

SELECTION OF ZOOPLANKTON PREY BY LARVAL YELLOW PERCH ACROSS
MULTIPLE LAKE SYSTEMS

By

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ABSTRACT

SELECTION OF ZOOPLANKTON PREY BY LARVAL YELLOW PERCH ACROSS MULTIPLE LAKE SYSTEMS

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Yellow perch *Perca flavescens* are widely distributed across North America where they inhabit a variety of aquatic ecosystems, playing an ecologically and economically significant role as both predator and prey. Like many fishes, successful recruitment of yellow perch depends on the availability of suitable densities and sizes of zooplankton prey at critical early life history periods. Thus, evaluation of prey selection may lend insight into processes driving year class strength. In order to assess prey selectivity, we collected larval yellow perch and zooplankton samples across a variety of inland lakes in Michigan's Lower Peninsula. The size structure of zooplankton taxa (e.g. *Bosmina* spp., cyclopoid copepods) was quite consistent across multiple system types, but zooplankton densities varied widely both within and between lakes. Selection for prey type and size varied in relation to fish size, but remained relatively consistent between eutrophic, mesotrophic and oligotrophic lakes. In my study lakes, I concluded that rotifers were not an important first food of larval yellow perch and analysis of prey selection patterns is confounded by a summative interaction of morphological limitations of the predators with behavioral preference for specific prey types within prey size classes. Additionally, I demonstrated that large numbers of samples were necessary to improve the level of confidence in measuring prey availability (e.g. density, species composition).

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INTRODUCTION

Yellow perch *Perca flavescens* are widely distributed across North America and inhabit a variety of lacustrine aquatic systems, ranging in size from 0.1 to 56,000 km² (Jenkins and Burkhead 1994), as well as riverine systems (McDonald et al. 2013) throughout their range. The yellow perch is an economically important species in both Canadian and U.S. waters of the Laurentian Great Lakes (Fielder and Thomas 2006; Michigan Department of Natural Resources 2013), providing significant income to commercial fisheries in both countries (Craig 2008). Additionally, recreational anglers target yellow perch throughout the Great Lakes as well as within inland waterbodies, contributing to local economies of nearby communities (Craig 2008). The presence of healthy yellow perch populations are also used as an indicator of the overall health of an ecosystem (Poe 1983), due to their ecologically important role as both predator and prey species in aquatic food webs throughout their range (Fielder and Thomas 2006; Roswell et al. 2014). Because of their socioeconomic (Craig 2008) and ecological (Roswell et al. 2014) significance, tremendous effort has focused on increasing our understanding of the mechanisms affecting the success of Great Lakes (Bremigan et al. 2003; Fulford et al. 2006a, 2006b; Farmer et al. 2015) and inland yellow perch populations (Hayes and Taylor 1990; Schael et al. 1991). Although much is known of yellow perch population dynamics, the processes influencing recruitment success across different lake system types remains a key source of uncertainty. Specifically, studies of the dynamics of yellow perch recruitment report similar broad trends in life history across various lake system types. However, few evaluate and synthesize similarities or differences found in the ecology of early life stages among a range of lake system types.

The early life history ecology of fishes plays an important role in fisheries recruitment (Houde and Hoyt 1987; Houde 1989; Cushing 1990). Variability in the survival of larval fishes is well-known to be a critical process driving year class strength (Sharp 1987). Larval survival of not only yellow perch, but all fishes, is the result of dynamic interactions of biological and environmental factors, such as larval predation (Fulford et al. 2006a), temperature fluctuations (Clady 1976; Farmer et al. 2015), turbidity, and algal blooms (Manning et al. 2014).

Furthermore, ecologists have observed that brief critical periods in the early life history of many fishes play especially important roles in recruitment success. For instance, the recruitment of yellow perch has been shown to depend on the availability of suitable densities and sizes of zooplankton prey during critical early life history periods (Dettmers et al. 2003). These critical periods include the transition from endogenous nutrition, dependent on yolk sac viability and larvae size, to development of the ability to sustain growth and life through exogenous feeding. Additionally, adequate food sources are needed for rapid growth and development of the motor skills that are necessary to seek, find, and capture prey, while at the same time evading predation. Thus, zooplankton prey community characteristics can have far reaching consequences to successful recruitment of yellow perch. For example, the invasion of *Bythotrephes longimanus* (Barbiero and Tuchman 2004; Barbiero et al. 2009; Bunnell et al. 2011) to the Great Lakes Basin, concurrent with changes in phytoplankton biomass resulting from invasive dreissenid mussels (Nalepa et al. 2007; Barbiero et al. 2009) has effectively altered available food resources throughout the Great Lakes region, including inland waterbodies, for all larval fishes during these critical periods (Barbiero and Tuchman 2004; Vanderploeg et al. 2015; Kerfoot et al. 2016). These changes in zooplankton community structures, coupled with competition and predation from exotics, such as rainbow smelt *Osmerus mordax*, alewife *Alosa pseudoharengus*

(Fulford et al. 2006a), and changing climatic conditions (Farmer et al. 2015), likely have resulted in changes to the survival, growth, and recruitment of young yellow perch throughout inland lake systems as well as areas within the Great Lakes (Fielder and Thomas 2006; Farmer et al. 2015).

One key component of the predator-prey relationship between larval yellow perch and zooplankton is the process of prey selection. Prey selection is not only behavioral and occurs when predators actively choose their prey, but for larval fishes, is also heavily dependent on limitations imposed by their structural morphology and size. Larval fish size and morphology are important components in predator-prey interactions and responsible for a larvae's ability to detect, encounter, capture, and consume prey. These components of feeding are apparent in all organisms, including fish, mammals, and birds, when looking at predatory behavior in selection of food items (Holling 1959a, 1959b, 1965). Specifically, characteristics such as visual acuity, swimming ability, and swim speed limit a larval fish's ability to detect and encounter prey as well as avoid predation. Many larval fishes, such as yellow perch, bluegill *Lepomis macrochirus*, and black crappie *Pomoxis nigromaculatus* are also gape-limited (Schael et al. 1991; Bremigan and Stein 1994; Bremigan et al. 2003) in their ability to consume prey. Prey size also interacts with a larvae's visual acuity and its ability to search for and locate suitable sizes of microscopic and transparent zooplankton prey. As such, the size and visibility of available prey types regulates a larvae's choice of prey types. Therefore, larval yellow perch prey choice may not simply be determined by which prey are most abundant, but also by their ability to detect and capture the prey.

Selective predation is defined as when the relative frequency of items found in a predator's gut is different than the relative frequency of available prey found in the environment (Ivlev 1961; Chesson 1978). Furthermore, selective predation may occur for a variety of reasons,

as discussed above, but if specific prey types are relatively more energy rich than other prey types due to larger size or higher lipid content, then the cost: benefit of capture will be lower and selective behavior may be apparent where larval fish actively choose for specific taxa within certain sizes of different prey types. Many approaches exist for determining a relative index of selective predation, all of which look to describe the relationship between a predator's diet and the availability of prey in the environment. Early approaches include Ivlev's Electivity Index (1961), Manly et al.'s Analysis of Selective Predation (1972), and Strauss's Linear Index of Food Selection (1979). These methods for the analysis of prey selectivity aimed to identify significant sources of error in the interpretation of food selection data and provided the foundation for indices of selective predation. One of the most widely used methods among early life history researchers to represent selection is Chesson's Index of Selective Predation (Chesson 1978, 1983). This method is popular among researchers due to its ability to incorporate in the analysis any number of prey types found in the environment, i.e. 2 through n prey types, as well as compare selection indices among environments with different numbers of prey types.

Prior insight into yellow perch prey selection has mainly been derived from laboratory studies (Letcher et al. 1996; Dettmers et al. 2003), studies of individual lake types (Schael et al. 1991) or portions of the Great Lakes, such as Green Bay (Bremigan et al. 2003), Saginaw Bay (Roswell et al. 2013, 2014), and Southern Lake Michigan (Fulford et al. 2006b). In Wisconsin's Lake Mendota, researchers were able to explain variability in average prey size as limited by predator gape size and noted the importance of copepod zooplankton to larval yellow perch, black crappie and freshwater drum *Aplodinotus grunniens* (Schael et al. 1991). In Southern Lake Michigan, researchers have documented consistent patterns of prey selection through a combination of laboratory experiments, empirical models, and field samples (Fulford et al.

2006b) citing the importance of rotifers as well as other small zooplankton prey to the first feeding period of larval yellow perch. In Lake Michigan's Green Bay, researchers compared prey selection through gut analysis of larval yellow perch to patterns of prey selection found in Southern Lake Michigan and found copepod nauplii and cyclopoid copepods to be important for larvae during first feeding periods (Bremigan et al. 2003). Additionally, they found gape-limitation to be an important predictor of selection for specific prey types. In Lake Huron's Saginaw Bay, a recent exploration of the importance of prey selection and availability throughout the first year of life (Roswell et al. 2013, 2014) described the relationship between the density and size of zooplankton prey with growth, survival, and successful recruitment of yellow perch. Although these studies have explored relationships between larval success and prey availability through both lab and field methods, there is currently a knowledge gap regarding how general patterns of prey selection might vary across multiple system types, such as Michigan's inland waters.

Patterns observed to date have been specific to each researcher's particular waterbody. While there appears to be an expectation among researchers that generally similar patterns of prey selectivity would occur across different system types, research completed to date does not include a robust comparison of prey selection among different lake trophic categories. With the wide range of lake trophic state among Michigan's inland lakes – from oligotrophic to eutrophic– it would be valuable to know whether prey selection patterns vary across this range. Zooplankton community structure and density have been observed to vary across trophic conditions (Patalas 1972), leading to differences in available prey fields. Moreover, water clarity varies with trophic state, possibly leading to differences in prey selection through systematic difference in detectability of prey (Vanderploeg et al. 2015).

The overall goal of this study was to evaluate patterns of prey selection by larval yellow perch across multiple system types in inland lakes of Michigan's Lower Peninsula. I hypothesize that general overall patterns of prey selection for larval yellow perch exist and can be expected regardless of system size or trophic state. Additionally, I hypothesize that selective predation by larval yellow perch is primarily driven by larval fish morphology, i.e., gape limitation. While some variation in selective predation may occur among different system types, I expect to see a common pattern across different lake system types. However, if patterns of selective predation depend partly on system type, then quantification of prey selection indices across multiple system types will reveal system-specific patterns of prey selection that will be useful for future assessments of yellow perch recruitment dynamics. Also, if larvae actively choose certain taxa over other taxa of similar size, then quantification of this behavior across multiple systems will increase our understanding of factors likely influencing early life history yellow perch survival. My objectives were to determine if 1) patterns of selection for zooplankton prey differed among different lake system types, and 2) patterns of selection for zooplankton prey in inland lakes differed in comparison to established patterns of selection from laboratory and field studies focused on Great Lakes proper waterbodies and Wisconsin's Lake Mendota, and 3) patterns of prey selection were driven primarily by morphological characteristics of larvae.

METHODS

Study Area

To meet the primary goal of this study, I included a broad range of inland lake systems ranging from small, < 200 acres, to some of the largest inland lakes in Michigan, i.e. ~20,000

acres, as well as ranging in productivity from eutrophic to oligotrophic states (Figures 1 and 2). Discussions with regional stakeholders (i.e. bait shop owners, anglers, and fisheries biologists) led me to non-randomly choose these lakes, based on size, trophic state, geographic location, and well known populations of naturally reproducing yellow perch. The intent was to include a broad range of systems to provide a representative sample of Michigan inland lakes containing yellow perch populations and provide opportunity for high contrast in predator diet and prey availability data, thereby increasing our understanding of general patterns in larval yellow perch prey selection. Table 1 provides an overview of lake characteristics including surface area, maximum depth, and location by county. Some of the study lakes were included in a previous study of the ‘Inland Waterway’ where larval fish and zooplankton had been previously collected and processed. The Inland Waterway is a series of large inland lakes running across the northern lower peninsula of Michigan that provide a connecting channel between Lakes Michigan and Huron and it is comprised of Crooked, Pickerel, Burt, and Mullet Lakes. Several other large systems were selected in the northern Lower Peninsula after consultation with the regional MDNR biologist to help expand the scope of my comparison. These samples provided new information on yellow perch population dynamics for these lakes, which previously had been limited to knowledge of the presence of yellow perch. These systems included Black, Grand, Long, and Hubbard Lakes. Southern study lakes were much smaller in size and depth and included Park Lake, Lake Lansing, Lake Ovid, and Lobdell Lake. To further expand my comparison across variable system types, I included Higgins Lake during the 2015 field season because of its well-known and valued yellow perch fishery. Also, I included Houghton Lake during the 2015 field to incorporate a large eutrophic system because my other eutrophic lakes were rather small in size.

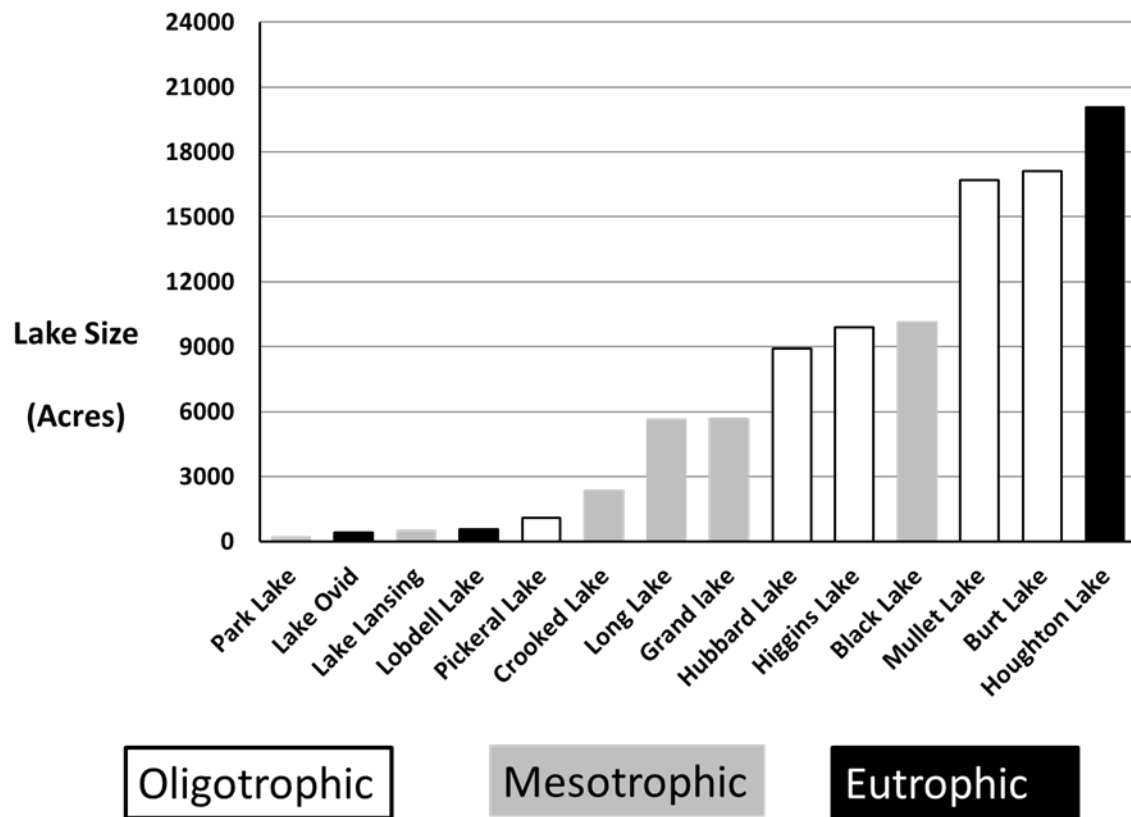


Figure 1. Size distribution and trophic status of study lakes. Black shade depicts eutrophic lakes, gray shade depicts mesotrophic lakes, and white box depicts oligotrophic lakes.

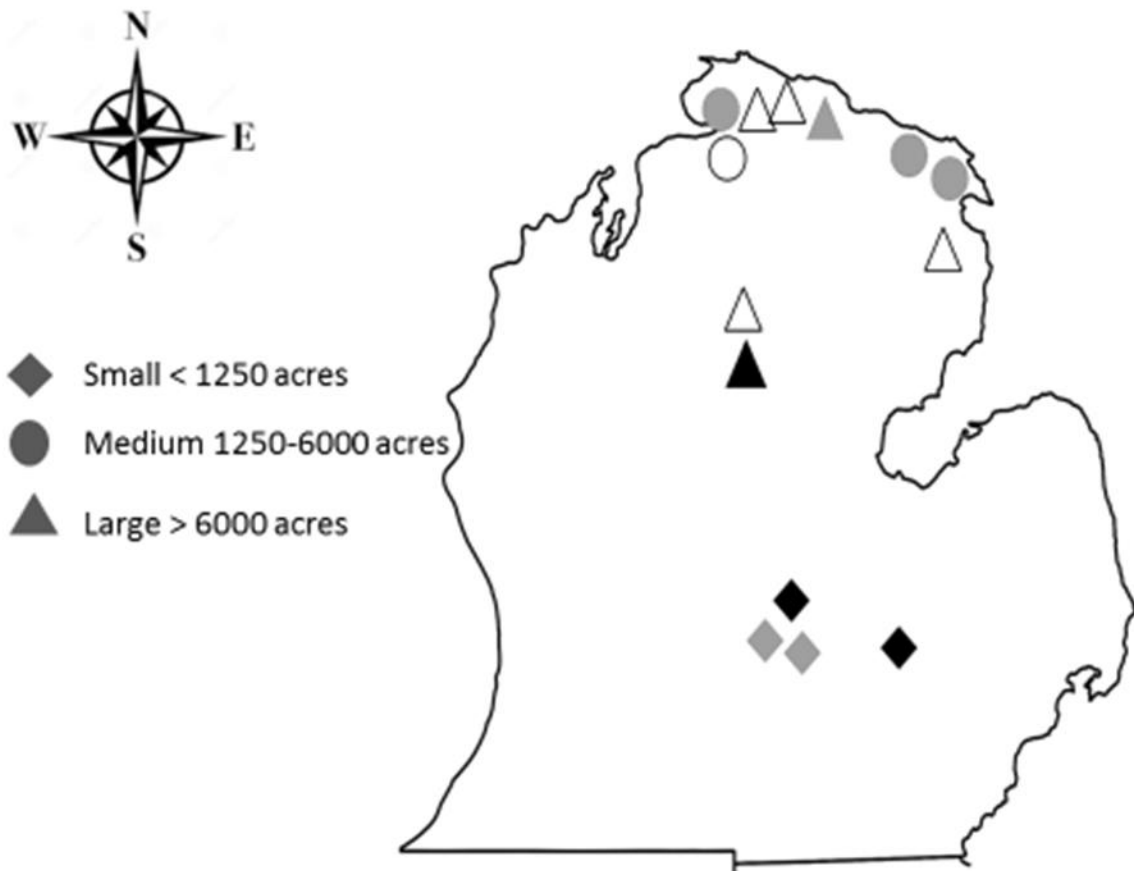


Figure 2. Location, relative size, and trophic status of study lakes. Diamonds represent small lakes (<4 km²), circles represent medium lakes (4 to 25 km²), and triangles represent large lakes (25 to 82 km²). Solid symbols represent eutrophic systems, shaded symbols represent mesotrophic systems, and open symbols represent oligotrophic systems.

Table 1. Characteristics of study lakes. Lake trophic status was inferred from Secchi disk readings where oligotrophic is >5 m, mesotrophic 2-5 m, and eutrophic <2 m (Secchi depth ranges taken from 2007 Michigan Inland Lakes Assessment Report, MDEQ 2010). Lake area and maximum depths were taken from USGS spatial database (<http://miwebmapper.er.usgs.gov>). N (Days) represents the number of sampling events across all years of the study.

Waterbody	Area (km ²)	Acres	N (Days)	Mean Secchi (m)	Trophic Status	Max depth (m)	County
Park Lake	0.8	185	9	3.1	Mesotrophic	6.1	Clinton
Lake Ovid	1.7	420	5	1.2	Eutrophic	9.1	Clinton
Lake Lansing	2.0	494	7	4.2	Mesotrophic	10.7	Ingham
Lobdell Lake	2.2	544	1	1.9	Eutrophic	23.8	Genesee
Pickerel Lake	4.4	1087	11	6.2	Oligotrophic	22.9	Emmet
Crooked Lake	9.5	2348	12	3.6	Mesotrophic	15.2	Emmet
Long Lake	22.7	5609	2	2.3	Mesotrophic	7.6	Alpena/Presque Isle
Grand lake	22.9	5659	3	3.1	Mesotrophic	6.1	Presque Isle
Hubbard lake	36.0	8896	2	5.1	Oligotrophic	26.0	Alcona
Higgins Lake	40.0	9884	1	7.2	Oligotrophic	41.2	Roscommon
Black Lake	41.0	10131	5	2.7	Mesotrophic	15.2	Cheboygan
Mullet lake	67.6	16704	8	5.3	Oligotrophic	44.0	Cheboygan
Burt Lake	69.3	17124	12	5.6	Oligotrophic	22.3	Cheboygan
Houghton Lake	81.1	20045	3	1.8	Eutrophic	6.4	Roscommon

Ichthyoplankton Collection

Larval fish collections occurred from late April through June during the 2011-13 field seasons as part of the Inland Waterway Study. Additionally, collection efforts occurred for the 2014-15 field seasons from late April through June, beginning with southern study lakes and progressing north as water temperatures rose. The following methods were consistent across all sampling years unless otherwise noted. Initial sampling began approximately two weeks after study lakes were ice free and continued until fewer than 5 yellow perch were collected via ichthyoplankton trawling per sampling event. At each lake sampling event, I conducted a minimum of 3 replicate larval trawling events, but up to 15 when additional sampling was

required to locate and capture larval fish. Typically, yellow perch are susceptible to surface collection from the yolk-sac stage until approximately 20 mm. Larger than 20 mm yellow perch larvae become able to escape surface collection efforts. For this reason, I targeted larval fish from ~5 mm, (i.e. yolk sac fry), to 20 mm for collection. At each lake, collection sites in nearshore areas were chosen based on previously published methods as spawning yellow perch are known to associate with sub-surface vegetation (Post and McQueen 1988; Sullivan and Stepien 2014; Massicotte et al. 2015). Ichthyoplankton trawling occurred from approximately 1400 until 2300 hours, when larval yellow perch actively feed (Post and McQueen 1988; Leclerc et al. 2011). Larvae were collected from the top 0.5 m of the water column using a standard side mounted 500 μ m ichthyoplankton trawl net with 50 cm mouth opening. A flow meter was suspended in the center of the mouth opening to estimate volume of water sampled. For the field seasons 2011-14, a standard side mounted ichthyoplankton net was towed in a straight line, parallel to the shoreline in 1-3 meter deep water with occasional collections occurring in deeper waters, ~4-10 meters, for 5 minutes per tow at approximately 1-1.5 m/sec (Figure 3). In 2015, tow duration was reduced to 2.5 minutes per tow at approximately 1-1.5 m/sec (Figure 4). I reduced trawling time in 2015 to allow time for additional zooplankton collection events (*See Zooplankton Collection*) for each larval trawl. Regardless of year and upon completion of the tow, the net was retrieved from the water and rinsed from the outside with lake water. The cod-end was removed, rinsed from the outside with lake water and contents transferred to an 8 inch by 13 inch picking tray. Large pieces of vegetation were picked from the sample, rinsed with lake water and checked for entrained larvae. The remaining contents, including larval fish, were euthanized with a 10 % solution of 95% ethanol, i.e. 10 mL ethanol/ 90mL of lake water. After euthanization of the larval fish, contents of the picking tray were drained, transferred to 1 L

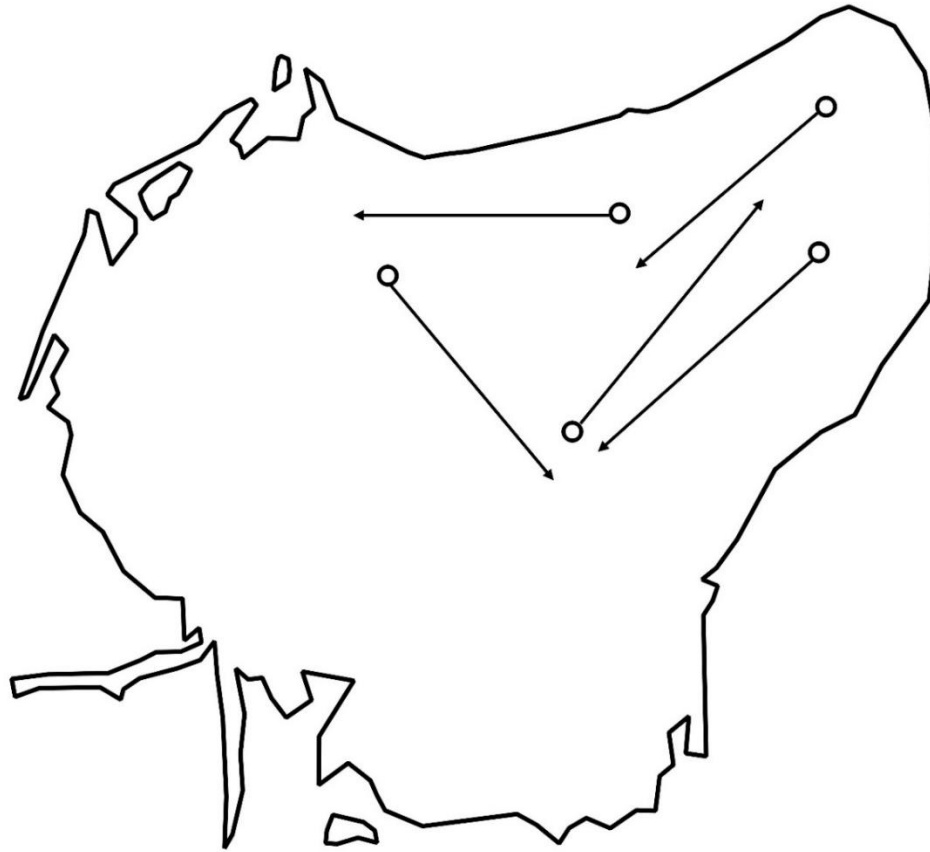


Figure 3. Representative 2014 sampling event from Park Lake. Open circles represent location of vertical zooplankton tows. Solid lines represent location and relative distance of horizontal ichthyoplankton trawls. The combination of one zooplankton tow and one ichthyoplankton trawl is considered a 'Tow Group'.



Figure 4. Representative 2015 sampling event from Park Lake. Open circles represent location of vertical zooplankton tows. Solid lines represent location and relative distance of horizontal ichthyoplankton trawls. The set of three zooplankton tows and one ichthyoplankton trawl broken in half is considered a ‘Tow Group’.

polyethylene bottles filled with 95% ethanol, and labeled with tow ID number, lake, and date.

After collection efforts ceased, typically the following morning, larvae were picked from the sample, enumerated, placed into 25 mL glass vials, and preserved in 95% ethanol for identification in the laboratory. Upon completion of field work, all larval fish were processed in the laboratory using a compound stereomicroscope. All larvae were removed from vials, enumerated, and identified to species (Auer et al. 1982). Auer et al. (1982) define larvae as the

phase of development from complete absorption of the yolk to development of the full complement of adult fin rays and absorption of the finfold. Juveniles are defined as the phase of development from complete fin ray development and finfold absorption to sexual maturity (Auer et al. 1982). Thus, samples collected during this study include the larval stage and early juvenile stage of development. However, I refer to all fish included in this study as larval yellow perch.

Zooplankton Collection

Field collections of micro-crustacean zooplankton occurred immediately adjacent to ichthyoplankton collection sites. During the 2011-14 field seasons, a matching zooplankton collection was gathered at the beginning of each ichthyoplankton trawl from a neutral position (i.e. drifting with prevailing wind/current to allow for a vertical tow) or while anchored by using a 12 cm diameter Wisconsin Plankton Net with 80 μ m mesh. Figure 3 illustrates this scheme for all study lakes, but is specific to Park Lake in 2014. The combination of one zooplankton tow and one ichthyoplankton trawl is considered a 'Tow Group'. In 2015, zooplankton collection efforts were increased and occurred at the beginning, mid-point, and end of each ichthyoplankton trawl. Figure 4 illustrates combined larval fish and zooplankton collections for all lakes during the 2015 field season, but is specific to Park Lake for 2015. The set of three zooplankton tows and one ichthyoplankton trawl which was broken in half to collect a zooplankton sample is considered a 'Tow Group'. For all years, 2011-15, water depth was recorded and the zooplankton net was lowered until it made slight contact with the substrate, then slowly (~30.5 cm/ sec) brought to the surface. After retrieval, the outside of the net was rinsed with lake water to wash planktonic crustaceans into the cod-end. At this point, the cod-end was rinsed with 95% ethanol, which effectively euthanized the samples collected. Samples were then transferred to a

125mL polyethylene bottle labeled with Tow ID, lake, and date, and then preserved in 95% ethanol for identification and enumeration in the laboratory.

Concurrent with ichthyoplankton identification, zooplankton were processed using the following lab protocols across all years, 2011-15, of this study. Because the emphasis of this research was the relationship between larval diet and prey density, species composition, and size composition, zooplankton sample processing focused on samples associated with positive catches of ichthyoplankton. Zooplankton samples were identified (Pennak 1953; Balcer et al. 1984) and placed into major groups for selectivity analysis, including small cladocerans (e.g. *Bosmina*, *Eubosmina*, *Chydorus*), large cladocerans (e.g. *Daphnia* spp.), calanoid copepods, cyclopoid copepods, copepod nauplii, ostracods, *Leptodoridae*, and harpacticoid copepods. Rare species were noted in order to be considered during larval diet analysis. Rotifers were also noted as general presence or absence within each zooplankton tow to be considered during larval analysis. Initial dissection of a random sample of the smallest larvae under a high power stereomicroscope yielded no evidence of rotifers in the guts of larval yellow perch. Therefore, it was decided to exclude rotifers from quantification as available prey. Each sample was drained of ethanol, rinsed with water, and diluted to 100mL for enumeration. Depending on observed density, counting methods varied. If density appeared by eye to be extremely low, common to early season northern lakes, the entire sample was counted. If the samples were moderately dense, they were split with a Folsom Plankton Splitter to 50%, 25% or 12.5%. Extremely dense samples were subsampled using a 2 mL Hensen-Stempel pipette. A minimum of 100 organisms were counted in samples that were split or subsampled and total density calculated by scaling the proportional contribution of each major group to the entire volume of water sampled during the respective zooplankton tow. Samples were placed into a Ward's Zooplankton Counting Wheel

and examined at 50X on a compound dissecting stereomicroscope. The first 10 micro-organisms of each major group for each zooplankton tow were measured to the nearest 0.01 mm following standard measurement protocol (U.S. Environmental Protection Agency (USEPA) 2003) by using an ocular micrometer calibrated prior to each session. Total density for binned size groups, i.e. <0.2 mm, 0.2 to <0.4 mm, 0.4 to <0.6 mm, etc., was calculated by the proportional contribution of each size group to the total density of the entire sample.

Diet Analysis

Typical of field collection of larval fishes, certain samples contained large numbers of larvae, while others contain only a few larvae. To avoid over-representing high density samples we subsampled by randomly selecting 5 larvae from each larval trawl. If the tow contained less than 5 yellow perch larvae, I dissected all fish in the sample. For field seasons 2011-13, I included at least one larval trawling event per day for a minimum of 5 larvae dissected per lake date combination. Additionally, I included a minimum of 3 individual days of samples per lake. For the 2014-15 field seasons, I included a minimum of 3 larval trawling events, but up to 15, per lake-date combination. In subsequent statistical analysis, the unit of replication is the ‘Tow Group’ as defined previously.

Larval length was measured to the nearest 0.01 mm at 10X using a compound stereomicroscope equipped with an ocular micrometer calibrated prior to each measurement. The stomach was removed from the anterior opening of the esophagus to the vent and contents removed. All contents of the stomach were identified to major group as defined above for zooplankton (Pennak 1953, Balcer et al. 1984), enumerated, and measured following above

microscopic techniques and standard measurement protocol (U.S. Environmental Protection Agency (USEPA) 2003).

Sample Size Analysis

Often, many studies rely on a single zooplankton tow per lake/date combination to describe the prey field available to larval fish (McDonnell et al. 2014; McCullough et al. 2015). Given the known patchiness and highly variable distribution of zooplankton within waterbodies, I used my replicate tow data to conduct an analysis to determine the implications for relative precision of estimates of mean zooplankton density where multiple tows per lake/date are collected. I based my analysis on zooplankton density data from the 2015 season, where three zooplankton tows per ichthyoplankton tow were consistently collected. I calculated the coefficient of variation (CV) across all 2015 sampling events using tow groups as described in Figure 4 above by taking the variance (s^2) averaged across all tow groups, and calculating the grand standard error (SE) by using the following series of equations (Krebs 1989):

$$\text{Mean density } \left(\frac{\#}{L} \right) \text{ for each tow group} = \frac{\sum_1^n \text{Density/tow}}{n}$$

Where L=Liter and n =tow group size (=3).

$$\text{Grand Mean } (\mu) = \frac{\sum_1^N (\text{Mean})}{N}$$

Where N =Total # of tow groups in 2015.

$$\text{Grand Variance } (s_G^2) = \frac{\sum_1^N s_{tow}^2}{N}$$

Where s_{tow}^2 =Variance in total density within each tow group.

$$\text{Grand Standard Error (SE)} = \sqrt{\frac{s_G^2}{n}}$$

Where $s_G^2 = \text{Grand Variance}$ and $n = 3$.

$$\text{Grand CV} = \frac{SE}{\mu}$$

Where $SE = \text{Grand Standard Error}$ and $\mu = \text{Grand Mean}$.

Utilizing the Grand CV from 2015 zooplankton collection efforts, I then calculated the estimated sample size necessary to detect differences in total density among tow groups whether within the same lake or among tow groups from different lakes by the following equation (Krebs 1989).

$$n = \left(\frac{100 * CV * t_{\alpha}}{r} \right)^2$$

Where $n = \text{estimated sample size}$, $CV = \text{Grand CV}$, $t_{\alpha} = \text{Student's } t \text{ with } n-1 \text{ degrees of freedom for } 1-\alpha \text{ level of confidence}$, and $r = \text{Desired relative error (Defined as } \pm 20\% \text{ relative precision of the mean)}$.

Because I was attempting to estimate a required sample size (n) for a specified level of precision, I would either have to solve iteratively for n or estimate t_{α} . Krebs 1989 offers that it is almost never worth the effort since t values for 95% confidence limits are almost always around 2. As such, I used the approximation of the Student's t value of $t_{\alpha}=2$ and estimated n for relative precision = $\pm 10\%$, $\pm 20\%$, $\pm 30\%$, and $\pm 40\%$.

Selectivity Data Analysis

Chesson's Index of Selective Predation (Chesson 1978, 1983) was used to compare yellow perch diet items with prey proportions in the environment to determine prey selectivity. This method is useful because it allows for multiple prey species with varying densities and only changes if an organisms behavior alters in response to those changes (Chesson 1978, 1983). This measure of preference is derived from a stochastic model involving the probability of encounter and the probability of capture upon encounter (Chesson 1978). Chesson's (α) is defined as:

$$\alpha_i = \frac{\left(\frac{r_i}{p_i}\right)}{\sum_1^n \left(\frac{r_i}{p_i}\right)}$$

Where α_i = selectivity coefficient of prey type i , r_i = proportion of prey type i in the diet, p_i = proportion of prey type i in the environment, and n = number of available prey types in the environment. Positive selection is indicated when $\alpha_i > (1/n)$, neutral selection when $\alpha_i = (1/n)$, and negative selection when $\alpha_i < (1/n)$. Although α_i is useful when comparing selection within one experiment where n is uniform, it is not easy to compare the strength of non-random selection when comparing sites with varying numbers of available prey taxa. To address this, Chesson's Rescaled Index of Selection (Chesson 1983) was calculated and yields a measure of preference ranging from -1 to 1, with -1 indicative of complete avoidance, 0 representing neutral selection and 1 displaying complete selection for prey type i . Chesson's Rescaled Index of Selection (α'_i) is defined as:

$$\alpha'_i = \frac{n \alpha_{i-1}}{(n-2)\alpha_{i+1}} , \quad i = 1, \dots, n$$

Where α'_i =rescaled selectivity coefficient of prey type i .

Establishing Patterns of Selection

To examine overall patterns of selection across multiple system types and throughout the larval and early juvenile phase of yellow perch life history, I plotted Chesson's Rescaled Index of Selectivity (α'_i) for each major prey taxa group against larval fish total length for all individual larvae across all lakes. Additionally, I plotted Chesson's Rescaled Index of Selectivity (α'_i) for each prey size group against larval fish total length for all individual larvae across all lakes. Next, in order to assess differences in patterns of selection among different lake trophic states, I plotted Chesson's Rescaled Index of Selectivity (α'_i) as before, but stratified by lake trophic state. I overlaid these plots of major prey taxa and prey size by trophic state as a method to visually evaluate differences in patterns of selection among trophic states. I examined selection patterns for taxa, selection patterns for size, and plots of the size distribution of each zooplankton taxa to infer if selection for specific taxa and selection for specific prey size are totally confounded or if prey selection results from the additive effects of both of these parameters. Lastly, I applied a Locally Weighted Scatterplot Smoothing (LOESS) function to each α'_i plot and calculated a 95% confidence interval of the smoothing function (Cleveland 1979; Cleveland and Devlin 1988) for each trophic state. Overlaying these plots and looking for overlap of 95 % confidence intervals between trophic lake types for all predator-prey selectivity functions allowed me to assess whether selectivity patterns differed substantially among lake trophic types.

RESULTS

Zooplankton communities

Zooplankton density and community structure varied substantially among tows within a lake-day sampling event, across dates within a lake, and among lakes (Appendix Table A1). *Bosmina* spp. ranged from 0 to 700 organisms per liter, calanoid copepods ranged from 0 to 87 per liter, cyclopoid copepods ranged from 0 to 248 per liter, *Daphnia* spp. ranged from 0 to 106 per liter, and nauplii ranged from 0 to 725 per liter. Additionally, proportions of zooplankton prey taxa (P_i) varied substantially across dates within a lake and among lakes within the three trophic states (Appendix Table A2, A3, A4). The total proportions of the main taxa encountered, calculated as a single proportion by combining all lakes within a trophic state, were quite consistent across lake trophic categories (Figure 5). However, *Bosmina* spp. tended to be more prevalent in eutrophic lakes while *Daphnia* spp. and calanoid copepods were less prevalent in eutrophic systems. Among all lake types, *Bosmina* spp. and copepod nauplii dominated the zooplankton community; the total proportions of *Bosmina* spp. ranged between 30% and 42%, and nauplii between 29% and 41%. Cyclopoid copepods were the next most common taxon, ranging between 15 and 19%. Calanoid copepods and *Daphnia* spp. were generally low in proportional contribution, making up from 4% to 9% and 1% to 8%, respectively. Other zooplankton (i.e. Leptodoridae, harpacticoid copepods, ostracods, and Bythotrephes) were also generally low in proportional contribution, making up between 2% and 5% of the overall zooplankton community.

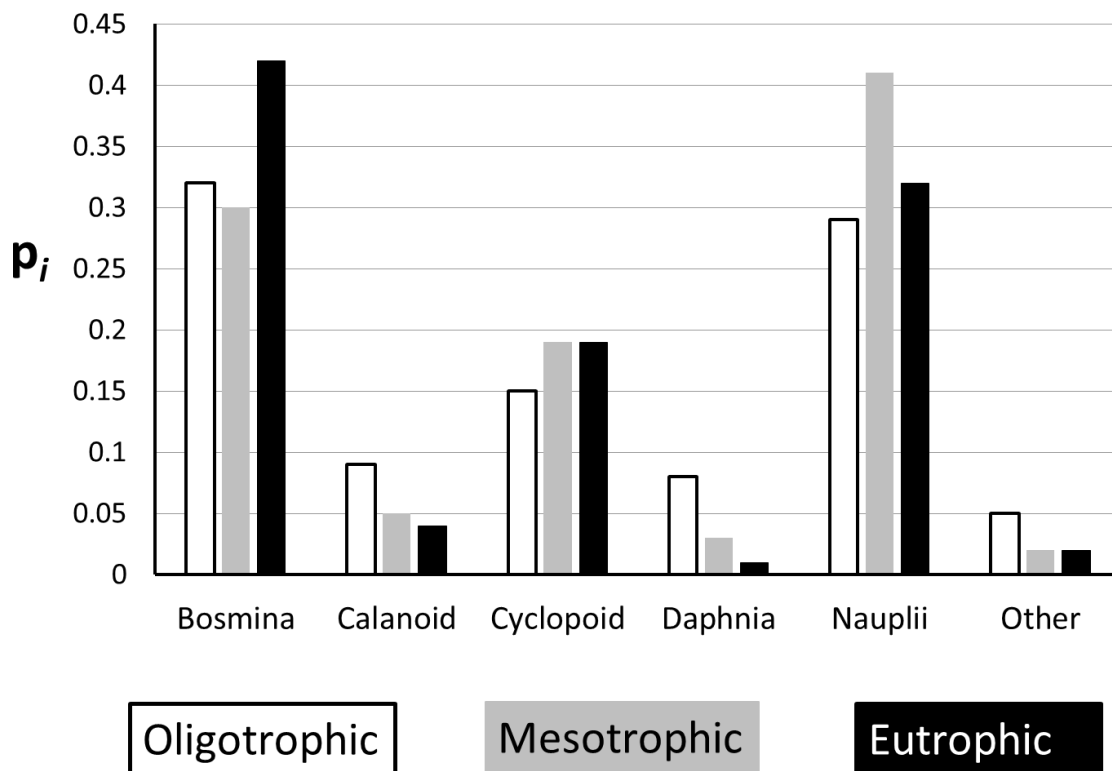


Figure 5. Total proportions of environmental prey by taxa across all oligotrophic lakes, mesotrophic lakes, and eutrophic lakes.

The proportions of zooplankton prey size classes (P_i) also varied substantially across dates within a lake and among lakes within the three trophic states (Appendix Table A5, A6, A7). However, total proportions of size classes encountered within each lake trophic state, calculated as a single proportion by combining all lakes within a trophic state, were also quite consistent across lake trophic categories (Figure 6). Across all system types, small zooplankton sizes (i.e. less than 0.4 mm) tended to make up a majority, greater than 50%, of available prey. The pattern continued with prey sizes of 0.4 mm to 0.6 mm making up the next largest proportion across all trophic states, ~ 22%, of zooplankton sampled. In all system types, larger

prey between 0.6 mm and 0.8 mm, made up the next largest proportion, ~12%, of available prey. Lastly, the smallest proportions of available prey were comprised of individuals greater than 0.8 mm. Although small differences occurred between trophic system types, a strikingly similar pattern of prey size structure was evident across lake trophic states.

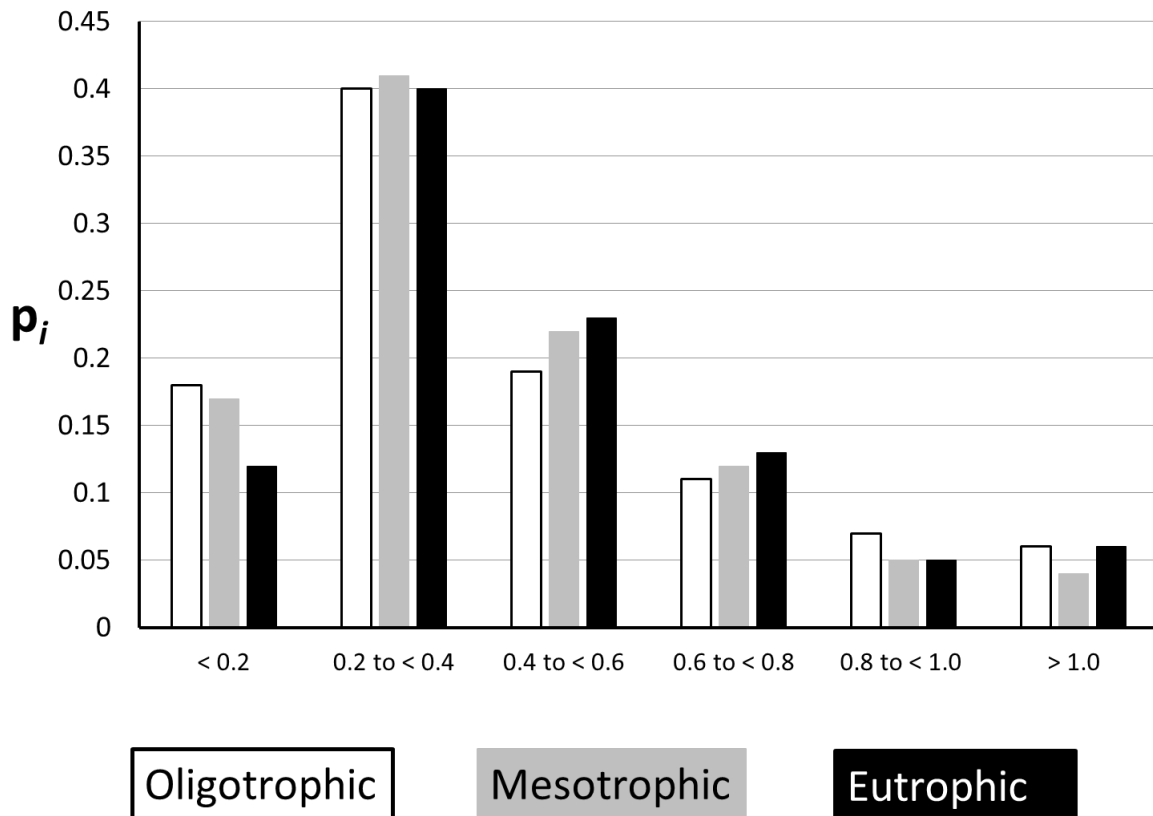


Figure 6. The total proportions of environmental prey by size across all oligotrophic lakes, mesotrophic lakes, and eutrophic lakes.

The size composition of individual zooplankton taxa showed variable degrees of overlap (Figure 7). Results indicate an overlap between copepod nauplii and *Bosmina* spp. for zooplankton prey less than 0.4 mm with some overlap of cyclopoid copepods also occurring

below 0.4 mm. Additionally, cyclopoid copepods, calanoid copepods, and *Daphnia* spp. displayed an overlap in size groups above 0.4 mm.

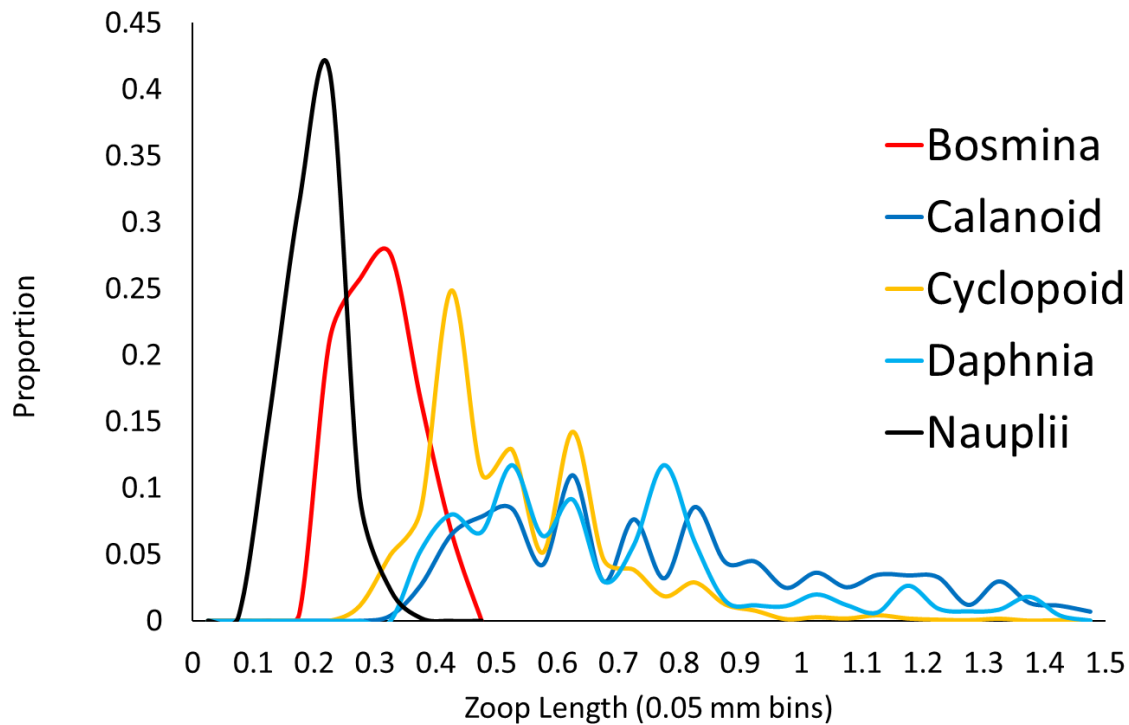


Figure 7. Proportions of environmental zooplankton prey size by taxon. Environmental zooplankton prey grouped into 0.05 mm bins and plotted as total proportion for all lakes.

Zooplankton sample size analysis

Analysis of total zooplankton density data from 2015 tow groups, as described in Figure 4, yielded a grand coefficient of variation of 53% with a grand mean of 151 organisms per liter, and grand mean variance of 19350. Average densities of tow groups, across all lakes, ranged between 1 organism per liter and 1,040 organisms per liter. This demonstrates the highly variable nature of zooplankton prey availability within my study lakes. Sample size analysis indicated a sample size requirement of ~28 replicate zooplankton tows per tow group in order to develop a \pm

20% relative precision of the mean estimate (Table 2) for total density among tow groups across all lakes in this study. Given I collected a minimum of 3 tow groups per lake-day combo during the 2015 field season, (i.e. minimum of 9 replicate zooplankton tows per lake-day combo), I can expect a roughly $\pm 35\%$ relative precision of the mean estimate for total zooplankton density among different tow groups, whether within a lake or among tow groups from different lakes.

Table 2. Estimate of required zooplankton sample size necessary to attain various relative precision of the mean estimates for total zooplankton densities among tow groups.

Relative Precision of the Mean	Sample Size
$n_{\pm 10\%}$ Relative Precision of Mean Estimate	112
$n_{\pm 20\%}$ Relative Precision of Mean Estimate	28
$n_{\pm 30\%}$ Relative Precision of Mean Estimate	12
$n_{\pm 40\%}$ Relative Precision of Mean Estimate	7

Copepod nauplii, cyclopoid copepods, and *Bosmina* spp. together typically made up the majority of the zooplankton prey community throughout all lakes (Figure 5). Sample size analysis of total density for the copepod nauplii prey group suggests 54 replicate zooplankton tows per tow group would be required in order to develop a $\pm 20\%$ relative precision of the mean estimate (Table 3) for total density of copepod nauplii among different tow groups, whether within a lake or among tow groups from different lakes. Analysis of total copepod nauplii density data from 2015 tow groups yielded a grand coefficient of variation of 74% with a grand mean of 74 organisms per liter, and grand mean variance of 4,150. Average copepod nauplii densities of tow groups, across all lakes, ranged between 1 organism per liter and 428 organisms per liter. This analysis suggests that with my sampling effort, I could expect a roughly $\pm 50\%$ relative precision of the mean

estimate for total copepod nauplii density among different tow groups, whether within a lake or among tow groups from different lakes.

Table 3. Estimate of required zooplankton sample size necessary to attain various relative precision of the mean estimates for copepod nauplii densities among tow groups.

Relative Precision of the Mean	Sample Size
$n_{\pm 10\%}$ Relative Precision of Mean Estimate	216
$n_{\pm 20\%}$ Relative Precision of Mean Estimate	54
$n_{\pm 30\%}$ Relative Precision of Mean Estimate	24
$n_{\pm 40\%}$ Relative Precision of Mean Estimate	14

Sample size analysis of total density for the cyclopoid copepod prey group suggests 36 replicate zooplankton tows per tow group would be required in order to develop a $\pm 20\%$ relative precision of the mean estimate (Table 4) for total density of cyclopoid copepods among different tow groups. Analysis of total cyclopoid copepod density data from 2015 tow groups yielded a grand coefficient of variation of 60% with a grand mean of 26 organisms per liter, and grand mean variance of 731. Average cyclopoid copepod densities of tow groups, across all lakes, ranged between 1 organism per liter and 193 organisms per liter. This analysis suggests that with my sampling effort, I could expect a roughly $\pm 40\%$ relative precision of the mean estimate for total cyclopoid copepod density among different tow groups, whether within a lake or among tow groups from different lakes.

Table 4. Estimate of required zooplankton sample size necessary to attain various relative precision of the mean estimates for cyclopoid copepod densities among tow groups.

Relative Precision of the Mean	Sample Size
$n_{\pm 10\%}$ Relative Precision of Mean Estimate	143
$n_{\pm 20\%}$ Relative Precision of Mean Estimate	36
$n_{\pm 30\%}$ Relative Precision of Mean Estimate	16
$n_{\pm 40\%}$ Relative Precision of Mean Estimate	9

Sample size analysis of total density for the *Bosmina* spp. prey group suggests 36 replicate zooplankton tows per tow group would be required in order to develop a $\pm 20\%$ relative precision of the mean estimate (Table 5) for total density of *Bosmina* spp. among tow groups. Analysis of total *Bosmina* spp. density data from 2015 tow groups yielded a grand coefficient of variation of 60% with a grand mean of 62 organisms per liter, and grand mean variance of 4,273. Average *Bosmina* spp. densities of tow groups, across all lakes, ranged between 1 organism per liter and 408 organisms per liter. This analysis suggests that with my sampling effort, I could expect a roughly $\pm 40\%$ relative precision of the mean estimate for total *Bosmina* spp. density among tow groups, whether within a lake or among tow groups from different lakes.

Table 5. Estimate of required zooplankton sample size necessary to attain various relative precision of the mean estimates for *Bosmina* spp. total densities among tow groups.

Relative Precision of the Mean	Sample Size
$n_{\pm 10\%}$ Relative Precision of Mean Estimate	145
$n_{\pm 20\%}$ Relative Precision of Mean Estimate	36
$n_{\pm 30\%}$ Relative Precision of Mean Estimate	16
$n_{\pm 40\%}$ Relative Precision of Mean Estimate	9

In summary, this analysis was designed in an attempt to determine an approximation of the number of zooplankton tows it would take per tow group to get a reasonably good estimate of zooplankton density within a lake, or by extension, a reasonably good estimate of zooplankton density among tow groups, whether from the same lake or among tow groups from different lakes. Based on the results of this analysis, it is reasonable to assume that, in general, large sample sizes per tow group would be required to develop a precise estimate of the mean density of zooplankton within a lake. Thus, by extension, prohibitively huge sample sizes would be required, whether from tow groups within the same lake or among lake types, in order to develop a precise estimate of the mean density of zooplankton among lakes, regardless of type.

Summary of larval traits and diet

In general and across all lakes, sampling events early in the season tended to yield smaller sizes of larvae (i.e. <8 mm), while as the season progressed, larger sizes (i.e. > 8 mm) became more predominant. The sizes of fish collected were highly variable within lake-day sampling events and among lakes (Table A8).

The gut contents of a total of 1003 yellow perch larvae were examined. These fish ranged in length from 4 mm to 21 mm, with over half between 5 and 8 mm (Figure 8). Abundance of fish in the catch declined steadily between 9 mm and 16 mm, and dropped off rapidly thereafter. Fish less than 7 mm had a substantial proportion of empty guts, up to 38%, but larvae between 7 and 12 mm displayed a much lower proportion of empty guts, ranging between 2 and 9 % across lake trophic types (Table 6). Nearly all larvae greater than 12 mm contained at least one prey item with proportion of empty guts at less than 1 % across all lake trophic types.

Table 6. Summary of total larvae processed, total with empty guts, and proportion of total empty guts by lake trophic state. Size ranges provided in mm.

Total Processed			
	Small (<7.01)	Medium (7.01 to ≤ 12)	Large (>12)
Eutrophic	32	87	26
Mesotrophic	216	354	56
Oligotrophic	52	112	67
Total Empty			
	Small (<7.01)	Medium (7.01 to ≤ 12)	Large (>12)
Eutrophic	8	2	0
Mesotrophic	83	7	0
Oligotrophic	16	10	1
Proportion Empty			
	Small (<7.01)	Medium (7.01 to ≤ 12)	Large (>12)
Eutrophic	0.25	0.02	0.00
Mesotrophic	0.38	0.02	0.00
Oligotrophic	0.31	0.09	0.01

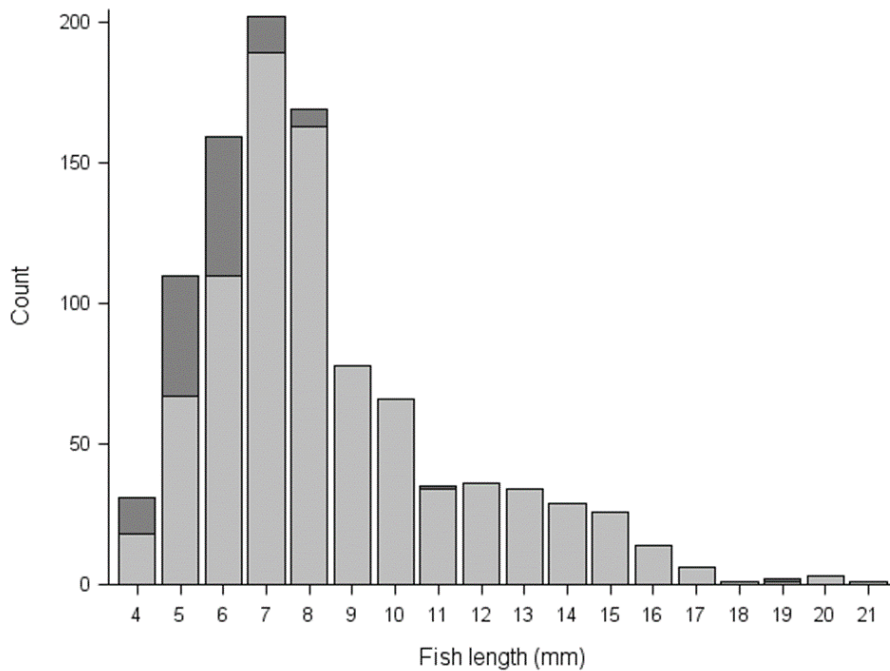


Figure 8. Total number and size distribution of larval and early juvenile yellow perch processed across all lakes and years. Dark shade depicts larvae with empty stomachs. Light shade depicts larvae with diet items present in gut.

The average contribution of major zooplankton taxa groups to larval diets varied substantially within lake-day sampling events, across dates within a lake, and across lake trophic types (Table A9). The average number of *Bosmina* spp. in larval diets from lake-day combinations across all lakes ranged between 0 and 64 organisms per larvae. The average number of calanoid copepods in larval diets from lake-day combinations across all lakes ranged between 0 and 63 organisms. The average number of cyclopoid copepods in larval diets from lake-day combinations across all lakes ranged between 0 and 69 organisms. The average number of *Daphnia* spp. in larval diets from lake-day combinations across all lakes ranged between 0 and 7 organisms. The average number of copepod nauplii in larval diets from lake-day combinations across all lakes ranged between 0 and 132 organisms (Table A9). Additionally, proportions of zooplankton prey taxa (P_i) in larval diets varied substantially across dates within a lake and among lakes within the three trophic states (Appendix Table A10, A11, A12). The total proportions within each lake trophic state of the main taxa consumed, calculated as a single proportion by combining all larval guts for lakes within a trophic state, were quite consistent when comparing oligotrophic to eutrophic systems (Figure 9). However, the total proportional contribution of cyclopoid copepods in mesotrophic systems was lower, and the proportion of copepod nauplii was higher compared to larval diets in oligotrophic and eutrophic systems.

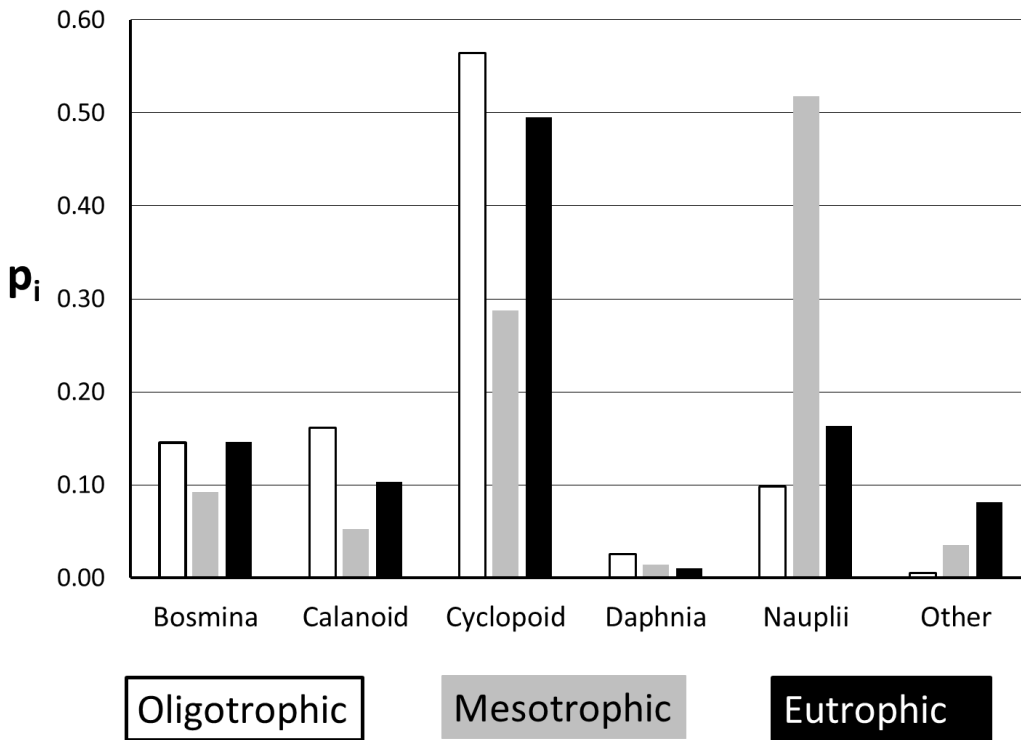


Figure 9. The total proportions of zooplankton prey taxa groups within larval guts by lake-day combo for oligotrophic lakes, mesotrophic lakes, and eutrophic lakes.

The average contribution of major zooplankton size groups to larval diets varied substantially within lake-day sampling events, across dates within a lake, and across lake trophic types (Table A13). The average < 0.2 mm zooplankton in larval diets from lake-day combinations across all lakes ranged between 0 and 52 organisms. The average 0.2 to < 0.4 mm zooplankton in larval diets from lake-day combinations across all lakes ranged between 0 and 81 organisms. The average 0.4 to < 0.6 mm zooplankton in larval diets from lake-day combinations across all lakes ranged between 0 and 56 organisms. The average 0.6 to < 0.8 mm zooplankton in larval diets from lake-day combinations across all lakes ranged between 0 and 48 organisms. The average 0.8 to < 1.0 mm zooplankton in larval diets from lake-day combinations across all lakes

ranged between 0 and 10 organisms. The average > 1.0 mm zooplankton in larval diets from lake-day combinations across all lakes ranged between 0 and 5 organisms (Table A13).

Additionally, proportions of zooplankton prey sizes (P_1) in larval diets varied substantially across dates within a lake and among lakes within the three trophic states (Appendix Table A14, A15, A16). The total proportions within each lake trophic state of the main size groups consumed, calculated as a single proportion by combining all larval guts for lakes within a trophic state, were quite consistent across trophic states for prey larger than 0.8 mm (Figure 9). However, total proportional contribution of smaller zooplankton prey, i.e. <0.2 to < 0.8 mm, display unique differences among trophic system status. For example, the total proportion of zooplankton < 0.2 mm in larval guts within oligotrophic systems accounts for less than 5% of their diet. However, < 0.2 mm zooplankton account for ~28% of larval diets in mesotrophic systems (Figure 10). In general, smaller zooplankton tended to account for larger proportions of overall larval diets in mesotrophic systems.

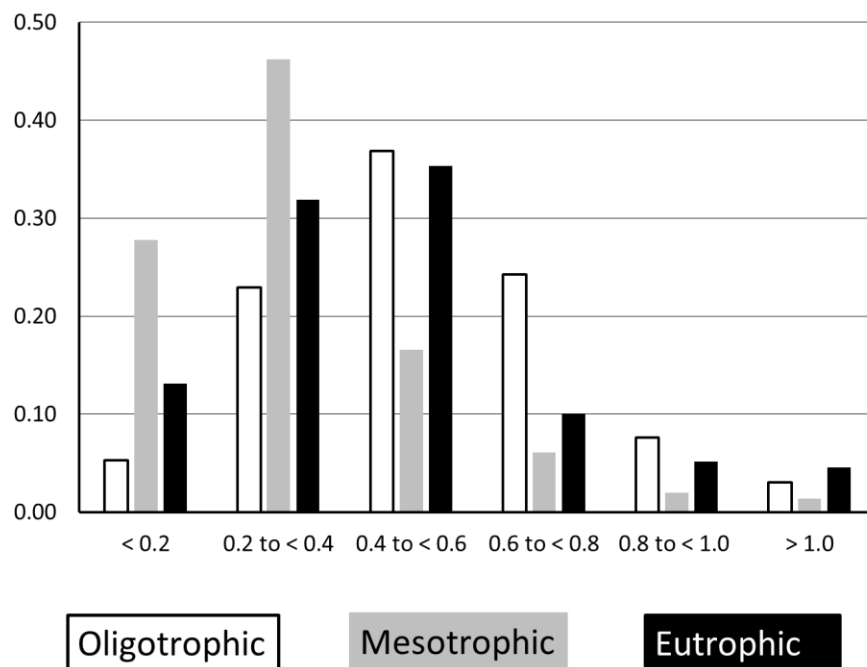


Figure 10. The total proportions of zooplankton prey size groups within larval guts by lake-day combo for oligotrophic lakes, mesotrophic lakes, and eutrophic lakes.

Overall taxon-specific selectivity

Selection of zooplankton prey by larval and early juvenile yellow perch predators varied considerably across all sampling events when calculating a single selectivity value for all fish in a given lake-day combination (Figure 11). For all major functional taxonomic groups, prey selectivity ranged from complete negative selection to complete positive selection. The average of Chesson's Rescaled Index of Selectivity for *Bosmina* spp. was -0.60. Average selection for calanoid copepods was -0.48. Average selection for cyclopoid copepods was 0.26. Out of all functional groups, cyclopoid copepods were the only taxon to display an average positive selection across all sampling events. Average selection for *Daphnia* spp. was -0.73. Average selection for copepod nauplii was -0.05. For all functional groups, copepod nauplii were the only taxon to have a nearly neutral average selection. Average selection for other taxa (i.e. *Leptidora*, harpacticoid copepods, ostracods, and *Bythotrephes*) was -0.71.

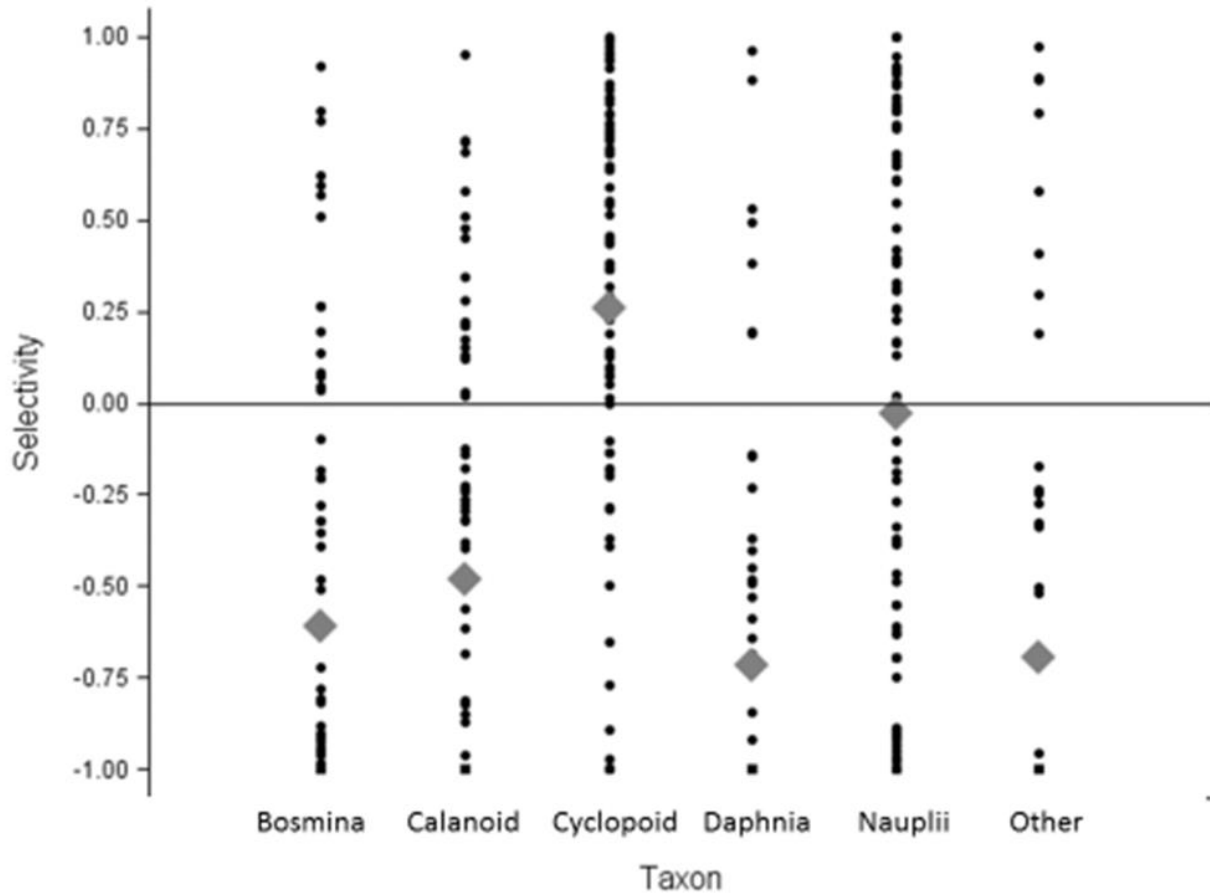


Figure 11. Chesson's Rescaled Index of selection of zooplankton prey by larval and early juvenile yellow perch for major taxonomic group. Filled circles represent a single selectivity value by combining all fish diets in a given lake-day combination. Shaded triangles represent overall mean selectivity. Zero represents neutral selection, 1.00 represents complete positive selection, and -1.00 represents complete negative selection.

Individual taxon-specific selection

Although selectivity varied widely across lake-date sampling, taxon-specific selectivity showed a clear progression across sizes of yellow perch. Copepod nauplii were strongly selected for by the smallest larvae (i.e. <7mm). As larvae grew in size, their selection for copepod nauplii declined and became neutral at ~ 9mm. Continuing this pattern, larger larvae began to negatively

select for nauplii after 9mm and approached complete avoidance (i.e. -1.00) when growing past 16 mm (Figure 12).

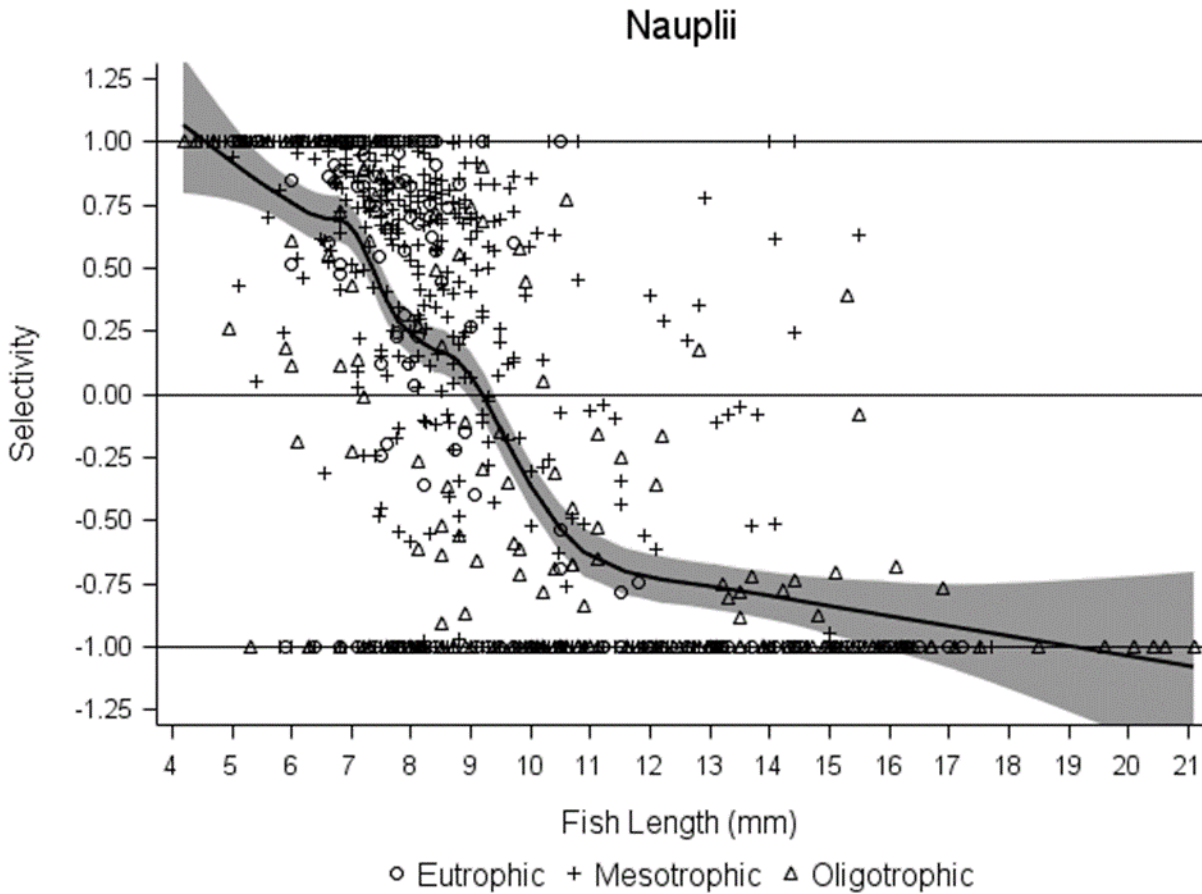


Figure 12. Chesson's Rescaled Index of selection for copepod nauplii by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

Additionally, patterns for selectivity of copepod nauplii remained relatively consistent among lake trophic types (Figure 13). However, selection for copepod nauplii was less positive for 7 mm to 10mm larvae in oligotrophic systems as compared to eutrophic and mesotrophic systems.

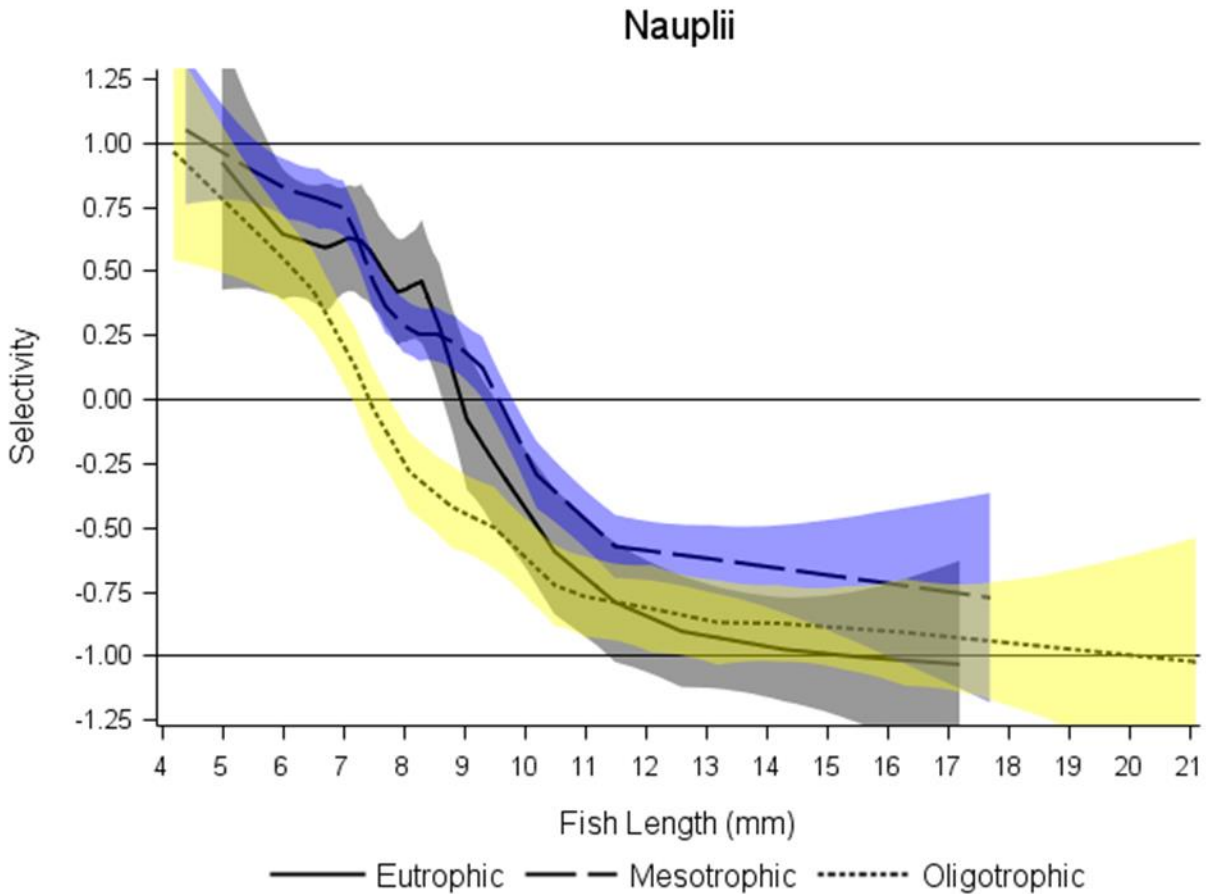


Figure 13. LOESS functions with 95% Confidence Intervals relating taxon-specific selectivity for copepod nauplii as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Selection by individual larvae for cyclopoid copepods also displayed a general pattern when applying a LOESS Function to individual data points across all sampling events. The smallest larvae (i.e. < 5mm) displayed complete avoidance for cyclopoid copepods. As larvae grew, selectivity increased and became neutral at ~ 7mm. The pattern for selection continued to increase to a peak of ~0.50 when larvae reached 9 to 11mm. At this point, selection began to decline back to neutral as the larvae grew into larger sizes (i.e. >11mm). Eventually selection for cyclopoids became negative again for the largest larvae (i.e. > 19mm). However, small sample

sizes of the largest larvae resulted in higher levels of uncertainty when applying the LOESS Function (Figure 14).

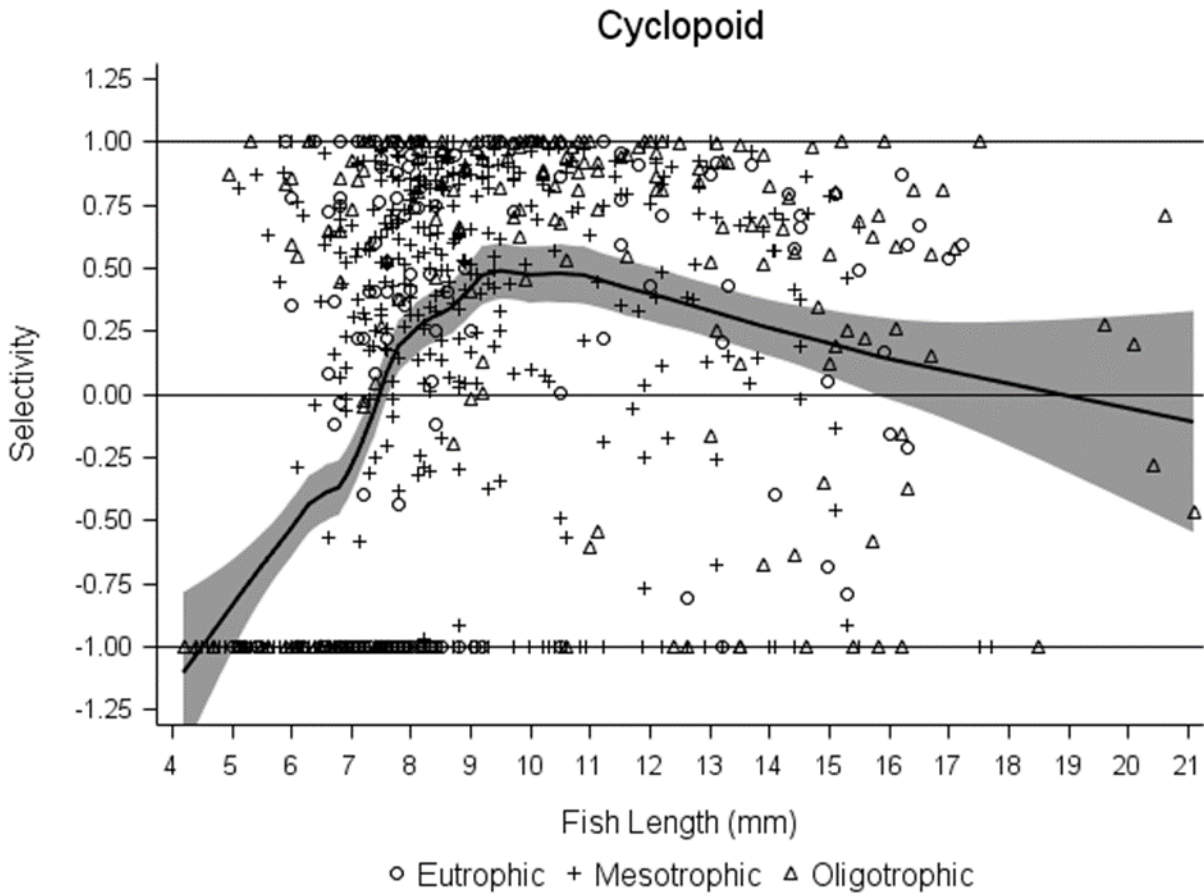


Figure 14. Chesson's Rescaled Index of selection for cyclopid copepods by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

Patterns for selectivity of cyclopid copepods remained relatively consistent among lake trophic types (Figure 15), with the exception that selection for cyclopid copepods was slightly more positive for 7 mm to 10mm larvae in oligotrophic systems as compared to eutrophic and mesotrophic systems.

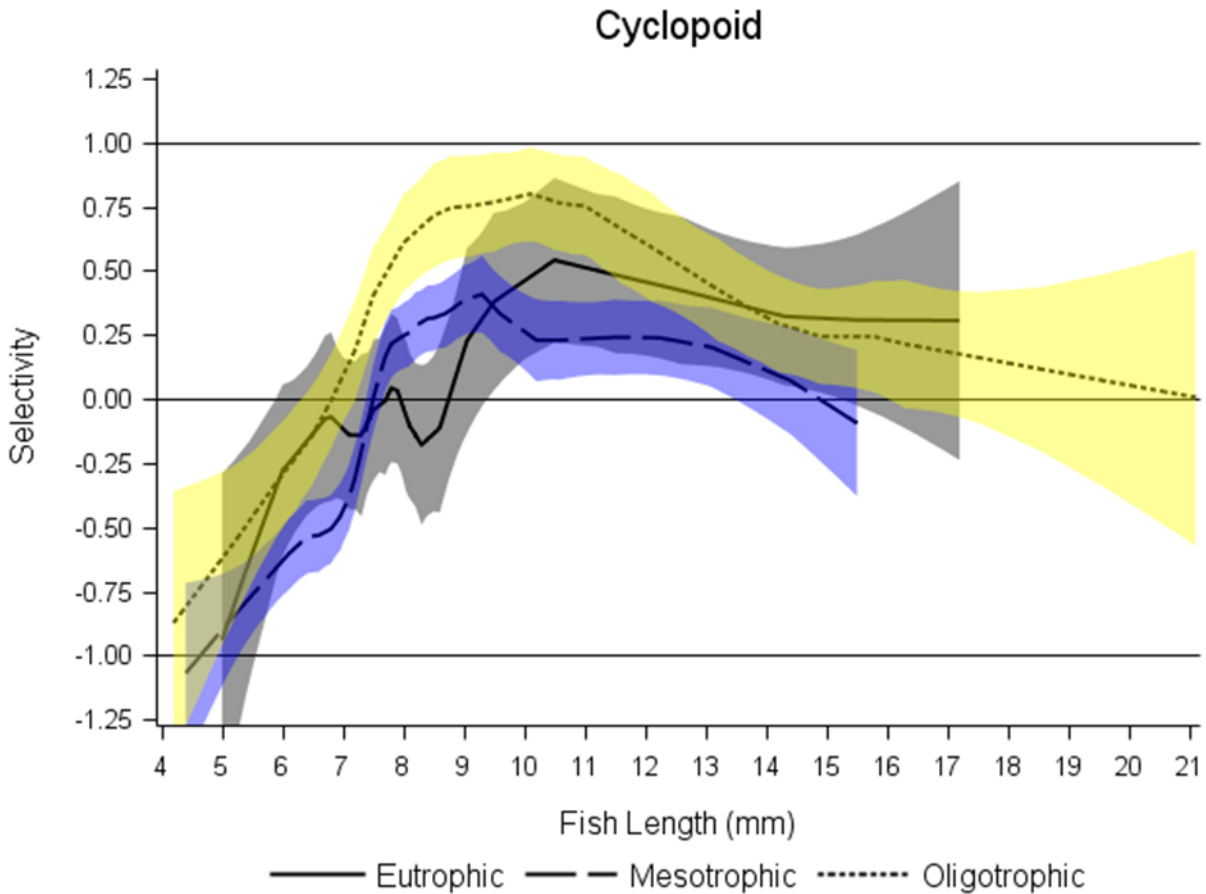


Figure 15. LOESS functions with 95% Confidence Intervals relating taxon-specific selectivity for cyclopid copepods as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Nearly all individual fish displayed complete avoidance for calanoid copepods at sizes of less than 7mm. After larvae grew past 7mm, selection for calanoid copepods began to increase until reaching neutral at ~15mm. The largest larvae began to positively select for calanoid copepods after 15mm. (Figure 16).

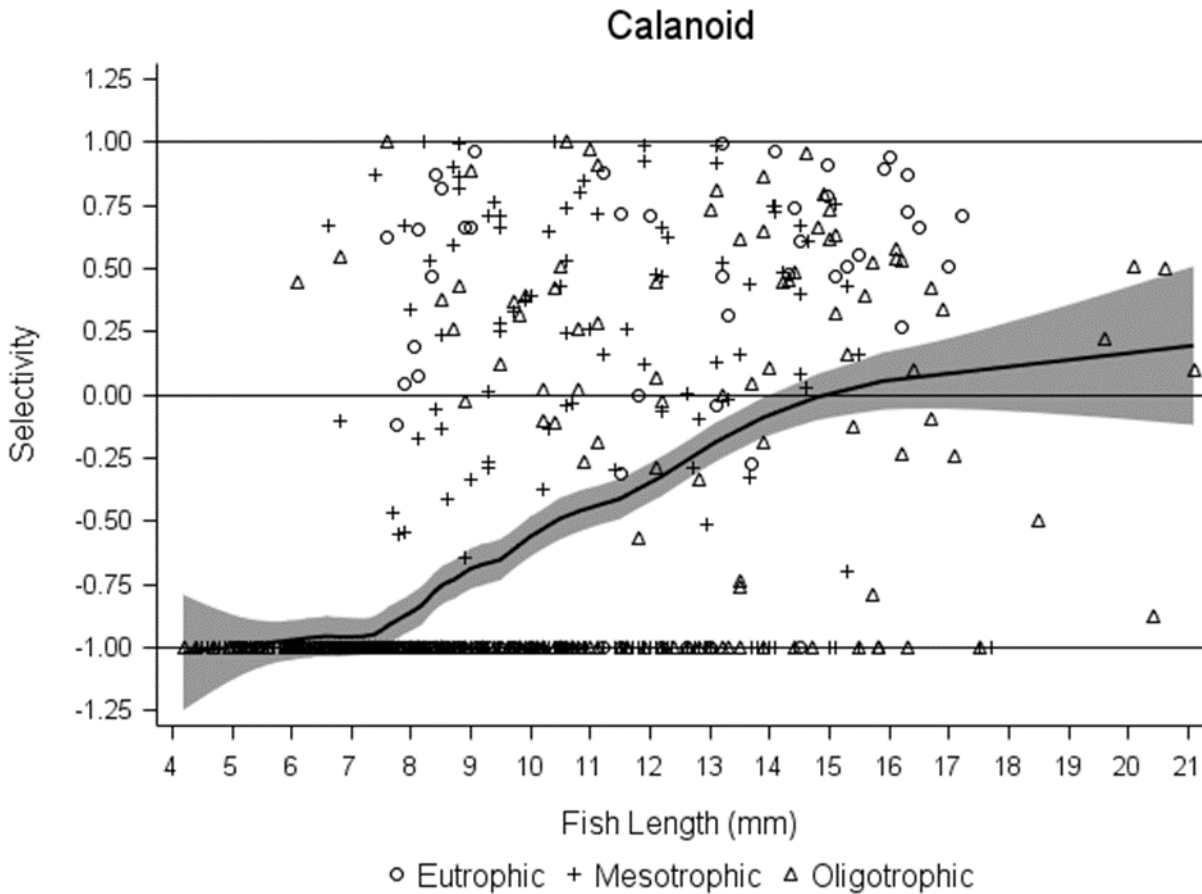


Figure 16. Chesson's Rescaled Index of selection for calanoid copepods by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

Patterns for selectivity of calanoid copepods remained relatively consistent among lake trophic types (Figure 17) for larvae up to 13 mm, although selection for calanoid copepods was more positive for larvae greater than 13mm in eutrophic systems as compared to oligotrophic and mesotrophic systems.

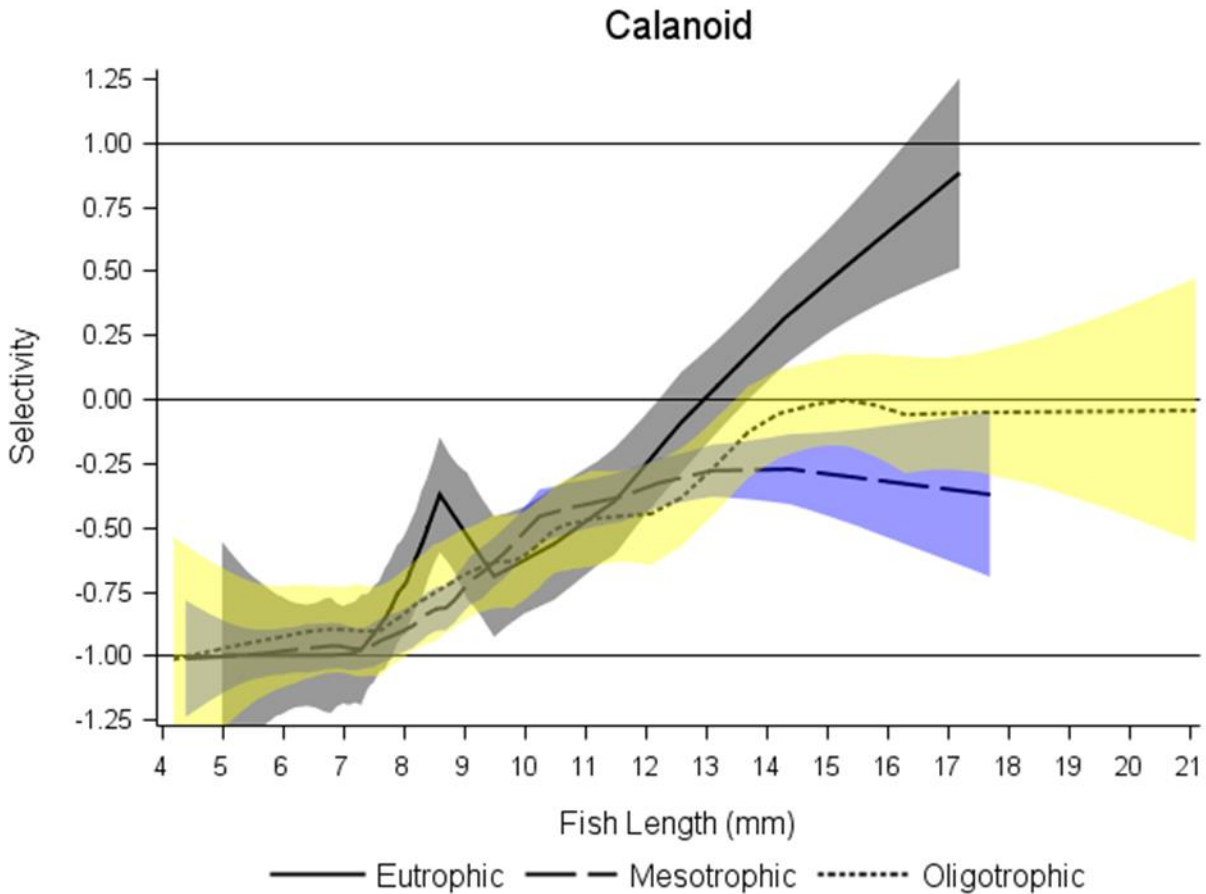


Figure 17. LOESS functions with 95% Confidence Intervals relating taxon-specific selectivity for calanoid copepods as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems

Similar to calanoid copepods, selection for *Bosmina* spp. showed an increasing trend with fish length (Figure 18). Larvae <7mm displayed complete avoidance, but as larvae grew past 7mm, selectivity of *Bosmina* spp. steadily increased until reaching neutral at ~19mm. After 19mm, selectivity became positive. However, small sample sizes of the largest fish (i.e. >19mm) add uncertainty to this aspect of yellow perch early life history.

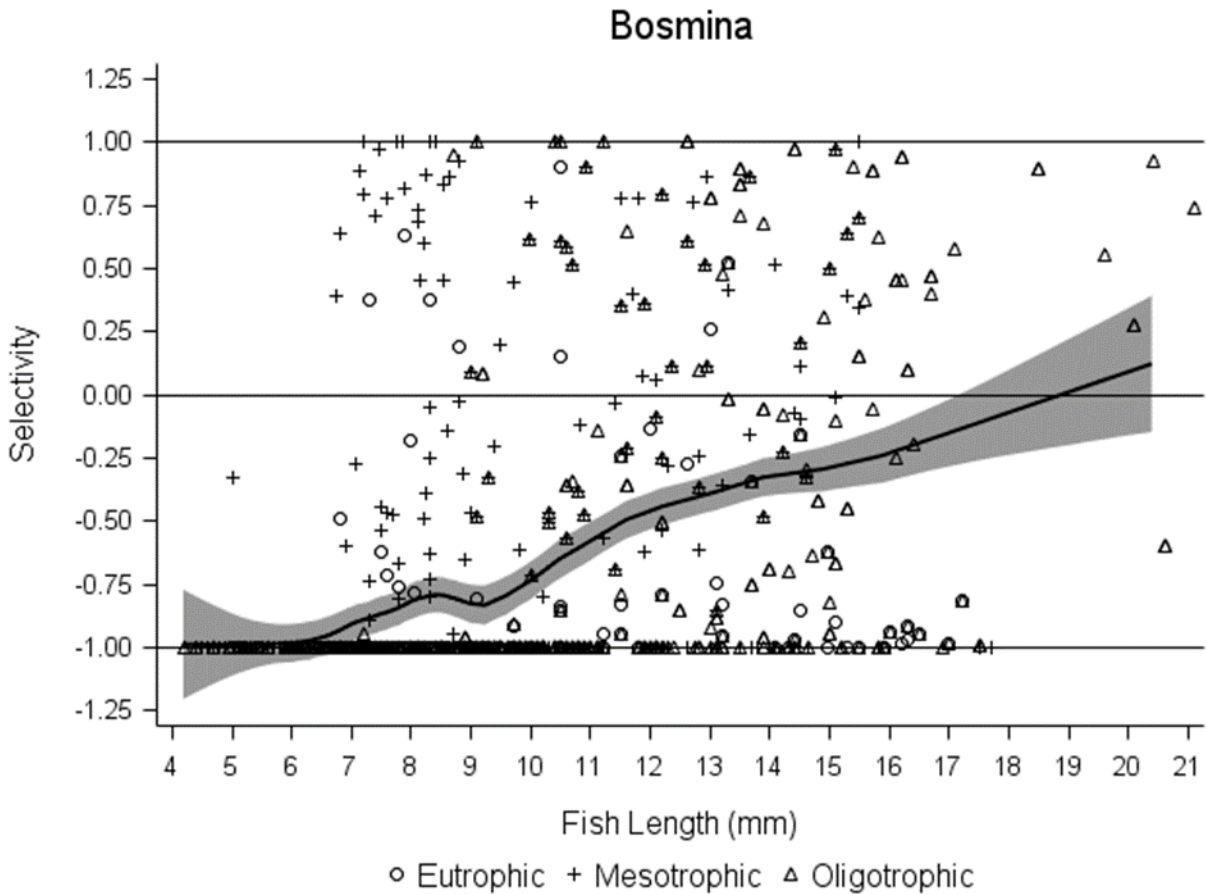


Figure 18. Chesson's Rescaled Index of selection for *Bosmina* spp. by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

Patterns for selectivity for *Bosmina* spp. remained relatively consistent among lake trophic types (Figure 19) for larvae up to 13 mm, except that selection for *Bosmina* spp. was less positive for larvae greater than 13mm in eutrophic systems as compared to oligotrophic and mesotrophic systems.

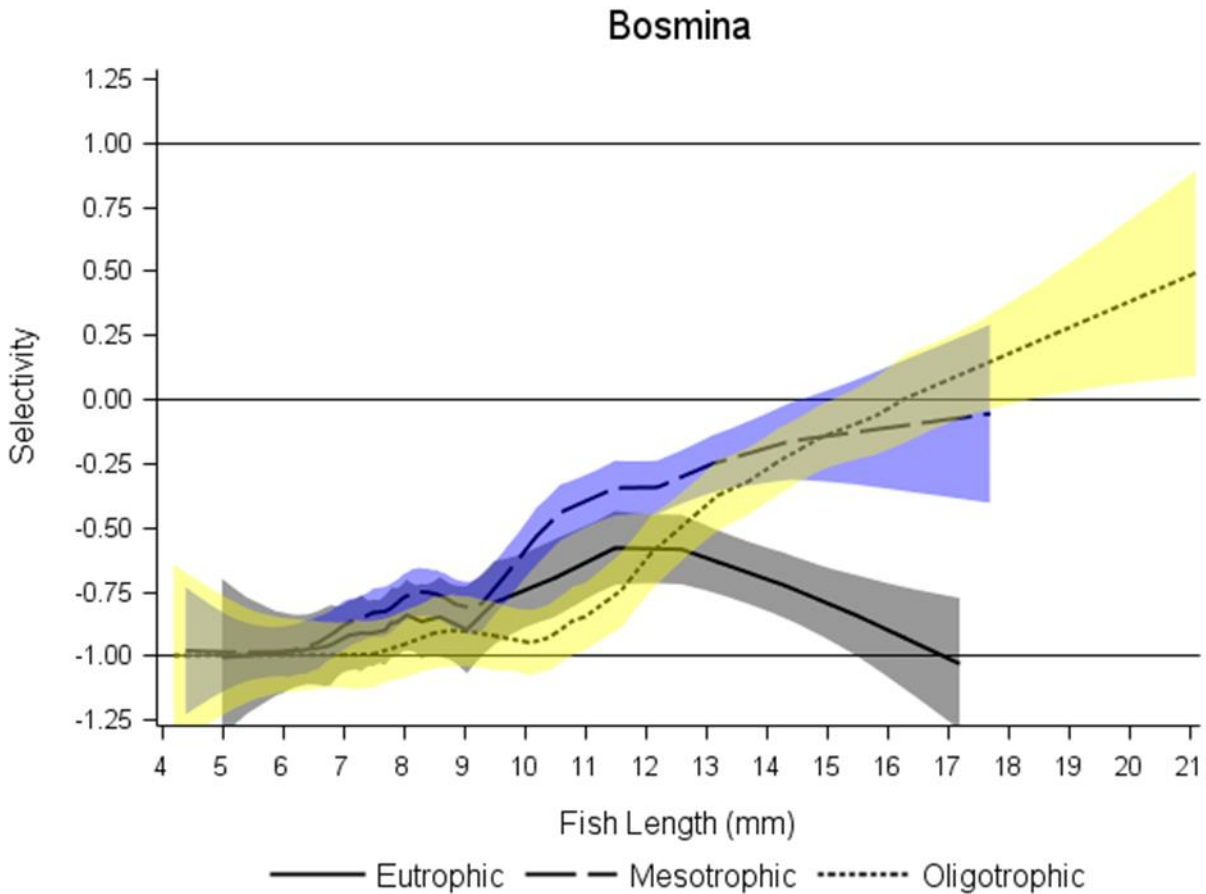


Figure 19. LOESS functions with 95% Confidence Intervals relating taxon-specific selectivity for *Bosmina* spp. as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Selection for *Daphnia* spp. also displayed a positive relationship with increasing length. Small larvae (i.e. <8mm) displayed complete avoidance while as fish grew, selection increased.

However, selection for *Daphnia* never became positive over the range of sizes of fish sampled (Figure 20).

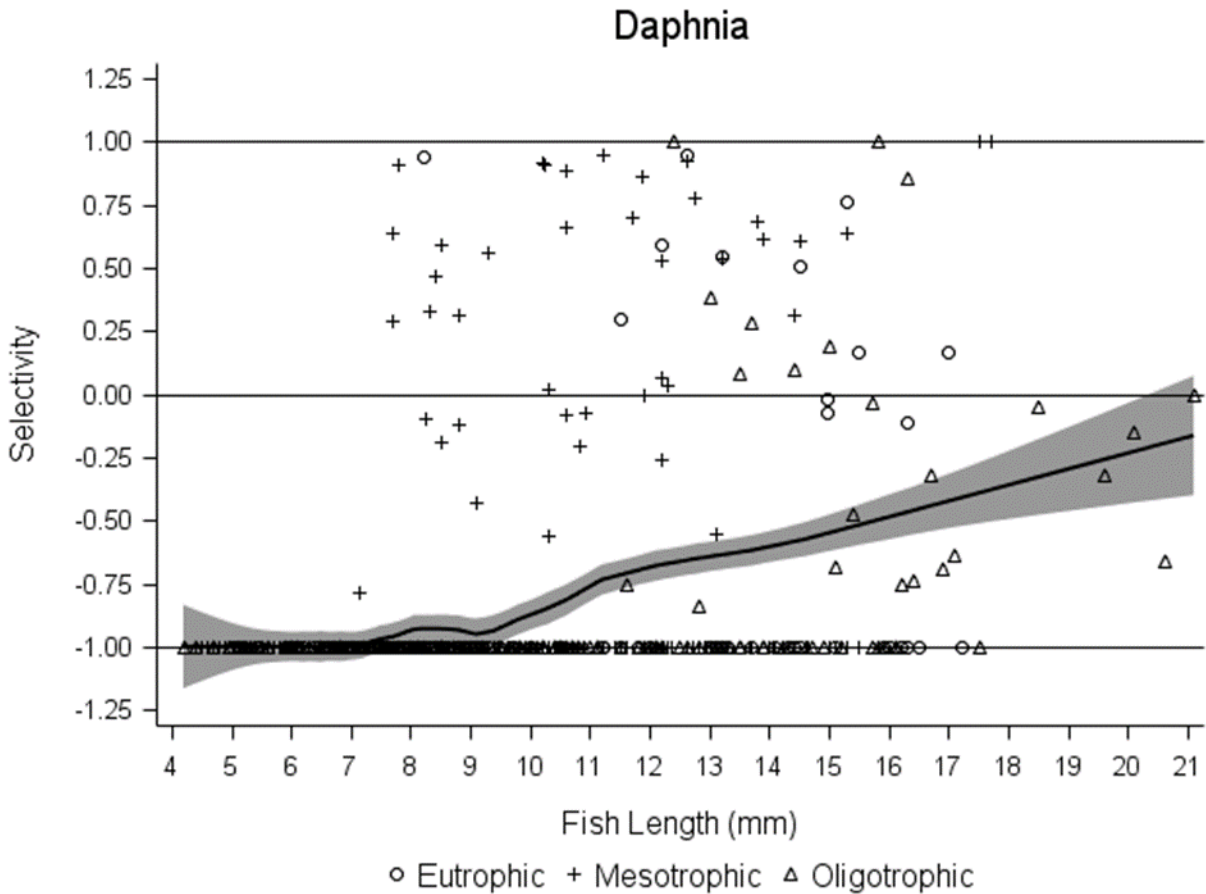


Figure 20. Chesson's Rescaled Index of selection for *Daphnia* spp. by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

Patterns for selectivity for *Daphnia* spp. remained strongly consistent among lake trophic types (Figure 21) for all sizes of larvae.

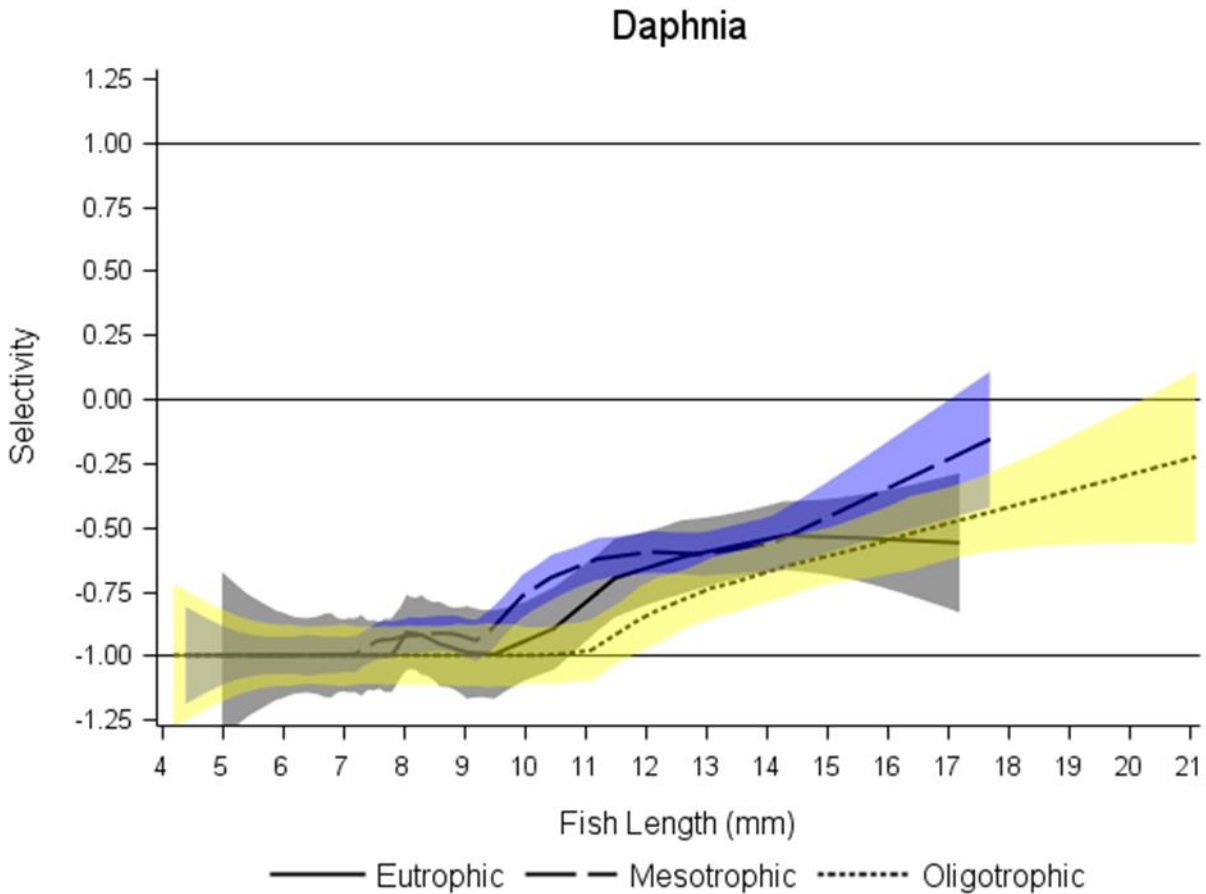


Figure 21. LOESS functions with 95% Confidence Intervals relating taxon-specific selectivity for *Daphnia* spp. as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Summary of taxon-specific selection

Although some differences were observed among lake trophic types, especially for copepod nauplii and cyclopoid copepods, overall taxon-specific selectivity showed a broadly similar ontogeny of selectivity across all lake trophic types. Copepod nauplii were preferred as a first food source of larval yellow perch less than 7 mm. As selection for nauplii declined, fish began to select more positively for cyclopoid species. As fish grew to ~11mm, this preference for cyclopoid copepods began to decline. Following closely this decline in selection for

cyclopoids, larvae continued to increase their preference for calanoid copepods, *Bosmina* spp., and *Daphnia* spp. (Figure 22) although *Daphnia* spp. were never positively selected, just avoided less.

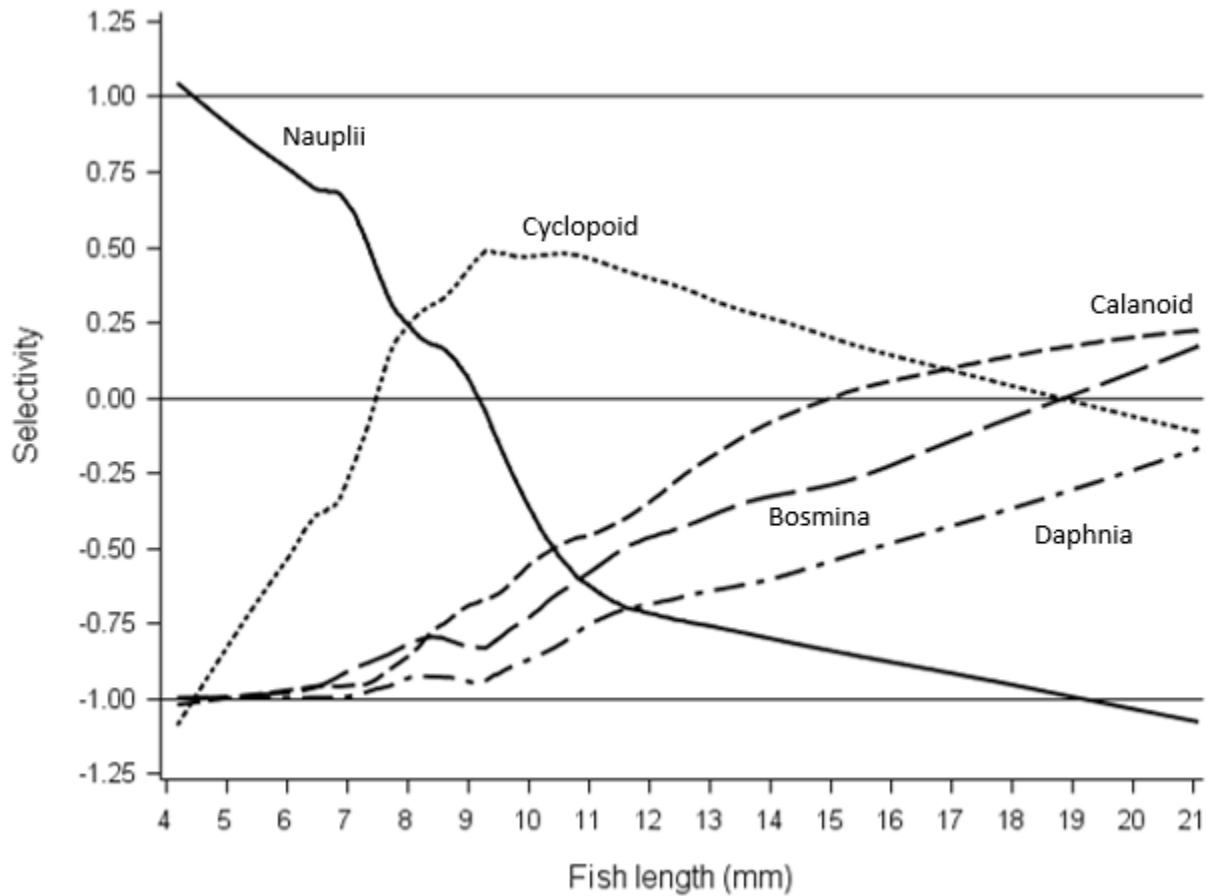


Figure 22. Summary of LOESS functions relating taxon-specific selectivity as a function of larval and early juvenile yellow perch length.

Overall prey size-specific selection

In general, larval yellow perch consumed relatively small zooplankton with few prey >1.0 mm being consumed. As fish grew in size, the average size of prey consumed increased as well. The average prey size consumed by the smallest fish was generally less than 0.2 mm. As fish grew into the 9 to 14 mm range, the average size of zooplankton prey increased to between

0.4 and 0.6 mm. This pattern continued as fish grew above 14 mm where the average size of prey was 0.6 mm (Figure 23).

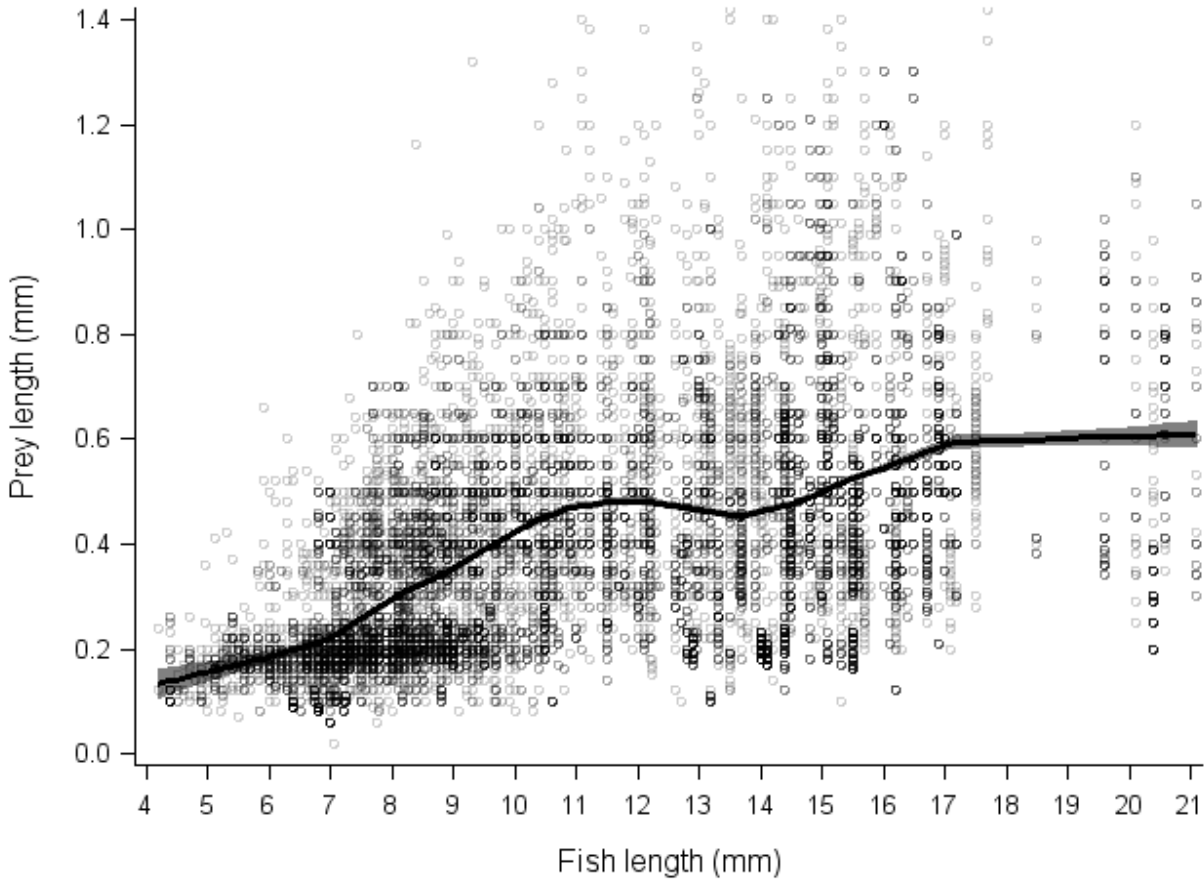


Figure 23. Length of prey found in larval and early juvenile yellow perch guts as a function of fish length. Open circles represent individual diet items. Solid line represents LOESS function fit with gray band representing 95% confidence interval of the mean.

A positive relationship between gape size and prey length was observed, although there was considerable variation around this relationship (Figure 24). At very small sizes, larval perch are able to consume prey approaching their gape size, but as gape size increases the ratio of prey size to gape size rapidly drops to less than 0.5 (Figure 25).

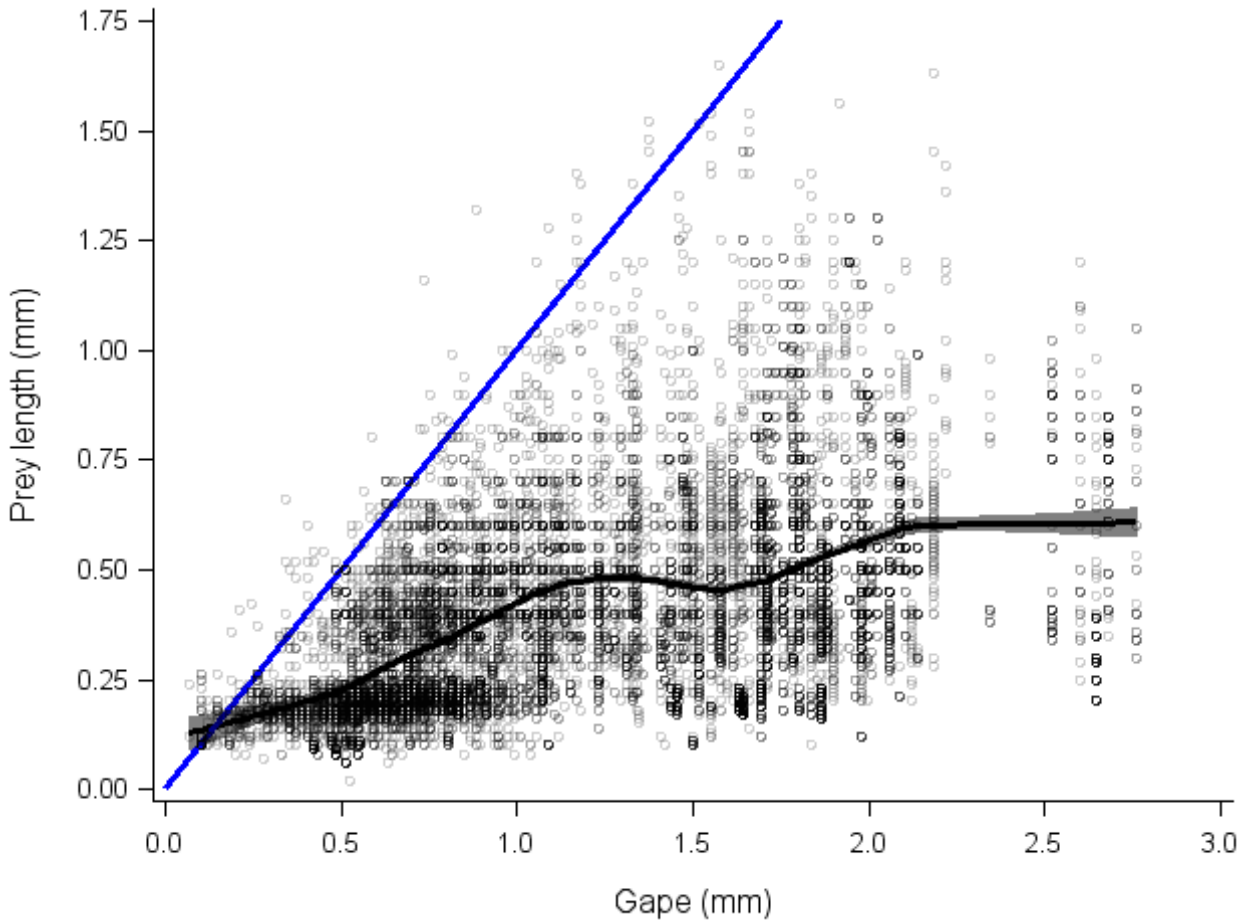


Figure 24. Length of prey found in larval and early juvenile yellow perch guts as a function of fish gape. Open circles represent individual diet items. Solid blue line represents 1:1 ratio of fish gape to prey length. Solid black line represents LOESS function fit with gray band representing 95% confidence interval of the mean. Gape size estimated using the following literature based regression. $Gape = 0.159(\text{Total length}) - 0.597$. (Schael et al. 1991)

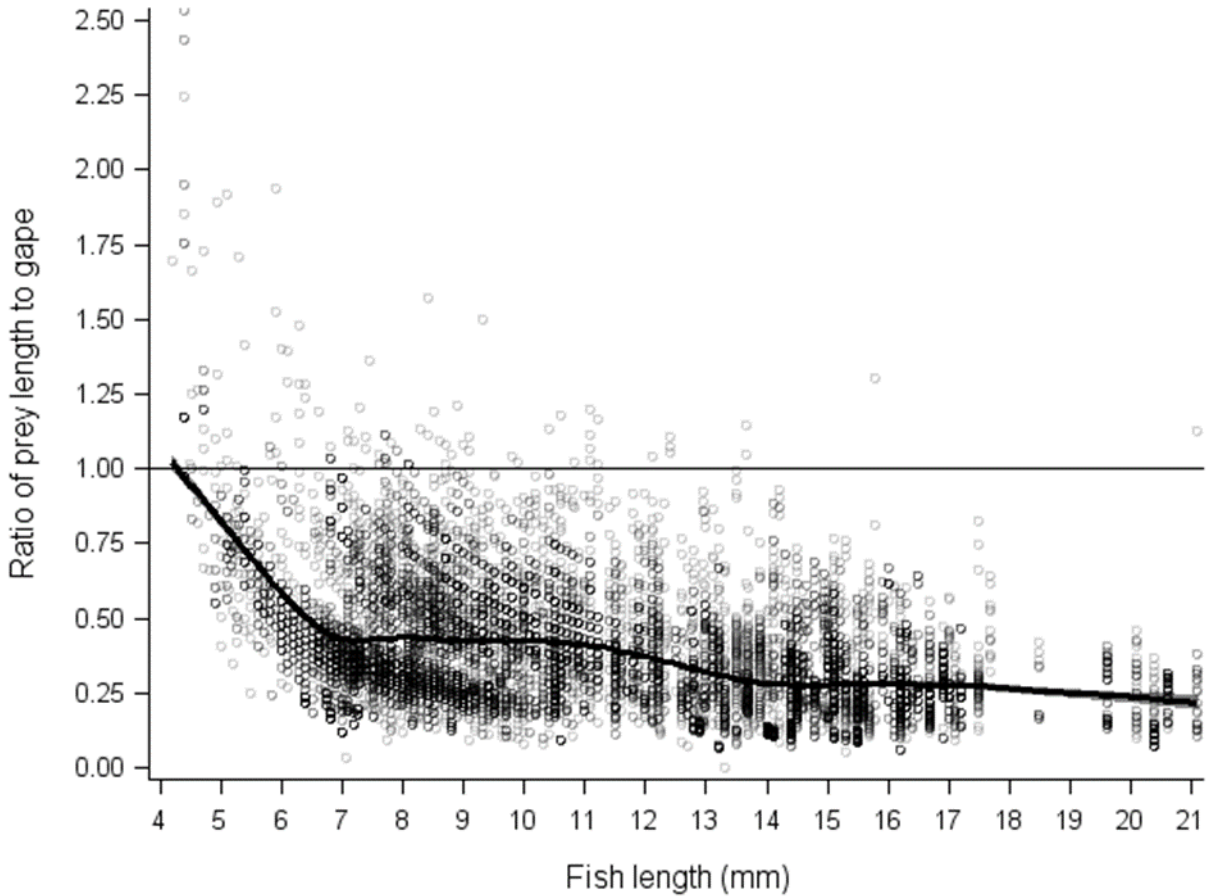


Figure 25. Ratio of prey length to gape as a function of fish length. Open circles represent the ratio for individual diet items. Solid line represents LOESS function fit with gray band representing 95% confidence interval of the mean.

Zooplankton were placed into 0.2 mm bins to determine selectivity for specific size ranges of zooplankton prey. Selection for size classes of zooplankton, irrespective of their taxonomic identity, varied considerably for all fish across all lakes, days, and years. For all size classes of zooplankton, Chesson's Rescaled Index of Selection ranged from complete avoidance (i.e. -1.00) to completely positive selection (i.e. 1.00). Selection for small prey declined with increasing larvae size (Figure 26). Specifically, average selection for zooplankton from 0 to < 0.2 mm was -

0.17. Average selection for zooplankton from 0.2 to < 0.4 mm was 0.03. Out of all size classes, the 0.2 to < 0.4 range was the only size class to have an average selection greater than 0. Average selection for zooplankton from 0.4 to < 0.6 mm was -0.28. The pattern continued as average selection for the 0.6 to < 0.8 mm size was -0.62. Average selection for the 0.8 to < 1.00 size class of zooplankton was -0.75. Lastly, average selectivity for zooplankton greater than 1.00 mm was nearly completely negative at -0.97.

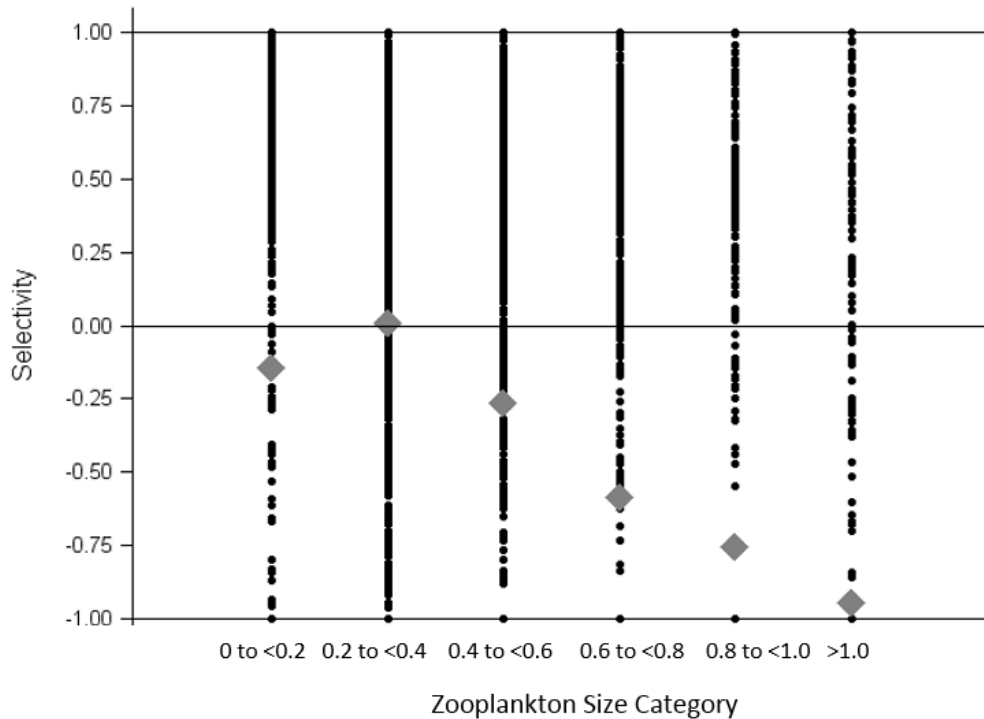


Figure 26. Chesson's Rescaled Index of selection of zooplankton prey by larval and early juvenile yellow perch as a function of prey size category. Filled circles represent a single selectivity value by combining all fish diets in a given lake-day combination. Shaded triangles represent overall mean selectivity. Zero represents neutral selection, 1.00 represents complete positive selection, and -1.00 represents complete negative selection.

Individual prey size-specific selectivity

Selection for size classes of zooplankton showed a clear progression with increasing fish size. The smallest larval yellow perch (i.e. < 5mm) strongly selected for the smallest zooplankton (i.e. <0.2 mm). As larvae grew, their selection of <0.2 mm zooplankton declined to neutral at ~8mm. The pattern continued as larvae increased in size past 8mm, with their selection of < 0.2 mm zooplankton steadily declined to complete avoidance at ~20 mm (Figure 27).

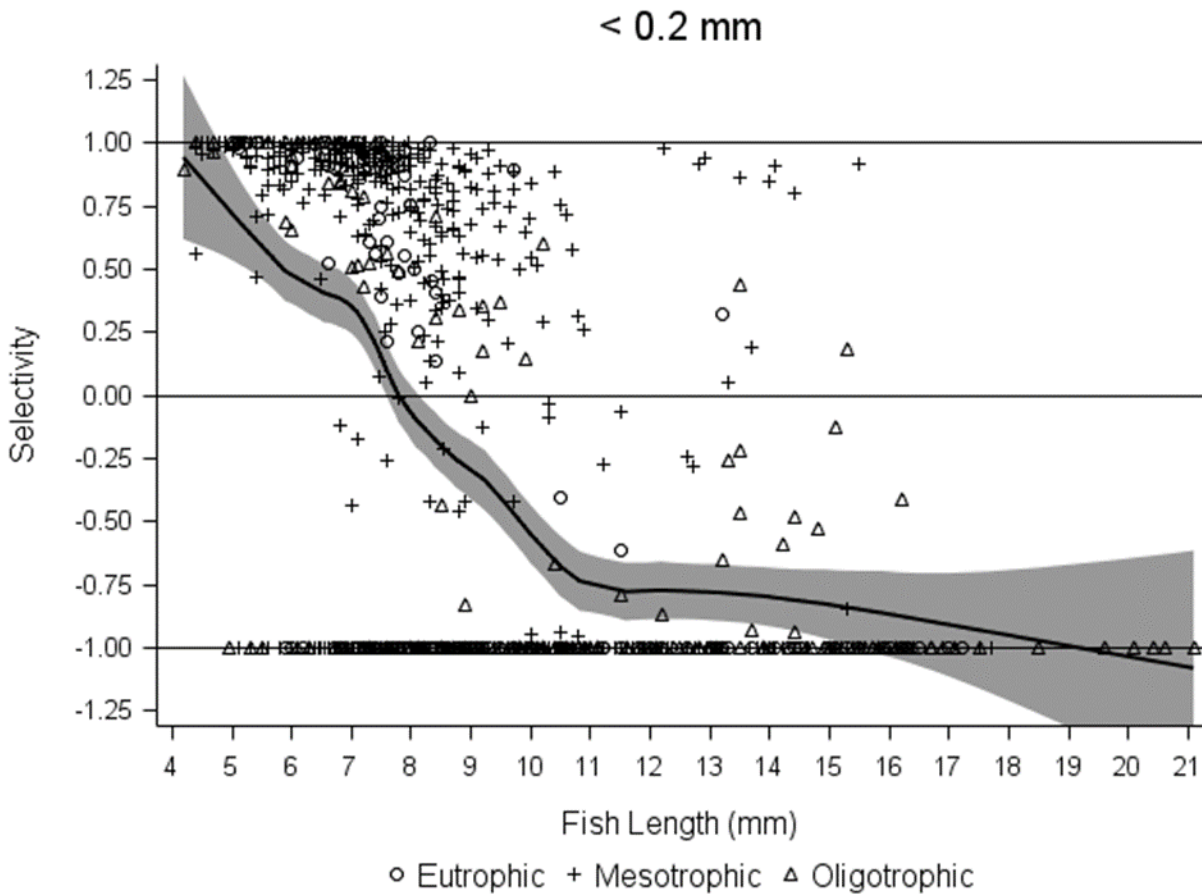


Figure 27. Chesson's Rescaled Index of selection for zooplankton less than 0.2 mm by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

General patterns of selectivity for < 0.2 mm zooplankton remained relatively consistent among lake trophic types (Figure 28) for larvae up to 13 mm, except that selection for < 0.2 mm zooplankton was more positive for larvae between 8 and 10 mm in mesotrophic systems as compared to eutrophic and oligotrophic systems.

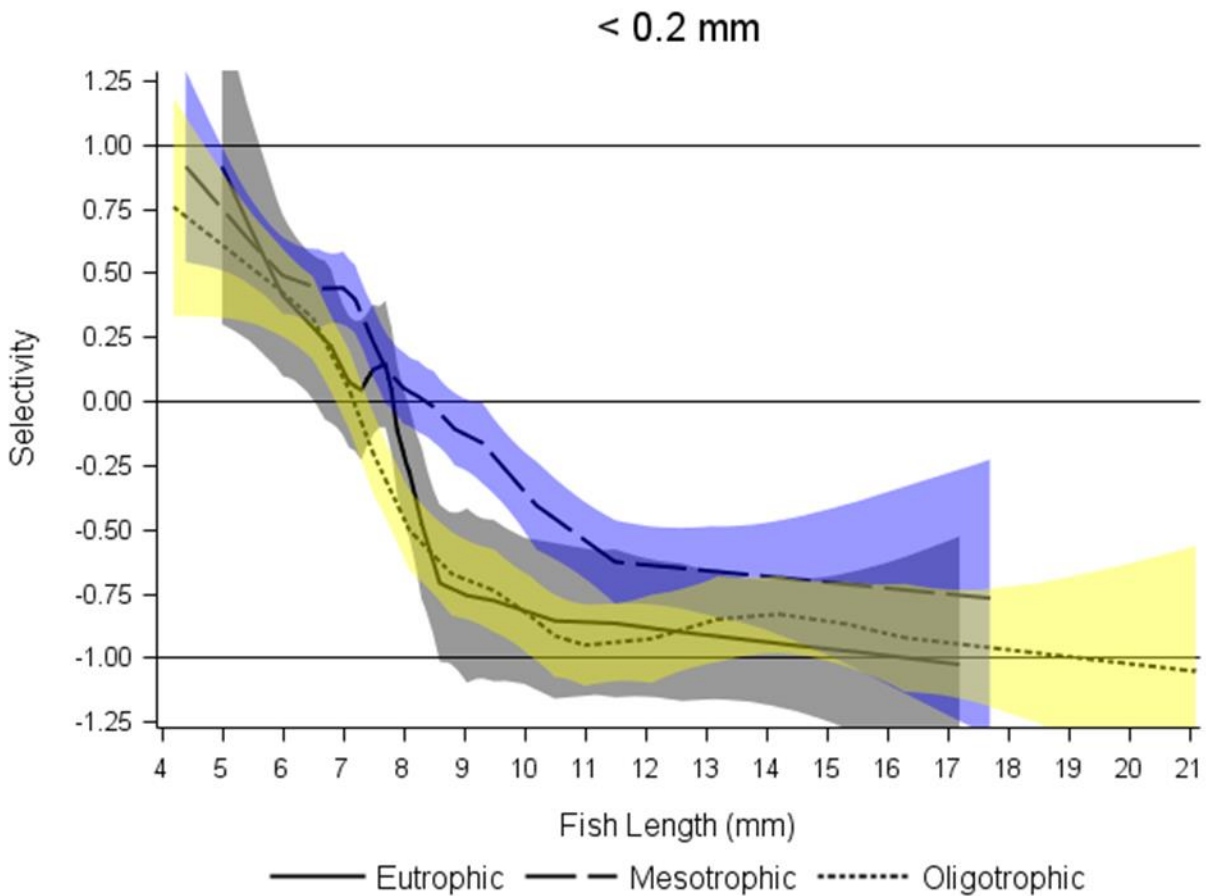


Figure 28. LOESS functions with 95% Confidence Intervals relating size-specific selectivity for zooplankton less than 0.2 mm as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Zooplankton in the 0.2 to <0.4 mm size class were negatively selected for by the smallest larval fish (i.e. < 5mm). As larvae grew to ~6 mm, selection increased to neutral and continued to

increase positively until larvae grew to ~8mm. At this point, selection for 0.2 to < 0.4 mm zooplankton began to decline steadily back to neutral at ~ 10 mm fish length. The pattern of selection continued to steadily decrease as larvae grew to 21 mm. Larvae never completely avoided zooplankton in the 0.2 to < 0.4 mm size class (Figure 29).

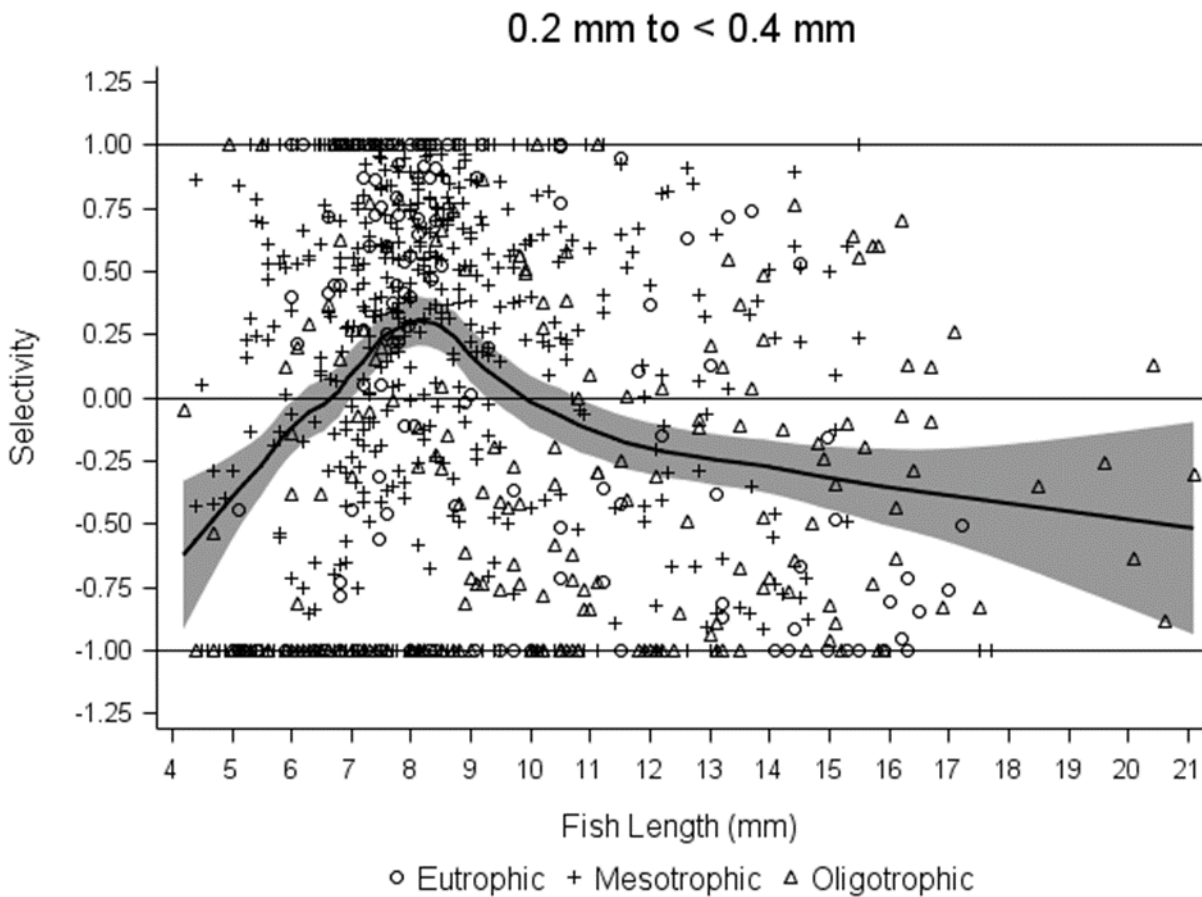


Figure 29. Chesson's Rescaled Index of selection for zooplankton 0.2 mm to less than 0.4 mm by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

General patterns of selectivity for 0.2 to < 0.4 mm zooplankton remained relatively consistent among lake trophic types (Figure 30), except that selection for 0.2 to < 0.4 mm zooplankton was

negative for larvae between 7 and 9 mm in oligotrophic systems as compared to mesotrophic and oligotrophic systems where selection for this size range was positive.

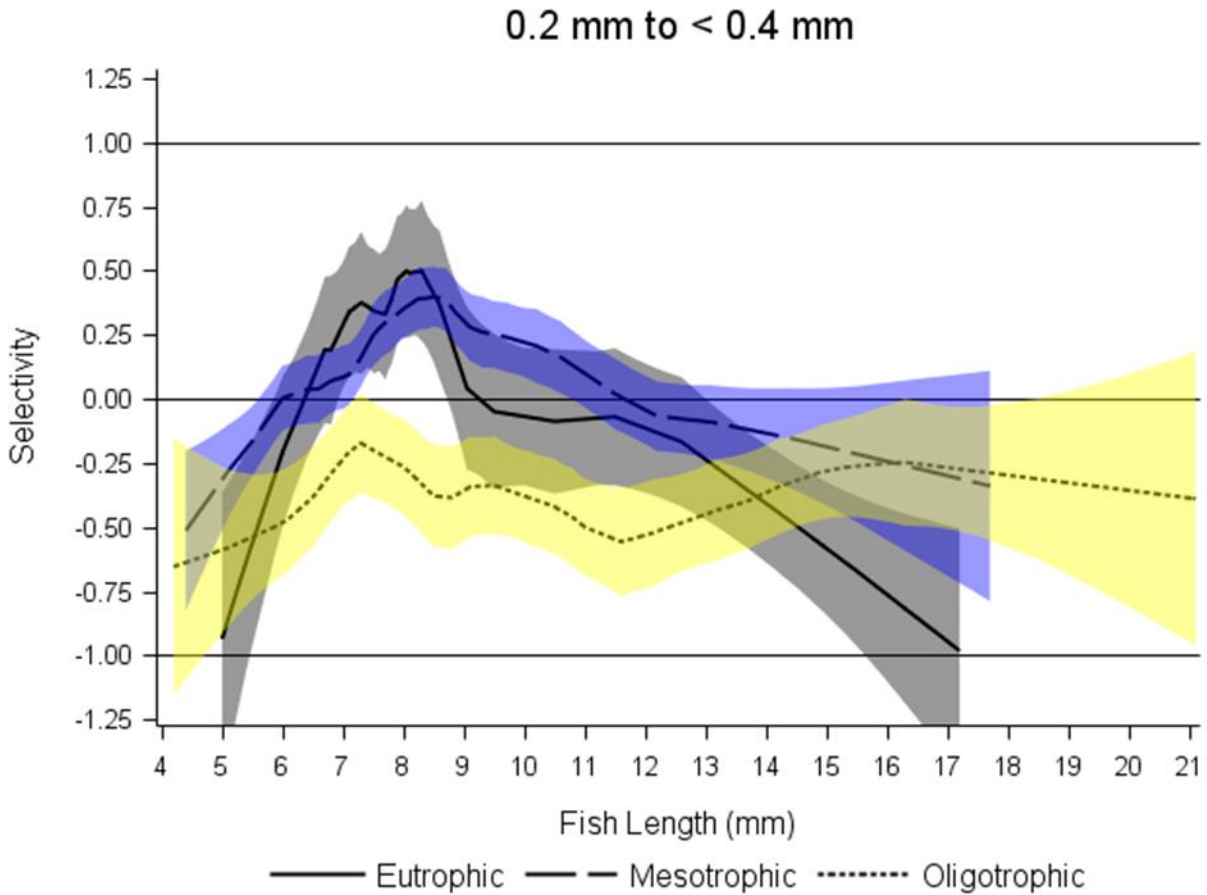


Figure 30. LOESS functions with 95% Confidence Intervals relating size-specific selectivity for zooplankton 0.2 mm to less than 0.4 mm as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Zooplankton in the 0.4 to < 0.6 mm size class were completely avoided by the smallest larvae (i.e. < 5mm). As larvae increased in size, selection for this zooplankton size class climbed to neutral at ~9 mm fish length. Briefly, selection became positive for larvae in the 9 to 13 mm

range, at which point, selection became steady at neutral and remained neutral as fish grew to 21 mm (Figure 31).

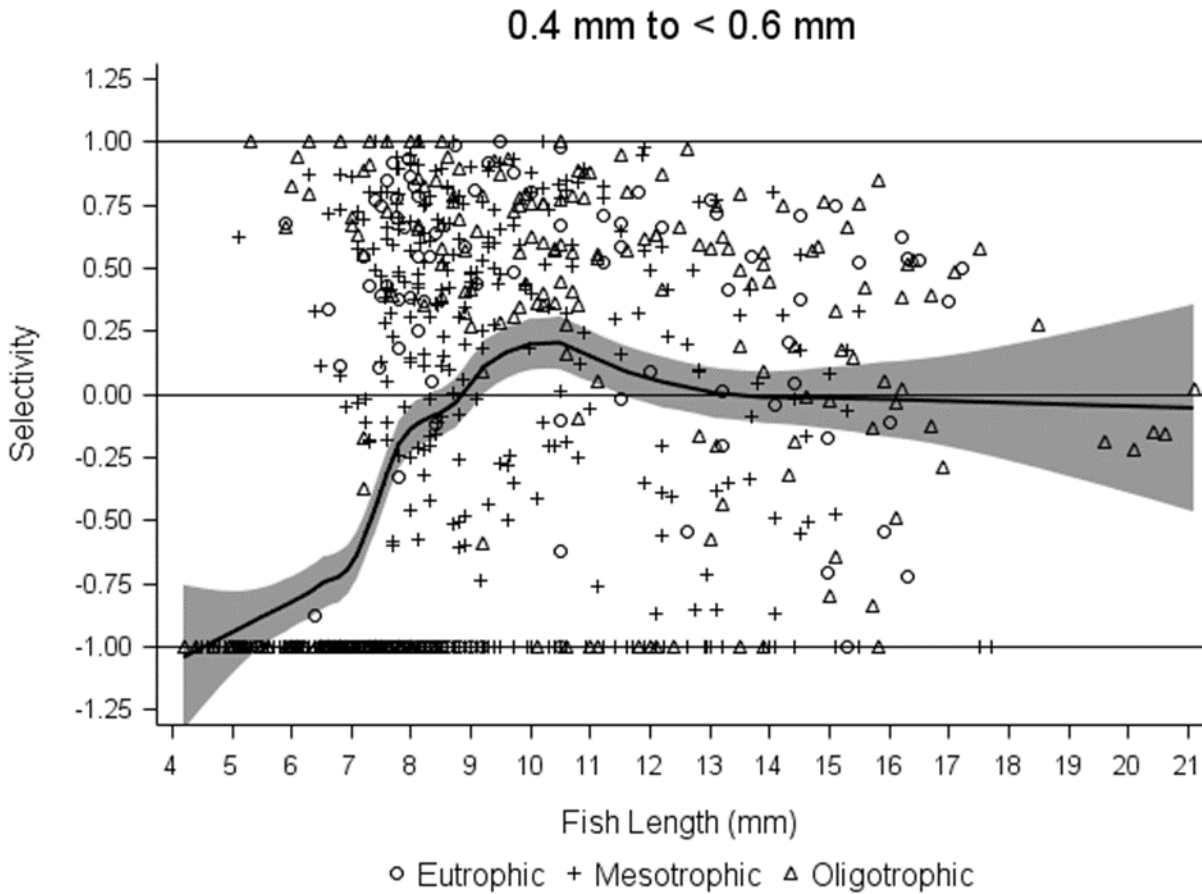


Figure 31. Chesson's Rescaled Index of selection for zooplankton 0.4 mm to less than 0.6 mm by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

General patterns of selectivity for 0.4 to < 0.6 mm zooplankton remained relatively consistent among lake trophic types (Figure 32), other than a slight tendency for more positive selection for larvae between 7 and 9 mm in oligotrophic systems as compared to mesotrophic and eutrophic systems.

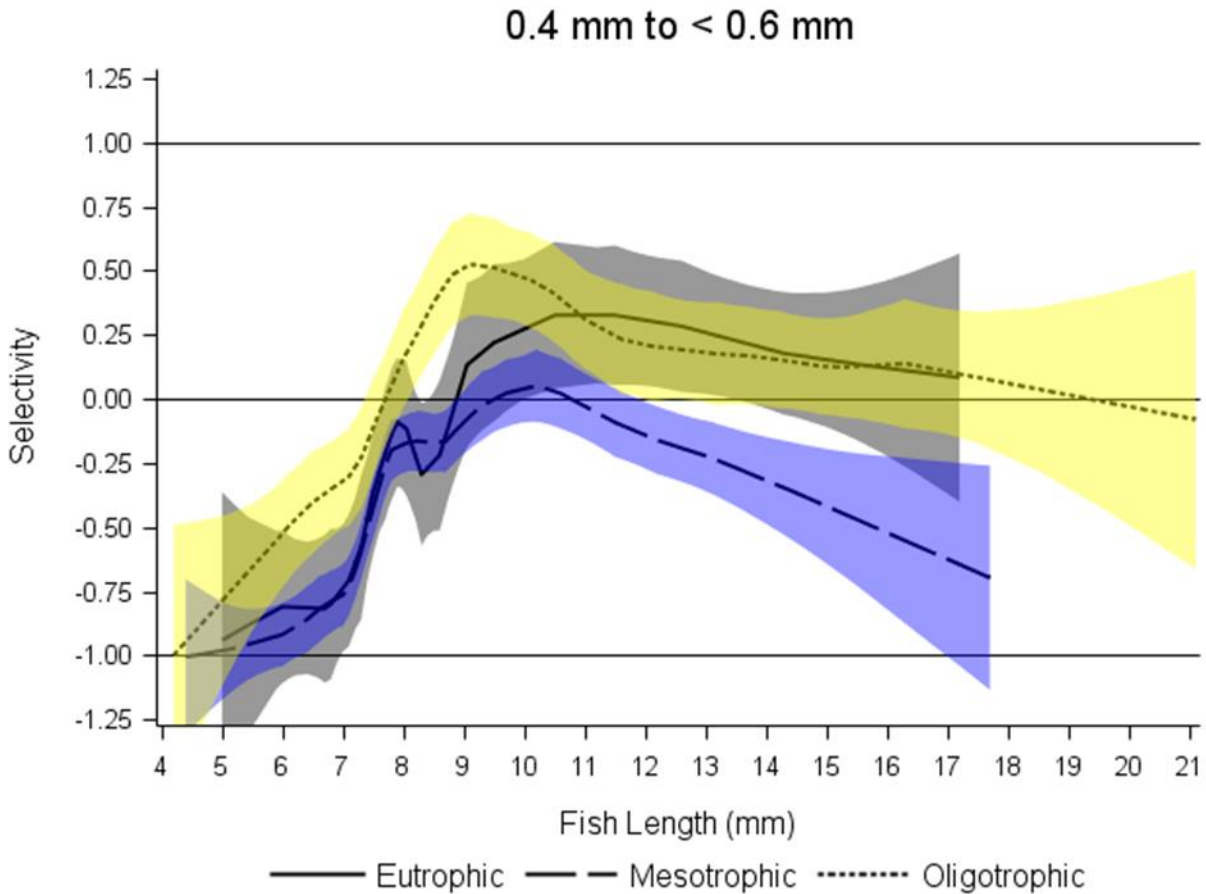


Figure 32. LOESS functions with 95% Confidence Intervals relating size-specific selectivity for zooplankton 0.4 mm to less than 0.6 mm as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Larvae never positively selected for 0.6 to <0.8 mm zooplankton. Small larvae < 6mm completely avoided zooplankton in this size class. At ~8 mm fish length, selectively began to become less negative and increase quickly until approaching neutral at ~12 mm. The pattern of selection for this size class remained steady and ranged from 0 to -0.1 for larvae greater than 12 mm (Figure 33).

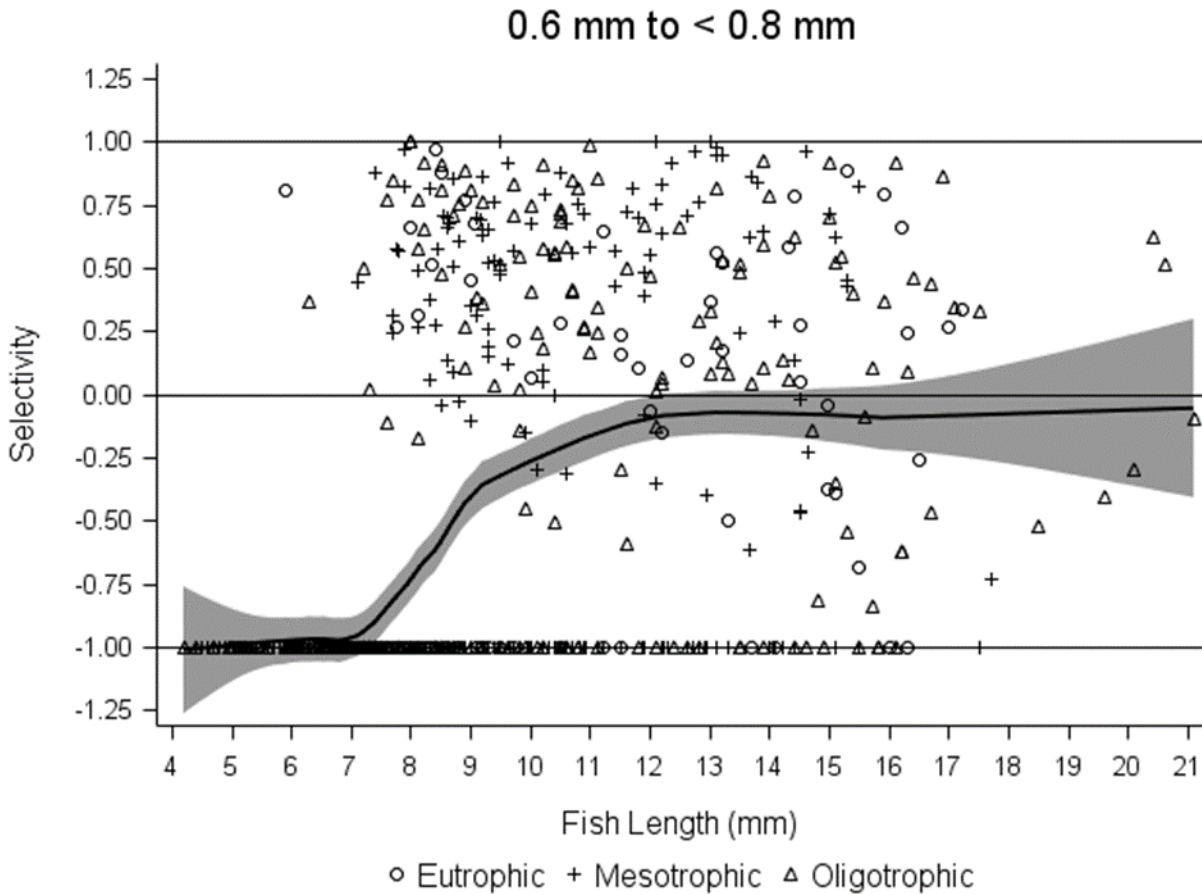


Figure 33. Chesson's Rescaled Index of selection for zooplankton 0.6 mm to less than 0.8 mm by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

General patterns of selectivity for 0.6 to < 0.8 mm zooplankton remained relatively consistent among lake trophic types (Figure 34), except for neutral selection for larvae between 7 and 11 mm in oligotrophic systems as compared to negative selection for mesotrophic and eutrophic systems.

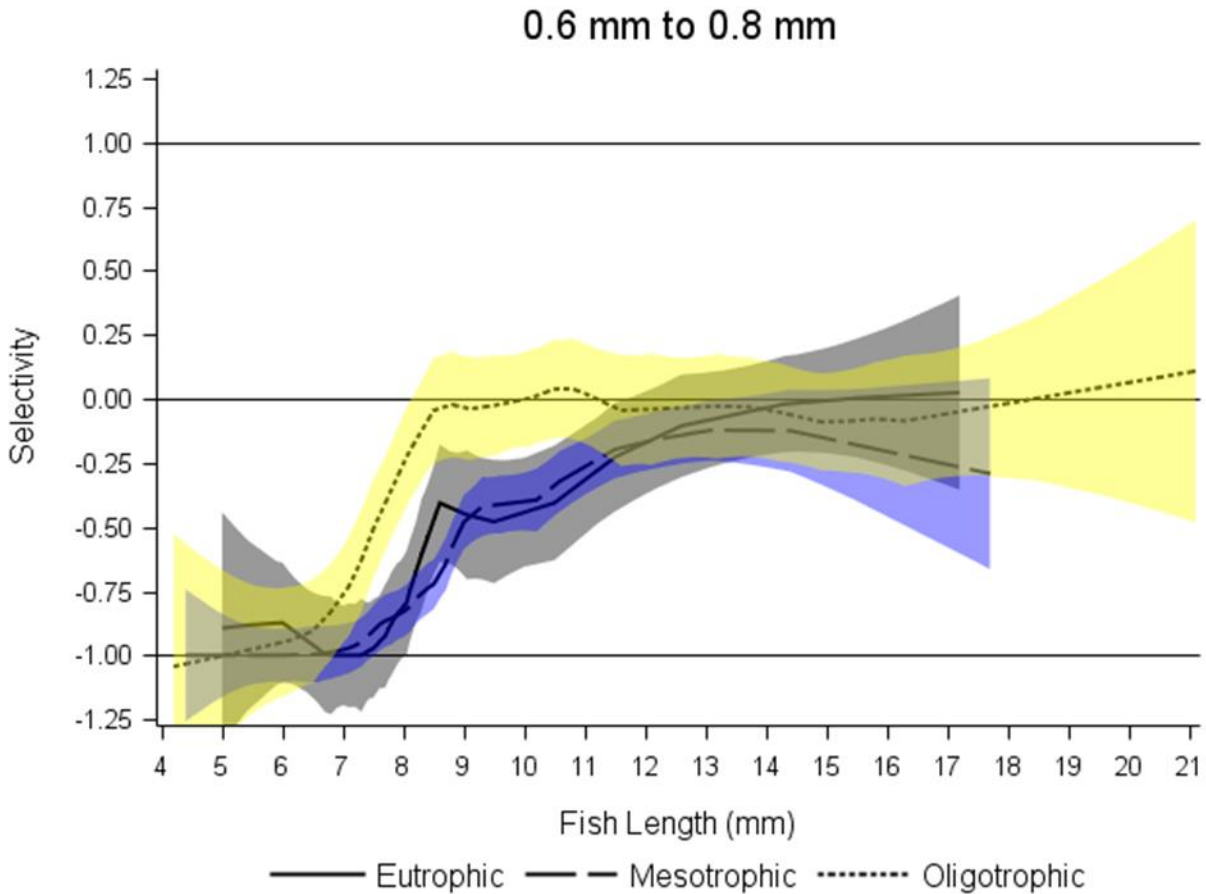


Figure 34. LOESS functions with 95% Confidence Intervals relating size-specific selectivity for zooplankton 0.6 mm to less than 0.8 mm as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

A strong positive relationship was evident between fish length and selection for 0.8 to < 1.0 mm zooplankton. Small larvae < 8mm completely avoided this size class of prey. As fish grew past 8 mm selection began to steadily increase and reach neutral at ~16 mm fish length. After 16mm, selection for 0.8 to < 1.0 mm zooplankton continued to increase steadily through 21 mm fish (Figure 35).

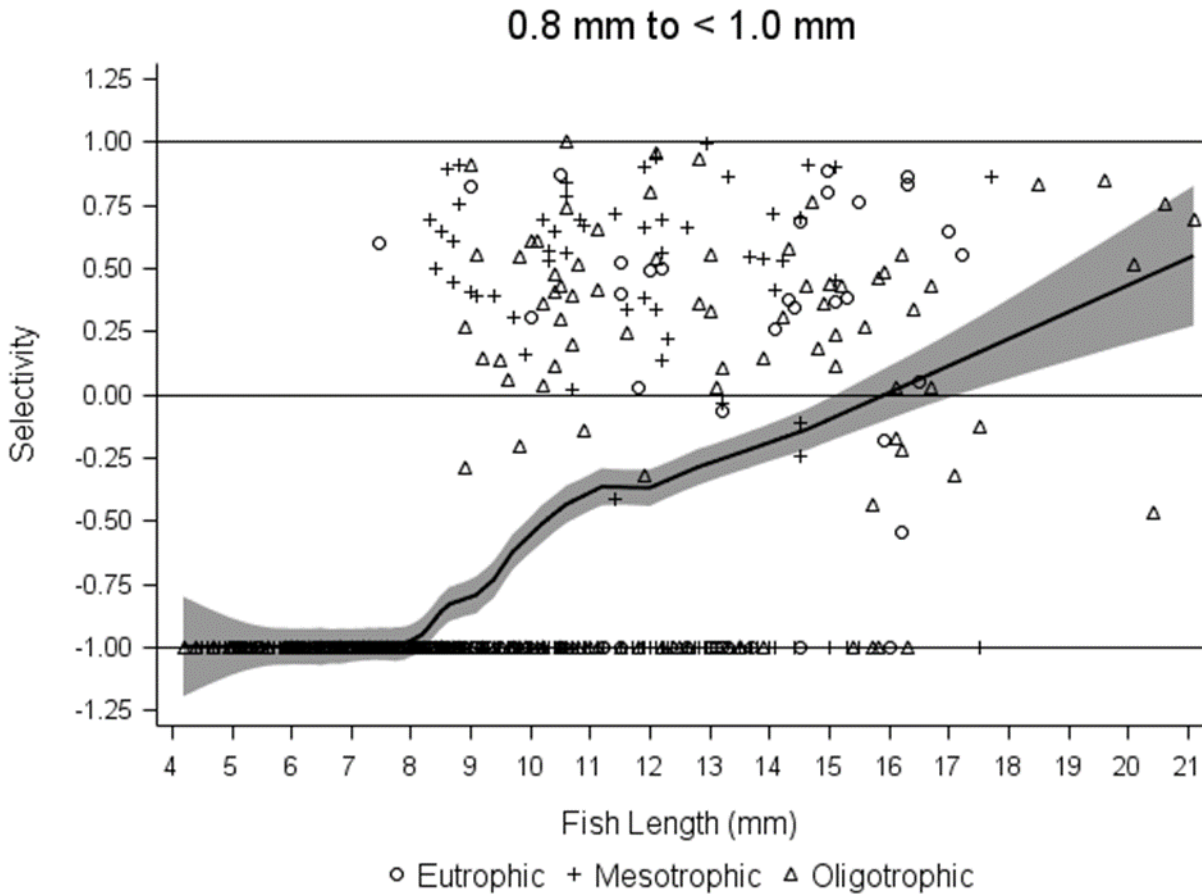


Figure 35. Chesson's Rescaled Index of selection for zooplankton 0.8 mm to less than 1.0 mm by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

General patterns of selectivity for 0.8 to < 1.0 mm zooplankton remained consistent among lake trophic types (Figure 36) for larvae less than 14 mm, but diverged as larvae grew past 14 mm.

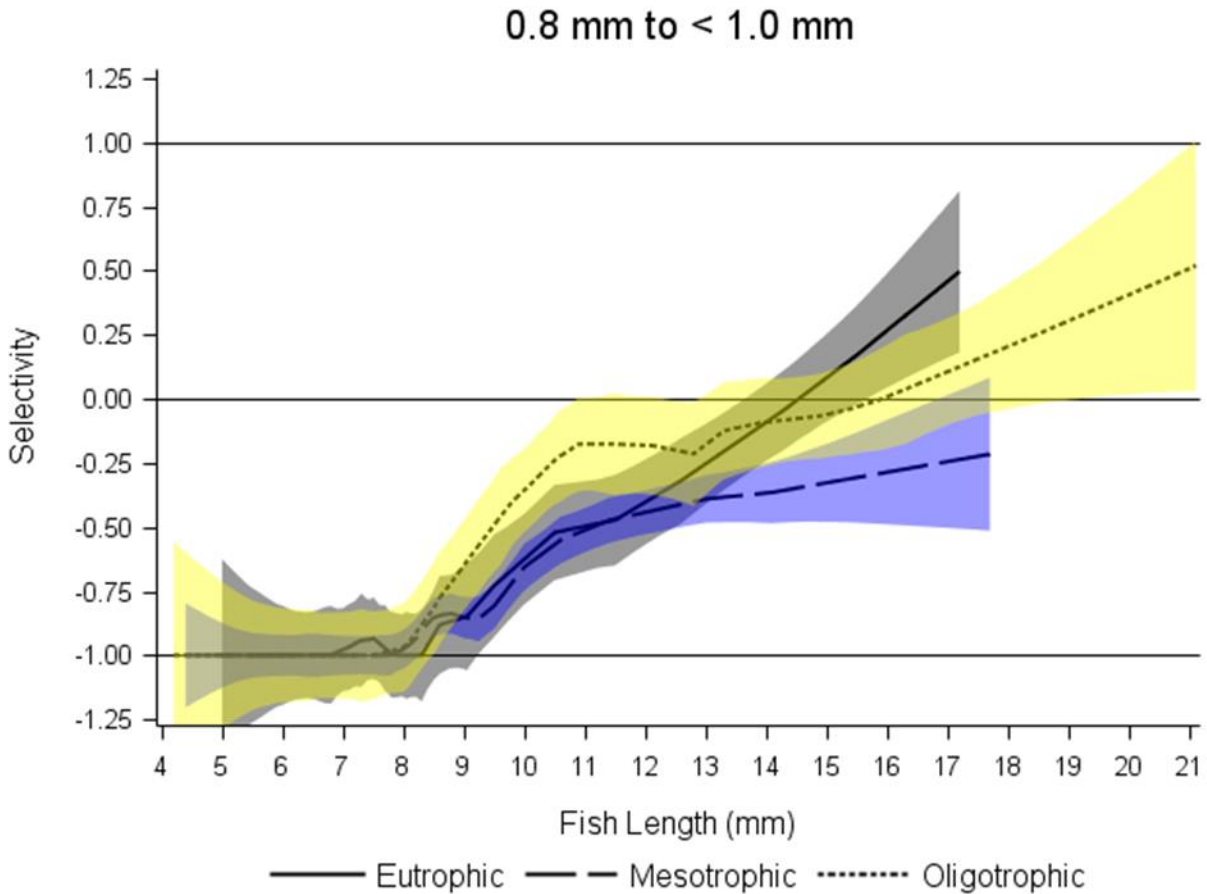


Figure 36. LOESS functions with 95% Confidence Intervals relating size-specific selectivity for zooplankton 0.8 mm to less than 1.0 mm as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Zooplankton greater than 1.0 mm were never positively selected for by this range of larval fish size. Larvae < 9 mm completely avoided greater than 1.0 mm zooplankton. As larvae grew from 9 mm to 21 mm, their selection for large zooplankton increased steadily to -0.45 (Figure 37).

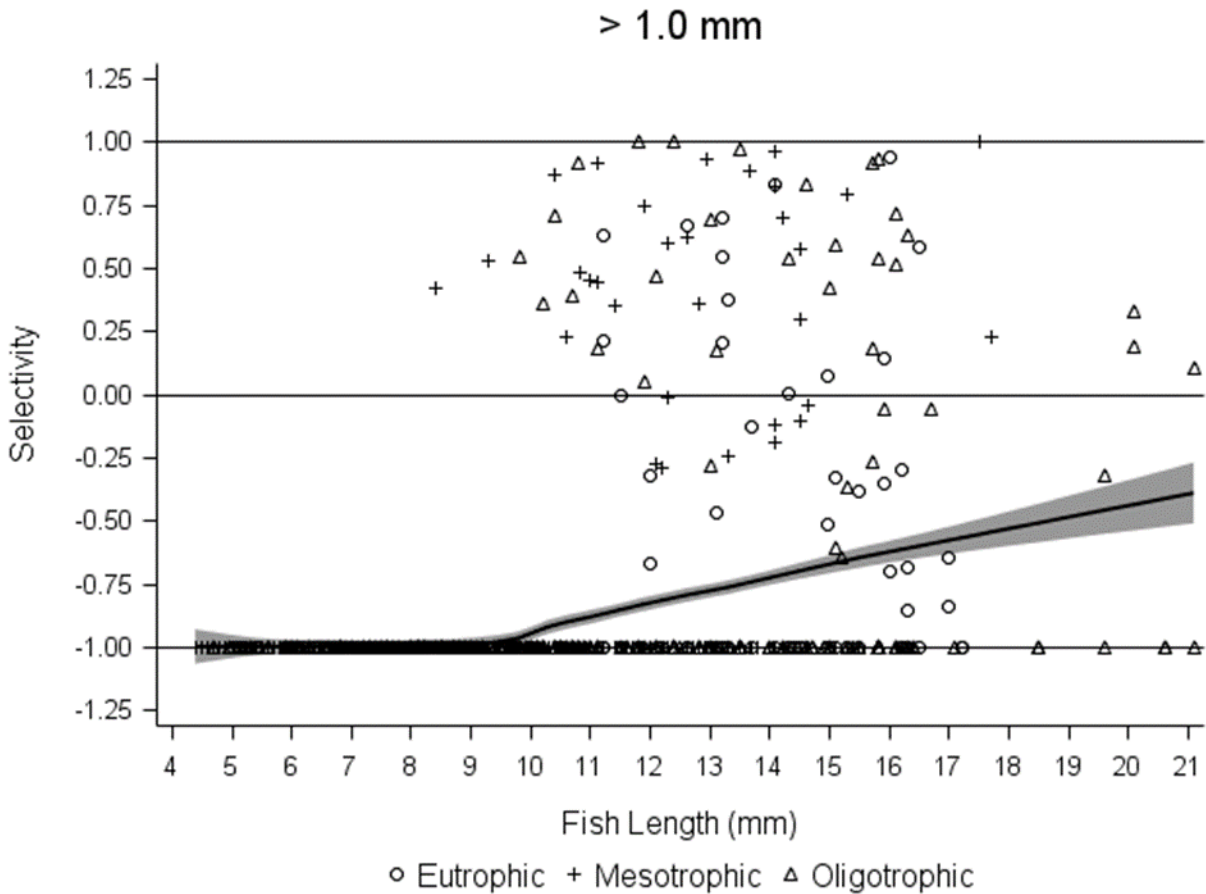


Figure 37. Chesson's Rescaled Index of selection for zooplankton greater than 1.0 mm by larval and early juvenile yellow perch. Circles represent individual selectivity from eutrophic lakes. Plus symbols represent individual selectivity from mesotrophic lakes. Triangles represent individual selectivity from oligotrophic lakes. Solid line depicts LOESS function fit to all data with gray band representing 95% confidence interval of the mean.

General patterns of selectivity for > 1.0 mm zooplankton remained consistent among lake trophic types (Figure 38) for larvae of all sizes.

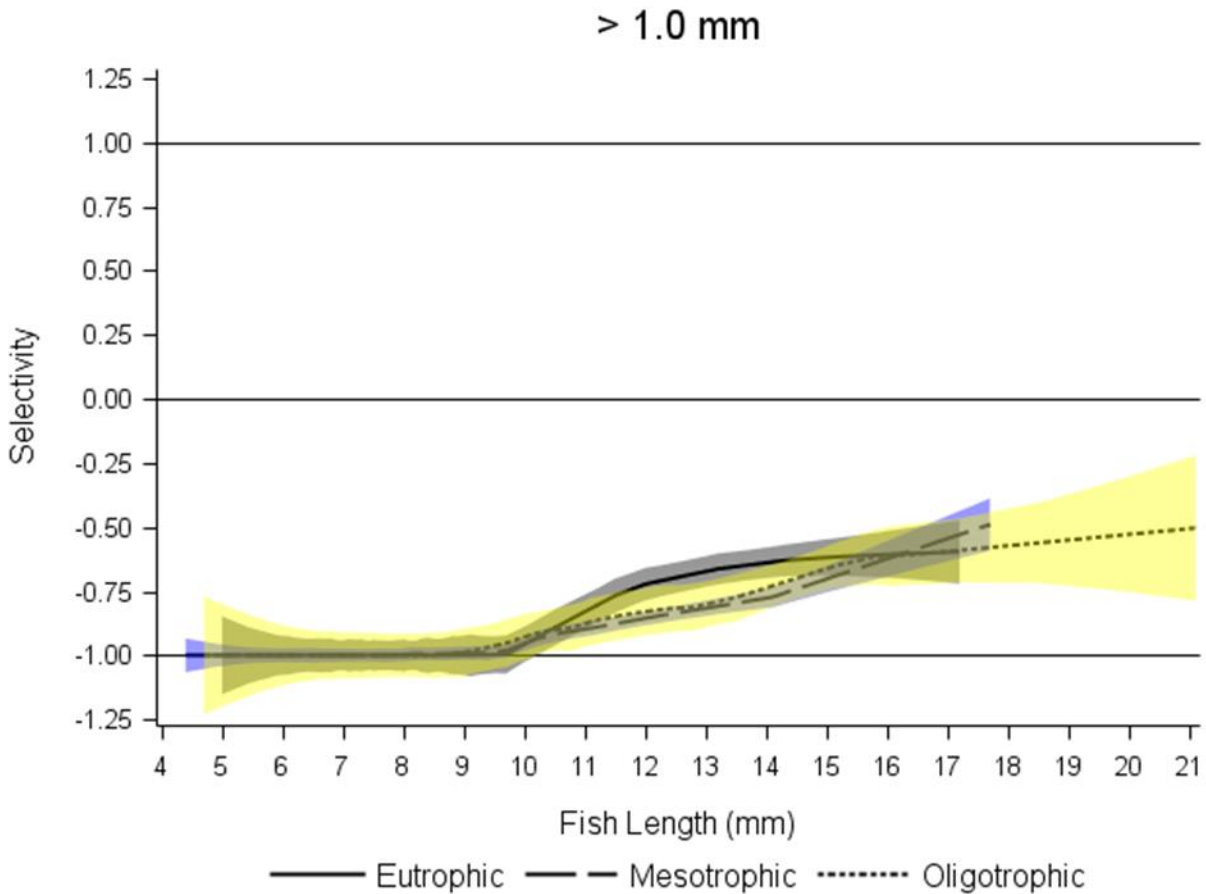


Figure 38. LOESS functions with 95% Confidence Intervals relating size-specific selectivity for zooplankton greater than 1 mm as a function of larval and early juvenile yellow perch length as influenced by system specific trophic status. Solid lines represent eutrophic systems, dashed lines represent mesotrophic systems, and dotted lines represent oligotrophic systems.

Summary of prey size-specific selection

A summary of size-specific selectivity showed a distinct ontogeny of selectivity for individual larvae across all lakes, days, and years (Figure 39). The smallest larvae (i.e. < 5mm) positively selected for zooplankton <0.2 mm. As larvae grew, they began to select more positively for the next size class of zooplankton (i.e. 0.2 to <0.4 mm). At ~8mm fish length, this increase in selection began to decline as larvae began selecting more for the next size class (i.e. 0.4 to < 0.6 mm). This ontogeny continued through the remaining size classes of zooplankton.

As fish grew to ~ 12 mm, their selection for 0.6 to < 0.8 mm zooplankton approached and remained near neutral. Larvae greater than 12 mm began selecting more for 0.8 to <1.0 mm zooplankton until reaching ~16mm. At this point, selection for this size class of zooplankton continued to increase positively until fish reach 21 mm. Selection for zooplankton >1.0 mm never became positive. In fact, larvae < 9mm completely avoided these larger prey.

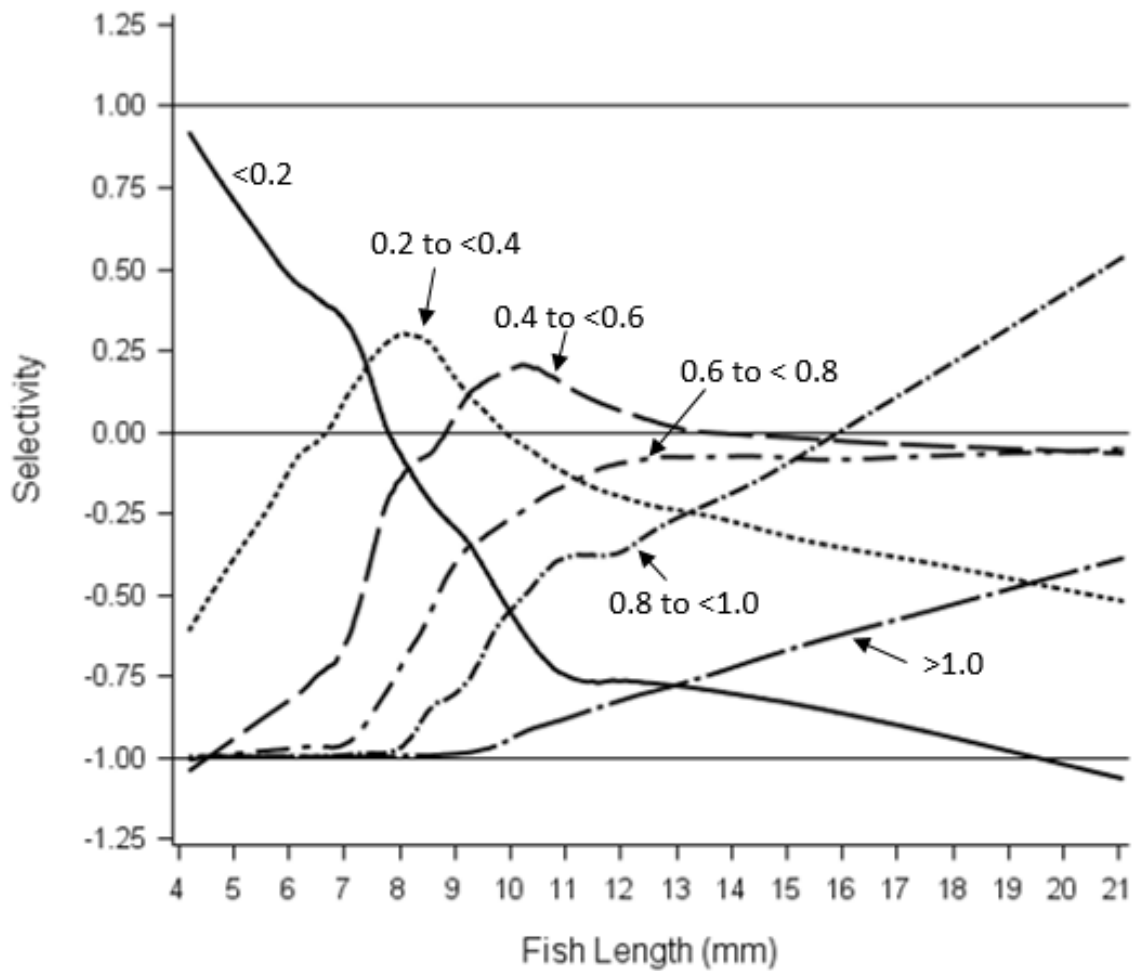


Figure 39. Summary of LOESS functions relating prey size-specific selectivity as a function of larval and early juvenile yellow perch length.

DISCUSSION

The overall goal of this study was to evaluate patterns of prey selection by larval yellow perch across a broad range of system types in inland lakes of Michigan's Lower Peninsula. The purpose behind this evaluation was to increase knowledge of yellow perch feeding during the transition from endogenous nutrition to exogenous feeding, specifically in terms of consistency among lakes. My goal was to reveal relationships during this critical period among prey availability, prey community structure, lake characteristics, and larval fish morphology. While the early life history of yellow perch has been the focus of a tremendous amount of effort in both field and laboratory experiments, these efforts tended to examine this period of yellow perch early life history within a laboratory setting or field study specific to individual lake systems. Such experiments advance our knowledge of yellow perch feeding ecology within the specific waterbody type, but then tend to be generalized across different lake system types without direct evidence. Predictive models developed from these expectations contain a level of uncertainty about the uniformity or differences in system specific processes. My research added an in-depth evaluation of prey selectivity across waterbodies with differing levels of productivity, thereby providing a more direct empirical basis for making such generalizations.

Zooplankton

One important aspect to consider in the feeding ecology of larval fishes is the availability of suitable densities and sizes of zooplankton prey at the critical transition period between endogenous and exogenous food sources (Dettmers et al. 2003). Several studies have stressed the importance of rotifers to the survival and growth of larval yellow perch during this critical period

(Siefert 1972; Post and McQueen 1988; Fulford et al. 2006b). However, others have found that the availability of rotifers in the environment is not necessarily an important component of larval yellow perch feeding ecology (Bremigan et al. 2003). Specifically, yellow perch larvae displayed negative selection for rotifer species in Lake Michigan's Green Bay (Bremigan et al. 2003). My study supports this conclusion. Across all of my study lakes, including eutrophic, mesotrophic, and oligotrophic waterbodies, rotifers were rarely found in the diet of yellow perch larvae. In fact, out of 1003 stomachs examined, only 21, from larvae ranging in size from 4.6 mm to 10.9 mm, were found with rotifers in their guts, and these were distributed relatively evenly across lake trophic type. During the course of zooplankton processing, rotifers were consistently evident in environmental prey samples, but mostly absent from diets of larval yellow perch. I conclude that while rotifers may be an occasional food item in naturally occurring larval yellow perch diets, they were not critically important to the successful feeding, growth, and survival of larval yellow perch in my study lakes. Consequently, individual based models which utilize laboratory findings citing the importance of the availability of rotifer species (Fulford et al. 2006b) to larval feeding ecology may not be representative of naturally occurring larval predator-prey interactions in all waterbodies.

I categorized my lakes on an *a priori* grouping of trophic classes, based on the commonly-used criterion of water clarity as indicated by Secchi disk depth. Although substantial variation was evident in zooplankton densities across lakes, dates, and even within lakes (Table A1), I found that the average proportions of the different zooplankton prey types were similar across these trophic categories. The same was true for the mean proportion of zooplankton present across size categories. This result is somewhat unexpected, given previous research showing differences in the zooplankton community across trophic classes (Patalas 1972). I

speculate that the similarity in proportions of zooplankton taxa and size composition may be a more conservative property of the zooplankton community across trophic states than overall density, however answering this question would require a different study design.

The substantial observed variation in densities of prey taxa and size classes among lake-day sampling events suggests that future investigators should carefully evaluate their sample size needs for quantification of available prey densities that are representative of an individual sampling event (i.e., lake/date combination or locale within a lake). My analysis indicates that relatively large sample sizes are necessary to achieve a high level of precision for mean density. However, a trade off exists between the goal of determining the availability and composition of prey resources with a high level of precision and the costs to collect and process the large numbers of samples required. Moreover, the ability to detect differences among systems depends not only on the variation within a lake on a specified date, but the variation across dates within a lake and across lakes. I suggest that it would be beneficial if a method could be developed to collect larvae and prey that better integrates spatial variation in zooplankton density. Currently, we typically rely on two different techniques in natural systems; one for predators where we collect a horizontal sample across a large spatial area, and another for prey where we collect a representative vertical sample in a very specific locale and use that information to extrapolate prey community structure to the whole system. I speculate that developing a method to collect fish larvae along with their prey resource would benefit our determination of predatory processes and increase our understanding of critical early life processes in naturally occurring systems. In many studies of larval fish diet and selection, a single zooplankton tow is used to characterize the available prey (McDonnell et al. 2014; McCullough et al. 2015); in my view one zooplankton sample is simply not enough to develop a

robust understanding of prey community density and structure. A potential method may be to capture every organism within a small area of a naturally occurring system by mechanical isolation, and then quantifying the entire sample. For example, this technique is often used to quadrat off benthic habitats, but could also be useful for capturing larval predators and zooplankton prey. This would potentially yield a direct measurement, (i.e. absolute encounter rates), of prey density, predator density, and environmental conditions, such as water clarity, which are known to influence larval feeding processes.

Selection

Yellow perch display an ontogenetic diet shift as fish grow in size during the larval and juvenile phase (Whiteside et al. 1985; Graeb et al. 2006). Yellow perch begin feeding on small zooplankton and as their body size increases, they switch to larger zooplankton (Mills et al. 1989; Graeb et al. 2004a). At approximately the 20 to 40 mm total length range, juvenile fish transition to a diet primarily composed of benthic invertebrates (Wu and Culver 1992). Lastly, as the fish reach approximately 80 mm, they begin to transition to a diet of prey fish (Graeb et al. 2006). Many studies focus on and stress the importance of these transitions to recruitment success by examining larger juvenile fish, (> 20 mm), while few have considered the importance of the finer-scale ontogeny of prey selection by larval fish in the early stages of exogenous feeding (Graeb et al. 2004a). Recent observations of prey selection by age 0 yellow perch in Lake Huron's Saginaw Bay demonstrate the absence of an ontogenetic shift from zooplankton to benthic invertebrates in this zooplankton rich system (Roswell et al. 2013), suggesting that this ontogeny is plastic and the shift from zooplankton to benthic invertebrates may depend on relative abundance and foraging profitability of these groups (Hayes and Taylor

1990; Hayes et al. 1992). Therefore, the finer-scale ontogeny displayed in my study through different zooplankton taxa and sizes may indeed present an important component for modeling survival and recruitment of yellow perch to existing fisheries.

A number of other studies have demonstrated that copepod nauplii are likely a very important first food source for newly hatched yellow perch larvae (Schael et al. 1991; Bremigan et al. 2003; Graeb et al. 2004b; Roswell et al. 2013, 2014). My study supports this theory. Across the different types of waterbodies that I sampled, only copepod nauplii were positively selected for by larvae in the 5 to 8 mm range. This is consistent with the findings of Bremigan et al. (2003) in Green Bay, Graeb et al. (2004) in Saginaw Bay, and Schael et al. (1991) in Lake Mendota, suggesting that this selection for copepod nauplii as a first food occurs across a variety of system types and may be of general importance to larval yellow perch. Interactions between copepod nauplii density and larval yellow perch early feeding success should be used in the formation of predictive models of the early life history of this species. This behavior is likely easily explained by the vulnerability and size of copepod nauplii as the consumption of prey by small larvae is limited by their gape size. My analysis of selection by size of prey supports this conclusion as only zooplankters <0.2 mm were found to be positively selected for across multiple system types by the smallest larvae. Copepod nauplii are the principal prey item in this size range, so my data do not allow assessment of whether selection for copepod nauplii by small larval yellow perch is driven by anything other than gape limitation. However, certain species of copepod nauplii such as calanoid copepod nauplii can be larger in size and begin to overlap with *Bosmina* spp. and cyclopoid copepod sizes (Figure 7). This provides some indication that selection on the basis of something other than prey size alone is occurring; as larvae increase in size, they begin to actively choose larger copepod nauplii over similarly-sized *Bosmina* spp. and

small cyclopoids. Patterns of selection for larvae are likely primarily regulated by gape limitation and evasive capabilities of the zooplankton prey, but are also affected by behavioral preference for certain prey types.

Positive selection for copepod nauplii is slightly lower in oligotrophic systems as compared to eutrophic and mesotrophic systems (Figure 13). Larval yellow perch are visual predators. Water clarity may play a critical role in selection during early feeding because increased visual acuity in clearer waters likely allows for less reliance on the slow moving small nauplii by increasing detection and capture distance for larger, more energy rich prey. Manning et al. (2014) describe turbidity and phytoplankton abundance as a driving force controlling consumption rates, growth, and starvation of larval yellow perch. They concluded feeding rates decreased significantly with higher levels of phytoplankton. Although my study quantified prey preference while their study quantified larval feeding rates, both demonstrate that water clarity plays a role in the predation process, which has implications for year class development for larval yellow perch.

Next in the ontogeny of prey selection by larval yellow perch is their preference for cyclopoid copepods. As in previous studies, I found that yellow perch larvae made a distinctive transition from copepod nauplii to cyclopoid copepods at roughly 8 mm total length and continued to transition to larger cyclopoids as the larvae grow in size (Schael et al. 1991; Bremigan et al. 2003). It has been postulated that net gains in energetic benefits due to larger prey size and less handling time explains this behavior (Graeb et al. 2004a). I found that my analysis of selection of prey size agrees with my findings of taxa selection as cyclopoid copepods vary considerably in size, but smaller, 0.2 to <0.4 mm, zooplankters were positively selected for by larvae in the 7 to 10 mm range. Then, selection began to shift to larger prey sizes,

0.4 to <0.6mm, as fish grew into the 9 to 13 mm range, followed by positive selection for larger and larger prey sizes as larvae grow past 13 mm in size. As they grow, larval fish increase their gape size, swimming ability, and visual acuity, which allows for the efficient capture and handling of larger and larger prey. However, prey selection is again likely to be a summation of both morphological limitations, (i.e. gape size), and preference for more energetically cost effective prey. Figure 7 demonstrates a small overlap in size for large nauplii, *Bosmina* spp., and small cyclopoids. Therefore, results of my study show that prey selection is a product of both morphological limitations and feeding behavior as larvae grow in size, as demonstrated by comparison of selection curves for cyclopoids and *Bosmina* spp. In other words, *Bosmina* spp. and small cyclopoids overlap in size, but selection curves for larvae in the 7 mm to 10 mm range demonstrate larvae consistently choose cyclopoid copepods over *Bosmina* spp. as a food source. Lastly, while variation exists in prey selection among trophic states for *Bosmina* spp. and smaller sizes of cyclopoids, i.e. 0.2 to <0.4mm, a general pattern is evidenced by selection curves for this size range of prey. Specifically, mid-size larvae displayed a higher preference for mid-sized zooplankton in oligotrophic lakes and compared to eutrophic and mesotrophic systems.

I found that selection for calanoid copepods, *Bosmina* spp., and *Daphnia* spp. only began to become positive as larvae begin to develop into juvenile fish. These findings are consistent with other studies (Bremigan et al. 2003; Graeb et al. 2004a) and make sense as these zooplankters are either more difficult to capture and handle because of evasive ability or they have protective defenses such as spines and hard carapaces. Also, they tend to be larger zooplankters, which make capture and consumption by smaller larvae nearly impossible. There is overlap in prey sizes > 0.4 mm among taxa, specifically, larger cyclopoid copepods, calanoid copepods, and *Daphnia* spp. (Figure 7). My results demonstrate that selection for cyclopoids, on

average and among the different lake types, remains positive for larvae, even as they grow into larger sizes. Only when they grow beyond 11 mm does selection for calanoid copepods and *Daphnia* spp. prey begin to become more positive. This supports the theory of gape-limitation in larval yellow perch, but also displays evidence of behavioral selection for certain prey types over others of similar size.

CONCLUSION

Other studies have found that variation in both selection and ontogeny of prey choice can be quite high within single waterbodies as well as across waters of different types (Roswell et al. 2013). My study supports this by demonstrating that selection of zooplankton prey varies considerably within and across waterbody types. However, it also provides evidence that general patterns of prey selection can be expected across a wide range of lakes. My results support what has generally been documented for larval yellow perch and other gape limited larval fish. My work contributes to this body of knowledge by expanding data coverage across a wide range of lakes, ranging from less than 200 acres to greater than 20,000 acres, and from oligotrophic to eutrophic. My *a priori* hypothesis is supported in that general, common patterns of selectivity by larval yellow perch do exist and can be expected in inland and waters of Michigan. I also suggest that selection for prey taxa and size by larval yellow perch is not only regulated by morphological characteristics of predator and prey, but also by behavioral choices for certain types of prey. I found that larvae consume prey well below a 1:1 gape to prey length ratio (Figure 25). If selective predation by larval yellow perch was solely regulated by morphological characteristics, then it follows that they would be consistently be consuming prey at or near the

1:1 gape to prey size ratio (i.e., the largest prey, regardless of taxon, that they are able to consume).

My research is limited by small sample sizes of larvae greater than 15 mm. This most likely reflects the capability of larger larvae to avoid my sampling gear because of increased motility and their tendency to switch to benthic prey. While I feel confident in my description of prey selection by larvae from first feed to about 15 mm, I also recommend that future researchers plan for and attempt to include more larvae greater than 15 mm. Switching from larval surface trawls to littoral seining techniques would assist with capturing larger larvae, but it is also likely that larger larval fish would begin feeding on benthic invertebrates, thus confounding analysis of selectivity indices for zooplankton prey. An interesting trend is seen in the larger larvae, where it appears that selection is increasing for larger prey, including calanoid copepods and *Daphnia* species, but with limited sample sizes in that fish size range, I feel that any inference I could make would be an extrapolation beyond the confines of my dataset. Also, my sample sizes for environmental prey limit my ability to detect modest differences in prey communities across different system types.

In closing, this study will be useful to researchers looking to develop models that include patterns of prey selection by larval yellow perch. Despite considerable variation both within and among lake trophic types, my findings indicate a general pattern that spans lake characteristics. This is an important result because project leaders can use this information when developing sampling schemes for future studies, utilizing my data to determine sample size requirements.

APPENDIX

Table A1. Mean number of zooplankton per liter with Standard Error (SE) of the mean, and number of samples collected and analyzed (N) for each lake-day sampling event.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Black	4-Jun-14	8	0.2	0.1	2.5	1.3	1.5	0.7	0.1	0.0	6.7	2.2	0.0	0.0
	18-Jun-14	9	0.1	0.0	1.8	0.4	1.6	0.3	0.2	0.1	7.2	1.4	1.0	0.3
	28-May-15	9	1.5	0.2	5.8	0.9	5.2	1.5	0.2	0.1	10.6	2.9	0.1	0.0
	4-Jun-15	6	1.2	0.5	0.1	0.1	1.6	1.2	0.2	0.1	111.2	45.5	0.0	0.0
	5-Jun-15	12	1.5	0.5	0.2	0.0	1.6	0.3	0.1	0.0	18.6	3.5	0.1	0.0
Burt	21-May-11	1	0.1	.	0.2	.	0.3	.	0.0	.	11.6	.	0.0	.
	4-Jun-11	1	31.3	.	0.2	.	0.3	.	0.4	.	0.8	.	0.0	.
	10-Jun-11	1	1.6	.	1.7	.	0.8	.	1.8	.	7.1	.	2.4	.
	8-May-12	1	2.2	.	0.7	.	1.8	.	0.4	.	2.5	.	0.0	.
	18-May-12	1	0.5	.	0.3	.	0.4	.	0.0	.	1.0	.	0.0	.
	31-May-12	1	2.9	.	18.1	.	4.1	.	1.2	.	10.1	.	2.1	.
	6-Jun-12	2	3.1	2.1	5.4	0.8	2.1	0.3	11.9	10.1	10.5	0.3	1.8	0.3
	8-May-13	1	4.2	.	1.2	.	5.4	.	1.0	.	15.9	.	7.0	.
	22-May-13	1	2.9	.	1.2	.	3.9	.	0.6	.	19.0	.	1.2	.
	31-May-13	1	3.3	.	0.4	.	2.4	.	0.7	.	4.8	.	1.3	.
	28-May-15	9	1.0	0.4	0.3	0.1	0.3	0.1	0.1	0.0	0.9	0.2	0.0	0.0
	6-Jun-15	6	1.5	0.9	0.6	0.2	0.7	0.5	0.2	0.1	9.5	2.6	0.4	0.1
Crooked	5-May-11	1	4.2	.	0.7	.	8.4	.	0.0	.	7.9	.	0.0	.
	16-May-11	1	1.4	.	0.1	.	4.3	.	0.1	.	11.2	.	1.8	.
	6-Jun-11	1	1.8	.	0.4	.	3.6	.	0.1	.	2.3	.	0.0	.
	13-Apr-12	1	16.3	.	1.7	.	43.5	.	0.0	.	17.4	.	0.0	.
	14-May-12	1	0.0	.	0.0	.	0.0	.	0.0	.	0.1	.	0.1	.
	22-May-12	1	4.9	.	1.5	.	8.1	.	0.0	.	3.8	.	22.5	.
	30-May-12	1	0.4	.	1.9	.	7.2	.	0.1	.	2.5	.	8.3	.

Table A1 cont.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Crooked	7-May-13	1	2.8	.	1.6	.	3.3	.	0.0	.	16.8	.	0.7	.
	14-May-13	1	11.0	.	2.5	.	19.3	.	0.2	.	7.7	.	12.8	.
	21-May-13	1	1.6	.	0.7	.	2.9	.	0.2	.	5.6	.	0.2	.
	28-May-13	1	11.8	.	3.4	.	4.4	.	0.6	.	3.8	.	0.1	.
	27-May-15	6	1.5	0.3	0.9	0.4	2.0	0.5	0.0	0.0	10.5	2.0	0.0	0.0
Grand	23-May-14	8	0.3	0.1	0.9	0.2	10.4	4.6	0.5	0.3	9.2	1.8	0.3	0.1
	5-Jun-14	5	9.4	3.2	0.6	0.1	2.1	0.2	0.6	0.3	26.1	2.6	12.3	0.7
	11-Jun-15	9	11.2	2.1	0.6	0.2	1.8	0.3	0.1	0.0	2.6	0.4	0.0	0.0
Higgins	9-Jun-15	12	1.2	0.6	0.3	0.2	1.1	0.3	0.1	0.1	2.2	1.1	0.0	0.0
Houghtor	20-May-15	12	6.7	1.1	0.7	0.1	6.2	1.1	0.7	0.1	9.6	2.0	0.3	0.0
	21-May-15	12	24.6	3.7	0.7	0.1	6.1	1.6	0.3	0.1	9.0	1.5	0.0	0.0
	27-May-15	9	72.9	22.4	3.5	0.8	14.3	2.1	1.4	0.6	14.0	4.5	0.0	0.0
Hubbard	6-Jun-14	5	0.4	0.2	0.4	0.2	0.1	0.1	0.7	0.3	6.4	1.8	0.1	0.0
	19-Jun-14	13	0.0	0.0	0.7	0.1	0.2	0.1	0.3	0.1	1.8	0.4	0.1	0.0
Lansing	30-Apr-14	4	10.3	4.3	6.8	2.6	12.4	4.4	2.5	1.3	24.3	8.9	0.0	0.0
	6-May-14	5	24.5	10.4	12.3	3.8	20.8	9.2	1.1	0.6	76.6	34.9	0.0	0.0
	16-May-14	4	67.0	18.7	38.2	17.4	31.3	6.7	5.3	1.9	83.0	14.2	6.1	2.9
	27-May-14	8	65.8	19.5	8.0	1.3	13.8	1.9	3.5	0.8	48.3	10.6	5.4	1.6
	7-May-15	9	62.3	8.8	23.6	3.2	25.6	3.1	1.7	0.5	39.4	7.0	0.9	0.2
	13-May-15	11	42.9	7.4	11.1	2.0	9.5	1.4	3.0	0.3	16.4	2.1	0.0	0.0
	19-May-15	9	67.4	14.8	16.3	2.3	15.9	3.1	6.2	1.7	5.7	0.8	0.3	0.1
Lobdell	11-May-14	3	24.8	10.8	2.6	1.7	68.8	15.0	1.3	0.2	148.6	30.5	9.1	4.0
Long	24-May-14	5	0.7	0.1	1.1	0.3	2.3	0.5	0.1	0.0	5.7	1.4	0.0	0.0
	5-Jun-14	6	1.0	0.3	2.5	1.0	1.2	0.5	0.1	0.1	2.8	0.3	2.8	0.9
	28-May-15	9	1.2	0.4	1.2	0.2	1.2	0.3	0.0	0.0	4.7	0.8	0.2	0.0

Table A1 cont.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Mullett	2-Jun-11	1	29.3	.	0.3	.	3.4	.	0.0	.	8.8	.	1.0	.
	12-Jun-11	1	18.8	.	0.0	.	4.4	.	0.2	.	17.6	.	2.6	.
	19-May-12	1	31.5	.	0.2	.	2.2	.	0.0	.	2.4	.	0.1	.
	31-May-12	1	2.7	.	0.3	.	2.2	.	0.1	.	4.0	.	5.6	.
	5-Jun-12	2	6.3	1.1	0.7	0.0	5.4	2.9	0.2	0.2	8.3	6.8	5.3	3.2
	15-May-13	1	0.2	.	0.2	.	0.7	.	0.0	.	0.9	.	0.2	.
	24-May-13	2	1.6	1.2	0.5	0.3	3.6	1.5	0.1	0.1	5.5	2.3	0.4	0.0
Ovid	6-May-14	5	72.4	21.6	13.5	5.8	27.1	4.2	4.2	1.4	49.5	13.9	7.4	6.2
	17-May-14	6	188.4	43.7	5.5	2.0	85.2	20.7	6.1	3.1	96.8	12.3	22.0	10.8
	30-Apr-15	12	258.5	51.7	22.8	6.6	114.1	21.3	3.7	1.1	133.0	22.9	0.0	0.0
	12-May-15	6	141.3	34.3	12.0	3.5	83.8	21.0	13.1	4.7	100.3	28.7	0.8	0.1
	14-May-15	15	216.5	35.9	27.4	4.5	102.0	14.7	4.7	1.2	262.6	46.4	0.0	0.0
Park	25-Apr-14	2	39.2	10.2	0.0	0.0	93.9	4.0	1.8	1.8	401.4	1.1	0.0	0.0
	5-May-14	5	15.2	11.3	0.8	0.5	66.6	26.9	0.7	0.4	125.2	62.9	0.0	0.0
	8-May-14	5	78.6	28.3	0.3	0.2	70.3	11.1	2.8	1.3	125.8	42.4	1.6	0.9
	12-May-14	5	113.1	58.9	0.4	0.3	58.9	12.2	0.9	0.4	120.1	26.9	4.5	1.1
	28-May-14	6	105.8	14.2	1.2	0.5	83.2	9.1	15.5	3.7	177.8	20.8	6.5	1.2
	28-Apr-15	9	43.4	21.0	2.9	1.1	53.5	22.2	1.7	0.6	131.9	46.4	0.0	0.0
	13-May-15	9	116.4	18.0	7.9	1.3	42.3	3.8	18.0	4.1	93.7	13.5	0.0	0.0
	19-May-15	6	179.4	44.0	13.5	3.7	31.0	8.2	19.5	5.1	20.4	4.1	0.7	0.1
	1-Jun-15	6	82.4	12.2	20.2	7.0	22.9	4.4	49.1	12.2	24.0	4.8	0.0	0.0
Pickerel	7-May-11	1	1.5	.	0.6	.	5.6	.	0.0	.	7.9	.	0.1	.
	17-May-11	1	1.8	.	0.2	.	9.4	.	0.0	.	14.4	.	0.4	.
	3-Jun-11	1	1.6	.	0.4	.	3.3	.	0.0	.	7.0	.	0.1	.
	9-May-12	1	0.7	.	0.7	.	4.9	.	0.0	.	1.9	.	0.0	.
	21-May-12	1	9.6	.	0.9	.	6.4	.	0.0	.	3.0	.	0.6	.
	3-Jun-12	1	2.0	.	4.8	.	1.7	.	0.0	.	2.3	.	0.7	.

Table A1 cont.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Pickerel	6-May-13	1	0.4	.	0.0	.	1.1	.	0.1	.	3.5	.	0.4	.
	13-May-13	1	1.6	.	0.3	.	8.9	.	0.0	.	6.4	.	0.0	.
	20-May-13	1	1.9	.	0.5	.	15.8	.	0.0	.	17.4	.	0.2	.
	27-May-13	1	1.6	.	0.1	.	4.9	.	0.0	.	10.2	.	0.1	.
	27-May-15	6	3.9	1.2	0.2	0.1	1.6	0.6	0.0	0.0	4.4	1.8	0.0	0.0

Table A2. Proportions of available zooplankton prey (P_i) by taxa for eutrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	Bosmina	Calanoid	Cyclopoid	Daphnia	Nauplii	Other
Houghton	20-May-15	0.285	0.029	0.253	0.030	0.403	0.001
	21-May-15	0.614	0.018	0.137	0.007	0.220	0.004
	27-May-15	0.686	0.031	0.131	0.015	0.133	0.004
Lobdell	11-May-14	0.099	0.009	0.268	0.005	0.580	0.038
Ovid	6-May-14	0.382	0.080	0.159	0.023	0.310	0.045
	17-May-14	0.452	0.014	0.198	0.016	0.257	0.062
	30-Apr-15	0.488	0.039	0.214	0.007	0.252	0.000
	12-May-15	0.395	0.037	0.236	0.035	0.295	0.001
	14-May-15	0.370	0.045	0.171	0.008	0.407	0.000
Mean proportion		0.421	0.039	0.192	0.013	0.319	0.016
Min		0.099	0.009	0.131	0.005	0.133	0.000
Max		0.686	0.080	0.268	0.035	0.580	0.062

Table A3. Proportions of available zooplankton prey (P_i) by taxa for mesotrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	Bosmina	Calanoid	Cyclopoid	Daphnia	Nauplii	Other
Black	4-Jun-14	0.013	0.217	0.146	0.006	0.617	0.001
	18-Jun-14	0.006	0.155	0.143	0.024	0.567	0.105
	28-May-15	0.061	0.236	0.233	0.008	0.459	0.003
	4-Jun-15	0.009	0.001	0.014	0.001	0.975	0.000
	5-Jun-15	0.072	0.006	0.062	0.002	0.857	0.000
Crooked	5-May-11	0.196	0.032	0.399	0.002	0.371	0.000
	16-May-11	0.075	0.007	0.228	0.002	0.591	0.096
	6-Jun-11	0.218	0.046	0.437	0.011	0.287	0.000
	13-Apr-12	0.206	0.022	0.552	0.000	0.220	0.000
	14-May-12	0.074	0.000	0.000	0.000	0.556	0.370
	22-May-12	0.121	0.037	0.199	0.000	0.094	0.550
	30-May-12	0.020	0.091	0.352	0.003	0.123	0.410
	7-May-13	0.112	0.064	0.130	0.002	0.666	0.026
	14-May-13	0.206	0.047	0.361	0.004	0.144	0.238
	21-May-13	0.148	0.061	0.257	0.017	0.504	0.013
	28-May-13	0.490	0.139	0.183	0.024	0.159	0.005
	27-May-15	0.102	0.058	0.136	0.001	0.704	0.000
Grand	23-May-14	0.020	0.044	0.442	0.019	0.461	0.014
	5-Jun-14	0.169	0.012	0.040	0.011	0.520	0.248
	11-Jun-15	0.694	0.041	0.105	0.004	0.155	0.000
Lansing	30-Apr-14	0.188	0.122	0.217	0.046	0.427	0.000
	6-May-14	0.188	0.100	0.165	0.008	0.540	0.000
	16-May-14	0.278	0.174	0.133	0.025	0.360	0.029
	27-May-14	0.415	0.064	0.112	0.030	0.341	0.039
	7-May-15	0.407	0.156	0.170	0.011	0.256	0.001
	13-May-15	0.520	0.134	0.112	0.036	0.197	0.000
	19-May-15	0.606	0.148	0.139	0.054	0.051	0.001
Long	24-May-14	0.061	0.117	0.241	0.007	0.572	0.001
	5-Jun-14	0.090	0.219	0.096	0.006	0.289	0.300
	28-May-15	0.139	0.136	0.156	0.000	0.567	0.001
Park	25-Apr-14	0.075	0.000	0.174	0.003	0.748	0.000
	5-May-14	0.052	0.003	0.347	0.003	0.595	0.000
	8-May-14	0.248	0.002	0.283	0.009	0.452	0.007
	12-May-14	0.326	0.002	0.236	0.003	0.416	0.017
	28-May-14	0.284	0.003	0.212	0.041	0.444	0.016
	28-Apr-15	0.185	0.013	0.234	0.007	0.560	0.000
	13-May-15	0.422	0.029	0.154	0.067	0.328	0.000
	19-May-15	0.674	0.051	0.122	0.072	0.080	0.001
	1-Jun-15	0.419	0.099	0.114	0.243	0.125	0.000
Mean Proportion		0.298	0.049	0.191	0.032	0.414	0.017
Min		0.006	0.000	0.000	0.000	0.051	0.000
Max		0.694	0.236	0.552	0.243	0.975	0.550

Table A4. Proportions of available zooplankton prey (P_i) by taxa for oligotrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	Bosmina	Calanoid	Cyclopoid	Daphnia	Nauplii	Other
Burt	21-May-11	0.006	0.014	0.023	0.000	0.957	0.000
	4-Jun-11	0.949	0.005	0.008	0.012	0.025	0.001
	10-Jun-11	0.105	0.113	0.052	0.115	0.461	0.153
	8-May-12	0.292	0.086	0.242	0.049	0.331	0.000
	18-May-12	0.228	0.142	0.172	0.007	0.446	0.007
	31-May-12	0.075	0.471	0.107	0.031	0.261	0.054
	6-Jun-12	0.100	0.156	0.064	0.317	0.310	0.053
	8-May-13	0.121	0.034	0.155	0.028	0.459	0.203
	22-May-13	0.101	0.041	0.135	0.020	0.662	0.041
	31-May-13	0.255	0.027	0.191	0.055	0.373	0.100
	28-May-15	0.386	0.132	0.112	0.015	0.355	0.000
	6-Jun-15	0.074	0.058	0.033	0.022	0.804	0.009
Higgins	9-Jun-15	0.262	0.065	0.272	0.023	0.378	0.000
Hubbard	6-Jun-14	0.026	0.056	0.006	0.144	0.764	0.003
	19-Jun-14	0.010	0.295	0.054	0.162	0.453	0.027
Mullett	2-Jun-11	0.686	0.006	0.080	0.000	0.205	0.022
	12-Jun-11	0.433	0.000	0.100	0.004	0.405	0.059
	19-May-12	0.865	0.006	0.061	0.000	0.066	0.003
	31-May-12	0.185	0.020	0.145	0.009	0.267	0.375
	5-Jun-12	0.244	0.026	0.208	0.006	0.313	0.203
	15-May-13	0.105	0.070	0.316	0.018	0.421	0.070
	24-May-13	0.146	0.044	0.320	0.011	0.445	0.033
Pickerel	7-May-11	0.095	0.036	0.360	0.000	0.505	0.004
	17-May-11	0.069	0.009	0.358	0.000	0.548	0.016
	3-Jun-11	0.125	0.035	0.269	0.000	0.561	0.010
	9-May-12	0.089	0.081	0.599	0.000	0.229	0.002
	21-May-12	0.470	0.044	0.314	0.000	0.144	0.029
	3-Jun-12	0.172	0.420	0.151	0.000	0.197	0.061
	6-May-13	0.078	0.000	0.203	0.013	0.634	0.072
	13-May-13	0.093	0.017	0.517	0.000	0.373	0.000
	20-May-13	0.054	0.014	0.441	0.000	0.486	0.005
	27-May-13	0.097	0.006	0.291	0.000	0.600	0.006
	27-May-15	0.363	0.023	0.171	0.002	0.441	0.000
Mean proportion		0.325	0.092	0.153	0.085	0.294	0.052
Min		0.006	0.000	0.006	0.000	0.025	0.000
Max		0.949	0.471	0.599	0.317	0.957	0.375

Table A5. Proportions of available zooplankton prey (P_i) by size for eutrophic systems with mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	<0.2	0.2 to <0.4	0.4 to < 0.6	0.6 to <0.8	0.8 to < 1.0	> 1.0
Houghton	20-May-15	0.128	0.335	0.212	0.133	0.089	0.103
	21-May-15	0.149	0.453	0.204	0.104	0.040	0.050
	27-May-15	0.056	0.392	0.231	0.091	0.035	0.168
Lobdell	11-May-14	0.186	0.443	0.250	0.050	0.021	0.050
Ovid	6-May-14	0.112	0.438	0.225	0.101	0.047	0.078
	17-May-14	0.174	0.467	0.217	0.069	0.051	0.022
	30-Apr-15	0.145	0.297	0.203	0.192	0.070	0.093
	12-May-15	0.108	0.314	0.265	0.196	0.049	0.069
	14-May-15	0.073	0.462	0.251	0.120	0.047	0.047
Mean Proportion		0.119	0.404	0.230	0.130	0.053	0.065
Min		0.056	0.297	0.203	0.050	0.021	0.022
Max		0.186	0.467	0.265	0.196	0.089	0.168

Table A6. Proportions of available zooplankton prey (P_i) by size for mesotrophic systems with mean, minimum (Min), and maximum

Lake	Date	<0.2	0.2 to <0.4	0.4 to <0.6	0.6 to <0.8	0.8 to < 1.0	> 1.0
Black	4-Jun-14	0.131	0.407	0.312	0.090	0.045	0.015
	18-Jun-14	0.236	0.297	0.241	0.130	0.061	0.034
	28-May-15	0.108	0.309	0.223	0.165	0.094	0.094
	4-Jun-15	0.108	0.477	0.215	0.092	0.062	0.046
	5-Jun-15	0.106	0.532	0.206	0.078	0.043	0.035
Crooked	5-May-11	0.122	0.341	0.268	0.122	0.122	0.024
	16-May-11	0.250	0.227	0.295	0.205	0.023	
	6-Jun-11	0.273	0.455	0.212		0.030	0.030
	13-Apr-12	0.242	0.273	0.364	0.030	0.061	0.030
	14-May-12	0.682	0.227	0.091			
	22-May-12	0.380	0.180	0.220	0.100	0.100	0.020
	30-May-12	0.340	0.255	0.170	0.170	0.043	0.021
	7-May-13	0.314	0.294	0.255	0.078	0.020	0.039
	14-May-13	0.250	0.269	0.154	0.231	0.038	0.038
	21-May-13	0.213	0.468	0.234	0.064	0.021	
	28-May-13	0.196	0.478	0.196	0.022		0.109
	27-May-15	0.207	0.428	0.192	0.087	0.072	0.014
Grand	23-May-14	0.196	0.375	0.313	0.065	0.034	0.017
	5-Jun-14	0.263	0.462	0.155	0.064	0.036	0.020
	11-Jun-15	0.117	0.425	0.142	0.175	0.075	0.067
Lansing	30-Apr-14	0.071	0.331	0.233	0.184	0.083	0.098
	6-May-14	0.171	0.343	0.217	0.144	0.080	0.046
	16-May-14	0.158	0.357	0.194	0.122	0.102	0.066
	27-May-14	0.223	0.372	0.215	0.102	0.045	0.045
	7-May-15	0.128	0.378	0.243	0.128	0.068	0.054
	13-May-15	0.107	0.390	0.181	0.160	0.088	0.074
	19-May-15	0.152	0.331	0.232	0.126	0.106	0.053
Long	24-May-14	0.087	0.377	0.290	0.126	0.048	0.072
	5-Jun-14	0.240	0.434	0.181	0.073	0.024	0.049
	28-May-15	0.092	0.447	0.296	0.092	0.013	0.059
Park	25-Apr-14	0.350	0.273	0.203	0.147	0.021	0.007
	5-May-14	0.230	0.358	0.236	0.109	0.058	0.010
	8-May-14	0.154	0.521	0.183	0.089	0.041	0.012
	12-May-14	0.180	0.438	0.230	0.124	0.017	0.011
	28-May-14	0.149	0.521	0.260	0.058	0.012	
	28-Apr-15	0.092	0.517	0.254	0.095	0.025	0.016
	13-May-15	0.140	0.379	0.228	0.148	0.068	0.037
	19-May-15	0.157	0.255	0.216	0.167	0.059	0.147
	1-Jun-15	0.130	0.460	0.170	0.050	0.060	0.130
Mean Proportion	0.168	0.405	0.223	0.115	0.049	0.039	
Min	0.071	0.180	0.091	0.022	0.012	0.007	
Max	0.682	0.532	0.364	0.231	0.122	0.147	

(Max) proportion.

Table A7. Proportions of available zooplankton prey (P_i) by size for oligotrophic systems with mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	<0.2	0.2 to <0.4	0.4 to < 0.6	0.6 to <0.8	0.8 to < 1.0	> 1.0
Burt	21-May-11	0.077	0.423	0.269	0.038		0.192
	4-Jun-11	0.067	0.350	0.217	0.317	0.050	
	10-Jun-11	0.217	0.300	0.150	0.150	0.117	0.067
	8-May-12	0.120	0.280	0.220	0.180	0.180	0.020
	18-May-12	0.159	0.295	0.273	0.159	0.114	
	31-May-12	0.291	0.255	0.255	0.200		
	6-Jun-12	0.194	0.339	0.185	0.169	0.065	0.048
	8-May-13	0.283	0.250	0.233	0.150	0.050	0.033
	22-May-13	0.178	0.289	0.267	0.178	0.067	0.022
	31-May-13	0.245	0.347	0.122	0.163	0.041	0.082
	28-May-15	0.236	0.382	0.163	0.098	0.065	0.057
	6-Jun-15	0.109	0.327	0.178	0.178	0.129	0.079
Higgins	9-Jun-15	0.147	0.420	0.156	0.183	0.054	0.040
Hubbard	6-Jun-14	0.030	0.418	0.149	0.097	0.030	0.276
	19-Jun-14	0.080	0.463	0.220	0.036	0.034	0.168
Mullett	2-Jun-11	0.189	0.378	0.270	0.108	0.027	0.027
	12-Jun-11	0.395	0.372	0.070	0.070	0.023	0.070
	19-May-12	0.121	0.515	0.152	0.061	0.091	0.061
	31-May-12	0.275	0.431	0.118	0.059	0.078	0.039
	5-Jun-12	0.254	0.377	0.217	0.058	0.051	0.043
	15-May-13	0.257	0.457	0.114	0.114		0.057
	24-May-13	0.320	0.267	0.133	0.160	0.080	0.040
Pickerel	7-May-11	0.077	0.436	0.282	0.154	0.051	
	17-May-11	0.180	0.311	0.197	0.230	0.049	0.033
	3-Jun-11	0.116	0.419	0.256	0.163	0.047	0.000
	9-May-12	0.227	0.341	0.227	0.023	0.068	0.114
	21-May-12	0.200	0.387	0.253	0.080		0.080
	3-Jun-12	0.240	0.520	0.120	0.020	0.100	
	6-May-13	0.186	0.419	0.233	0.163		
	13-May-13	0.219	0.406	0.125	0.125	0.063	0.063
	20-May-13	0.189	0.486	0.243	0.054		0.027
	27-May-13	0.250	0.438	0.281	0.031		
	27-May-15	0.123	0.548	0.274	0.014	0.041	
Mean proportion		0.181	0.395	0.189	0.109	0.065	0.059
Min		0.030	0.250	0.070	0.014	0.023	0.000
Max		0.395	0.548	0.282	0.317	0.180	0.276

Table A8. Number of fish processed (N) per lake-day sampling event with number of empty larval stomachs, mean total length (TL), standard error (SE) of total length, minimum size of larvae (Min), and maximum length of larvae (Max).

Lake	Date	N	Empty	TL	SE	Min	Max
Black	4-Jun-14	13	8	6.9	0.5	4.8	10.3
	18-Jun-14	15	0	5.0	0.1	4.4	5.6
	28-May-15	28	0	9.5	0.3	6.9	14.1
	4-Jun-15	4	0	14.5	0.3	14.0	15.5
	5-Jun-15	9	0	9.6	1.0	5.5	14.0
Burt	21-May-11	5	0	7.1	0.2	6.6	7.4
	4-Jun-11	5	0	14.4	0.8	13.2	17.5
	10-Jun-11	5	0	16.2	0.3	15.4	17.1
	8-May-12	5	0	8.1	0.3	7.2	8.9
	18-May-12	5	0	10.6	0.4	9.5	12.2
	31-May-12	5	0	13.9	0.9	12.1	16.9
	6-Jun-12	9	0	17.3	1.2	11.6	21.1
	8-May-13	3	2	5.2	0.1	5.0	5.4
	22-May-13	5	1	7.9	0.5	6.7	9.2
	31-May-13	5	0	11.9	1.1	8.7	14.7
	28-May-15	21	3	7.2	0.3	4.7	10.8
	6-Jun-15	4	0	12.3	2.2	5.9	15.7
	Crooked	5-May-11	5	5	6.2	0.3	5.0	6.5
16-May-11		5	1	7.2	0.4	5.7	8.3
6-Jun-11		5	0	7.5	0.8	5.4	9.7
13-Apr-12		5	3	6.7	0.1	6.3	7.0
14-May-12		5	0	9.9	0.5	8.2	10.8
22-May-12		4	0	14.2	0.5	12.8	15.1
30-May-12		4	0	16.4	0.7	15.1	17.7

Table A8 cont.

Lake	Date	N	Empty	TL	SE	Min	Max
Crooked	7-May-13	5	1	6.9	0.1	6.4	7.2
	14-May-13	5	0	8.0	0.3	7.2	8.8
	21-May-13	5	0	9.2	0.6	7.4	11.2
	28-May-13	5	0	11.8	1.8	5.6	15.5
	27-May-15	20	8	5.9	0.2	4.8	8.3
Grand	23-May-14	31	0	8.4	0.1	7.6	9.3
	5-Jun-14	22	4	9.2	0.7	4.2	15.5
	11-Jun-15	27	0	8.1	0.3	4.5	12.8
Higgins	9-Jun-15	40	1	9.4	0.3	4.5	11.9
Houghton	20-May-15	10	2	7.8	1.1	4.9	13.0
	21-May-15	17	1	9.3	0.7	5.0	13.3
	27-May-15	31	0	13.4	0.5	7.7	17.2
Hubbard	6-Jun-14	7	4	9.5	0.7	7.2	12.1
	19-Jun-14	4	1	15.3	1.6	12.4	19.5
Lansing	30-Apr-14	21	16	6.6	0.1	5.7	7.5
	6-May-14	20	2	7.4	0.1	6.5	8.8
	16-May-14	13	4	7.1	0.4	5.0	8.9
	27-May-14	18	4	7.6	0.5	4.9	12.2
	7-May-15	18	6	6.0	0.3	4.7	9.7
	13-May-15	28	5	7.2	0.4	4.7	13.1
	19-May-15	17	1	8.5	0.4	6.2	11.4
Lobdell	11-May-14	6	2	5.8	0.5	4.7	8.0
Long	24-May-14	18	7	7.1	0.3	5.3	8.7
	5-Jun-14	30	0	9.4	0.5	6.4	15.3
	28-May-15	24	0	9.1	0.5	5.4	13.5

Table A8 cont.

Lake	Date	N	Empty	TL	SE	Min	Max
Mullett	2-Jun-11	5	0	9.3	0.6	7.0	10.6
	12-Jun-11	5	0	13.7	0.8	12.0	15.9
	19-May-12	5	0	9.1	0.6	7.2	10.2
	31-May-12	5	0	12.8	0.6	11.1	14.9
	5-Jun-12	10	0	14.3	0.6	10.7	16.3
	15-May-13	1	0	7.8	.	7.8	7.8
	24-May-13	9	5	7.7	0.5	5.1	9.9
	Ovid	6-May-14	21	0	8.1	0.1	7.5	9.1
17-May-14		3	0	7.0	0.2	6.7	7.5
30-Apr-15		18	1	7.4	0.2	6.3	8.4
12-May-15		11	1	7.3	0.4	5.9	9.7
14-May-15		28	3	7.8	0.2	6.2	10.5
Park	25-Apr-14	8	1	7.0	0.1	6.5	7.3
	5-May-14	13	4	6.3	0.4	4.8	8.7
	8-May-14	25	3	7.1	0.3	4.7	9.6
	12-May-14	25	3	7.0	0.2	5.6	10.2
	28-May-14	26	2	9.9	0.6	4.8	13.9
	28-Apr-15	30	1	7.1	0.1	6.0	8.3
	13-May-15	30	1	8.7	0.3	6.6	13.8
	19-May-15	20	0	9.4	0.5	6.1	14.4
	1-Jun-15	20	0	10.0	0.5	6.3	13.2
Pickereel	7-May-11	5	2	6.5	0.1	6.2	6.7
	17-May-11	5	0	7.3	0.2	6.6	8.1
	3-Jun-11	5	0	15.7	0.4	14.8	16.7
	9-May-12	5	0	8.9	0.1	8.4	9.2
	21-May-12	5	0	14.6	0.5	13.1	15.5
	3-Jun-12	1	0	20.4	.	20.4	20.4

Table A8 cont.

Lake	Date	N	Empty	TL	SE	Min	Max
Pickereel	6-May-13	5	3	6.1	0.3	5.2	6.6
	13-May-13	5	1	7.2	0.3	6.3	8.0
	20-May-13	5	0	11.1	0.1	10.8	11.6
	27-May-13	5	0	13.8	0.2	13.2	14.4
	27-May-15	17	3	5.5	0.2	4.2	6.8

Table A9. Mean number of major zooplankton taxa groups per larval gut by date with Standard Error (SE) of the mean, and number of samples collected and analyzed (N) for each lake-day sampling event.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other		
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Black	4-Jun-14	13	0.0	0.0	0.0	0.0	0.5	0.5	0.1	0.1	0.4	0.2	0.0	0.0	
	18-Jun-14	15	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	5.1	1.0	3.3	1.8	
	28-May-15	28	0.0	0.0	3.2	0.5	3.8	0.8	0.1	0.1	2.3	0.6	0.1	0.1	
	4-Jun-15	4	0.3	0.3	0.0	0.0	1.0	1.0	0.0	0.0	132.8	33.8	0.0	0.0	
	5-Jun-15	9	1.0	0.5	0.1	0.1	1.9	0.8	0.0	0.0	14.7	6.0	0.1	0.1	
Burt	21-May-11	5	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.8	0.2	0.0	0.0	
	4-Jun-11	5	2.2	1.5	2.8	1.0	37.0	8.3	0.0	0.0	0.4	0.4	0.0	0.0	
	10-Jun-11	5	19.2	4.8	3.0	0.7	2.8	1.7	2.6	1.1	0.0	0.0	0.0	0.0	
	8-May-12	5	0.0	0.0	0.2	0.2	6.2	2.0	0.0	0.0	4.6	1.5	0.0	0.0	
	18-May-12	5	0.0	0.0	0.8	0.5	7.6	2.2	0.0	0.0	0.8	0.8	0.0	0.0	
	31-May-12	5	0.4	0.2	63.8	22.4	31.6	8.4	1.8	0.9	5.8	0.6	0.0	0.0	
	6-Jun-12	9	7.8	2.1	13.6	4.0	12.4	3.0	7.4	1.6	0.0	0.0	1.3	0.8	
	8-May-13	3	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.3	0.0	0.0	
	22-May-13	5	0.0	0.0	0.4	0.4	3.4	2.9	0.0	0.0	4.6	3.6	0.0	0.0	
	31-May-13	5	3.2	1.8	0.2	0.2	11.8	5.2	0.0	0.0	2.8	1.5	0.0	0.0	
	28-May-15	21	0.0	0.0	0.2	0.1	1.1	0.3	0.0	0.0	0.5	0.1	0.1	0.1	
	6-Jun-15	4	2.3	1.1	3.5	2.1	5.8	2.4	0.0	0.0	2.5	1.7	0.3	0.3	
	Crooked	5-May-11	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		16-May-11	5	0.0	0.0	0.0	0.0	9.4	3.2	0.0	0.0	2.8	1.2	0.0	0.0
6-Jun-11		5	0.0	0.0	0.0	0.0	32.6	12.3	0.0	0.0	10.2	3.1	0.0	0.0	
13-Apr-12		5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	
14-May-12		5	0.6	0.4	1.6	0.8	12.4	3.1	0.2	0.2	1.2	0.5	0.6	0.6	
22-May-12		4	9.3	4.6	5.8	2.2	25.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	
30-May-12		4	2.3	1.4	0.5	0.5	1.5	1.0	4.3	3.0	0.0	0.0	0.0	0.0	

Table A9 cont.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Crooked	7-May-13	5	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	4.6	1.5	0.0	0.0
	14-May-13	5	0.0	0.0	0.0	0.0	2.0	0.6	0.0	0.0	2.4	0.8	0.0	0.0
	21-May-13	5	0.4	0.4	0.2	0.2	2.6	0.5	0.2	0.2	0.8	0.4	0.0	0.0
	28-May-13	5	14.0	3.9	3.0	1.1	10.0	6.1	0.0	0.0	3.2	2.7	0.2	0.2
	27-May-15	20	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.2	0.1
Grand	23-May-14	31	0.0	0.0	0.1	0.1	8.7	0.9	0.0	0.0	6.9	1.0	0.1	0.0
	5-Jun-14	22	2.5	1.1	0.0	0.0	1.2	0.5	0.1	0.1	1.1	0.3	1.8	0.8
	11-Jun-15	27	0.7	0.2	0.2	0.1	2.4	0.3	0.0	0.0	1.4	0.4	0.2	0.1
Higgins	9-Jun-15	40	0.0	0.0	0.5	0.1	14.7	1.4	0.0	0.0	0.8	0.2	0.0	0.0
Houghton	20-May-15	10	0.7	0.5	0.3	0.3	7.1	3.0	0.2	0.2	1.4	0.8	0.1	0.1
	21-May-15	17	9.7	4.6	0.9	0.5	9.4	3.4	0.3	0.2	1.4	0.4	9.5	5.1
	27-May-15	31	4.4	1.4	5.9	1.1	23.0	3.0	0.5	0.2	0.0	0.0	0.4	0.2
Hubbard	6-Jun-14	7	0.0	0.0	0.4	0.3	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0
	19-Jun-14	4	0.3	0.3	0.3	0.3	0.0	0.0	2.5	0.9	0.0	0.0	0.0	0.0
Lansing	30-Apr-14	21	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.9	0.6	0.0	0.0
	6-May-14	20	0.0	0.0	0.2	0.1	0.7	0.2	0.0	0.0	2.5	0.5	0.0	0.0
	16-May-14	13	0.1	0.1	0.0	0.0	1.0	0.4	0.0	0.0	2.3	0.8	0.0	0.0
	27-May-14	18	1.4	0.8	0.4	0.3	2.4	1.0	0.1	0.1	4.6	1.1	0.3	0.3
	7-May-15	18	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	1.6	0.4	0.0	0.0
	13-May-15	28	0.1	0.1	0.1	0.1	0.6	0.2	0.0	0.0	3.0	0.6	0.0	0.0
	19-May-15	17	1.2	0.5	0.9	0.3	6.7	1.0	0.2	0.1	1.8	0.5	0.2	0.1
	11-May-14	6	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	2.7	1.4	0.2	0.2
	Long	24-May-14	18	0.1	0.1	0.0	0.0	1.6	0.4	0.0	0.0	0.7	0.2	0.0	0.0
5-Jun-14		30	4.5	1.0	2.7	0.9	2.4	0.5	0.0	0.0	3.9	1.1	3.6	1.3
28-May-15		24	1.7	0.5	1.4	0.4	4.7	0.7	0.0	0.0	18.1	3.0	0.0	0.0

Table A9 cont.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Mullett	2-Jun-11	5	2.8	1.9	0.0	0.0	25.8	9.0	0.0	0.0	0.8	0.5	0.0	0.0
	12-Jun-11	5	0.4	0.2	6.0	3.7	18.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0
	19-May-12	5	0.2	0.2	0.0	0.0	14.0	3.8	0.0	0.0	6.0	2.1	0.0	0.0
	31-May-12	5	4.6	1.8	1.0	0.3	3.2	2.7	0.0	0.0	0.0	0.0	0.0	0.0
	5-Jun-12	10	4.7	1.5	2.5	1.2	11.0	3.2	0.3	0.2	0.8	0.4	0.2	0.2
	15-May-13	1	0.0	.	0.0	.	1.0	.	0.0	.	3.0	.	0.0	0.0
	24-May-13	9	0.0	0.0	0.1	0.1	1.9	1.1	0.0	0.0	1.7	1.3	0.0	0.0
Ovid	6-May-14	21	0.2	0.1	1.1	0.3	4.4	0.7	0.0	0.0	4.9	1.1	0.0	0.0
	17-May-14	3	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	3.3	1.5	0.3	0.3
	30-Apr-15	18	0.0	0.0	0.0	0.0	1.3	0.3	0.0	0.0	5.4	0.8	0.0	0.0
	12-May-15	11	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	1.2	0.4	0.0	0.0
	14-May-15	28	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	2.8	0.4	0.0	0.0
Park	25-Apr-14	8	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	4.9	1.5	0.3	0.3
	5-May-14	13	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	2.3	0.9	0.0	0.0
	8-May-14	25	0.0	0.0	0.2	0.2	2.8	0.9	0.0	0.0	3.1	0.5	0.0	0.0
	12-May-14	25	0.0	0.0	0.0	0.0	0.8	0.2	0.0	0.0	5.4	0.8	0.0	0.0
	28-May-14	26	0.5	0.2	0.1	0.1	5.0	1.2	0.3	0.2	1.6	0.5	0.0	0.0
	28-Apr-15	30	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	10.5	1.3	0.0	0.0
	13-May-15	30	0.0	0.0	0.0	0.0	1.2	0.3	0.2	0.1	8.7	1.1	0.1	0.1
	19-May-15	20	2.6	0.9	0.2	0.1	2.8	0.7	0.3	0.1	4.0	1.1	0.6	0.4
	1-Jun-15	20	3.1	0.8	0.8	0.2	1.0	0.3	1.9	0.5	2.3	0.9	0.7	0.4
Pickereel	7-May-11	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.6	0.0	0.0
	17-May-11	5	0.0	0.0	0.0	0.0	9.2	1.9	0.0	0.0	8.2	3.5	0.2	0.2
	3-Jun-11	5	34.2	7.6	15.6	1.3	69.0	9.0	0.0	0.0	6.6	4.9	1.2	1.2
	9-May-12	5	0.4	0.4	0.0	0.0	13.0	0.5	0.0	0.0	7.0	2.1	0.2	0.2
	21-May-12	5	10.6	7.1	2.4	0.8	28.4	7.6	0.0	0.0	4.4	2.9	0.0	0.0
	3-Jun-12	1	64.0	.	3.0	.	8.0	.	4.0	.	0.0	.	0.0	0.0

Table A9 cont.

Lake	Date	N	Bosmina		Calanoid		Cyclopoid		Daphnia		Nauplii		Other	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Pickereel	6-May-13	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0
	13-May-13	5	0.0	0.0	0.0	0.0	1.6	0.6	0.0	0.0	0.4	0.4	0.0	0.0
	20-May-13	5	0.2	0.2	0.4	0.4	6.8	1.4	0.0	0.0	0.2	0.2	0.0	0.0
	27-May-13	5	5.0	1.8	0.2	0.2	4.8	1.2	0.0	0.0	0.4	0.2	1.2	0.7
	27-May-15	17	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	3.2	0.8	0.1	0.1

Table A10. Average proportion of zooplankton prey (P_i) taxa per larval gut by lake-day combo for eutrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	Bosmina	Calanoid	Cyclopoid	Daphnia	Nauplii	Other
Houghton	20-May-15	0.072	0.031	0.732	0.021	0.144	0.000
	21-May-15	0.311	0.030	0.302	0.009	0.043	0.304
	27-May-15	0.129	0.172	0.672	0.014	0.000	0.012
Lobdell	11-May-14	0.000	0.000	0.105	0.000	0.842	0.053
Ovid	6-May-14	0.018	0.104	0.416	0.000	0.462	0.000
	17-May-14	0.000	0.000	0.083	0.000	0.833	0.083
	30-Apr-15	0.000	0.000	0.198	0.000	0.802	0.000
	12-May-15	0.000	0.000	0.458	0.000	0.542	0.000
	14-May-15	0.057	0.000	0.034	0.011	0.898	0.000
Mean proportion		0.065	0.037	0.333	0.006	0.507	0.050
Min		0.000	0.000	0.034	0.000	0.000	0.000
Max		0.311	0.172	0.732	0.021	0.898	0.304

Table A11. Average proportion of zooplankton prey (Pi) taxa per larval gut by lake-day combo for mesotrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	Bosmina	Calanoid	Cyclopoid	Daphnia	Nauplii	Other	
Black	4-Jun-14	0.000	0.000	0.538	0.077	0.385	0.000	
	18-Jun-14	0.000	0.000	0.008	0.000	0.602	0.391	
	28-May-15	0.000	0.336	0.399	0.015	0.243	0.007	
	4-Jun-15	0.002	0.000	0.007	0.000	0.991	0.000	
	5-Jun-15	0.057	0.006	0.107	0.000	0.830	0.000	
Crooked	16-May-11	0.000	0.000	0.770	0.000	0.230	0.000	
	6-Jun-11	0.000	0.000	0.762	0.000	0.238	0.000	
	13-Apr-12	0.000	0.000	0.000	0.000	1.000	0.000	
	14-May-12	0.036	0.096	0.747	0.012	0.072	0.036	
	22-May-12	0.231	0.144	0.625	0.000	0.000	0.000	
	30-May-12	0.265	0.059	0.176	0.500	0.000	0.000	
	7-May-13	0.000	0.000	0.042	0.000	0.958	0.000	
	14-May-13	0.000	0.000	0.455	0.000	0.545	0.000	
	21-May-13	0.095	0.048	0.619	0.048	0.190	0.000	
	28-May-13	0.464	0.099	0.331	0.000	0.106	0.000	
	27-May-15	0.100	0.000	0.000	0.000	0.900	0.000	
	Grand	23-May-14	0.000	0.006	0.552	0.000	0.437	0.004
		5-Jun-14	0.382	0.000	0.181	0.007	0.160	0.270
11-Jun-15		0.143	0.032	0.524	0.000	0.302	0.000	
Lansing	30-Apr-14	0.000	0.000	0.053	0.000	0.947	0.000	
	6-May-14	0.000	0.045	0.197	0.000	0.758	0.000	
	16-May-14	0.023	0.000	0.295	0.000	0.682	0.000	
	27-May-14	0.157	0.048	0.265	0.006	0.500	0.024	
	7-May-15	0.000	0.000	0.263	0.000	0.737	0.000	
	13-May-15	0.029	0.019	0.152	0.010	0.790	0.000	
	19-May-15	0.112	0.085	0.606	0.016	0.165	0.016	
Long	24-May-14	0.047	0.000	0.674	0.000	0.279	0.000	
	5-Jun-14	0.261	0.158	0.138	0.002	0.230	0.211	
	28-May-15	0.065	0.053	0.182	0.000	0.700	0.000	
Park	25-Apr-14	0.000	0.000	0.070	0.000	0.907	0.023	
	5-May-14	0.000	0.000	0.211	0.000	0.789	0.000	
	8-May-14	0.000	0.039	0.454	0.000	0.507	0.000	
	12-May-14	0.000	0.000	0.130	0.000	0.870	0.000	
	28-May-14	0.071	0.015	0.663	0.036	0.214	0.000	
	28-Apr-15	0.000	0.000	0.065	0.000	0.935	0.000	
	13-May-15	0.003	0.000	0.116	0.020	0.861	0.000	
	19-May-15	0.267	0.015	0.287	0.026	0.405	0.000	
	1-Jun-15	0.341	0.089	0.106	0.212	0.251	0.000	
Mean proportion		0.083	0.037	0.310	0.026	0.519	0.026	
Min		0.000	0.000	0.000	0.000	0.000	0.000	
Max		0.464	0.336	0.770	0.500	1.000	0.391	

Table A12. Average proportion of zooplankton prey (Pi) taxa per larval gut by lake-day combo for oligotrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	Bosmina	Calanoid	Cyclopid	Daphnia	Nauplii	Other
Burt	21-May-11	0.000	0.000	0.200	0.000	0.800	0.000
	4-Jun-11	0.052	0.066	0.873	0.000	0.009	0.000
	10-Jun-11	0.696	0.109	0.101	0.094	0.000	0.000
	8-May-12	0.000	0.018	0.564	0.000	0.418	0.000
	18-May-12	0.000	0.087	0.826	0.000	0.087	0.000
	31-May-12	0.004	0.617	0.306	0.017	0.056	0.000
	6-Jun-12	0.183	0.319	0.292	0.175	0.000	0.031
	8-May-13	0.000	0.000	0.500	0.000	0.500	0.000
	22-May-13	0.000	0.048	0.405	0.000	0.548	0.000
	31-May-13	0.178	0.011	0.656	0.000	0.156	0.000
	28-May-15	0.000	0.128	0.615	0.000	0.256	0.000
	6-Jun-15	0.158	0.246	0.404	0.000	0.175	0.018
Higgins	9-Jun-15	0.000	0.030	0.919	0.000	0.052	0.000
Hubbard	6-Jun-14	0.000	0.375	0.625	0.000	0.000	0.000
	19-Jun-14	0.083	0.083	0.000	0.833	0.000	0.000
Mullett	2-Jun-11	0.095	0.000	0.878	0.000	0.027	0.000
	12-Jun-11	0.016	0.246	0.738	0.000	0.000	0.000
	19-May-12	0.010	0.000	0.693	0.000	0.297	0.000
	31-May-12	0.523	0.114	0.364	0.000	0.000	0.000
	5-Jun-12	0.241	0.128	0.564	0.015	0.041	0.010
	15-May-13	0.000	0.000	0.250	0.000	0.750	0.000
	24-May-13	0.000	0.030	0.515	0.000	0.455	0.000
Pickerel	7-May-11	0.000	0.000	0.000	0.000	1.000	0.000
	17-May-11	0.000	0.000	0.529	0.000	0.471	0.000
	3-Jun-11	0.270	0.123	0.545	0.000	0.052	0.009
	9-May-12	0.019	0.000	0.631	0.000	0.340	0.010
	21-May-12	0.231	0.052	0.620	0.000	0.096	0.000
	3-Jun-12	0.810	0.038	0.101	0.051	0.000	0.000
	6-May-13	0.000	0.000	0.000	0.000	1.000	0.000
	13-May-13	0.000	0.000	0.800	0.000	0.200	0.000
	20-May-13	0.026	0.053	0.895	0.000	0.026	0.000
	27-May-13	0.481	0.019	0.462	0.000	0.038	0.000
	27-May-15	0.000	0.000	0.069	0.000	0.931	0.000
Mean proportion		0.124	0.089	0.483	0.036	0.266	0.002
Min		0.000	0.000	0.000	0.000	0.000	0.000
Max		0.810	0.617	0.919	0.833	1.000	0.031

Table A13. Mean number of major zooplankton size groups per larval gut by date with Standard Error (SE) of the mean, and number of samples collected and analyzed (N) for each lake-day sampling event.

Lake	Date	N	<0.2	0.2 to <0.4	0.4 to <0.6	0.6 to <0.8	0.8 to <1.0	>1.0						
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Black	4-Jun-14	13	.	.	1.5	0.5	4	.	1.5	0.5	.	.	.	.
	18-Jun-14	15	51.8	18.2	81.5	17.1	3.0	.	.	.	.	.	.	.
	28-May-15	28	8.9	3.4	10.8	3.7	3.7	1.5	.	.	1.0	.	.	.
	4-Jun-15	4	7.0	1.8	2.9	0.8	1.0	.	.	.	.	.	.	.
	5-Jun-15	9	3.1	0.7	3.3	0.5	4.0	0.7	2.2	0.3	2.1	0.3	1.5	0.3
Burt	21-May-11	5	2.0	.	4.0	2.0	17.2	3.6	20.2	4.6	1.7	0.3	1.7	0.3
	4-Jun-11	5	.	.	6.8	1.7	10.6	1.5	12.7	4.6	9.9	2.9	2.3	0.6
	10-Jun-11	5	2.0	1.0	5.3	3.4	3.3	1.9	2.7	0.9	5.0	2.0	2.5	0.5
	8-May-12	5	4.7	1.3	7.0	1.7	3.0	1.0	1.5	0.5	1.0	.	.	.
	18-May-12	5	.	.	2.0	.	.	.	.	.	.	.	.	.
	31-May-12	5	.	.	16.0	4.1	5.0	1.6	4.6	1.2	2.0	0.0	2.0	1.0
	6-Jun-12	9	4.0	.	2.5	0.5	7.8	1.6	2.0	.	1.5	0.5	1.0	.
	8-May-13	3	1.0	0.0	1.0	0.0	.	.	.	.	.	.	.	.
	22-May-13	5	2.0	1.0	7.7	4.2	3.3	2.3	5.0	.	.	.	.	.
	31-May-13	5	1.3	0.2	1.0	0.0	1.6	0.2	1.6	0.2	.	.	1.0	.
	28-May-15	21	1.3	0.3	11.2	2.4	34.6	5.9	48.0	23.6	8.6	5.2	1.0	.
	6-Jun-15	4	1.0	0.0	5.6	0.9	9.0	4.4	3.0	0.0	2.0	1.0	.	.
Crooked	5-May-11	5	5.5	1.2	7.3	2.3	36.0	10.9	19.0	.	.	.	.	.
	16-May-11	5	4.8	1.4	1.3	0.3	1.0	.	.	.	.	.	.	.
	6-Jun-11	5	1.0	0.0	.	.	.	.	.	.	.	.	.	.
	13-Apr-12	5	1.0	0.0	3.6	0.4	5.4	1.9	5.2	1.7	2.0	0.6	1.0	0.0
	14-May-12	5	2.3	1.0	1.8	0.5	1.5	0.3	.	.	.	.	.	.
	22-May-12	4	2.0	0.0	7.7	0.3	8.0	2.1	.	.	.	.	.	.
	30-May-12	4	1.0	0.0	2.7	1.2	1.3	0.3	2.0	1.0	1.0	.	.	.

Table A13 cont.

Lake	Date	N	<0.2		0.2 to <0.4		0.4 to <0.6		0.6 to <0.8		0.8 to <1.0		>1.0	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Crooked	7-May-13	5	1.0	0.0	2.7	1.2	1.3	0.3	2.0	1.0	1.0	.	.	.
	14-May-13	5	.	.	13.0	6.4	26.3	6.4	4.3	0.9	4.3	0.9	1.5	0.5
	21-May-13	5	1.2	0.1	1.0	0.0	.	.	.	.	.	.	.	.
	28-May-13	5	5.0	4.0	15.2	3.1	9.3	3.2	8.3	5.3	1.3	0.3	.	.
	27-May-15	20	.	.	4.5	1.5	1.5	0.5	2.0	1.0	4.5	1.5	3.0	.
Grand	23-May-14	31	4.5	1.5	5.5	1.7	3.0	0.7	3.5	1.5	.	.	.	.
	5-Jun-14	22	1.8	0.5	2.6	0.3	1.9	0.3	1.7	0.4	.	.	.	.
	11-Jun-15	27	2.1	0.5	10.1	1.4	5.2	0.8	3.0	0.6	.	.	.	.
Higgins	9-Jun-15	40	1.0	0.0	2.7	0.4	7.6	0.8	6.7	0.7	1.8	0.2	1.0	0.0
Houghton	20-May-15	10	3.5	1.2	3.7	1.3	12.8	1.3	2.8	0.5	3.7	0.9	.	.
	21-May-15	17	19.2	8.7	13.3	5.0	8.3	2.6	5.3	1.8	2.8	1.0	1.6	0.4
	27-May-15	31	.	.	9.1	2.1	17.3	2.5	8.0	1.5	5.2	1.0	3.8	0.9
Hubbard	6-Jun-14	7	.	.	1.0	.	.	.	.	.	2.0	.	2.5	0.5
	19-Jun-14	4	.	.	1.0	.	.	.	1.0	.	1.0	.	.	.
Lansing	30-Apr-14	21	2.1	0.4	1.9	0.3	1.8	0.6	.	.	1.0	.	.	.
	6-May-14	20	2.0	0.8	3.1	0.7	.	.	.	.	.	.	.	.
	16-May-14	13	3.3	0.7	2.5	0.4	1.8	0.5	1.0	0.0	.	.	.	.
	27-May-14	18	2.0	0.5	3.1	1.0	1.6	0.4	.	.	.	.	.	.
	7-May-15	18	2.0	0.3	5.1	0.6	4.9	0.9	2.7	1.0	1.3	0.3	1.0	.
	13-May-15	28	4.1	0.7	6.4	1.4	4.1	1.2	.	.	.	.	.	.
	19-May-15	17	3.0	2.0	3.3	1.3	.	.	.	.	.	.	.	.
Lobdell	11-May-14	6	4.3	1.7	.	.	.	.	2.0	.	.	.	.	.
Long	24-May-14	18	7.4	2.2	9.0	1.4	4.2	1.2	3.4	1.0	5.3	2.2	2.0	0.4
	5-Jun-14	30	1.2	0.2	1.5	0.4	2.2	0.4	1.0	0.0	1.0	.	.	.
	28-May-15	24	11.6	1.7	15.6	2.6	4.1	0.8	2.5	0.3	3.5	0.5	1.0	0.0

Table A13 cont.

Lake	Date	N	<0.2		0.2 to <0.4		0.4 to <0.6		0.6 to <0.8		0.8 to <1.0		>1.0	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Mullett	2-Jun-11	5	1.5	0.5	4.5	2.0	17.2	6.5	8.3	1.6	3.5	1.5	.	.
	12-Jun-11	5	.	.	4.0	0.9	5.7	1.3	9.7	3.8	4.3	1.5	2.0	0.8
	19-May-12	5	.	.	1.0	0.0	9.5	2.4	10.8	4.7	4.0	1.5	4.0	1.0
	31-May-12	5	1.0	.	3.0	.	.	.	.	.	.	.	.	.
	5-Jun-12	10	5.0	1.0	11.2	2.0	7.0	2.9	.	.	.	.	.	.
	15-May-13	1	5.0	1.0	3.8	1.9	3.0	1.0	1.0	0.0	.	.	.	.
24-May-13	9	1.0	.	3.0	1.4	3.8	1.0	1.5	0.5	2.5	1.5	1.5	0.5	
Ovid	6-May-14	21	1.9	0.3	5.9	1.1	4.2	0.7	1.8	0.4	1.0	0.0	.	.
	17-May-14	3	2.3	0.8	1.6	0.4	1.0	0.0	1.0	.	.	.	.	.
	30-Apr-15	18	1.7	0.2	3.0	0.4	1.0	.	.	.	.	.	.	.
	12-May-15	11	2.7	1.2	1.3	0.3	.	.	.	.	.	.	.	.
	14-May-15	28	3.1	1.0	5.0	0.5	1.9	0.3	.	.	.	.	.	.
Park	25-Apr-14	8	5.4	1.4	4.6	0.8	2.4	0.6	2.6	0.7	1.6	0.3	1.0	0.0
	5-May-14	13	1.7	0.3	3.1	1.2	1.0	.	.	.	.	.	.	.
	8-May-14	25	3.2	0.5	5.1	1.0	1.4	0.2	1.0	0.0	.	.	.	.
	12-May-14	25	4.6	0.6	3.0	0.4	1.0	0.0	.	.	.	.	.	.
	28-May-14	26	4.9	0.5	5.5	0.8	1.3	0.1	2.5	0.7	1.0	.	.	.
	28-Apr-15	30	4.1	0.6	4.8	1.1	1.4	0.2	4.5	1.5	1.0	0.0	1.0	.
	13-May-15	30	4.0	1.5	5.0	1.3	1.0	0.0	.	.	.	.	.	.
	19-May-15	20	3.5	0.7	3.1	0.6	3.5	1.9	7.1	1.8	1.4	0.2	1.0	0.0
	1-Jun-15	20	8.8	1.1	4.0	0.7	1.1	0.1	.	.	.	.	.	.
Pickereel	7-May-11	5	8.0	3.1	39.2	3.2	56.8	7.1	9.8	3.2	10.0	1.1	5.0	1.7
	17-May-11	5	.	.	61.0	.	9.0	.	5.0	.	4.0	.	.	.
	3-Jun-11	5	1.0	0.0	.	.	.	.	.	.	.	.	.	.
	9-May-12	5	2.0	0.6	.	.	.	.	.	.	.	.	.	.
	21-May-12	5	7.5	2.3	2.0	0.4	11.2	0.9	3.0	0.0	.	.	.	.
	3-Jun-12	1	2.0	.	1.0	.	2.3	0.7	.	.	.	.	.	.

Table A13 cont.

Lake	Date	N	<0.2		0.2 to <0.4		0.4 to < 0.6		0.6 to <0.8		0.8 to < 1.0		> 1.0	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Pickereel	6-May-13	5	5.2	1.3	8.2	4.7	6.3	1.2	2.0	.	.	.	.	.
	13-May-13	5	.	.	2.4	0.9	6.3	1.9	2.3	1.3	.	.	.	.
	20-May-13	5	10.0	.	17.3	12.2	21.6	8.0	9.0	3.5	1.0	0.0	1.0	.
	27-May-13	5	2.3	1.3	7.0	1.4	3.0	0.6	2.0	1.0	.	.	.	.
	27-May-15	17	3.4	0.7	2.0	0.5	.	.	.	.	.	.	.	.

Table A14. Average proportion of zooplankton prey (Pi) size group per larval gut by lake-day combo for eutrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	<0.2	0.2 to <0.4	0.4 to < 0.6	0.6 to <0.8	0.8 to < 1.0	> 1.0
Houghton	20-May-15	0.143	0.112	0.520	0.112	0.112	0.000
	21-May-15	0.326	0.377	0.189	0.070	0.021	0.017
	27-May-15	0.000	0.200	0.497	0.145	0.084	0.074
Lobdell	11-May-14	0.895	0.000	0.000	0.105	0.000	0.000
Ovid	6-May-14	0.086	0.484	0.357	0.063	0.009	0.000
	17-May-14	0.667	0.333	0.000	0.000	0.000	0.000
	30-Apr-15	0.231	0.661	0.107	0.000	0.000	0.000
	12-May-15	0.375	0.458	0.125	0.042	0.000	0.000
	14-May-15	0.193	0.795	0.011	0.000	0.000	0.000
Mean Proportion		0.324	0.380	0.201	0.060	0.025	0.010
Min		0.000	0.000	0.000	0.000	0.000	0.000
Max		0.895	0.795	0.520	0.145	0.112	0.074

Table A15. Average proportion of zooplankton prey (P_i) size group per larval gut by lake-day combo for mesotrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	<0.2	0.2 to <0.4	0.4 to <0.6	0.6 to <0.8	0.8 to <1.0	> 1.0
Black	4-Jun-14	0.000	0.462	0.308	0.231	0.000	0.000
	18-Jun-14	0.766	0.227	0.008	0.000	0.000	0.000
	28-May-15	0.105	0.263	0.312	0.192	0.102	0.026
	4-Jun-15	0.386	0.608	0.006	0.000	0.000	0.000
	5-Jun-15	0.388	0.538	0.069	0.000	0.006	0.000
Crooked	16-May-11	0.098	0.377	0.525	0.000	0.000	0.000
	6-Jun-11	0.113	0.149	0.738	0.000	0.000	0.000
	13-Apr-12	1.000	0.000	0.000	0.000	0.000	0.000
	14-May-12	0.063	0.375	0.563	0.000	0.000	0.000
	22-May-12	0.000	0.325	0.494	0.081	0.081	0.019
	30-May-12	0.000	0.333	0.111	0.148	0.333	0.074
	7-May-13	0.792	0.167	0.042	0.000	0.000	0.000
	14-May-13	0.409	0.318	0.273	0.000	0.000	0.000
	21-May-13	0.100	0.400	0.250	0.200	0.050	0.000
	28-May-13	0.068	0.514	0.250	0.169	0.000	0.000
	27-May-15	0.857	0.143	0.000	0.000	0.000	0.000
Grand	23-May-14	0.039	0.622	0.308	0.031	0.000	0.000
	5-Jun-14	0.267	0.570	0.111	0.052	0.000	0.000
	11-Jun-15	0.138	0.462	0.254	0.146	0.000	0.000
Lansing	30-Apr-14	0.316	0.684	0.000	0.000	0.000	0.000
	6-May-14	0.409	0.439	0.136	0.000	0.015	0.000
	16-May-14	0.286	0.524	0.190	0.000	0.000	0.000
	27-May-14	0.268	0.536	0.196	0.000	0.000	0.000
	7-May-15	0.263	0.737	0.000	0.000	0.000	0.000
	13-May-15	0.472	0.443	0.066	0.019	0.000	0.000
	19-May-15	0.085	0.410	0.388	0.085	0.021	0.011
Long	24-May-14	0.140	0.279	0.465	0.093	0.023	0.000
	5-Jun-14	0.249	0.503	0.117	0.048	0.042	0.042
	28-May-15	0.298	0.577	0.085	0.016	0.011	0.011
Park	25-Apr-14	0.273	0.682	0.045	0.000	0.000	0.000
	5-May-14	0.316	0.658	0.026	0.000	0.000	0.000
	8-May-14	0.336	0.605	0.046	0.013	0.000	0.000
	12-May-14	0.623	0.364	0.013	0.000	0.000	0.000
	28-May-14	0.145	0.306	0.145	0.368	0.036	0.000
	28-Apr-15	0.652	0.321	0.027	0.000	0.000	0.000
	13-May-15	0.405	0.510	0.049	0.033	0.003	0.000
	19-May-15	0.314	0.440	0.082	0.130	0.024	0.010
	1-Jun-15	0.255	0.406	0.151	0.094	0.073	0.021
Mean Proportion		0.308	0.428	0.180	0.057	0.022	0.006
Min		0.000	0.000	0.000	0.000	0.000	0.000
Max		1.000	0.737	0.738	0.368	0.333	0.074

Table A16. Average proportion of zooplankton prey (P_i) size group per larval gut by lake-day combo for oligotrophic systems with the mean, minimum (Min), and maximum (Max) proportion.

Lake	Date	<0.2	0.2 to <0.4	0.4 to < 0.6	0.6 to <0.8	0.8 to < 1.0	> 1.0
Burt	21-May-11	0.400	0.600	0.000	0.000	0.000	0.000
	4-Jun-11	0.010	0.058	0.417	0.490	0.024	0.000
	10-Jun-11	0.000	0.580	0.181	0.167	0.043	0.029
	8-May-12	0.255	0.509	0.164	0.055	0.018	0.000
	18-May-12	0.089	0.111	0.689	0.044	0.067	0.000
	31-May-12	0.008	0.118	0.366	0.507	0.000	0.000
	6-Jun-12	0.000	0.164	0.256	0.307	0.240	0.032
	8-May-13	0.000	1.000	0.000	0.000	0.000	0.000
	22-May-13	0.095	0.548	0.238	0.119	0.000	0.000
	31-May-13	0.022	0.311	0.500	0.100	0.067	0.000
	28-May-15	0.200	0.100	0.475	0.200	0.000	0.025
	6-Jun-15	0.071	0.286	0.179	0.143	0.179	0.143
Higgins	9-Jun-15	0.003	0.097	0.453	0.378	0.059	0.009
Hubbard	6-Jun-14	0.000	0.125	0.000	0.000	0.250	0.625
	19-Jun-14	0.000	0.083	0.000	0.083	0.083	0.750
Mullett	2-Jun-11	0.020	0.122	0.585	0.224	0.048	0.000
	12-Jun-11	0.000	0.017	0.322	0.458	0.136	0.068
	19-May-12	0.099	0.554	0.347	0.000	0.000	0.000
	31-May-12	0.025	0.300	0.475	0.075	0.125	0.000
	5-Jun-12	0.000	0.186	0.294	0.299	0.155	0.067
	15-May-13	0.250	0.750	0.000	0.000	0.000	0.000
	24-May-13	0.303	0.455	0.182	0.061	0.000	0.000
Pickerel	7-May-11	1.000	0.000	0.000	0.000	0.000	0.000
	17-May-11	0.295	0.466	0.216	0.023	0.000	0.000
	3-Jun-11	0.040	0.325	0.471	0.081	0.083	0.000
	9-May-12	0.291	0.078	0.544	0.087	0.000	0.000
	21-May-12	0.044	0.307	0.480	0.160	0.000	0.009
	3-Jun-12	0.000	0.772	0.114	0.063	0.051	0.000
	6-May-13	1.000	0.000	0.000	0.000	0.000	0.000
	13-May-13	0.200	0.100	0.700	0.000	0.000	0.000
	20-May-13	0.000	0.316	0.500	0.184	0.000	0.000
	27-May-13	0.121	0.603	0.207	0.069	0.000	0.000
	27-May-15	0.733	0.267	0.000	0.000	0.000	0.000
Mean proportion		0.169	0.395	0.189	0.109	0.065	0.059
Min		0.000	0.000	0.000	0.000	0.000	0.000
Max		1.000	1.000	0.700	0.507	0.250	0.750

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