17 different types of prey; females consumed 12. Chironomids are the most abundance prey found in both diets and both feed on a variety of different types of crustaceans and insects.

Post-breeding redbreast and bluegill females from Lake Mahopac have a sharp decrease in dietary species diversity with both feeding on four different prey types with small numbers of total organisms consumed, 46 for redbreasts and 9 for bluegills. Post-breeding females from Long Pond had only a small decrease in the overall amount of prey consumed from the breeding period to the post-breeding period. Fordham and Trippel found in their 1999 study that Atlantic cod (*Gadus morhua*) have an increase in food intake post-spawning. Recent research conducted by Paulo-Martins, et al. in 2011 yielded evidence that scaldfish (*Arnoglossus laterna*) females consume more prey during non-spawning times than do males; males consume more during the actual time of spawning. Bluegills and redbreast females decrease their food intake post-spawning. Since the time periods were based upon water temperature and therefore are loosely defined it is possible that Long Pond females were still spawning at their time of capture, which would explain why they were still consuming larger amounts of prey when compared to their Lake Mahopac counterparts.

Post-breeding redbreast males have an increase in their dietary consumption in Lake Mahopac but Mahopac bluegill males' consumption drops down to a low total abundance of only 13 prey items. Even if the anostraca were not consumed during the breeding period bluegill males will still have consumed more food during that time period. Long Pond bluegill males also increase their dietary intake after spawning.

The strange inconsistancies in dietary habits of the post-breeding males is puzzling. There is no overlap in the redbreast and bluegill males' diets and yet bluegills still have a very low dietary intake. It may be possible that the presence of largemouth bass influences the behavior of bluegill during this time. Since bluegill are a major food source for largemouth bass (Olson, 1996), largemouth bass most likely move into areas where easily caught fry would be found. Since there is no weed cover for the bluegills, they would be forced to disperse into deeper waters (Savino and Stein, 1989), which would explain the low number of bluegills captured in Lake Mahopac post-breeding and the presence of largemouth bass may be the cause of the disruption in foraging in the males and females.

Is there a difference between the bluegill populations from Lake Mahopac and Long Pond?

Because there is a difference in the ecosystems of the two lakes it was important to compare the populations of the bluegills from both; redbreast sunfish comparisons could not be done because the population is obviously very small in Long Pond since only five fish were collected over several years. It seems that the locale plays a role in how the bluegill sunfish forage. In a 2003 paper Olson et al., found that prey selection and diets may be related to bluegill sunfish population density. The bluegill sunfish populations in the more densely populated Cozad Lake are more opportunistic than the population found in the lower populated Watts Lake. Both lakes are located in Nebraska. Since Lake Mahopac has been devegetated by the grass carp introduced in 1994, bluegills are forced to forage in open waters for the duration of their lives. Younger and smaller bluegills prefer to feed in vegetated areas to avoid predation by largemouth bass (Werner and Hall, 1988).

Even though the ecosystems are different in the two lakes (Long Pond is relatively undisturbed and has large aquatic weed beds while Lake Mahopac is more suburbanized and has little to no aquatic vegetation) there is little difference in the morphology of the two populations. The size and mass of the bluegills are almost equal for both lakes. Both populations feed as opportunists. The differences lie with dietary preference and overall consumption of the chosen prey. Lake Mahopac females consume almost double the amount of prey during the pre-breeding period compared to Long Pond females. This is unusual since more females were sampled from Long Pond. This is not the case with the males of the same period, in which it is the bluegills from Long Pond who consume almost double the amount of prey, but the number of male bluegills sampled from each lake is equal, N=6. The inconsistency may be due to the habitat in which each population is found. There is quite a bit of overlap between the diets of the redbreast males and females at this point and may indicate that the females are ingesting more prey in order to prepare for spawning. Redbreast females (and males) are better able to capture macroinvertebrates in open waters since they can be found in a number of habitats that are not highly vegetated (Freeman, 1995); bluegills must adapt to the lack of aquatic vegetation and gain proficiency in foraging in a habitat that doesn't have the benefit of weed beds (Ehlinger, 1990). Redbreast males had similar dietary richness as the bluegill males during the pre-breeding period with 12 different prey items being chosen; bluegill males chose 11 but total abundance was more than half of what was consumed by the redbreast males. Bluegill males must forage amongst both the redbreast females and males and bluegill females in Lake Mahopac, and thus they may not be able to capture as much prey as the bluegill males from Long Pond, where the bluegill population is dominant and possible competition for prey is reduced.

Long Pond females have a much more diverse diet during the breeding period compared to Lake Mahopac females and consume chironomids as the majority of their diet, whereas Lake Mahopac females foraged mainly on sididae, which is apparently not abundant in Long Pond. Males from Lake Mahopac consumed large amounts of anostraca, which was not found in Long Pond; like the females, Long Pond males consume chironomids as the bulk of their diet. The difference between the two populations is most likely due to the differences in habitat. If sididae and anostraca were abundant prey in Long Pond, they may be highly sought out prey items.

Only a small number of bluegills were captured from Lake Mahopac during the post-breeding period. The fish that were sampled had low prey density in their stomachs and the variety of prey items also decreased. As was stated earlier, largemouth bass forage on bluegill; in fact it is their favorite fish prey (Olson, 1996). Their presence in the shallows may increase post-spawning as they search for bluegill fry and small adult bluegill. Because of the lack of weed beds, the fish would be forced to avoid the largemouth bass by swimming to deeper waters. Prey capture decreases as depth increases; bass can only effectively prey on bluegill along the periphery of weed beds (Trebitz et al., 1997). In the case of Lake Mahopac there are no weed beds but the bass would still hunt along the periphery of the banks of the lake; foraging success is partially dependent upon water clarity (McMahon and Holanov, 1995), which decreases in deeper water. Since bluegill (especially juveniles and young adults) prefer to forage for prey in the littoral zone (Mittelbach, 1988), it is possible that being forced to forage in open waters may be causing the decrease in prey capture and consumption. Attempts to capture bluegill from deeper waters yielded no success; this may be due to the fact that the population of bluegills is small in Lake Mahopac.

Long Pond males and females consume ample amounts of prey during the post-breeding period. Avoidance of possible predation by the bass is more achievable by the dense vegetation that is found in the littoral zone of Long Pond.

Studies have shown that bluegills have the capacity to adapt to various environmental conditions (Ehlinger and Wilson, 1988; Ehlinger, 1990) and much of this ability is based upon morphological features (Ehlinger and Wilson, 1988), such as the insertion of pectoral fins and the length of anal and dorsal fins. Certain body types are more suitable for openwater foraging (a more fusiform structure that decreases drag) and bluegills that display this type of morphology would be better able to cope with the lack of weed beds. Certain mutations of morphological characteristics can bestow some reproductive selective advantage if these mutations are found to increase longevity (Hirsch, 1979). Bluegills that have a more fusiform morphology would have greater reproductive advantage in waters devoid of weed beds. If there are more streamlined bluegills present in Lake Mahopac and they do indeed breed more successfully, then perhaps the population of bluegills will increase in number whether or not the weed beds return.

Is there a preference for certain prey items?

Despite the lack of change in feeding behavior, there were differences in the diets based upon the time period. Redbreast and bluegill females from Lake Mahopac consumed larger amounts of chironomids during the pre-breeding period, but when the E* values were calculated it was not a preferred item. Since this index is based on the proportions of the food item in question from both the environment and the stomach contents of the species in question, if there is a very large amount of that particular organism in the environment compared to what is found in the diet, a negative value for E* may result. Chironomids made up 67% of the overall pre-breeding redbreast females' diet and 60% of the pre-breeding bluegill females. Pre-breeding bluegill females from Long Pond did not consume as many chirnomids as the Lake Mahopac fish during the same period but it was one of the largest parts of their diet, 22%. Chironomids are an important caloric food source for fish (Bernard et al., 1997) containing large amounts of polyethenoid fatty acids, which is associated with the fat of fish (Grindley, 1951).

The consumption of chironomids declines for Lake Mahopac redbreast and bluegill females during the breeding and post-breeding periods. Post-breeding redbreast females consumed no chironomids at all, though chironomids are still widely-available in the environment (Appendix A). Instead 91% of their diet came from ant swarms floating on the lake surface. This prey item is found in many of the fish stomachs; it makes up 69% of the post-breeding redbreast males' diets. Ant swarms are quite common in the later summer months (Nagel and Rettenmeyer, 1973; Leprince and Francoeur, 1986; O'Neill, 1994) and often become trapped by bodies of water. Based upon the idea of optimal foraging theory (organisms forage or hunt for prey that will not cause them to expend more energy than they will gain when the prey is consumed), it is an energy efficient food source.

Interestingly enough breeding bluegill females from Long Pond had an increase in the consumption of chironomids with 71% of the overall diet being made up of this prey at this time period. Almost the same amount of bluegill females were sampled from both lakes for this time period, 12 for Lake Mahopac and 14 for Long Pond. There is no explanation as to why Lake Mahopac females of both species practically ignore chironomids while Long Pond females obviously seek them out.

As was pointed out earlier, Lake Mahopac males of both species are opportunists; Long Pond males are also opportunists. As we have frequently seen with the females, males feed predominately on chironomids. This is not suprising considering their abundance in both lakes. Chironomids were found to be a large portion of the diets of bluegills in coastal Mississippi (Peterson, et al. 2006). In a 2008 study, Nikolova et al. found that the major food source for pumpkinseed sunfish (*Lepomis gibbosus*) was the chironomid. Pumpkinseeds are close relatives to both redbreasts and bluegills and have been known to interbreed with both species (Clark, et al., 1984; Jordan, et al., 2009). Because of this close association, it can be presumed that redbreasts and bluegills will feed on similar organisms as the pumpkinseed sunfish.

Cladocerans were frequently consumed by both redbreasts and bluegills. Lake Mahopac pre-breeding and breeding females consumed daphnia, as did pre-breeding bluegill females from the same lake. Daphnia were consumed by pre-breeding bluegill females and males and post-breeding males from Long Pond. During the breeding period, Lake Mahopac redbreast and bluegill females had large amounts of sididae in their stomachs but no cladocerans of any kind were found in the breeding bluegill stomachs from Long Pond. In fact, relatively few sididae were found in Long Pond. No sididae were captured using traditional sampling methods (Appendix A). Cladocerans are very sensitive to changes in their habitat and are frequently used to test water quality (Hickey 1989, Cowgill and Milazzo 1990, Bossuyt and Janssen 2005, Meyer et al. 2009). It is possible that there are contaminants in Long Pond that have not been discovered as of yet but the distinctive low levels of cladocerans point to a possible problem. Water tests in this study measured only dissolved oxygen, pH, and phosphorus (Table 3) but did not test for salinity or metals.

Conclusion

This study led to some surprising findings. Because of the lack of vegetation in Lake Mahopac, the population of bluegills is very low; the bluegill population in Long Pond is flourishing, but there are so few redbreast sunfish in this lake it was difficult to collect enough to study. This fact has led to a belief that the populations are usually not equal and is most likely attributed to habitat. Redbreast sunfish prefer moving water and there are currents in Lake Mahopac due to underground streams and the inlet and outlet. Long Pond is more stagnant but provides the necessary weed beds that bluegills need in order to thrive. Another factor is bluegill are the primary fish prey for largemouth bass; since Lake Mahopac has inadequate aquatic weed beds the bluegills may have difficulty evading the bass, especially after spawning when the abundance of fry would be very enticing to the predator. Adults may be forced into deeper waters earlier than redbreasts, which may explain why so few are found in the littoral zone in late summer.

There is not much change in the feeding habits of the sunfish that were studied; all the fish in Lake Mahopac are opportunists except for the post-breeding redbreast females, which became specialists. Long Pond bluegill sunfish females and males are also opportunists throughout all three periods. In Rachlin's 1989 paper on niche breadth, it was found that bluegill sunfish are true feeding specialists. Fish used in this study were from a tributary of the Croton River drainage of northeastern Westchester County, New York. This body of water has more current than Long Pond, which is relatively stagnant. It may be that location has a great deal of bearing on the feeding habits of bluegills as previous studies have indicated (Ehlinger, 1990; Olson et al., 2003).

Although the fish, for the most part, do not change their behavior in the way they feed, during the pre-breeding period redbreast sunfish females and males did choose more larval insects, possibly because of their availability as well as their energy content. There is a definite decrease in the amount of food that is consumed by the redbreast sunfish females post-breeding but the redbreast sunfish males' increase their dietary intake during this time.

Overlap in diet occurs in several cases. Pre-breeding females of both species have overlap in their diets. Ten out of twelve prey items found in the pre-breeding bluegill sunfish stomachs are also part of the female redbreast sunfish diet during the same period, although redbreast sunfish females have a much larger diversity in their diets consuming twenty different items. The overlap between the females' diets decreases as the summer progresses. There is no overlap in the two diets during spawning and a small amount of overlap found in the post-breeding period. If competition were to occur between the females it would be strongest early on in the season during the pre-breeding period. No overlap was found between the redbreast sunfish and bluegill sunfish in Lake Mahopac and diversity in the diets is significant.

There is overlap in the diets of the male and female redbreast sunfish in Lake Mahopac during the pre-breeding period but not during the actual breeding season. The highest value for the Schoener % overlap index was 0.835, which occurred post-breeding. There is little to no overlap in the diets of the bluegill sunfish in the same lake. However, the male and female bluegill sunfish found in Long Pond do have overlap in their diets throughout the different periods and like Lake Mahopac redbreast sunfish the overlap is strongest during post-breeding and if there was a decrease in the favored food items the fish would either compete for the prey or have a dietary shift in feeding behavior. Crowder and Cooper (1982) found in their study that when macrophyte populations are low, bluegill sunfish have narrower diets than when the macrophyte populations are moderate to high, therefore it stands to reason that the fish would change their foraging strategy in Long Pond if prey became scarce.

There is little difference in the amount of diversity between the two lakes; both have ample populations of invertebrates to support the fish populations at this time. Species richness is higher in Lake Mahopac than it is in Long Pond, unsusual because of the devegetation. Evenness of the macroinvetebrates is similar to both lakes with values that indicate some species populations are larger than others. There are some common species of crustaceans that are found in Lake Mahopac that are either very scarce (sididae) or are completely lacking (anostraca) from Long Pond. Both of these organisms are very sensitive to changes in the water quality and the fact that they are so low in abundance or completely missing indicates that further studies upon the water quality of Long Pond is necessary. This study focused only on basics, such as dissolved oxygen, pH, water temperature, and phosphorus levels.

The most surprising finding was the fact that Lake Mahopac bluegill sunfish populations have decreased over the years due to the lack of vegetation that was caused by the introduction of grass carp in 1994. Bluegill sunfish prefer areas with adequate weeds beds in order to breed and for the fry to forage in a protective area (ODWC, 2010). Although the two habitats are quite different, there has been little effect at this time on the morphology of the fish. The two populations have similar average length and mass but the sheer number of bluegill sunfish in Lake Mahopac has been diminished by half for smaller individuals of eight centimeters in length.

In a case like Lake Mahopac, bluegill sunfish are forced to feed out in open waters and may suffer from more predation in the early stages of development than populations that live in environments with ample weed beds but because of the lack of vegetation, young fish are able to feed upon a more diverse food base. If the fish that are forced to grow up in unprotected waters survive to adulthood, over time the population in Lake Mahopac may adapt to the situation and a new type of bluegill sunfish may arise, one that breeds and forages in open waters, much like redbreast sunfish. This is definitely a possibility as other studies have focused on habitat change and adaptive flexibility of bluegills (Ehlinger and Wilson, 1988; Ehlinger, 1990).

Biological control of an invasive species can be an effective way of dealing with the problem at hand, but often leads to distinct changes in the habitat as is evidenced by the decline of the populations of fish in Lake Mahopac. The introduction of the rosy wolf snail to many Pacific islands as a biological control for the invasive giant African snail created an even bigger threat to the native snail population since they foraged upon these animals as well as the invasive species (Hadfield et al., 1993). Grass carp (*Ctenopharyngodon idella*) have been problematic in other bodies of water that have been overpopulated by the invasive aquatic weed Eurasian watermilfoil (*Myriophyllum spicatum*). McKnight and Hepp conducted a study from 1992 to 1993 on the effects of grass carp on the watermilfoil population in an Alabama reservoir (McKnight and Hepp, 1995). They found that the grass carp reduced native aquatic plant species that provide food for waterfowl while ignoring the watermilfoil in some areas of the reservoir. Their conclusion was that grass carp need to be carefully introduced, especially in areas that have more highly-palatable plant species that will often be decimated before the watermilfoil is even touched.

The grass carp population has essentially died off in Lake Mahopac, but there is talk of another introduction of the fish in smaller numbers. If an overestimation of the quantity of fish to be introduced occurs again, the native weed beds may be permanently lost and further decline and possible eradication of the bluegill sunfish in the lake will occur.

Redbreast sunfish seem to have benefitted from the lack of vegetation and actually have had an increase in population size. This gives some evidence that the two species may have interspecific competition for food. Bluegill sunfish do compete with pumpkinseed sunfish (*Lepomis gibbosus*) when the pumpkinseed sunfish are small, below 7.0 centimeters. They both feed on soft-bodied macroinvertebrates that are found in vegetated waters to avoid predation; when they grow larger than 7.0 centimeters they move into open waters. Bluegill sunfish continue to consume zooplankton and macroinvertebrates while pumpkinseed sunfish are now able to break open the shells of gastropods (Arendt and Wilson, 1999). Since the weed beds have been eradicated from Lake Mahopac bluegill sunfish are forced to feed out in the open even during their early development leaving them open to predation.

Since the bluegill population has decreased, redbreast sunfish have less competition for the macroinvertebrates and zooplankton that they both consume therefore increasing their numbers as the bluegill sunfish population diminishes; this points to the possibility bluegill sunfish might also compete for resources with redbreast sunfish. It was shown in this study that there is definite overlap between the females of the two species during the pre-breeding period. Since most studies do not group the species in question based upon gender and time period as this study has done but calculate % overlap on entire sampled populations, it was important to determine if there is overlap between redbreasts and bluegills from Lake Mahopac if they were not separated into the groups (pre-breeding, breeding, post-breeding) that had been established for the rest of the study. It seems that when the redbreasts and bluegills are treated as two sampled populations without further separation into groups there is no overlap between the two species. Since this is the case, the decline in the bluegill population in Lake Mahopac is most likely due to lack of weed beds. Weed beds are not not only where many bluegills forage for food, but also serves as a hiding area from predacious largemouth bass. Largemouth bass have easier access to fry and small adults where there is no vegetation and it is almost certain that they played a large role in the decimation of the bluegills of Lake Mahopac. It is hoped that as time passes, the bluegills will become more adept at foraging (and escaping) in open waters so that their populations can increase.

Summary of Conclusions:

1. For the most part, redbreasts do not change their feeding habits and are opportunists regardless of time period; only post-breeding redbreasts switch from opportunists to specialists.
2. Bluegill populations from both lakes are opportunists; the lack of vegetation does not seem to have changed the habits of the Lake Mahopac population. Both Lake Mahopac and Long Pond residents feed upon mainly crustaceans and insect larvae. However, in Lake Mahopac, sididae and anostraca were found in the stomach contents and in fact sididae was a preferred item for females during the breeding period and anostraca was preferred during the same time for males.
3. Redbreast and bluegill sunfish frequently forage for chironomids, this prey item being found in large quantities in many of the fish stomachs. Despite that, it was never calculated to be preferred. Since it is so abundant in the environment it may be that the niche breadth calculations fail to measure how important this prey item is to the two populations. Insect larvae in general are highly caloric and nutrient rich. It seems that even though the calculations indicate it is not preferred, the fish are actively seeking it out.

4. Females and males of both species have similar diets, consuming mainly crustaceans and insect larvae. What is different for the females in Lake Mahopac is that they consume more calories during the pre-breeding period than the males; it is opposite for sampled population from Long Pond where males consumed slightly more than females. Post-breeding females of both species in Lake Mahopac have a sharp decline in species richness and abundance, whereas redbreast males increase in both but post-breeding bluegill males do not. In fact bluegill males and females from Lake Mahopac both have very low species richness and abundance. Male and female bluegills from Long Pond have high species richness and high total abundance of prey consumed.
5. There is very little overlap between the two species in Lake Mahopac; pre-breeding and post-breeding females have a small amount. Pre-breeding and post-breeding redbreast males and females have quite a bit of overlap in their diets. Pre-breeding redbreast females consume such a large array of prey items that some overlap between their diet and the male diet was almost inevitable; post-breeding females and males both consumed mainly formicidae, which is why there is overlap during this period in time.
6. There has not been a decline in the species richness in Lake Mahopac due to the lack of vegetation; in fact there is as much if not more different macroorganisms then are found in Long Pond. Certain crustaceans that are very common in lakes and ponds (sididae and anostraca) are found in Lake Mahopac in large numbers but are either very scarce (sididae) or absent (anostraca). These organisms are used to test water quality and it is possible that there are some undetected contaminants in the waters of Long Pond that are affecting the populations of these two crustaceans.

7. Because of the lack of vegetation that is due to the introduction of grass carp into Lake Mahopac, the bluegill populations have declined by almost half since 1994. This is opposite of what is seen with the redbreast population, which has increased by almost double since that same time period. Bluegills use weed beds for foraging areas, as well as protection for fry and small, young adults to avoid predation from largemouth bass populations. Although the largemouth bass populations have also sharply decreased, the lack of weed cover renders the bluegill population more vulnerable to attack. Redbreasts may be thriving because many of the macroinvertebrates that make up their diet are now forced to use other substrates for breeding and foraging rather than aquatic vegetation making them more easily captured by the open water foraging redbreasts. If the present conditions remain the same, adaptations may have to occur in the bluegill population in order for them to survive the changes that have occurred in their environment or they may eventually become extinct from the waters of Lake Mahopac.

<u>**Figures**</u>

<u>Figure 9: Cumulative frequency of prey items for pre-breeding redbreast sunfish (*Lepomis auritus*) females, Lake Mahopac</u>

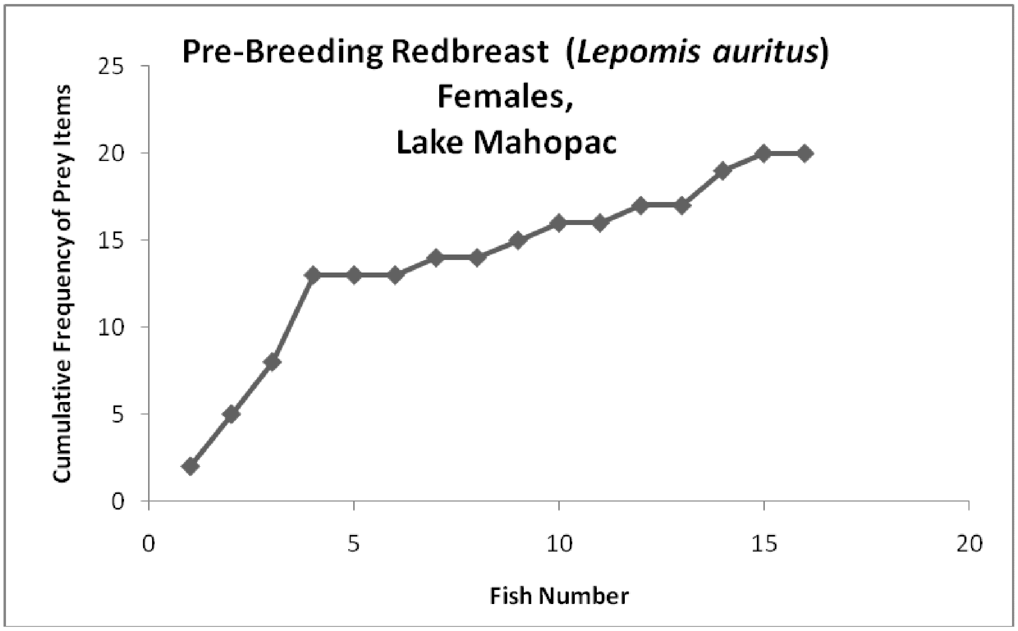


Figure 10: Cumulative frequency of prey items for breeding redbreast sunfish, (*Lepomis auritus*) females, Lake Mahopac

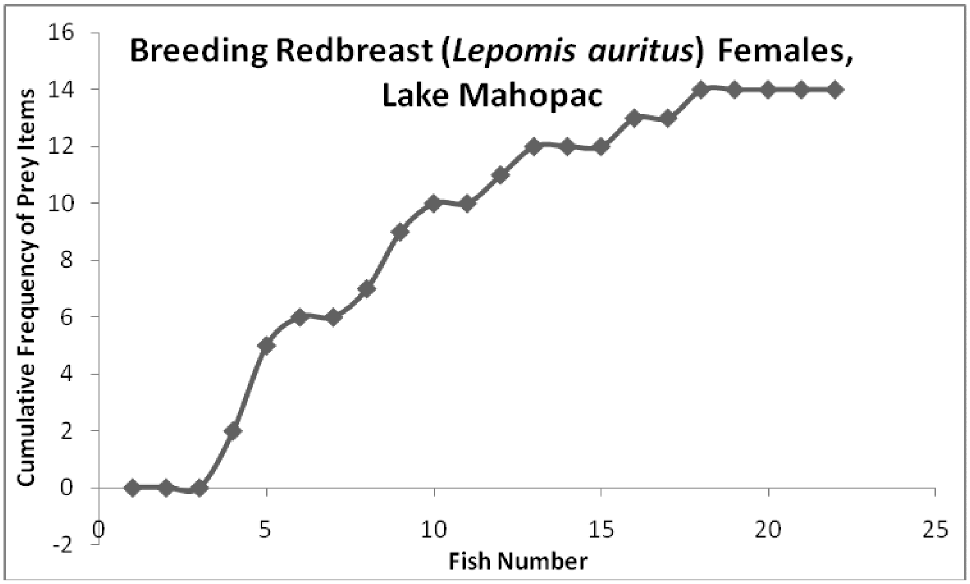


Figure 11: Cumulative frequency of prey items for post-breeding redbreast sunfish, (*Lepomis auritus*) females, Lake Mahopac

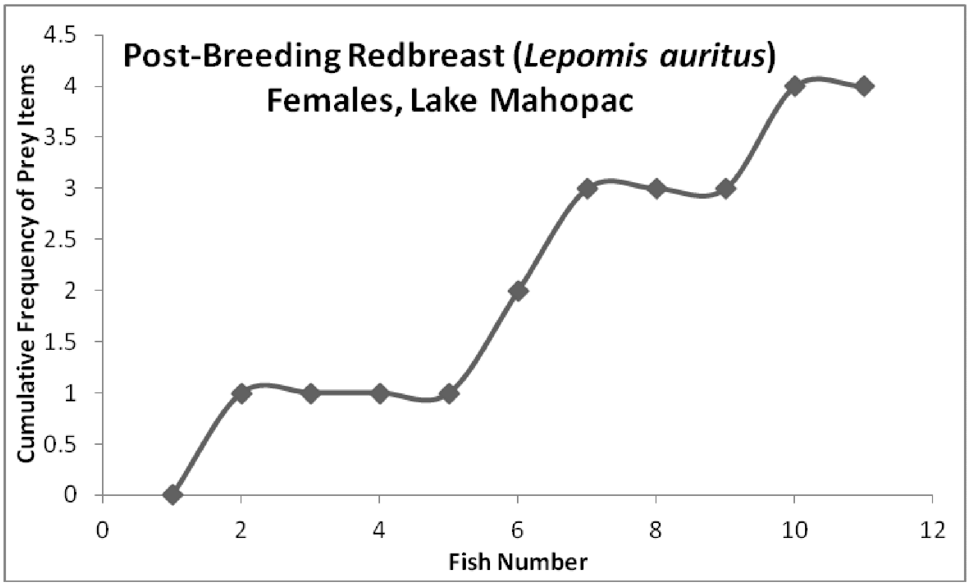


Figure 12: Cumulative frequency of prey items for pre-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

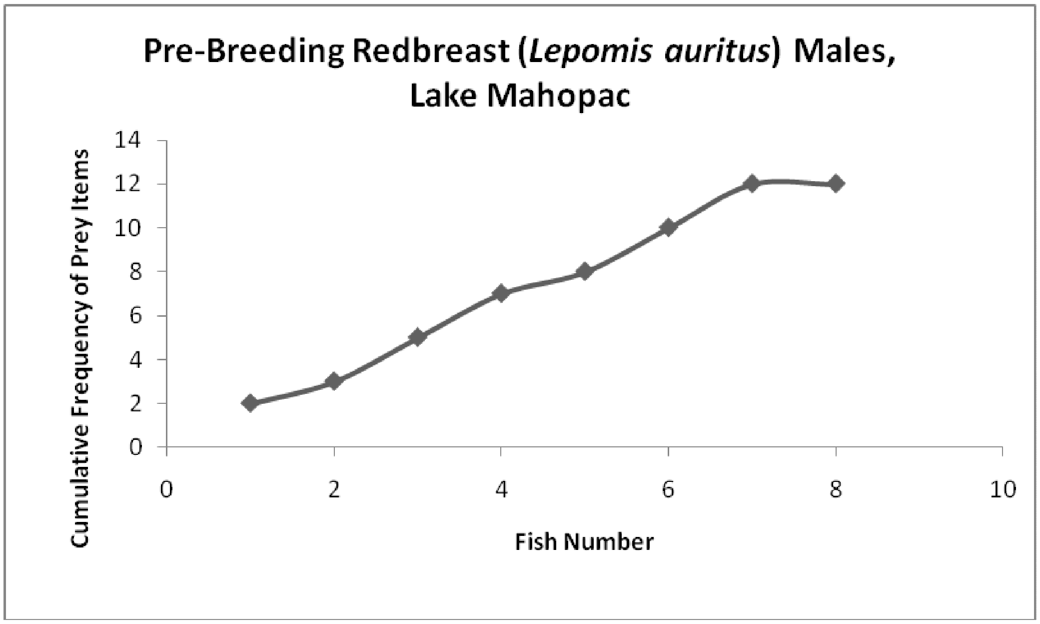


Figure 13. Cumulative frequency of prey items for breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

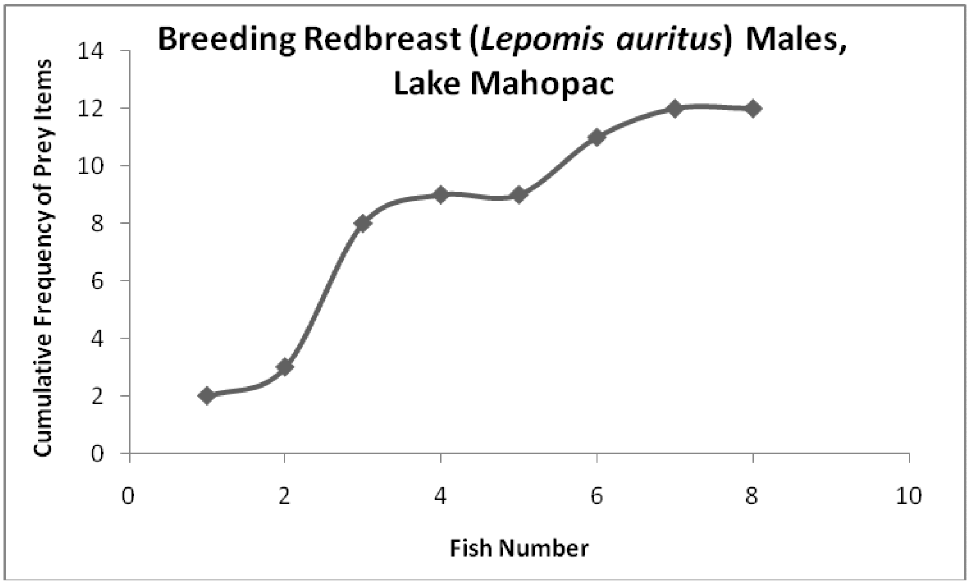


Figure 14: Cumulative frequency of prey items for post-breeding redbreast sunfish, (*Lepomis auritus*) males, Lake Mahopac

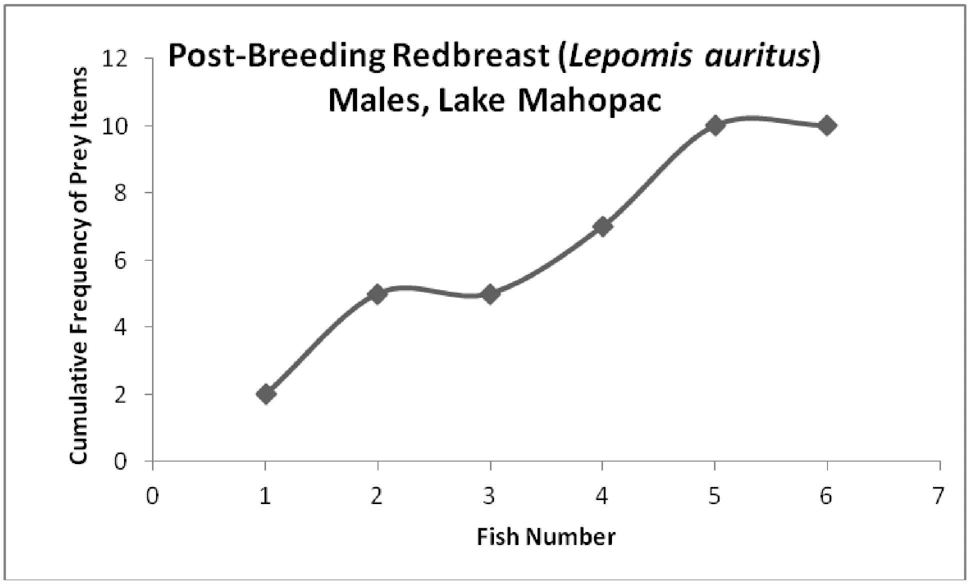


Figure 15: Cumulative frequency of prey items for pre-breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac

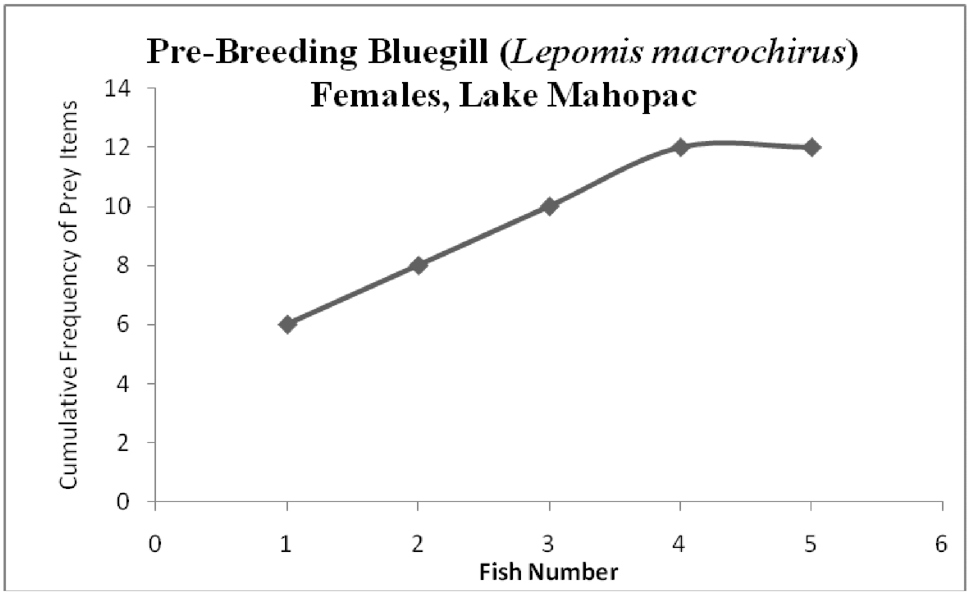


Figure 16: Cumulative frequency of prey items for breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac

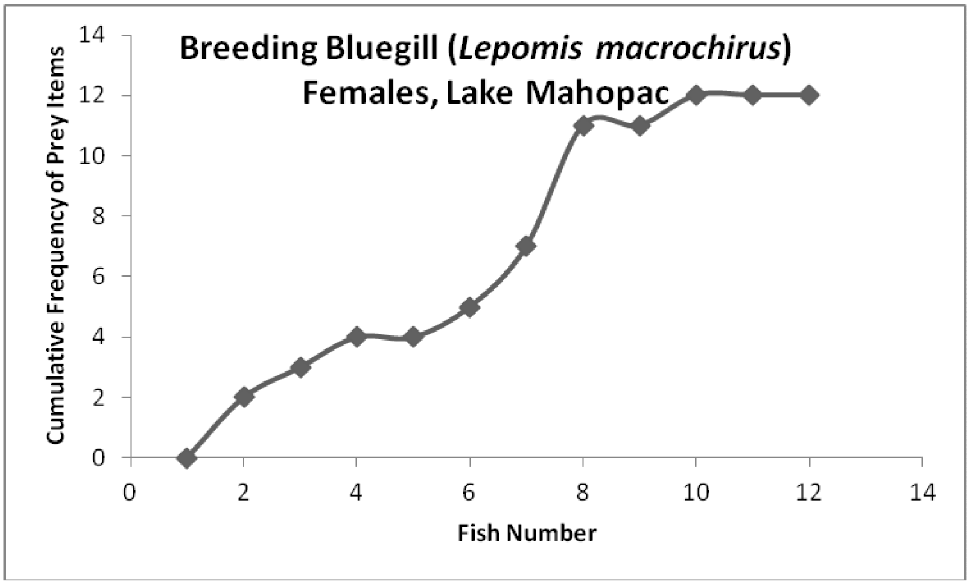


Figure 17: Cumulative frequency of prey items for post-breeding bluegill sunfish, (*Lepomis macrochirus*) females, Lake Mahopac

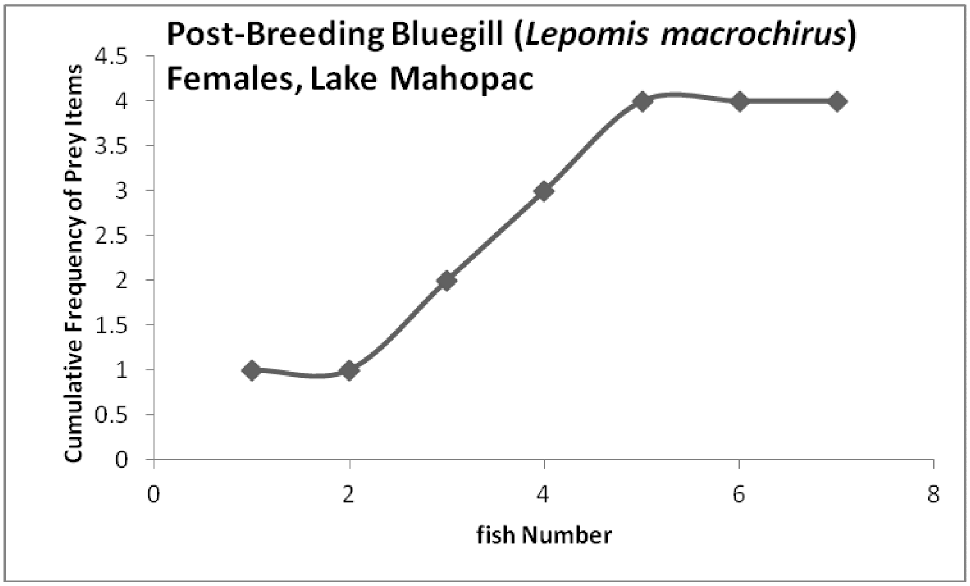


Figure 18: Cumulative frequency of prey items for pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

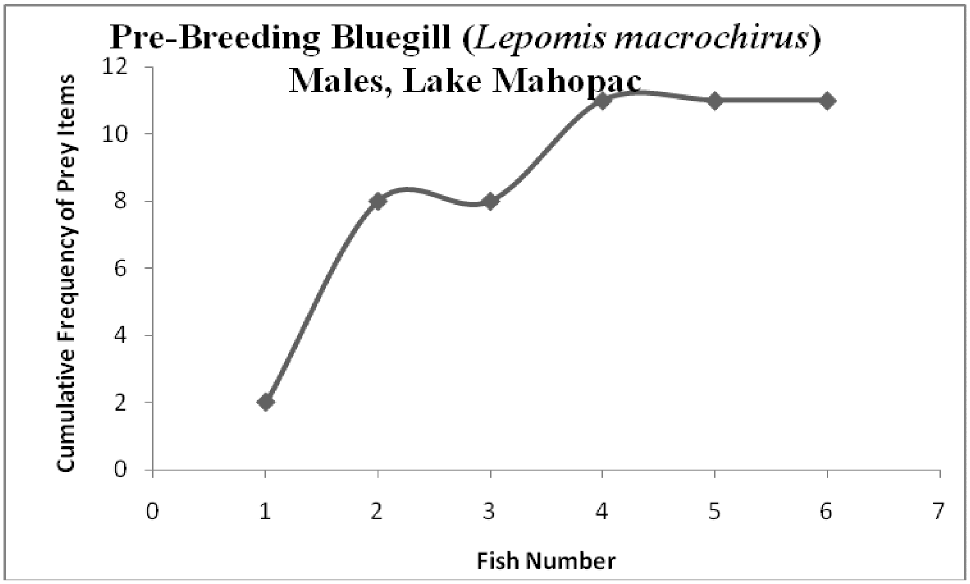


Figure 19: Cumulative frequency of prey items for breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

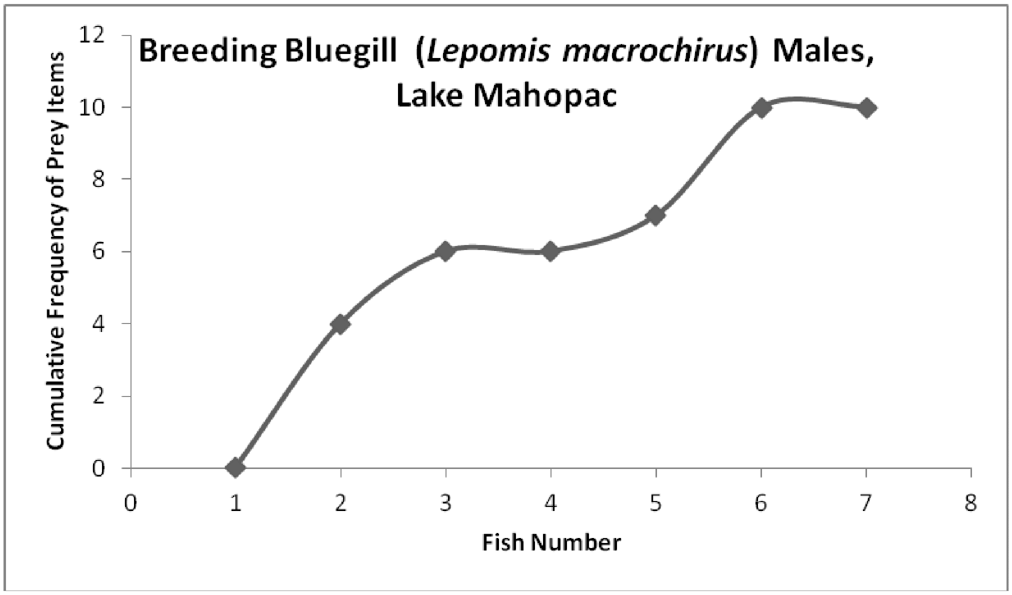


Figure 20: Cumulative frequency of prey items for post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

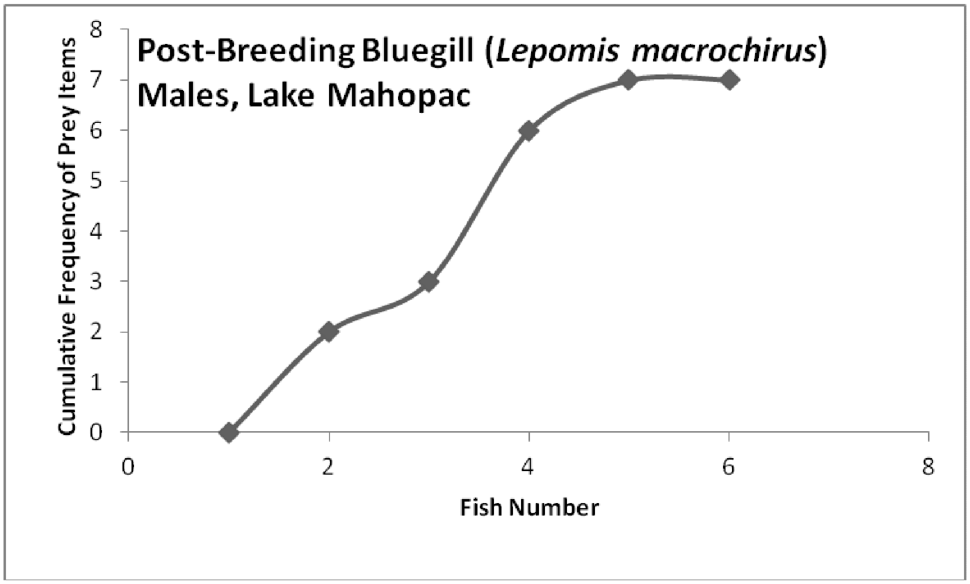


Figure 21: Cumulative frequency of prey items for pre-breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond

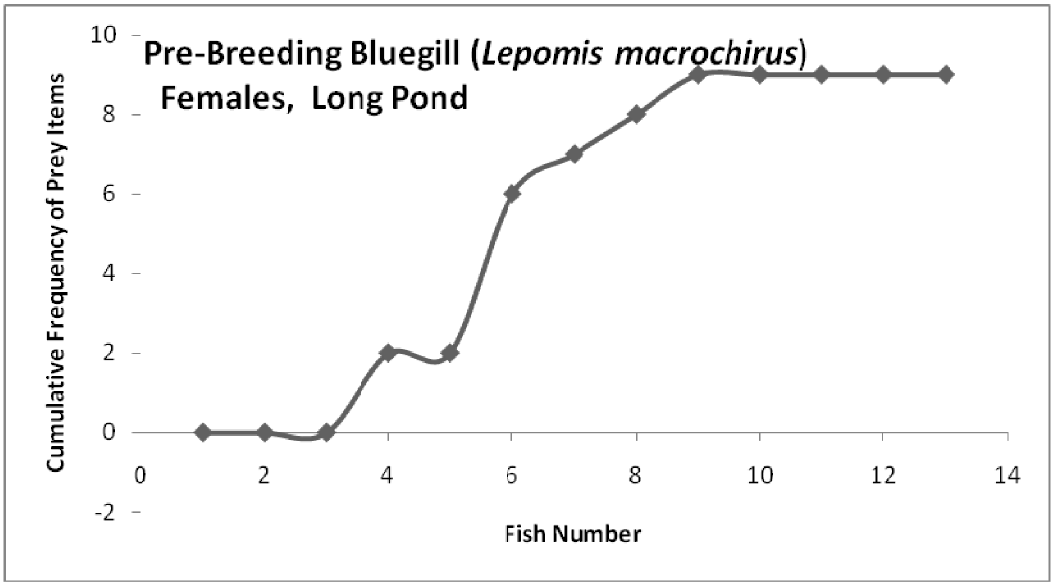


Figure 22: Cumulative frequency of prey items for breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond

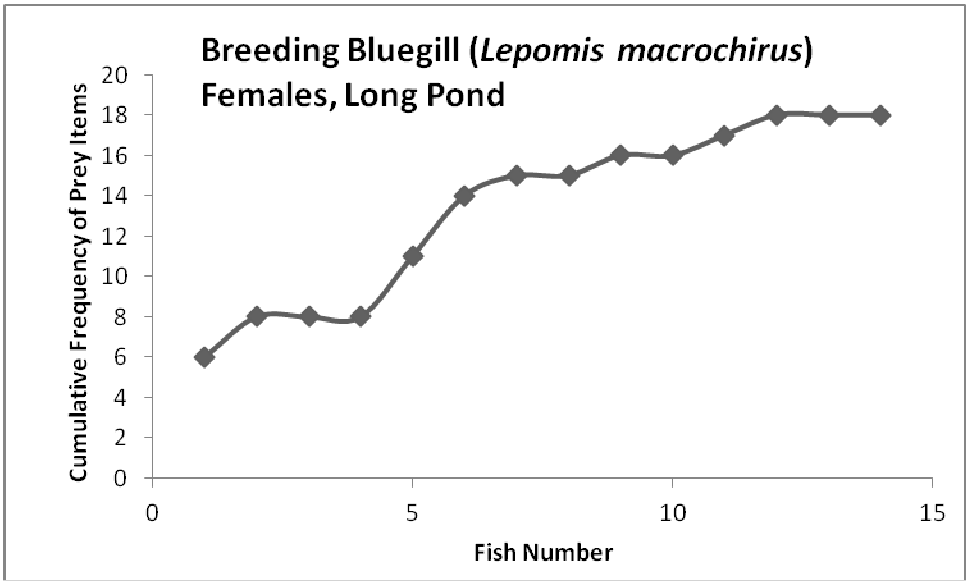


Figure 23: Cumulative frequency of prey items for post-breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond

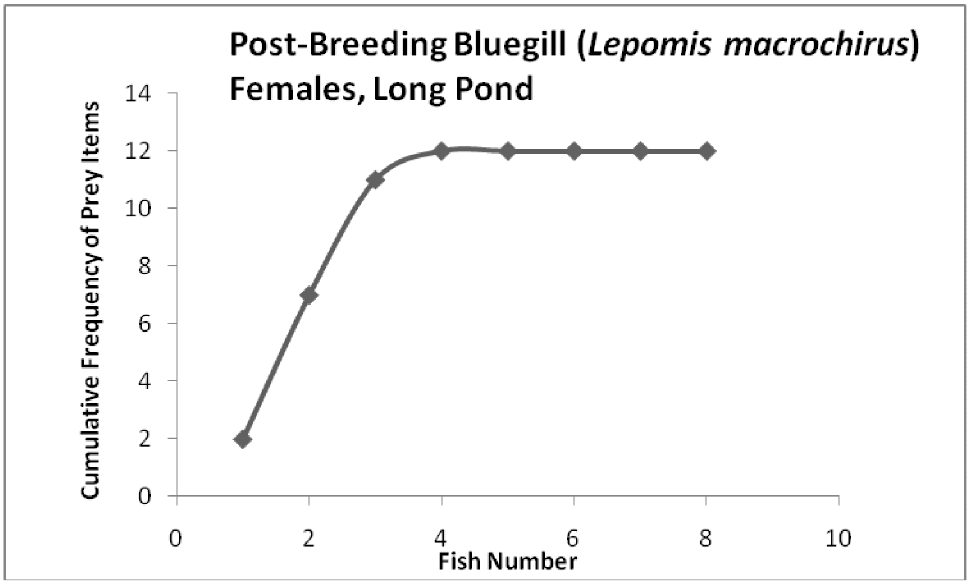


Figure 24: Cumulative frequency of prey items for pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

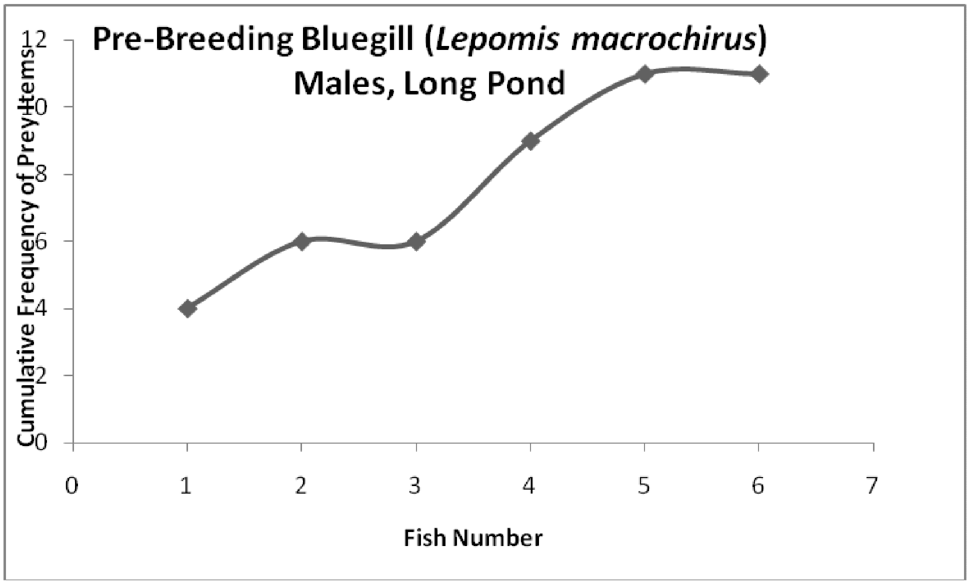


Figure 25: Cumulative frequency of prey items for breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

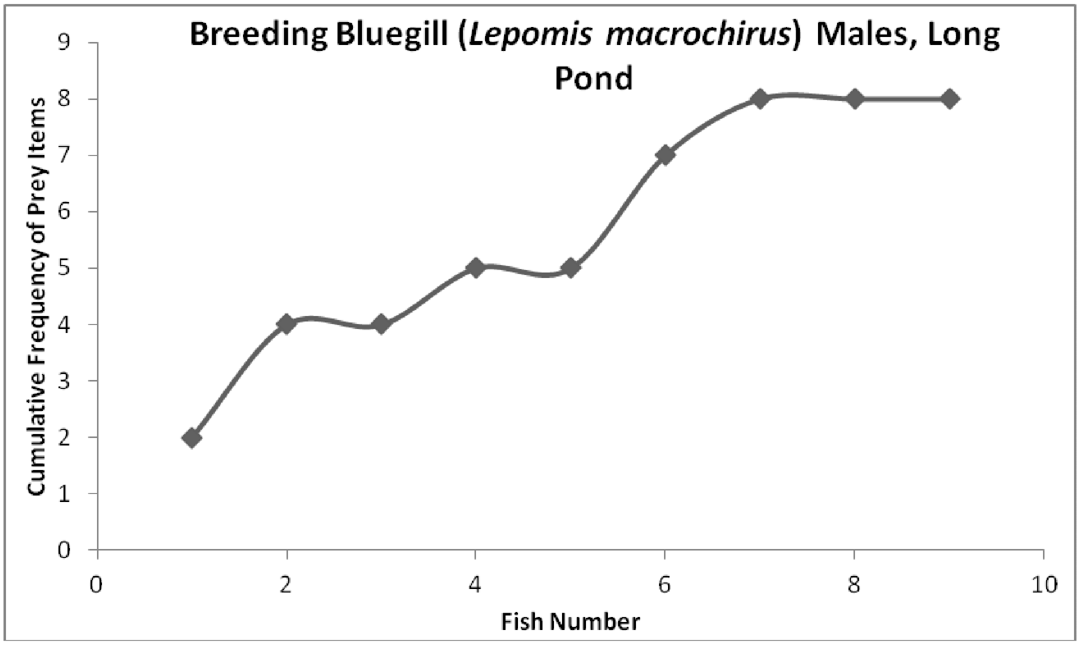
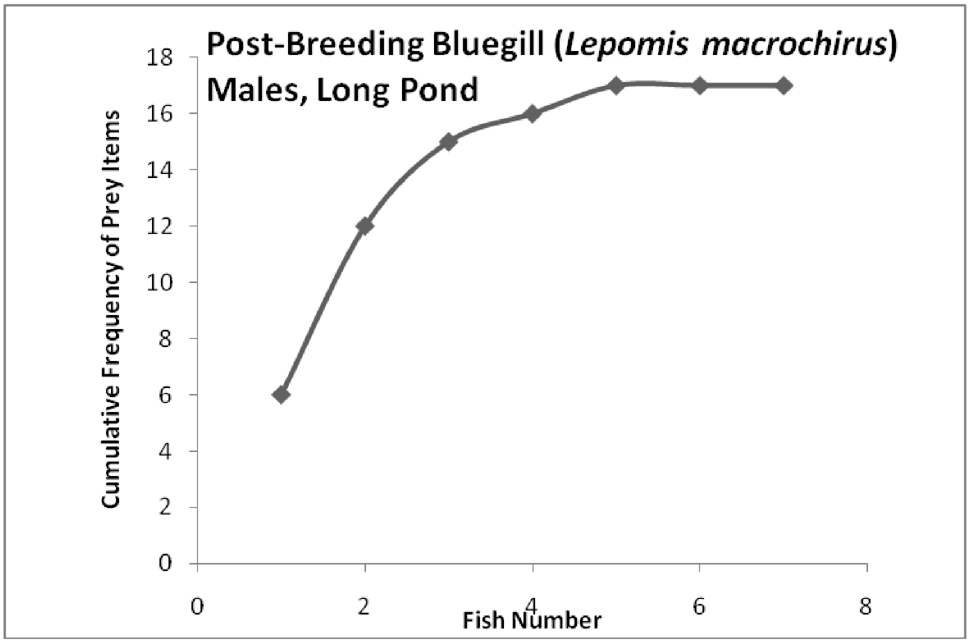


Figure 26: Cumulative frequency of prey items for post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond



Tables

Table 1: Measurements of water parameters for Lake Mahopac and Long Pond

Date:	**19 – April-2008**	**28-May-2008**	**6-June-2008**	**12-June-2008**
Location:	Lake Mahopac	Lake Mahopac	Lake Mahopac	Lake Mahopac
Water Temperature:	14.5°C	16.5°C	19.8°C	26.0°C
Dissolved Oxygen:	10.5ppm	11.5ppm	10.4ppm	9.0ppm
pH:	8.0	8.0	8.0	8.0
Phosphate:	0.5	0	0.5	0.5
Date:	**27-June-2008**	**7-July-2008**	**28-July-2008**	**31-July-2008**
Location:	Lake Mahopac	Lake Mahopac	Lake Mahopac	Lake Mahopac
Water Temperature:	24.0°C	26.5°C	27.0°C	28.0°C
Dissolved Oxygen:	9.4ppm	9.6ppm	7.7ppm	8.2ppm
pH:	8.0	7.0	8.0	8.0
Phosphate:	1.0	0.5	1.0	0.5
Location	Lake Mahopac	Lake Mahopac		
Date:	**21-Aug-2008**	**5-Sept-2008**		
Water Temperature:	25.0°C	24.0°C		
Dissolved Oxygen:	9.0ppm	8.0ppm		
pH:	8.0	8.0		
Phosphate:	0.5	0.5		
Date:	**30-June-2008**	**10-July-2008**	**28-July-2008**	**22-Aug-2008**
Location:	Long Pond	Long Pond	Long Pond	Long Pond
Water Temperature:	27.0°C	28.0°C	28.0°C	26.0°C
Dissolved Oxygen:	9.6ppm	8.2ppm	7.7ppm	8.2ppm
pH:	8.0	8.0	8.0	8.0
Phosphate:	0	0	0	0
Date:	**1-Sept-2008**			
Location:	Long Pond			
Water Temperature:	24.5°C			
Dissolved Oxygen:	8.0ppm			
pH:	8.0			
Phosphate:	0			
Date:	**24-April-2009**	**13-May-2009**	**20-May-2009**	**8-June-2009**
Location:	Lake Mahopac	Lake Mahopac	Lake Mahopac	Lake Mahopac
Water Temperature:	11.0°C	16.5°C	18.0°C	22.0°C
Dissolved Oxygen:	14.8ppm	12.0ppm	9.3ppm	8.0ppm
pH:	8.0	8.0	8.0	8.0
Phosphate:	0.5	0.5	0	0
Date:	**10-July-2009**	**21-July-2009**	**19-Aug-2009**	
Location:	Lake Mahopac	Lake Mahopac	Lake Mahopac	
Water Temperature:	24.0°C	28.0°C	26.5°C	
Dissolved Oxygen:	8.2ppm	8.7ppm	8.0ppm	
pH:	8.0	8.0	8.0	
Phosphate:	0	0	0	

Table 1: Measurements of water parameters for Lake Mahopac and Long Pond continued

Date:	**14-May-2009**	**25-May-2009**	**23-Aug-2009**	**7-Sept-2009**
Location:	Long Pond	Long Pond	Long Pond	Long Pond
Water Temperature:	17.0°C	24.0°C	27.5°C	23.0°C
Dissolved Oxygen:	8.7ppm	8.2ppm	7.7ppm	7.2ppm
pH:	8.0	8.0	7.5	7.5
Phosphate:	0	0	0	0
Date:	**April 1, 2010**	**April 30, 2010**	**May 10, 2010**	
Location:	Lake Mahopac	Lake Mahopac	Lake Mahopac	
Water Temperature:	10.0°C	13.4°C	21°C	
Dissolved Oxygen:	13.0ppm	13.4ppm	9.0	
Ph:	7.3	7.7	7.5	
Phosphate:	0	0.5ppm	0	
Date:	**May 15, 2010**	**May 20, 2010**	**May 23, 2010**	**May 25, 2010**
Water Temperature:	18°C	21°C	21°C	22°C
Dissolved Oxygen:	13.3ppm	10.1ppm	9.9ppm	9.0ppm

Table 2: Calculated niche breadth (NB) and proportional similarity in feeding (PS) for redbreast sunfish (*Lepomis auritus*) and bluegill sunfish (*Lepomis macrochirus*) from Lake Mahopac and Long Pond

Lake Mahopac

Fish Category	NB	PS
Pre-Breeding Redbreast Sunfish (*Lepomis auritus*) Females	0.05	0.82
Pre-Breeding Redbreast Sunfish (*Lopomis auritus*) Males	0.05	0.87
Breeding Redbreast Sunfish (*Lepomis auritus*) Females	0.11	0.98
Breeding Redbreast Sunfish (*Lepomis auritus*) Males	0.06	0.84
Post-Breeding Redbreast Sunfish (*Lepomis auritus*) Females	0.03	0.57
Post-Breeding Redbreast Sunfish (*Lepomis auritus*) Males	0.06	0.82
Pre-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Females	0.07	0.85
Pre-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Males	0.18	0.91
Breeding Bluegill Sunfish (*Lepomis macrochirus*) Females	0.04	0.85
Breeding Bluegill Sunfish (*Lepomis macrochirus*) Males	0.04	0.89
Post-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Females	0.08	0.73
Post-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Males	0.08	0.77

Long Pond

Fish Category	NB	PS
Pre-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Females	0.24	0.92
Pre-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Males	0.22	0.94
Breeding Bluegill Sunfish (*Lepomis macrochirus*) Females	0.08	0.92
Breeding Bluegill Sunfish (*Lepomis macrochirus*) Males	0.15	0.91
Post-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Females	0.08	0.95
Post-Breeding Bluegill Sunfish (*Lepomis macrochirus*) Males	0.11	0.98

Table 3: Calculated Schoener % overlap index for redbreast sunfish (*Lepomis auritus*) and bluegill sunfish (*Lepomis macrochirus*) from Lake Mahopac and Long Pond

Lake Mahopac

Pre-Breeding Females (Redbreasts and Bluegills)	0.670
Pre-Breeding Males (Redbreasts and Bluegills)	0.360
Breeding Females (Redbreasts and Bluegills)	0.303
Breeding Males (Redbreasts and Bluegills)	0.112
Post-Breeding Females (Redbreasts and Bluegills)	0.643
Post-Breeding Males (Redbreasts and Bluegills)	0.499
Pre-Breeding Redbreast Sunfish (Females and Males)	0.765
Pre-Breeding Bluegill Sunfish (Females and Males)	0.570
Breeding Redbreast Sunfish (Females and Males)	0.592
Breeding Bluegill Sunfish (Females and Males)	0.491
Post-Breeding Redbreast Sunfish (Females and Males)	0.835
Post-Breeding Bluegills (Females and Males)	0.111
Redbreasts and Bluegills (Total Sample Populations)	0.278

Long Pond

Pre-Breeding Bluegill Sunfish (Females and Males)	0.673
Breeding Bluegill Sunfish (Females and Males)	0.706
Post-Breeding Bluegill Sunfish (Females and Males)	0.825

Table 4: Resource base calculated from combined Hester-Dendy/plankton net samples and pooled stomach contents, Lake Mahopac

Food Item	Number	Proportion
Annelida		
Oligochaeta	73	0.0302
Hirudinea		
Glossiphoniidae	9	0.0037
Piscicolidae	1	0.0004
Crustacea		
Hydracarina	29	0.0120
Cladocera		
Sididae	348	0.1439
Daphniidae	21	0.0087
Anostraca		
Chirocephelidae	393	0.1625
Decapoda		
Cambaridae	1	0.0004
Ostracoda		
Myodocopidae	50	0.0207
Amphipoda		
Hyalellidae	60	0.0248
Isopoda		
Asellidae	71	0.0294
Gastropoda		
Planorbidae	8	0.0033
Valvatidae	7	0.0029
Undetermined	3	0.0012
Bivalvia		
Unionidae	3	0.0012
Sphaeriidae	4	0.0017
Insecta		
Coleoptera		
Elmidae	3	0.0012
Hydrophilidae	1	0.0004
Haplidae	1	0.0004
Scarabidae	14	0.0058
Dytisicidae	1	0.0004

Table 4: Resource base calculated from combined Hester-Dendy/plankton net samples and pooled stomach contents, Lake Mahopac continued

Food Item	Number	Proportion
Ephemeroptera	6	0.0025
Ephemerellidae		
Heptageniidae	2	0.0008
Undetermined	7	0.0029
Odonata		
Coenagrionidae	1	0.0004
Calopterygidae	8	0.0033
Aeshnidae	6	0.0025
Hemiptera		
Veliidae	1	0.0004
Megaloptera	1	0.0004
Sialidae	1	0.0004
Trichoptera		
Hydropsychidae	12	0.0050
Lepidostomatidae	47	0.0195
Hymenoptera		
Formicidae	205	0.0847
Lepidoptera	1	0.0004
Naviculales		
Naviculaceae	48	0.0199
Hydroida		
Hydridae	12	0.0050
Arachnida		
Araneae	4	0.0017
Eggs		
Undetermined	55	0.0228

Table 5: Resource base calculated from combined Hester-Dendy/plankton net/plant samples and pooled stomach contents, Long Pond

Food Item	Number	Proportion
Annelida		
Oligochaeta	4	0.0054
Hirudinea		
Glossiphoniidae	2	0.0027
Gastropoda		
Planorbidae	10	0.0135
Valvatidae	5	0.0067
Physidae	2	0.0027
Bivalvia		
Sphaeriidae	3	0.0040
Crustacea		
Cladocera		
Daphniidae	26	0.0351
Sididae	9	0.0121
Amphipoda		
Hyalellidae	32	0.0432
Isopoda		
Asellidae	3	0.0040
Ostracoda		
Myodocopidae	45	0.0607
Insecta		
Coleoptera		
Hydrophilidae	5	0.0067
Coccinellidae	2	0.0027
Scarabidae	4	0.0054
Diptera		
Chironomidae	408	0.5506
Ephydridae	1	0.0013
Ceratopogonidae	62	0.0837
Chaoboridae	1	0.0013
Unidentified	9	0.0121
Ephemeroptera		
Heptageniidae	9	0.0121
Odonata		
Coenagrionidae	3	0.0040
Aeshnidae	9	0.0121
Undetermined	5	0.0067
Hemiptera		
Gerridae	2	0.0027

Table 5: Resource base calculated from combined Hester-Dendy/plankton net/plant samples and pooled stomach contents, Long Pond continued

Food Item	Number	Proportion
Cicadellidae	2	0.0027
Trichoptera		
Lepidostomatidae	7	0.0094
Hymenoptera		
Formicidae	7	0.0094
Juncales		
Juncaceae	42	0.0568
Naviculales		
Naviculaceae	4	0.0054
Hydroida		
Hydridae	5	0.0067
Statoblast		
Undetermined	1	0.0013

Table 6: Comparison of the diversities of macroinvertebrates of Lake Mahopac and Long Pond

Lake Mahopac	Long Pond
Shannon-Wiener Diversity Index 2.217	Shannon-Wiener Diversity Index 1.942
Species Richness (S) 44.0	Species Richness (S) 32.0
Total Abundance 2418	Total Abundance 741
Evenness 0.586	Evenness 0.560

Table 7: Mean length and mass of redbreast (*Lepomis auritus*) and bluegill (*Lepomis macrochirus*) sunfish from Lake Mahopac and Long Pond

Fish Species (Lake Mahopac)	Sex	Number of Fish	Mean Standard Length In Centimeters ± SD	Range	Mean Total Mass in Grams ± SD	Range
Redbreast	Female	52	9.8 ± 1.5	7.2 – 13.5	32.5 ±16.8	13.4 – 93.9
Redbreast	Male	22	11.1 ± 2.1	8.2 – 17.0	47.5 ± 29.4	13.0 – 119.3
Bluegill	Female	24	9.9 ± 2.1	6.8 – 13.9	39.1 ± 25.2	8.3 – 8.7
Bluegill	Male	19	9.5 ±1.9	6.7 – 13.2	30.3 ± 20.5	7.6 – 69.7
Fish Species (Long Pond)	Sex	Number of Fish	Mean Standard Length In Centimeters ± SD	Range	Mean Total Mass in Grams ± SD	Range
Bluegill	Female	35	9.6 ± 1.8	6.7 – 14.1	31.5 ± 16.8	11.0 – 72.4
Bluegill	Male	22	9.5 ± 1.9	6.9 – 13.2	31.2 ± 20.0	10.5 – 77.1
Redbreast	Female	5	11.4 ±2.5	9.2 – 14.1	70.2 ± 49.7	39.9 – 127.5

Table 8: Stomach contents of pre-breeding redbreast sunfish (*Lepomis auritus*) females, Lake Mahopac

Food Item	Number	Proportion
Annelida		
Oligochaeta	2	0.004
Crustacea		
Hydracarina	8	0.016
Cladocera		
Daphniidae	6	0.012
Amphipoda		
Hyallelidae	15	0.029
Isopoda		
Asellidae	5	0.010
Gastropoda		
Planorbidae	4	0.008
Valvatidae	2	0.004
Unionoida		
Unionidae	1	0.002
Insecta		
Coleoptera		
Scarabidae	2	0.004
Dytisicidae	1	0.002
Diptera		
Chironomidae	347	0.669
Ceratopogonidae	19	0.037
Empididae	1	0.002
Trichoptera		
Hydropsychidae	11	0.022
Lepidostomatidae	27	0.053
Ephemeroptera		
Ephemerellidae	2	0.004
Hymenoptera		
Formicidae	7	0.014
Naviculales		
Naviculaceae	5	0.010
Arachnida		
Araneae	1	0.002
Eggs, Undetermined	53	0.104

Table 9: Diet preference of pre-breeding redbreast sunfish (*Lepomis auritus*) females based upon data collected from pooled stomach content data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Annelida		
Oligochaeta	- 0.887	N
Crustacea		
Hydracarina	- 0.252	N
Cladocera		
Daphniidae	- 0.236	N
Amphipoda		
Hyallelidae	- 0.312	N
Isopoda		
Asellidae	- 0.887	N
Gastropoda		
Planorbidae	+0.042	Y
Valvatidae	- 0.236	N
Unionoida		
Unionidae	- 0.144	N
Insecta		
Coleoptera		
Scarabidae	- 0.527	N
Dytisicidae	+0.383	Y
Diptera		
Chironomidae	- 0.092	N
Ceratopogonidae	+0.248	Y
Empididae	+0.383	Y
Trichoptera		
Hydropsychidae	+0.326	Y
Lepitodostomatidae	+0.098	Y
Ephemeroptera		
Ephemerellidae	+0.383	Y
Hymenoptera		
Formicidae	- 0.862	N
Naviculales		
Naviculaceae	- 0.631	N
Arachnida		
Araneae	- 0.309	N
Eggs, Undetermined	+0.343	Y

Table 10: Comparison of pre-breeding redbreast sunfish (*Lepomis auritus*) females to pre-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

Pre-breeding redbreast sunfish (*Lepomis auritus*) females, Lake Mahopac	Pre-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac
Shannon-Wiener Diversity Index 1.396	Shannon-Wiener Diversity Index 1.208
Species Richness 20.0	Richness 12.0
Total Abundance 519	Total Abundance 72
Evenness 0.466	Evenness 0.486

Table 11: Stomach contents of breeding redbreast sunfish (*Lepomis auritus)* females, Lake Mahopac

Food Item	Number	Proportion
Annelida		
Oligochaeta	1	0.005
Crustacaea		
Cladocera		
Sididae	61	0.274
Daphniidae	6	0.027
Isopoda		
Asellidae	27	0.121
Bivalvia		
Sphaeriidae	2	0.009
Insecta		
Coleoptera		
Scarabidae	4	0.018
Diptera		
Chironomidae	31	0.139
Psychodidae	1	0.005
Ceratopogonidae	2	0.009
Hemiptera		
Veliidae	1	0.005
Ephemeroptera		
Heptageniidae	1	0.005
Trichoptera		
Lepidostomatidae	8	0.036
Hymenoptera		
Formicidae	77	0.345
Arachnidae		
Araneae	1	0.005

Table 12: Diet preference of breeding redbreast sunfish (*Lepomis auritus)* sunfish females based upon data collected from pooled stomach content data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Annelida		
Oligochaeta	- 0.919	N
Crustacaea		
Cladocera		
Sididae	- 0.343	N
Daphniidae	- 0.114	N
Isopoda		
Asellidae	+0.027	Y
Bivalvia		
Sphaeriidae	+0.152	Y
Insecta		
Coleoptera		
Scarabidae	- 0.113	N
Diptera		
Chironomidae	- 0.819	N
Psychodidae	+0.525	Y
Ceratopogonidae	- 0.626	N
Hemiptera		
Veliidae	+0.525	Y
Ephemeroptera		
Heptageniidae	- 0.386	N
Trichoptera		
Lepidostomatidae	- 0.357	N
Hymenoptera		
Formicidae	+0.023	Y
Arachnidae		
Araneae	- 0.140	N

Table 13: Comparison of breeding redbreast sunfish (*Lepomis auritus*) females to breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

Breeding redbreast sunfish (*Lepomis auritus*) females, Lake Mahopac	Breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac
Shannon-Wiener Diversity Index 1.746	Shannon-Wiener Diversity Index 1.384
Species Richness (S) 14.0	Species Richness (S) 11.0
Total Abundance 223	Total Abundance 44
Evenness 0.662	Evenness 0.577

Table 14: Comparison of post-breeding redbreast sunfish (*Lepomis auritus*) females to post-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

Post-breeding redbreast sunfish (*Lepomis auritus*) females, Lake Mahopac	Post-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac
Shannon-Wiener Diversity Index 0.386	Shannon-Wiener Diversity Index 1.055
Species Richness (S) 4.0	Species Richness (S) 10.0
Total Abundance 46	Total Abundance 89
Evenness 0.278	Evenness 0.453

Table 15: Stomach contents of post-breeding redbreast sunfish (*Lepomis auritus*) females, Lake Mahopac

Food Item	Number	Proportion
Insecta		
Coleoptera		
Elmidae	1	0.022
Odonata		
Coenagrionidae	2	0.004
Hymenoptera		
Formicidae	42	0.913
Ephemeroptera		
Heptageniidae	1	0.022

Table 16: Diet preference of post-breeding redbreast sunfish (*Lepomis auritus*) females based upon data collected from pooled stomach content data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Insecta		
Coleoptera		
Elmidae	- 0.522	N
Odonata		
Coenagrionidae	- 0.628	N
Hymenoptera		
Formicidae	+0.340	Y
Ephemeroptera		
Heptageniidae	+0.176	Y

Table 17: Stomach contents of pre-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Hydracarina	2	0.028
Cladocera		
Sididae	1	0.014
Amphipoda		
Hyallelidae	1	0.014
Decapoda		
Cambaridae	1	0.014
Isopoda		
Asellidae	1	0.014
Insecta		
Coleoptera		
Scarabidae	1	0.014
Diptera		
Chironomidae	52	0.732
Dixidae	3	0.042
Trichoptera		
Lepidostomatidae	1	0.014
Ephemeroptera		
Heptageniidae	2	0.028
Hymenoptera		
Formicidae	5	0.070
Naviculales		
Naviculaceae	2	0.028

Table 18: Diet preference of pre-breeding redbreast sunfish (*Lepomis auritus*) males based upon data collected from and pooled stomach contents data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea		
Hydracarina	- 0.437	N
Cladocera		
Sididae	- 0.967	N
Amphipoda		
Hyallelidae	- 0.868	N
Decapoda		
Cambaridae	+0.709	Y
Isopoda		
Asellidae	- 0.851	N
Insecta		
Coleoptera		
Scarabidae	- 0.424	N
Diptera		
Chironomidae	- 0.492	N
Dixidae	+0.457	Y
Trichoptera		
Lepidostomatidae	- 0.786	N
Ephemeroptera		
Heptageniidae	+0.237	Y
Hymenoptera		
Formicidae	- 0.754	N
Naviculales		
Naviculaceae	- 0.618	N

Table 19: Stomach contents of breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

Food Item	Number	Proportion
Crustacaea		
Cladocera		
Sididae	1	0.023
Ostracoda		
Myodocopidae	1	0.023
Isopoda		
Asellidae	1	0.023
Insecta		
Coleoptera		
Hydrophilidae	1	0.023
Scarabidae	3	0.070
Diptera		
Chironomidae	29	0.674
Ephemeroptera		
Heptageniidae	1	0.023
Lepidoptera		
Undetermined	1	0.023
Hymenoptera		
Formicidae	1	0.023
Naviculales		
Naviculaceae	2	0.047
Eggs		
Undetermined	2	0.047

Table 20: Diet preference of breeding redbreast sunfish (*Lepomis auritus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacaea		
Cladocera		
Sididae	- 0.976	N
Ostracoda		
Myodocopidae	- 0.842	N
Isopoda		
Asellidae	- 0.896	N
Insecta		
Coleoptera		
Hydrophilidae	+0.639	Y
Scarabidae	- 0.460	N
Diptera		
Chironomidae	- 0.753	N
Ephemeroptera		
Heptageniidae	- 0.244	N
Lepidoptera		
Undetermined	+0.630	Y
Hymenoptera		
Formicidae	- 0.959	N
Naviculales		
Naviculaceae	- 0.699	N
Eggs		
Undetermined	- 0.733	N

Table 21: Stomach contents of post-breeding redbreast sunfish (*Lepomis auritus*) males, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Cladocera		
Sididae	18	0.202
Ostracoda		
Myodocopidae	2	0.023
Gastropoda		
Undetermined	1	0.011
Insecta		
Diptera		
Chironomidae	1	0.011
Coleoptera		
Scarabidae	1	0.011
Hymenoptera		
Formicidae	61	0.685
Ephemeroptera		
Undetermined	1	0.011
Hemiptera		
Undetermined	1	0.011
Arachnida		
Araneae	1	0.011
Naviculales		
Naviculaceae	2	0.023

Table 22: Diet preference of post-breeding redbreast sunfish (*Lepomis auritus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/ plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea		
Cladocera		
Sididae	- 0.360	N
Ostracoda		
Myodocopidae	- 0.457	N
Gastropoda		
Undetermined	+0.509	Y
Insecta		
Diptera		
Chironomidae	- 0.980	N
Coleoptera		
Scarabidae	- 0.223	N
Hymenoptera		
Formicidae	+0.461	Y
Ephemeroptera		
Undetermined	- 0.845	N
Hemiptera		
Undetermined	- 0.845	N
Arachnida		
Araneae	+0.369	Y
Naviculales		
Naviculaceae	- 0.441	N

Table 23: Comparison of pre-breeding bluegill sunfish (*Lepomis macrochirus*) females to pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

Pre-breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac	Pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac
Shannon-Wiener Diversity Index 1.569	Shannon-Wiener Diversity Index 2.128
Species Richness (S) 12.0	Species Richness (S) 11.0
Total abundance 85	Total Abundance 31
Evenness 0.631	Evenness 0.888

Table 24: Stomach contents of pre-breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Hydracarina	6	0.071
Cladocera		
Sididae	2	0.024
Daphniidae	5	0.059
Amphipoda		
Hyalellidae	1	0.012
Isopoda		
Asellidae	3	0.035
Bivalvia		
Sphaeriidae	2	0.024
Insecta		
Coleoptera		
Scarabidae	2	0.024
Diptera		
Chironomidae	51	0.600
Ceratopogonidae	2	0.024
Hymenoptera		
Formicidae	5	0.059
Arachnidae		
Araneae	1	0.012
Naviculales		
Naviculaceae	5	0.059

Table 25: Diet preference of pre-breeding bluegill sunfish (*Lepomis macrochirus*) females based upon data collected from pooled stomach contents data and Hester-Dendy/ plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea		
Hydracarina	+0.198	Y
Cladocera		
Sididae	- 0.675	N
Daphniidae	+0.262	Y
Amphipoda		
Hyalellidae	- 0.782	N
Isopoda		
Asellidae	- 0.538	N
Bivalvia		
Sphaeriidae	+0.562	Y
Insecta		
Coleoptera		
Scarabidae	+0.022	Y
Diptera		
Chironomidae	- 0.408	N
Ceratopogonidae	- 0.246	N
Hymenoptera		
Formicidae	- 0.702	N
Arachnidae		
Araneae	+0.281	Y
Naviculales		
Naviculaceae	- 0.144	N

Table 26: Comparison of breeding bluegill sunfish (*Lepomis macrochirus*) females to breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

Breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac	Breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac
Shannon-Wiener Diversity Index 0.746	Shannon-Wiener Diversity Index 0.606
Species Richness (S) 11.0	Species Richness (S) 9.0
Total Abundance 240	Total Abundance 454
Evenness 0.311	Evenness 0.276

Table 27: Stomach contents of breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Hydracarina	1	0.004
Cladocera		
Sididae	200	0.833
Ostracoda		
Myodocopidae	2	0.008
Amphipoda		
Hyalellidae	16	0.067
Isopoda		
Asellidae	3	0.013
Gastropoda		
Undetermined	2	0.008
Insecta		
Diptera		
Chironomidae	3	0.013
Undetermined	1	0.004
Odonata		
Calopterygidae	1	0.004
Hymenoptera		
Formicidae	1	0.004
Naviculales		
Naviculaceae	10	0.042

Table 28: Diet preference of breeding bluegill sunfish (*Lepomis macrochirus*) females based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea		
Hydracarina	- 0.704	N
Cladocera		
Sididae	+0.525	Y
Ostracoda		
Myodocopidae	- 0.662	N
Amphipoda		
Hyalellidae	+0.145	Y
Isopoda		
Asellidae	- 0.651	N
Gastropoda		
Undetermined	+0.549	Y
Insecta		
Diptera		
Chironomidae	- 0.965	N
Undetermined	- 0.846	N
Odonata		
Calopterygidae	- 0.846	N
Hymenoptera		
Formicidae	- 0.953	N
Naviculales		
Naviculaceae	+0.021	Y

Table 29: Comparison of post-breeding bluegill sunfish (*Lepomis macrochirus*) females to post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

Post-breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac	Post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac
Shannon-Wiener Diversity Index 1.215	Shannon-Wiener Diversity Index 1.411
Species Richness (S) 4.0	Species Richness (S) 6.0
Total Abundance 9	Total Abundance 13
Evenness 0.876	Evenness 0.787

Table 30: Stomach contents of post-breeding bluegill sunfish (*Lepomis macrochirus*) females, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Hydracarina	4	0.444
Insecta		
Diptera		
Chironomidae	1	0.111
Ceratopogonidae	1	0.111
Hymenoptera		
Formicidae	3	0.333

Table 31: Diet preference of post-breeding bluegill sunfish (*Lepomis macrochirus*) females based upon data collected from pooled stomach contents data Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea	+0.478	Y
Hydracarina		
Insecta		
Diptera		
Chironomidae	- 0.954	N
Ceratopogonidae	- 0.082	N
Hymenoptera		
Formicidae	- 0.538	N

Table 32: Stomach contents of pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Hydracarina	1	0.032
Cladocera		
Sididae	2	0.065
Anostraca		
Chirocephelidae	1	0.032
Bivalvia		
Unionidae	2	0.065
Insecta		
Coleoptera		
Scarabidae	2	0.065
Elmidae	1	0.032
Diptera		
Chironomidae	7	0.226
Phoridae	2	0.065
Odonata		
Calopterygidae	2	0.065
Hymenoptera		
Formicidae	3	0.097
Trichoptera		
Lepidostomatidae	8	0.258

Table 33: Diet preference of pre-breeding bluegill sunfish (*Lepomis macrochirus*) males based upon data collected from pooled stomach content data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea		
Hydracarina	- 0.842	N
Cladocera		
Sididae	- 0.955	N
Anostraca		
Chirocephalidae	- 0.982	N
Bivalvia		
Unionidae	+0.470	Y
Insecta		
Coleoptera		
Scarabidae	- 0.271	N
Elmidae	- 0.154	N
Diptera		
Chironomidae	- 0.938	N
Phoridae	+0.612	Y
Odonata		
Calopterygidae	+0.142	Y
Hymenoptera		
Formicidae	- 0.989	N
Trichoptera		
Lepidostomatidae	- 0.193	N

Table 34: Diet preference of breeding bluegill sunfish (*Lepomis macrochirus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Crustacea Hydracarina	- 0.768	N
Cladocera Sididae	- 0.979	N
Anostraca Chirocephalidae	+0.617	Y
Ostracoda Myodocopidae	+0.083	Y
Isopoda Asellidae	- 0.898	N
Gastropoda Valvatidae	+0.042	Y
Insecta Diptera Chironomidae	- 0.839	N
Trichoptera Lepidostomatidae	- 0.558	N
Naviculales Naviculaceae	+0.321	Y

Table 35: Stomach contents of breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

Food Item	Number	Proportion
Crustacea		
Hydracarina	1	0.002
Cladocera		
Sididae	1	0.002
Anostraca		
Chirocephelidae	392	0.863
Ostracoda		
Myodocopidae	14	0.031
Isopoda		
Asellidae	1	0.002
Gastropoda		
Valvatidae	2	0.004
Insecta		
Diptera		
Chironomidae	18	0.040
Trichoptera		
Lepidostomatidae	3	0.007
Naviculales		
Naviculaceae	22	0.049

Table 36: Stomach contents of post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Lake Mahopac

Food Item	Number	Proportion
Annelida		
Oligochaeta	1	0.077
Crustacea		
Cladocera		
Sididae	1	0.077
Insecta		
Diptera		
Chironomidae	7	0.539
Dixidae	1	0.077
Undetermined	2	0.154
Odonata		
Calopterygidae	1	0.077

Table 37: Diet preference of post-breeding bluegill sunfish (*Lepomis macrochirus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net samples, Lake Mahopac

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net Samples	
	E*	P^
Annelida		
Oligochaeta	- 0.905	N
Crustacea		
Cladocera		
Sididae	+0.979	Y
Insecta		
Diptera		
Chironomidae	- 0.940	N
Dixidae	+0.559	Y
Undetermined	- 0.975	N
Odonata		
Calopterygidae	- 0.220	N

Table 38: Comparison of pre-breeding bluegill sunfish (*Lepomis macrochirus*) females to pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

Pre-breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond	Pre-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond
Shannon-Wiener Diversity Index 1.943	Shannon-Wiener Diversity Index o 1.969
Species Richness (S) 9.0	Species Richness (S) 11.0
Total Abundance 45	Total Abundance 58
Evenness 0.884	Evenness 0.821

Table 39: Diet preference of pre-breeding bluegill sunfish (*Lepomis macrochirus*) females based upon data collected from pooled stomach contents data Hester-Dendy samples/plankton net/plant samples, Long Pond

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net/Plant Samples	
	E*	P^
Crustacea		
Hydracarina	+0.339	Y
Cladocera		
Daphniidae	+0.221	Y
Ostracoda		
Myodocopidae	- 0.736	N
Insecta		
Diptera		
Chironomidae	- 0.844	N
Ceratopogonidae	- 0.712	N
Undetermined	+0.032	Y
Odonata		
Aeshnidae	+0.076	Y
Hemiptera		
Cicadellidae	+0.263	Y
Juncales		
Juncaceae	- 0.720	N

Table 40: Stomach contents of pre-breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond

Food Item	Number	Proportion
Crustacea		
Hydracarina	7	0.156
Cladocera		
Daphniidae	12	0.267
Ostracoda		
Myodocopidae	2	0.044
Insecta		
Diptera		
Chironomidae	10	0.222
Ceratopogonidae	3	0.067
Undetermined	5	0.111
Odonata		
Aeshnidae	3	0.067
Hemiptera		
Cicadellidae	1	0.022
Juncales		
Juncaceae	2	0.044

Table 41: Comparison of breeding bluegill sunfish (*Lepomis macrochirus*) females to breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

Breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond	Breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond
Shannon-Wiener Diversity Index 1.279	Shannon-Wiener Diversity Index 1.564
Species Richness (S) 18.0	Species Richness (S) 8.0
Total Abundance 219	Total Abundance 47
Evenness 0.442	Evenness 0.752

Table 42: Stomach contents of breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond

Food Item	Number	Proportion
Gastropoda		
Planorbidae	1	0.005
Bivalvia		
Sphaeriidae	1	0.005
Crustacea		
Hydracarina	1	0.005
Amphipoda		
Hyalellidae	7	0.032
Isopoda		
Asellidae	2	0.019
Ostracoda		
Myodocopidae	3	0.014
Insecta		
Coleoptera		
Scarabidae	2	0.019
Diptera		
Chironomidae	155	0.708
Ceratopogonidae	19	0.087
Undetermined	2	0.019
Odonata		
Aeshnidae	1	0.005
Coenagrionidae	1	0.005
Undetermined	4	0.018
Ephemeroptera		
Heptageniidae	2	0.019
Hemiptera		
Cicadellidae	2	0.009
Trichoptera		
Lepidostomatidae	1	0.005
Naviculales		
Naviculaceae	3	0.014
Juncales		
Juncaceae	12	0.055

Table 43: Diet preference of breeding bluegill sunfish (*Lepomis macrochirus*) females based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net/plant samples, Long Pond

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net/Plant Samples	
	E*	P^
Gastropoda		
Planorbidae	- 0.609	N
Bivalvia		
Sphaeriidae	- 0.100	N
Crustacea		
Hydracarina	- 0.665	N
Amphipoda		
Hyalellidae	- 0.348	N
Isopoda		
Asellidae	+0.513	Y
Ostracoda		
Myodocopidae	+0.738	Y
Insecta		
Coleoptera		
Scarabidae	+0.394	Y
Diptera		
Chironomidae	- 0.087	N
Ceratopogonidae	- 0.191	N
Undetermined	+0.012	Y
Odonata		
Aeshnidae	- 0.575	N
Coenagrionidae	- 0.100	N
Undetermined	+0.274	Y
Ephemeroptera		
Heptageniidae	+0.012	Y
Hemiptera		
Cicadellidae	+0371	Y
Trichoptera		
Lepidostomatidae	- 0.485	N
Naviculales		
Naviculaceae	+0.258	Y
Juncales		
Juncaceae	- 0.891	N

Table 44: Comparison of post-breeding bluegill sunfish (*Lepomis macrochirus*) females to post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

Post-breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond	Post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond
Shannon-Wiener Diversity Index 1.267	Shannon-Wiener Diversity Index 1.678
Species Richness (S) 12.0	Species Richness (S) 17.0
Total Abundance 185	Total Abundance 133
Evenness 0.510	Evenness 0.592

Table 45: Stomach contents of post-breeding bluegill sunfish (*Lepomis macrochirus*) females, Long Pond

Food Item	Number	Proportion
Crustacea		
Hydracarina	3	0.016
Cladocera		
Sididae	7	0.038
Amphipoda		
Hyalellidae	2	0.011
Ostracoda		
Myodocopidae	15	0.081
Insecta		
Diptera		
Chironomidae	126	0.681
Ceratopogonidae	3	0.016
Undetermined	3	0.016
Ephemeroptera		
Heptageniidae	1	0.005
Odonata		
Undetermined	2	0.011
Trichoptera		
Lepidostomatidae	6	0.032
Naviculales		
Naviculaceae	1	0.005
Juncales		
Juncaceae	16	0.087

Table 46: Diet preference of post-breeding bluegill sunfish (*Lepomis macrochirus*) females based upon data collected from pooled stomach contents data and Hester-Dendy/ plankton net/plant samples and, Long Pond

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net/Plant Samples	
	E*	P^
Crustacea		
Hydracarina	- 0.174	N
Cladocera		
Sididae	+0.395	Y
Amphipoda		
Hyalellidae	- 0.699	N
Ostracoda		
Myodocopidae	- 0.030	N
Insecta		
Diptera		
Chironomidae	- 0.069	N
Ceratopogonidae	+0.761	Y
Undetermined	- 0.033	N
Ephemeroptera		
Heptageniidae	- 0.189	N
Odonata		
Undetermined	+0.079	Y
Trichoptera		
Lepidostomatidae	+0.416	Y
Naviculales		
Naviculaceae	- 0.174	N
Juncales		
Juncaceae	+0.035	Y

Table 47: Stomach Contents of pre-breeding bluegill (*Lepomis machrochirus*) males, Long Pond

Food Item	Number	Proportion
Gastropoda		
Valvatidae	3	0.052
Crustacea		
Cladocera		
Sididae	1	0.017
Daphniidae	7	0.121
Amphipoda		
Hyalellidae	5	0.086
Ostracoda		
Myodocopidae	7	0.121
Insecta		
Diptera		
Chironomidae	16	0.276
Ceratopogonidae	14	0.241
Undetermined	1	0.017
Odonata		
Aeshnidae	2	0.035
Coenagrionidae	1	0.017
Juncales		
Juncaceae	1	0.017

Table 48: Diet preference of pre-breeding bluegill sunfish (*Lepomis macrochirus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net/plant samples, Long Pond

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net/Plant Samples	
	E*	P^
Gastropoda		
Valvatidae	+0.495	Y
Crustacea		
Cladocera		
Sididae	- 0.302	N
Daphniidae	+0.136	Y
Amphipoda		
Hyalellidae	- 0.136	N
Ostracoda		
Myodocopidae	- 0.134	N
Insecta		
Diptera		
Chironomidae	- 0.676	N
Ceratopogonidae	+0.047	Y
Undetermined	- 0.302	N
Odonata		
Aeshnidae	+0.049	Y
Coenagrionidae	+0.237	Y
Juncales		
Juncaceae	- 0.795	N

Table 49: Stomach Contents of breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

Food Item	Number	Proportion
Gastropoda		
Planorbidae	1	0.021
Crustacea		
Amphipoda		
Hyalellidae	17	0.362
Ostracoda		
Myodocopidae	6	0.128
Insecta		
Coleoptera		
Scarabidae	2	0.043
Diptera		
Chironomidae	16	0.340
Ceratopogonidae	2	0.044
Ephemeroptera		
Heptageniidae	1	0.021
Juncales		
Juncaceae	2	0.043

Table 50: Diet preference of breeding bluegill sunfish (*Lepomis macrochirus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/plankton net/plant samples, Long Pond

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net/Plant Samples	
	E*	P^
Gastropoda		
Planorbidae	- 0.310	N
Crustacea		
Amphipoda		
Hyalellidae	+0.294	Y
Ostracoda		
Myodocopidae	- 0.167	N
Insecta		
Coleoptera		
Scarabidae	+0.459	Y
Diptera		
Chironomidae	- 0.655	N
Ceratopogonidae	+0.698	Y
Ephemeroptera		
Heptageniidae	- 0.260	N
Juncales		
Juncaceae	- 0.592	N

Table 51: Stomach contents of post-breeding bluegill sunfish (*Lepomis macrochirus*) males, Long Pond

Food Item	Number	Proportion
Gastropoda		
Planorbidae	2	0.015
Bivalvia		
Sphaeriidae	1	0.008
Crustacea		
Hydracarina	1	0.008
Cladocera		
Daphniidae	1	0.008
Sididae	12	0.090
Amphipoda		
Hyalellidae	1	0.008
Ostracoda		
Myodocopidae	3	0.023
Insecta		
Coleoptera		
Coccinellidae	2	0.015
Scarabidae	1	0.008
Diptera		
Chironomidae	73	0.549
Ceratopogonidae	20	0.150
Chaoboridae	1	0.008
Undetermined	1	0.008
Ephemeroptera		
Heptageniidae	2	0.015
Odonata		
Aeshnidae	5	0.038
Hymenoptera		
Formicidae	4	0.030
Juncales		
Juncaceae	3	0.023

Table 52: Diet preference of post-breeding bluegill sunfish (*Lepomis macrochirus*) males based upon data collected from pooled stomach contents data and Hester-Dendy/ plankton net/plant samples, Long Pond

Food Item	Pooled Stomach Contents/Hester-Dendy/Plankton Net/Plant Samples	
	E*	P^
Gastropoda		
Planorbidae	- 0.369	N
Bivalvia		
Sphaeriidae	- 0.124	N
Crustacea		
Hydracarina	- 0.678	N
Cladocera		
Daphniidae	- 0.838	N
Sididae	+0.512	Y
Amphipoda		
Hyalellidae	- 0.867	N
Ostracoda		
Myodocopidae	- 0.732	N
Insecta		
Coleoptera		
Coccinellidae	+0.395	Y
Scarabidae	- 0.269	N
Diptera		
Chironomidae	- 0.415	N
Ceratopogonidae	- 0.145	N
Chaoboridae	+0.411	Y
Undetermined	+0.440	Y
Ephemeroptera		
Heptageniidae	- 0.320	N
Odonata		
Aeshnidae	+0.133	Y
Hymenoptera		
Formicidae	+0.142	Y
Juncales		
Juncaceae	- 0.963	N

Appendixes

Appendix A: Hester-Dendy Plate/Plankton Net/Plant Sample Data

Lake Mahopac

June 21, 2006 (2 weeks) Hester-Dendy Plates
Pelagic Zone

Chironomidae	
G. lobiferous	48
Pentanuera	1
Cladocera	
Sida crystallina	6
Coleoptera	
Elmidae	
Microcylloepsus	
Amphipoda	
Hyallela	12
Annelida	
Oligochaeta	45
Ostracoda	
Myodocopidae	10
Cladocera	
Daphniidae	
Daphnia	2
Hydra	3
Ephemeroptera	
Ephemerellidae	
Dannella	1

June 29, 2006 (3 weeks) Hester-Dendy Plates
Pelagic Zone

Chironomidae	2
Amphipoda	
Hyallela	2
Ostracoda	
Myodocopidae	7
Cladocera	
Sida crystallina	1
Hydracarina	1
Annelida	

Oligochaeta	1
Copapoda	
Sididae	
Harpacticoida	1

July 8, 2006 (4 weeks) Hester-Dendy Plates
Pelagic

Chironomidae	
G. lobiferous	68
Unidentified	20
A. mallochi	1
Pupae	5
Amphipoda	
Hyallela	4
Trichoptera	6
Cladocera	
Sididae	
Sida crystallina	47
Hydra	2
Annelida	
Oligochaeta	6
Ephemeroptera	
Leucrocuta	2
Ostracoda	
Myodocopidae	6
Hydracarina	2

July 23, 2006
Plates missing from site

September 4, 2006 (8 weeks) Hester Dendy Plates
Pelagic Zone

Mollusca	
Gastropoda	
G. parvus	3
V. piscinalis	3
Sphaeriidae	1
Isopoda	
Caecidotea	29
Amphipoda	
Hyallela	2

Hirudinea
Glossiphiid
Helobdella stagnalis 6
H. fusca 1
Annelida
Lumbriculidae 4

October 27, 2007 (8 weeks) Hester-Dendy Plates
Benthic Sample

Amphipoda
Hyallela 1
Chironomidae
Chironomini
G. lobiferous 47
Tanypodinae
A. mallochi 14
Hirudinea
Helobdella stagnalis 1
Ostracoda
Myodocopidae 1
Annelida
Oligochaete 1
Hydracarina
Odonata
Coenagrionidae
E. geminatum 5
Hydra 3
Copepoda 1

October 27, 2007 (8 weeks) Hester-Dendy Plates
Pelagic Zone

Insecta
Diptera
Chironomidae
A. mallochi 14
G. lobiferous 85
Coleoptera
Elmidae 1
Trichoptera 1
Odonata
Anisoptera
E. geminatum 1
Hemiptera
Mesoveliidae 1

Crustacea				
	Amphipoda			
			Hyallela	4
	Ostracoda			17
	Cladocera			
		Sididae		
			S. crystallina	91
	Copepoda			1
	Daphniidae			
			Daphnia	
Hydracarina				
Statoblast				1
Mollusca				
	Gastropoda			1
Hydra				5
Annelida				
	Oligochaeta			9
	Hirudinea			
			H. stagnalis	1

July 2, 2008 (2 weeks) Hester-Dendy Plates
Pelagic

Diptera				
	Chironomidae			
		Chironomini		2
		Unidentified		20
			Polypidelum	1
		Diamesinae		
			P. longimanus	1
Crustacea				
	Amphipoda			
			Hyallela	2
Annelida				
	Oligochaeta			
		Lumbriculidae		2
Hydra				1

July 4, 2008 Plankton Net
Empty

July 18, 2008 (4 weeks) Hester Dendy Plates
Plates missing from site

August 1, 2008 (8 weeks) Hester—Dendy Plates
Pelagic Zone

Crustacea				
	Amphipoda			
			Hyallela	2
	Isopoda		*Caecidotea*	1
Hydracarina				2
Annelida				
	Oligochaeta			8
Insecta				
	Chironomidae			
		Chironomini		
			Polypidelum	1
			G. lobiferous	1
			Dicrotendipes	1
	Ephemeroptera			
		Heptagenidae		
			Leucrocuta	1
	Coleoptera			
		Haplidae		
			Haliplus	1
	Trichoptera			
		Hydropsychidae		1
	Megaloptera			
		Sialidae		
			Sialis	1
Hirudinea				
		Piscicolidae		
			M. lugubrus	1

September 1, 2008 Plankton Net

Crustacea				
	Cladocera			
		Daphniidae		
			Daphnia	4
		Sididae		
			S. crystallina	3
Insecta				
	Odonata			

Zygoptera

Calopteryx 1

Hemiptera

Veliidae 1

Statoblast 1

September 27, 2008 (4 weeks) Hester-Dendy Plates
Benthic Sample

Isopoda

Asellota

Caecidotea 5

Odonata

Zygopera 1

Anisoptera

Basiaeshna 1

Annelida

Oligochaeta

Lumbriculidae 1

Long Pond

July 15, 2008 (2 weeks) (Hester-Dendy)
Benthic

Empty plates

July 28 2008 (4 weeks) (Hester-Dendy)

Coleoptera		
Hydrophilidae		4
Hirudinea		
	Helabdella fusca	2
Mollusca		
Gastropoda		
	Gyrayulus parvus	4
	Valvatidae piscinalis	2
	Physella integra	1
Chironomidae		
Chironomini		
	Polypedilum fallax	2
Statoblast		1

September 1, 2008 (Plankton Net)

Inflorescences			6
Crustacea			
Cladocera			
	Daphniidae		
		Daphnia	5
Copepoda			1
Ostracoda			6
Hydra			3
Annelida			
Oligochaeta			2
Insecta			
Chironomidae			3
Adult Chironomids			2
Ephemeroptera			1
Hemiptera			
	Gerridae		
		Limnogonus	2
Odonata			
	Zygoptera		
		Nehalennia	1

Sept 12, 2008 (6 weeks) Hester-Dendy Plates

Isopoda			
	Caecidotea		1
Molluska			
		Sphaeriidae	1
	Gastropoda		
		Physella integra	1
		Gyraulus parvus	1
Ostracoda			
	Myodocopidae		1

July 12, 2009 (2 weeks) Hester-Dendy Plates

Empty Plates

July 21, 2009 (4 weeks) (Hester-Dendy Plates)

Plates missing from site

August 23, 2009 (Plant Sample)
Jar contaminated by fungus, no specimens obtained

September 1, 2009 (Plant Sample)

Mollusca			
	Gastropoda		
		Labrundinia pilosella	1
Diptera			
	Ephydridae		1
Ostracoda			
	Myodocopidae		2
Copepoda			
	Daphniidae		
		Daphnia	1

September 27, 2009 (Plankton Net)

Hemiptera	
Gerridae	
Limnogonus	2
Ephemeroptera	1
Hydra	2
Annelida	
Oligochaeta	2
Odonata	
Zygoptera	
Nehalennia	1
Chironomidae	
Chironimini	1
Ostracoda	
Myodocopidae	1

Appendix B: List of prey items for individual fish specimens from Lake Mahopac and Long Pond

Pre-Breeding Redbreast Females (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
May 23, 2007	2	Hymenoptera	
		Formicidae	1
		Diptera	
		Empididae	1
May 18, 2008	1	Diptera, Terrestrial	8
		Hymenoptera	
		Formicidae	1
		Algae	
		Navicula	2
		Diptera	
		Chironomididae, Larval	7
June 8, 2008	2	Mollusks	
		Gastropoda	
		Planorbidae	4
		Valvatidae	
		V. sincera	2
		Bivalvia	
		Anodonta imbecilus	1
		Hymenoptera	
		Formicidae	2
		Diptera	
		Chironomid	
		Tanypodinae	
		A. mallochi	1
		Chironomini	42

Date	Fish Number	Prey Items	Number of Items
June 8, 2008	4	Amphipoda	
		Talitridae	
		Hyalella	2
		Cladocera	
		Daphniidae	
		Daphnia	4
		Diptera	
		Ceratopogonidae	
		Bezzia	1
		Algae	
		Navicula	
		Crustacea	
		Hydracarina	5
May 20, 2009	1	Diptera,	
		Chironomid	
		Pupae s.p.	12
	2	Chironomid	
		Pupae	12
		Coleoptera, Mast.	1
		Diptera, Mast.	1
	3	Chironomid, Pupae	11
		Isopoda	
		Asellota	
		Caecidotea	4

Date	Fish Number	Prey Items	Number of Items
June 8, 2009	6	Chironomidae	
		Chironomini	
		C. decorus	33
		D. neomodestus	111
	7	Chironomidae	
		Chironomini	
		D. neomodestus	32
		Coleoptera	1
		Diptera	
		Chironomidae, Terr.	7
		Coleoptera, Pupae	6
		Hymenoptera	1
	8	Ephemeroptera	1
	9	Ephemeroptera	1
		Coleoptera	
		Dytiscidae	1
		Amphipoda	
		Hyallela	2
May 24, 2010	4	Coleoptera, Adult	1
		Chironomida	
		Pupae	2
		Larvae	5
		Trichoptera	10
	5	Hymenoptera	
		Formicidae	1
		Algae	
		Navicula	3
		Cladocera	
		Daphniidae	1

Date	Fish Number	Prey Items	Number of Items
		Diptera	
		Chironomidae	
		Chironomini	
		Chironomus decorus	12
	6	Trichoptera	
		Lepidostomatidae	8
		Annelida	
		Oligochaeta	1
	7	Trichoptera	
		Lepidostomatidae	8
		Arachnida	
		Spider	1
	8	Trichoptera	
		Lepidostomatidae	19
		Hymenoptera	2
		Chironomidae	
		Larvae	1
		Pupae	3
		Annelida	
		Oligochaeta	1

Date	Fish Number	Prey Items	Number of Items
May 24, 2010	9	Hydracarina	
		Oxus	1
		s.p.	2
		Amphipoda	
		Talitridae	
		Hyallela	1
		Chirnomididae	
		Chironomini	
		Chironomus decorus	2
		s.p.	5
		Orthocladiinae	
		Cricotopus sylvestris	1
		Orthocladius, s.p.	4
		Diamesinae	
		Potthastia longimanus	1
		Tanytarsini	
		Zavrelia, s.p.	1
	10	Chironomidae	
		Tanypodinae	
		Ablabesmyia mallochai	4
		Chironomini	
		Chironomous decorus	1
		Glyptotendipes lobiferous	1
		Orthocladiinae	
		Orthocladius, s.p.	1
		Cladocera	
		Daphniidae	
		Daphnia	1
		Eggs, type unknown	53
		Isopoda	
		Asellota	
		Caecidotea	1

Date	Fish Number	Prey Items	Number of Items
May 24, 2010	11	Amphipoda	
		Talitridae	
		Hyallela	10
		Trichoptera	
		Hydropsycidae	1
		Chironomidae	
		Tanypodinae	
		Djelmabatista	3
		A. mallochai	5
		Chironomini	
		C.decorus	19
		Orthocladiinae	
		Orthocladius s.p,	1

<u>Pre-Breeding Redbreast Males</u> (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
May 29, 2007	3	Trichoptera	1
		Hydracarina	1
	4	Diptera	
		Dixidae	1
	5	Hymenoptera	3
		Diptera, unidentified	1
		Coleoptera	1
	6	Hymenoptera	2
		Diptera	
		Dixidae	1
		Isopoda	
		Asellota	
		Caecidotea	1
		Ephemeroptera	1
	7	Diptera	
		Chironomidae	25
		Cladocera	
		Sididae	
		Sida crystallina	1

Date	Fish Number	Prey Items			Number of Items
June 8, 2008	3	Amphipoda			
			Talitridae		
				Hyallela	1
		Algae			
				Navicula	2
		Chironomidae			1
June 8, 2009	10	Chironomidae			
			Tanypodinae		
				Djelmabatista	3
				A. mallochai	5
			Chironomini		
				C. decorous	19
May 24, 2010	3		Decapoda		
				Cambaridae	1
			Ephemeroptera		1

<u>Breeding Redbreast Females</u> (Lake Mahopac)

Date	Fish Number	Prey Items			Number of Items
June 9, 2007	9	Empty			
	10	Empty			
	11	Empty			
June 25, 2007	12	Ephemeroptera			1
		Isopoda			
			Asellota		
				Caecidotea	26
June 27, 2007	17	Diptera			
			Chironomidae		11
		Cladocera			
			Sididae		
				Sida crystallina	61
			Daphniidae		
				Daphnia	6

Date	Fish Number	Prey Items	Number of Items
June 27, 2007	18	Coleoptera	1
	19	Empty	
	20	Diptera	
		Ceratopogonidae	2
July 23, 2007	22	Mollusca	
		Sphaeriidae	
		Sphaerium	1
		Diptera	
		Chironomidae	
		Tanypodinae	
		A. mallochi	3
		Trichoptera	8
July 31, 2007	26	Chironomidae	1
Aug 9, 2007	27	Empty	
June 12, 2008	6	Chironomidae	
		Chironomini	
		C. *riparius*	1
		Pupae	2
		Coleoptera	1
		Arachnidae	
		Araneae	1
		Hemiptera	1
	7	Diptera	
		Chironomidae	
		Chironomini	
		C. riparius	1
		Isopoda	
		Asellota	
		Caecidotea	1
	8	Chironomidae	1
		Coleoptera	1

Date	Fish Number	Prey Items	Number of Items
June 27, 2008	11	Coleoptera	1
		Chironomidae	
		Chironomini	
		C. riparius	7
June 27, 2008	12	Chironomidae	
		Orthocladiniinae	
		Crycotopus	2
		Diptera	
		Psychodidae	1
		Annelida	
		Oligochaeta	1
July 7, 2008	15	Hymenoptera	
		Formicidae	76
	16	Mollusca	
		Bivalvia	1
		Hymenoptera	
		Formicidae	1
	17	Chironomidae	
		Chirnomini	
		C. riparius	1
		C. fulvus	1
July 28, 2008	21	Empty	
July 31, 2008	30	Empty	
	31	Empty	

<u>Breeding Redbreast Males</u> (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
June 7, 2007	7	Diptera	
		Chironomidae	24
		Cladoceran	
		Sididae	1
June 25, 20007	13	Diptera	
		Chironomidae	1
		Coleoptera, Terr.	1
June 26, 2007	16	Hymenoptera	
		Formicidae	2
		Lepidoptera	1
		Ephemeroptera	1
June 12, 2008	9	Diptera	
		Chironomidae	
		Chironomini	
		C. raparius	1
		Isopoda	
		Hyallela	1
June 27, 2008	10	Diptera	
		Chironomidae	1
		Coleoptera	1
June 28, 2008	22	Diptera	
		Chironomidae	1
		Coleoptera	
		Parachymus	1
		Ostracoda	1
	24	Unidentified egg	2
July 31, 2008	29	Hymenoptera	
		Formicidae	1
		Algae	
		Navicula	2
		Coleoptera	1

<u>Post-Breeding Redbreast Female</u> (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
August 9, 2007	27	Empty	
	30	Hymenoptera	
		Formicidae	42
	35	Empty	
	36	Empty	
	37	Empty	
August 21, 2007	32	Ephemeroptera	1
September. 5, 2008	34	Odonata	
		Zygoptera	
		Enallagma	1
	36	Empty	
	37	Empty	
	38	Odonata	
		Zygoptera	
		Enallagma	1
		Coleoptera	
		Elmidae	
		Dubirapha	1
	39	Empty	

<u>Post-Breeding Redbreast Male</u> (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
August 24, 2007	31	Mollusca	
		Gastropoda	1
		Hymenoptera	
		Formicidae	55
	32	Coleoptera, Terr.	1
		Hemiptera, Terr.	1
		Hymenoptera	
		Formicidae	6
		Navicula	2
September 5, 2008	35	Empty	
	40	Coleoptera	1
		Arachnidae	
		Araneae	1
	41	Diptera	
		Chironomidae	1
		Ostracoda	2
		Cladocera	
		Sididae	
		Sida crystallina	18
	42	Empty	

<u>Pre-Breeding Bluegill Female</u> (Lake Mahopac)

Date	Fish Number	Prey Items				Number of Items
June 8, 2008	4	Diptera				
			Chironomidae			
				Tanypodinae		
					A. mallochi	2
				Chironomi		
					P. illinoense	3
				Orthocladinae		
					C. sylvestrus	31
					Crichotopus	1
					Eukiefferiella	1
		Cladocera				
				Daphniidae		
					Daphnia	4
		Diptera				
			Ceratopogonidae			
					Bezzia	1
		Algae				
					Navicula	1
		Hydracarina				5
		Diptera Larvae				1
June 20, 2009	5	Hymenoptera				1
		Diptera				
			Chironomidae			
				Chironomini		
					C. decorus	12
			Pupa			1
		Algae				
					Navicula	4
		Amphipoda				
					Hyallela	1
		Cladocera				
				Daphniidae		
					Daphnia	1

Date	Fish Number	Prey Items	Number of Items
May 24, 2010	1	Isopoda	
		Asellota	
		Caecidotea	3
		Mollusca	
		Bivalvia	
		Sphaerium	2
		Hydracarina	1
	4	Coleoptera	
		Scarabidae	1
		Hymenoptera	2
		Cladocera	
		Sididae	
		Sida crystallina	2
		Arachnidae	
		Araneae	1
	5	Hymenoptera	2
		Coleoptera	1
		Scarabidae	

<u>Pre-Breeding Bluegill Male</u> (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
May 23, 2007	1	Hydracarina	1

Date	Fish Number	Prey Items	Number of Items
June 8, 2008	5	Odonata	
		Anisoptera	1
		Eubranchiopoda	1
		Eubranchipus	1
		Coleoptera	
		Scarabidae	1
		Elmidae	
		Dubiraphia	1
		Hymenoptera	
		Formicidae	1
		Diptera	
		Chironomidae	2
		Cladoceran	2
June 8, 2009	11	Empty	
May 24, 2010	2	Mollusca	
		Bivalvia	
		Anodonta imbecilis	2
		Diptera	
		Phoridae	2
		Chironomidae, larval	1
		Hymenoptera	2
		Odonata	
		Anisoptera	1
		Trichoptera	8
	13	Chironomidae	1
	14	Coleoptera	1
		Chironomidae	2

<u>Breeding Bluegill Female</u> (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
June 25, 2007	14	Empty	
July 17, 2007	21	Chironomidae, Adult	1
		Chironomidae larva	1
July 31, 2007	25	Algae	
		Navicula	6
August 9, 2007	28	Odonata	
		Anisoptera	1
	29	Algae	
		Navicula	3
June 27, 2008	14	Ostracoda	2
		Chironomidae	
		Tanypodinae	
		A. mallochi	1
		Chironomini	
		Polypodium	1
		Cladocera	
		Sididae	
		Sida crystallina	200
July 10, 2008	18	Amphipoda	
		Hyallela	16
		Isopoda	
		Asellota	
		Caecidotea	3
		Mollusca	
		Gastropoda	2

Date	Fish Number	Prey Items	Number of Items
July 28, 2008	23	Empty	
July 31, 2008	25	Hymenoptera	
		Formicidae	1
	27	Empty	
	28	Hydracarina	1
July 20, 2009	5	Algae	
		Navicula	1

<u>Breeding Bluegill Male</u>, (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
June 25, 2007	15	Empty	
July 30, 2007	23	Chironomidae	
		Chironomini	
		G. lobiferus	4
		Cladocera	
		Sididae	
		Sida crystallina	1
		Ostracoda	6
July 31, 2007	24	Chironomidae	12
		Algae	
		Navicula	6
		Hydracarina	1
		Ostracoda	6

Date	Fish Number	Prey Items	Number of Items
June 27, 2008	13	Ostracoda	2
		Chironomidae	
		Tanypodinae	
		A. mallochi	1
		Chironomini	
		Polypedilum	1

Date	Fish Number	Prey Items	Number of Items
July 10, 2008	19	Eubranchiopoda	
		Eubranchipus	392
July 28, 2008	20	Algae	
		Navicula	16
		Isopoda	
		Asellota	
		Caecidotea	1
		Trichoptera	
		Hydropsychidae	3
		Mollusca	
		Gastropoda	
		Valvatidae	1
July 31, 2008	26	Mollusca	
		Gastropoda	
		Valvatidae	1

Post –Breeding Bluegill Female (Lake Mahopac)

Date	Fish Number	Prey Items	Number of Items
July 31, 2008	25	Hymenoptera	
		Formicidae	1
	27	Empty	
	28	Hydracarina	1
August 21, 2008	33	Larval Insect	
		Undetermined	1

Date	Fish Number	Prey Items			Number of Items
2009					
August 23, 2009	6	Chironomidae			
			Undetermined		1
	8	Hydracarina			
			Undetermined		3
	9	Hymenoptera			
			Formicidae		2

<u>Post-Breeding Bluegill Males</u> (Lake Mahopac)

Date	Fish Number	Prey Items			Number of Items
August 24, 2007	33	Empty			
	38	Chironomidae			
			Tanypodinae		
				A. mallochi	1
			Undetermined		1
		Diptera			
			Terrestrial adult		1

Date	Fish Number	Prey Items			Number of Items
August 24, 2007	39	Annelida			
			Oligochaeta		1
		Chirnomidae			
			Tanypodinae		
				A. mallochi	2
			Chironomini		
				G. lobiferous	1
			Undetermined		2
		Diptera			
			Dixidae		1
		Cladocera			
			Sididae		
				S. crystallina	1

Date	Fish Number	Prey Items	Number of Items
August 23, 2009	12	Diptera	
		Undetermined terr.	1
		Odonata	
		Anisoptera	1
	13	Empty	
	14	Empty	

<u>Pre-Breeding Bluegill Females</u> (Long Pond)

Date	Fish Number	Prey Items	Number of Items
May 25, 2010	1	Empty	
	2	Empty	
	3	Empty	
	4	Diptera larva	
		Bezzia	1
		Hemiptera	1
	5	Empty	

Date	Fish Number	Prey Items	Number of Items
May 25, 2010	6	Diptera	
		Brachycera	1
		Diptera	
		Ceratopogonidae	
		Bezzia	1
		Chironomidae	
		Undetermined	1
		Pupa	1
		Juncales	
		Juncaceae	1

Date	Fish Number	Prey Items	Number of Items
May 25, 2010	7	Diptera	
		Undetermined larva	1
		Juncales	
		Juncaceae	1
	10	Chironomidae pupae	1
		Adult	1
		Diptera	
		Undetermined terr.	2
		Ostracoda	1

Date	Fish Number	Prey Items	Number of Items
May 25, 2010	11	Cladocera	
		Daphniidae	
		Daphnia	12
		Chironomidae	
		Undetermined	2
		Hydracarina	
		Undetermined	1

Date	Fish Number	Prey Items	Number of Items
May 23, 2010	12	Ostracoda	1
		Chironomidae	
		Undetermined	1
	14	Odonata	
		Anisoptera	3
		Chironomidae	
		Chironomini	
		G. lobiferous	1
		Diptera	
		Ceratopogonidae	
		Bezzia	1
	17	Chironomidae	
		Undetermined	2

Date	Fish Number	Prey Items	Number of Items
May 23, 2010	19	Empty	
	20	Hydracarina	6
		Ostracoda	1

<u>Pre-Breeding Bluegill Males</u> (Long Pond)

Date	Fish Number	Prey Items	Number of Items
May 25, 2010	8	Chironomidae	
		Chironomini	
		G. lobiferous	1
		Diptera	
		Ceratopogonidae	
		Bezzia	2
		Ostracoda	1
		Odonata	
		Anisoptera	1
	9	Diptera	
		Brachycera	1
		Odonata	
		Zygoptera	1
		Ostracoda	2
May 23, 2010	13	Empty	
May 23, 2010	15	Diptera	
		Chironomidae, Adult	1
		Ostracoda	1
		Cladocera	
		Sididae	
		Sida crystallina	1
		Juncales	
		Juncaceae	1

Date	Fish Number	Prey Items			Number of Items
May 23, 2010	16	Amphipoda			
				Hyallela	5
		Gastropoda			
			Valvatidae		
				V. piscinalis	3
		Odonata			
			Anisoptera		1
		Cladocera			
			Daphniidae		
				Daphnia	1
		Chironomidae			
			Unidentified		1
	18	Ostracoda			3
		Cladocera			
			Daphniidae		
				Daphnia	6
		Chironomidae			
			Chironomini		
				G. lobiferous	13
		Diptera			
			Ceratopogonidae		
				Bezzia	12

Breeding Bluegill Females (Long Pond)

Date	Fish Number	Prey Items			Number of Items
August 1, 2007	1	Chironomidae			
			Unidentified		7
		Ephemeroptera			
			Unidentified		1
		Hemiptera			
			Unidentified		2
		Algae			
				Navicula	3

Date	Fish Number	Prey Items	Number of Items
August 1, 2007	2	Hydracarina	
		Unidentified	1
		Chironomidae	
		Chironomini	
		D. nervosus	11
		Tanypodinae	
		A. mallochi	1
		Tanytarsini	
		Unidentified	1
		Unidentified	102
		Diptera	
		Ceratopogonidae	
		Bezzia	9
	5	Chironomidae	
		Unidentified	1

Date	Fish Number	Prey Items	Number of Items
June 30, 2008	2	Empty	
	3	Empty	
	4	Odonata	
		Anisoptera	1
		Chironomidae	
		Undetermined	8
		Ceratopogonidae	
		Bezzia	2
		Juncales	
		Juncaceae	11

Date	Fish Number	Prey Items	Number of Items
July 10, 2008	5	Diptera	
		Unidentified terr.	2
		Isopoda	
		Asellota	
		Caecidotea	2
		Diptera Pupae	5
		Amphipoda	
		Hyallela	1
		Chironomidae	
		Unidentified	1
		Trichopera	1
	6	Empty	

Date	Fish Number	Prey Items	Number of Items
July 10, 2010	7	Ephemeroptera	
		Unidentified	1
		Chironomidae	
		Tanypodinae	
		A. mallochi	11
		Tanytarsini	
		Micropsectra polita	1
		Chironomini	
		P. albimanus	1
		Diptera	
		Ceratopogonidae	
		Bezzia	1
		Odonata	
		Unidentified	1
		Ostracoda	2
		Amphipoda	
		Hyallela	1
		Mollusca	
		Gastropoda	
		Unidentified	1

Date	Fish Number	Prey Items	Number of Items
July 10, 2010	8	Diptera	
		Ceratopogonidae	
		Bezzia	2
		Amphipoda	
		Hyallela	2
		Coleoptera	
		Unidentified Terr.	1
July 28, 2008	9	Odonata	
		Unidentified Larva	1
		Diptera	
		Unidentified Larva	1
August 22, 2008	12	Chironomidae	
		Unidentified Larva	1
		Odonata	
		Unidentified Larva	1

Date	Fish Number	Prey Items	Number of Items
August 22, 2008	13	Amphipoda	
		Hyallela	1
		Ostracoda	1
		Odonata	
		Unidentified Larva	1
		Tricoptera	
		Unidentified Larva	1
		Chironomidae	
		Tanypodinae	
		A. mallochi	1
		Tanytarsini	1
		Chironomini	
		D. neomodestus	1
		Juncales	
		Juncaceae	1

Date	Fish Number	Prey Items	Number of Items
August 22, 2008	14	Chironomidae	
		Tanypodinae	
		A. mallochi	1
		Chirnomini	
		G. lobiferous	4
		Amphipoda	
		Hyallela	1
August 7, 2009	1	Mollusca	
		Bivalvia	
		Spaeriidae	1
		Chironomidae	
		Chironomini	
		Chironomus riparius	1
		Amphipoda	
		Hyallela	1

<u>Breeding Bluegill Male</u> (Long Pond)

Date	Fish Number	Prey Items	Number of Items
August 1, 2007	3	Amphipoda	
		Hyallela	1
		Ostracoda	
		Unidentified	1
		Juncales	
		Juncaceae	1
	4	Ostracoda	1
		Diptera	
		Ceratopogonidae	
		Bezzia	1
		Chironomidae	
		Unidentified	2
		Juncales	
		Juncaceae	1

Date	Fish Number	Prey Items	Number of Items
August 1, 2007	6	Chironomidae	
		Tanypodinae	
		A. mallochi	7
		Ostracoda	1
	1	Juncales	
		Juncaceae	1
July 28, 2008	10	Coleoptera, Terrestrial	
		Unidentified	1

Date	Fish Number	Prey Items	Number of Items
July 28, 2008	11	Amphipoda	
		Hyallela	16
		Ostracoda	2
		Ephemeroptera	
		Unidentified	1
		Ceratopogonidae	
		Bezzia	1
		Chironomidae	
		Tanypodinae	
		A. mallochi	1
		Orthocladiinae	
		Crycotopus	1
		Chironomini	
		Dicrotendipes	1
August 7, 2009	2	Ostracoda	1
	3	Gastropoda	
		Unidentified	1
		Chironomidae	
		Chironomini	
		Chironomus	4

Post-Breeding Bluegill Female (Long Pond)

Date	Fish Number	Prey Items	Number of Items
August 11, 2007	7	Unidentified insect	1
		Juncales	
		Juncaceae	1

Date	Fish Number	Prey Items	Number of Items
August 11, 2007	8	Chironomidae	
		Unidentified	3
		Diptera	
		Ceratopogonidae	
		Bezzia	2
		Ephemeroptera	
		Unidentified	1
		Trichoptera	
		Lepidostomatidae	5
		Ostracoda	
		Unidentified	2
		Juncales	
		Juncaceae	5
August 11, 2007	9	Cladocera	
		Sididae	
		Sida crystallina	6
		Hydracarina	
		Unidentified	2
		Diptera, Terrestrial	
		Unidentified	2
		Chironomidae	
		Unidentified Pupae	1
		Chironomidae	
		Tanypodinae	
		A. mallochi	1
		Amphipoda	
		Hyallela	1
		Ostracoda	
		Unidentified	10
		Diptera	
		Ceratopogonidae	
		Bezzia	1

Date	Fish Number	Prey Items	Number of Items
August 26, 2007	11	Algae	
		Navicula	1
	15	Chironomidae	
		Chironomini	
		Polypedilum	3
		Unidentified	3
		Hydracarina	
		Unidentified	1
		Ostracoda	
		Unidentified	1
		Cladocera	
		Sididae	1
		Juncales	
		Juncaceae	10

Date	Fish Number	Prey Items	Number of Items
August 22, 2008	12	Chironomidae	
		Unidentified	1
		Odonata	
		Unidentified	1
		Ostracoda	
		Unidentified	1
	13	Amphipoda	
		Hyallela	1
		Ostracoda	
		Unidentified	1
		Chironomida	
		Tanypodinae	
		A. mallochi	1
		Chironomini	
		D. neomodestus	1
		Tanytarsini	1
		Odonata	
		Undetermined	1
		Trichoptera	
		Undetermined	1

Date	Fish Number	Prey Items			Number of Items
August 23, 2009	6	Chironomidae			
			Chironomini		
				D. modestus	111

<u>Post- Breeding Bluegill Male</u> (Long Pond)

Date	Fish Number	Prey Items			Number of Items
August 11, 2007	10	Chironomidae			
			Tanypodinae		
				A. mallochi	2
			Chironomini		
				Polypidelum	1
		Diptera			
			Ceratopogonidae		
				Bezzia	5
		Ostracoda			
			Unidentified		1
		Cladocera			
			Sididae		
				Sida crystallina	12
			Daphniidae		
				Daphnia	1
		Ephemeroptera			
			Unidentified		2

Date	**Fish Number**	**Prey Items**	**Number of Items**
August 26, 2007	12	Coleoptera	
		Coccinellidae	2
		Diptera	
		Ceratopogonidae	
		Bezzia	4
		Chaoboridae	
		Chaoborus	1
		Hymenoptera	
		Formicidae	2
		Odonata	
		Anisoptera	1
		Chironomidae	
		Unidentified	1
		Juncales	
		Juncaceae	3
	13	Mollusca	
		Gastropoda	
		Unidentified	2
		Hymenoptera	
		Formicidae	1
		Odonata	
		Anisoptera	2
		Hydracarina	
		Unidentified	1
		Chironomidae	
		Chironomini	
		Chironomus	1
		Orthocladiiinae	
		P. psilopterus	1
		Unidentified	6

Date	Fish Number	Prey Items				Number of Items
August 22, 2008	14	Chironomidae				
			Tanypodinae			
				A. mallochi		1
			Chironomini			
				G. lobiferus		4
		Mollusca				
			Bivalvia			
				Undetermined		1
		Amphipoda				
				Hyallela		1
	15	Chironomidae				
			Tanypodinae			
				A. mallochi		2
			Chironomini			
				D. nervosus		2
				Polypedilum		2
				C. riparus		1
				Phaenopsectra		
					flavipes	1
				Unidentified		4
		Odonata				
			Anisoptera			1
		Diptera				
				Unidentified		1
		Ostracoda				
				Unidentified		1
		Ceratopogonidae				
					Bezzia	4
August 23, 2009	5	Chironomidae				
			Undetermined			1
		Hymenoptera				
			Formicidae			3
		Hydracarina				
			Undetermined			1
		Ostracodae				
			Myodocopidae			1

Date	Fish Number	Prey Items	Number of Items
August 23, 2009	7	Chironomidae	
		Chironomini	
		D. neomodestus	32
		Odonata	
		Anisoptera	1
		Coleoptera, Terrestrial	
		Unidentified	1
		Diptera	
		Chironomidae adults	7
		Hymenoptera	
		Unidentified	1
		Coleoptera pupae	
		Unidentified	7

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