# Growth and survival rate of nearshore fishes in Lake Michigan, 2011

Sara M. Creque and Sergiusz J. Czesny

INHS Technical Report

Prepared for Illinois Department of Natural Resources, Division of Fisheries

Issue Date: October 15, 2012

Sponsor: Division of Fisheries, Illinois Department of Natural Resources
Grant/Contract No: Federal Aid Project F-138-R-15

Unrestricted: for immediate online release

Prairie Research Institute, University of Illinois at Urbana Champaign
Mark R. Ryan, Executive Director

Illinois Natural History Survey
Geoff Levin, Interim Director
1816 South Oak Street
Champaign, IL 61820
217-333-6830

# Growth and Survival Rate of Nearshore Fishes in Lake Michigan

**August 1, 2011 – July 31, 2012**

Sara M. Creque and Sergiusz J. Czesny
University of Illinois
Institute of Natural Resources Sustainability
Illinois Natural History Survey

submitted to
Division of Fisheries, Illinois Department of Natural Resources
in fulfillment of the reporting requirements of
F-138 R-15

____________________ ________________________

Sergiusz J. Czesny
Principal Investigator

Associate Director for Research

October 2012

This study is conducted under a memorandum of understanding between the Illinois Department of Natural Resources and the Board of Trustees of the University of Illinois. The actual research is performed by the Illinois Natural History Survey, a division of the Illinois Department of Natural Resources. The project is supported through Federal Aid in Sport Fish Restoration by the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not the Illinois Department of Natural Resources.

## Table of Contents

## List of Tables



## List of Figures

## Executive Summary

Research described in this report focuses on Illinois waters of Lake Michigan and provides essential information for the Illinois Department of Natural Resources (IDNR) to better understand factors contributing to nearshore fish community assemblages in a spatial and habitat related context. Information presented herein expands limited data and directly aids fisheries management efforts. This report describes results obtained during 2011 field season and marks the fourth year of major changes to the project, which included changing sampling locations, expanding sampling sites to include different habitat types, and expanding sampling techniques to collect juvenile fish.

Data analysis from field sampling conducted in 2012 is ongoing and lab processing is not complete. As such, a complete reporting of data collected during the 2011 sampling season is presented, covering data from Segments 14 and 15. Further, some objectives are based on long term data collection and insights will become clearer as results accrue through future sampling; therefore, results for each objective may not be specifically discussed in this report. Below, we present the study objectives and several research highlights.

**Study 101: Quantify seasonal abundance, composition and growth of juvenile fishes**

1. Yellow perch was the most abundant fish at all three locations. CPE (catch-per-effort) peaked in July at Highland Park (M2) and Chicago (S2), but was highest in August at Dead River (DR).
2. Alewife CPE was highest at DR, and catches declined from north to south. CPE was variable throughout June-October at all three locations.
3. Round goby CPE was at least three times higher at M2 and S2 compared to DR. Abundance was highest in early summer at M2 and S2.
4. Size of fish captured in the small-mesh gill nets ranged from 51-271 mm, giving us a variety of juvenile age classes for the different fish species.

**Study 102: Quantify nearshore zooplankton abundance and taxonomic composition**

1. Annual mean zooplankton density (crustaceans and rotifers) ranged from 7.0 – 9.9 ind/L and did not differ between the three locations.
2. Rotifers, nauplii and Bosminidae were the most abundant taxa.

**Study 103: Estimate relative abundance and taxonomic composition of benthic invertebrates**

1. Mean annual density of benthic invertebrates collected in cores and ponar grabs at 7 m ranged from 730 ± 1282 ind/m$^2$ at S2 to 2849 ± 4372 ind/m$^2$ at DR.
2. Annelid, chironomids, nematodes and Dreissenids were the most abundant taxa at all three locations. Amphipods were not collected at DR and numbers of ostracods were extremely small at M2.
3. Densities of invasive Dreissenid mussels in cores were very low at DR and S2 (June-August), however they were the most abundant taxa collected in ponar grabs at DR in September and October and at S2 during October.
4. No rocks were ever collected at the very sandy DR site. 18 taxa were collected on rocks from M2. Taxa collected on rocks not found in other sampling included Ephemeroptera and Hydroids.

**<u>Study 104:</u> Explore multivariate patterns in nearshore fishes and prey communities**

1. Yellow perch CPE had a positive correlation with bottom temperatures. No significant relationship with bottom temperature was found for the other fish species caught in gill nets.
2. Benthic invertebrate and fish communities at the three locations were similar during 2011, compared to differences seen in previous years.
3. Analysis of 8 prey taxa in diets of five fish species showed high diet similarity between round goby, yellow perch, and spottail shiner at all locations during 2010. A second grouping showed similar diets for alewife and rainbow smelt.

## Introduction

Great Lakes management strategies are shifting away from an individual species perspective towards the broader and more comprehensive fish community approach. Thus in 2008 we began focusing sampling on juvenile fish of varying age classes in different habitat types across seasons, to better understand fish community composition, seasonal habitat use, habitat overlap, diet overlap, and interactions of native species with invasive ones.

An overlap in the distribution of species (e.g., alewife, *Alosa pseudoharengus* and rainbow smelt, *Osmerus mordax*) may reduce the fitness of one or both species if they compete for limited resources (Stewart et al. 1981). For example, food quantity and timing of food availability are critical determinants of first-year growth and survival of fish (Miller et al. 1988). Results of Confer et al. (1990) and Miller et al. (1990) suggest that the decline of bloaters and other native planktivores in Lake Michigan during the 1960s and 1970s may have been largely the result of shifts in zooplankton composition associated with intense planktivory by alewife. Other Great Lakes native species have experienced strong negative effects of high alewife abundances, including yellow perch, deepwater sculpins, emerald shiners, burbot and lake trout (Madenjian et al. 2008). Alewife is just one of many invasive species that have impacted the ecology of Lake Michigan. Other pelagic invaders include rainbow smelt, and two spiny Cladocerans (*Bythotrephes* and *Cercopagis*). Zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*) and round goby (*Neogobius melanostomus*) have dramatically changed the benthic community in recent years (Kuhns and Berg 1999; Vanderploeg et al. 2002; Barton 2005).

Changes caused by invasive species can affect diet and competitive interactions of Lake Michigan fish. Hrabik et al. (2001) found young-of-year (YOY) rainbow smelt and yellow perch competing for zooplankton and their diets overlapped more than 45%. Round goby < 70 mm consume a variety of benthic invertebrates, very similar to small yellow perch and other native fish (Vanderploeg et al. 2002). Stomach analysis from 2000-2007 in southwestern Lake Michigan revealed that diets of age-0 yellow perch in August and September overlapped with alewife ≤ age 1 and age-0 rainbow smelt (Creque et al. 2007; Creque and Czesny 2012).

Diet overlap and competition can also occur between varying age-classes of the same species or congeners. In a field study of yellow perch, annual dietary overlap between consecutive year classes was above 68% for both taxonomic and prey size categories (Keast 1977). Persson (1983) found high overlap values between age 2 and 3 European perch (*Perca fluviatilis*), which with low prey resources could indicate intraspecific competition. Data from southwestern Lake Michigan indicated that yellow perch diets overlapped in October, when both YOY and age-1 perch switched primarily to amphipods (Creque and Czesny 2012). Although this shift reduced yellow perch diet overlap with spottail shiner and alewife, it may increase intra-specific competition, especially if amphipods declined. We have seen a *Diporeia* abundances collapse in Illinois waters, as occurred prior on the eastern side of Lake Michigan (Nalepa et al. 1998; Madenjian et al. 2002), which could have a severe impact on age-0 yellow perch. Competitive interactions between two successive age-classes could result in reduced growth rates of younger fish thus reducing their over-winter survival (Persson 1983).

Both plankton and benthic resources have declined since the high yellow perch abundances of the 1980s. Thus, increased competition due to declining prey levels may be the reason for lack of back to back successful year classes of yellow perch since the late 1980s. Continuous expansion of round goby northward and their recent establishment in the Waukegan area could create additional competitive pressure through diet overlap for young cohorts of yellow perch.

Species diversity tends to increase with increasing habitat complexity (Keast and Eadie 1985; Danehy et al. 1991; Pratt and Smokorowksi 2003). Within the Great Lakes, there are generally large homogenous regions of soft, sandy substrate for nearshore communities; regions of structured/hard bottoms are few but disproportionately important habitats (Danehy et al. 1991; Janssen et al. 2005). The critical importance of such habitat was highlighted by Danehy et al. (1991), who found that yellow perch captured at cobble sites grew faster than those collected at sandy sites in Lake Ontario. Winnell and Jude (1987) collected over 190 species of invertebrates from rocky, littoral habitats showing richness and diversity of food for fish in such areas.

There are a large number of studies of pelagic productivity, but few focus on the littoral zone (Vadeboncouer et al. 2002). There are many more studies on soft bottom habitats because of their ease of sampling, and the lack of data on hard substrates prevents complete understanding of the ecosystem (Winnell and Jude 1987; Janssen et al. 2005). Rocky nearshore habitats are critical for many fish and invertebrate species, and steps must be taken to increase our knowledge of the community interactions at these areas.

Our objectives for this study are continued monitoring of zooplankton, invertebrates, fish, and fish diets through a sampling scheme to include additional habitat types. The use of more effective sampling methods will help develop a better understanding of the combined influence of biotic and abiotic factors on fish recruitment in southwestern Lake Michigan. Multiple years of data will allow us to explore multivariate patterns in nearshore fish communities and yellow perch growth in relation to habitat differences, prey availability, and invasive species. This information will provide key insights into nearshore areas with the best growth and survival potential for both native and non-native fish.

**Study site**

Segment 15 marks the fourth season with sampling sites slightly different than in previous segments to reflect the new objectives. Sampling associated with all studies described below occurred at three selected locations along the Illinois shoreline of Lake Michigan during June-October. The Illinois shoreline of Lake Michigan is naturally divided into three distinct geologic regions: Zion beach-ridge plain, Lake Border Moraines bluff coast, and Chicago/Calumet lake plain (Chrzastowski and Trask 1995). Nearshore bottom substrate within each of these areas is unique. More specifically, we sampled at a location in the Zion beach-ridge plain, 3.7 km north of Waukegan Harbor at the mouth of the Dead River (DR; Figure 1). An area in southern Illinois waters, located between Chicago's Rainbow Park water treatment plant and 59th Street Harbor (S2), represents the Chicago/Calumet lake plain area. The DR and S2 locations were also sampled in Segments 1 – 11. The Lake Border Moraine Bluff coast region is represented at a location off of Highland Park, IL (M2). This location was part of the preliminary sampling in Segments 10 and 11.

## Methods

Sampling was conducted at each location twice a month, weather permitting, from June through October. Within each location we established a grid of nine sites covering an area of approximately 1.5 $km^2$. There are three transects perpendicular to shore with sites at roughly 3, 5 and 7.5 meters water depth (Figure 1). All three water depths are sampled during each outing, with specific site selection chosen by random draw with replacement. On each sampling date, ambient water temperature and secchi disk measurements were recorded. Continuously recording temperature probes to monitor water temperatures throughout our sampling season are located at a site south of Waukegan Harbor (T4), which is also sampled as part of related project F-123-R, and at the artificial reef in Chicago (Figure 1).

**Study 101: Quantify seasonal abundance, composition and growth of juvenile fishes**

*Job 101.1: Quantify abundance and composition of juvenile fish community*

Juvenile fish were sampled using monofilament small-mesh gill nets. These nets consist of 33-foot panels of 0.31, 0.50, 0.75, and 1.0-in stretch mesh. Nets were fished at 3, 5 and 7.5 meter depths at each location and set for 2-4 hours during the day. Fish in each net were identified to species and counted; a subsample was preserved for laboratory analysis and the remaining fish were measured for length and returned to the lake. Yellow perch larger than 170 mm were measured and returned alive to the lake.

*Job 101.2: Diet analysis of juvenile nearshore fishes and adult sport fishes*

Fish preserved in small-mesh gill net subsamples were later analyzed in the laboratory. Each fish was assigned a unique identification number; length was measured in mm and weight in grams. Fish were dissected to remove stomachs and otoliths. During diet analysis prey taxa were identified to the lowest practical level and length measurements were taken on up to 20 organisms of each taxon in good condition. Otoliths were placed in individual vials for later reading.

*Job 101.3: Data analysis and report preparation*

Data were entered and checked in Access databases. Analysis was performed with SAS software. Catch per effort in small-mesh gill nets was calculated as number of fish per hour set. CPE was analyzed as both total and mean.

**Study 102: Quantify nearshore zooplankton abundance and taxonomic composition**

*Job 102.1: Sample zooplankton at selected nearshore sites*

Duplicate zooplankton samples were taken at the 3, 5 and 7.5 meter sites during June-October. At each site a 63-µm mesh 0.5-m diameter plankton net was towed vertically from 0.5 m above the bottom to the surface. Sampling the entire water column generates a representative sample of the zooplankton community composition and abundance. Samples were stored immediately in 5% sugar formalin.

*Job 102.2: Identify and enumerate zooplankton collected under Job 102.1*

In the lab, samples were processed by examining up to three 5-ml subsamples, taken from adjusted volumes that provided a count of at least 20 individuals of the most dominant taxa. Zooplankton were enumerated and identified into the following categories: cyclopoid copepodites, calanoid copepodites, copepod nauplii, rotifers, cladocerans to genus (*Daphnia* to species), Macrothrididae spp., Sididae spp., and *Dreissena sp.* veligers. Uncommon and exotic taxa were noted.

*Job 102.3: Data analysis and report preparation*

Zooplankton data was entered into Excel and Access databases, and checked for errors. Errors were corrected in all files, and copies of field and lab sheets were made. Analysis of zooplankton abundance and species composition were run using SAS version 9 and Primer-E software. For this report, total zooplankton includes crustaceans and rotifers. *Dreissenid* veligers are analyzed separately in density analyses.

**<u>Study 103:</u> Estimate relative abundance and taxonomic composition of benthic invertebrates in three different habitat areas**

*Job 103.1: Sample benthic invertebrates in soft sediments*

SCUBA divers collected benthic invertebrates once a month at the 3, 5 and 7.5 meter sites at each location using a 7.5-cm diameter core sampler. Four replicate samples from the top 7.5 cm of the soft substrate were collected and preserved in 95% ethanol (Fullerton et al. 1998). When soft to sandy substrate sediments were limited, especially at M2 and S2, sample depth was reduced to 3.75 cm. When diving was not possible, three replicates of bottom substrate were collected with a petite ponar that sampled a surface area of 251 $cm^2$ (Pothoven et al 2001; Breneman et al. 2000).

*Job 103.2: Sample benthic invertebrates on rocky substrates*

While diving for benthic cores, SCUBA divers randomly selected four baseball sized rocks and placed them in individual Ziploc bags. If there were no suitable rocks in the vicinity, they swam approximately 100 meters to look for any. If none were found, the site was noted as having no rocks.

*Job 103.3: Identify and enumerate benthic invertebrates*

In the lab, benthic core and ponar samples were sieved through 363-μm mesh screens to remove sand. Organisms were sorted from the remaining sediment debris. Organisms were identified to the lowest practicable level, typically to genus; total length (mm) and head capsule width were measured for each individual. All taxa were enumerated and total density estimates were calculated. Rocks collected were carefully scraped and rinsed to remove attached organisms. Taxa were identified and measured using the same techniques as with cores. The rocks were labeled with a sample number for later calculation of surface area.

*Job 103.4: Data analysis and report preparation*

Data was entered into Excel and Access databases, and checked for errors. Errors were corrected in all files, and copies of field and lab sheets were made. Analysis of benthic invertebrate abundance and taxa composition were run using SAS version 9 software.

**<u>Study 104:</u> Explore multivariate patterns in nearshore fishes and prey communities in Lake Michigan**

*Job 104.1: Explore multivariate patterns of zooplankton, invertebrate and nearshore fish communities*

Percent composition by density was analyzed for benthic invertebrate and fish data to give an indication of community patterns by month and location. Data were square root transformed and analysis was performed in Primer-E multivariate software. We also ran correlation analysis on small-mesh gill net catch rates and bottom water temperatures.

*Job 104.2: Explore impact of round goby on yellow perch*

Diet data from yellow perch, round goby, spottail shiner, alewife, and rainbow smelt collected in June-October 2010 were analyzed for similarity trends. These species were grouped by total length into two size classes: small (TL ≤ 80 mm) and large (TL > 80 mm). Percent composition by number in individual stomachs was determined for 7 major prey groups and this data was analyzed in Primer-E software using cluster, non-metric multi-dimensional scaling (NMDS), similarity percentages (SIMPER), and analysis of similarity (ANOSIM) methods.

*Job 104.3: Report preparation*

Multivariate analyses of 2011 benthic invertebrate and fish community data and 2010 fish diet data were included in this report.

## <u>Results</u>

Segment timing of this project runs from August through July and thus one field season is covered by two consecutive segments. However, to draw meaningful conclusions and present data in the most logical format, results are presented for the entire 2011 sampling season (June – October) which includes data collected in Segment 14 and Segment 15. Differences in number of samples collected at the three locations result from occasional weather related cancellations of sample outings, equipment issues, and boat repairs.

**<u>Study 101:</u> Quantify seasonal abundance, composition and growth of juvenile fishes**

*Job 101.1: Quantify abundance and composition of juvenile fishes*

A total of 23, 30 and 22 small-mesh gill nets were set at DR, M2 and S2 respectively; annual mean catch rates (fish/hour) were 14.7 ± 19.8, 12.3 ± 9.2, and 13.3 ± 17.6, respectively. Extra nets were set at M2 due to an additional project. Limited sampling occurred in June at S2 and none during August at S2 due to boat motor problems.

Number of age-0 yellow perch caught in 2011 was less than ten across all locations and months. Mean length of perch measured in the field was >100 mm indicating most were age-1 or older. Most alewife were also age-1 or older. Yellow perch (age 1+) was the most abundant fish caught in small mesh gill nets at all three locations. Annual mean number of perch caught per hour was 6.7 ± 13.2 at DR, 4.8 ± 7.0 at M2 and 9.0 ± 17.5 at S2 (Figure 2). Spottail shiner mean annual abundance was similar at all three locations, ranging from 1.7 fish/hour at M2 to 2.3 fish/hour at DR. In contrast, alewife mean annual abundance was highest at DR, 5.2 ± 8.3 fish/hour, and lowest at S2 (< 1 fish/hour). Round goby CPE was 50 and 100 times higher at S2 and M2, respectively, compared to DR. Rainbow smelt were collected in low numbers at the two north locations, but none were caught at S2 (Figure 2). Other fish species were collected in very small numbers; they included ninespine stickleback, bloater, juvenile largemouth bass, rock bass, sand shiner and longnose dace. Adult fish caught in the nets as by-catch were freshwater drum, Chinook salmon, coho salmon, lake trout and lake chub.

There were some seasonal patterns in fish abundances. Alewife densities at M2 were highest in June and July, while at DR alewife CPE peaked during September and none were captured in October (Figure 3). Round goby CPE declined from June through October at both M2 and S2. Spottail shiner CPE exhibited a different seasonal pattern at each location; spottail shiner CPE peaked during August at M2, September at DR and October at S2. Yellow perch abundances were at least 9 times higher in June and July at S2 compared to the late summer and fall months, while at DR the opposite pattern occurred, yellow perch CPE was higher in August and September compared to June and July.

Round goby catches were highest at the 5 and 7 m depth sites across all 3 locations (Figure 4). Sand shiners were never collected at 7 m and spottail shiner CPE was lowest at 7 m except at S2. Yellow perch depth patterns were opposite at DR compared to M2 and S2; DR CPE was highest at 7m and lowest at 5 m, while CPE at M2 and S2 was highest at 3 m and lowest at 7 m depths. Alewife showed no clear patterns in CPE by depth.

*Job 101.2: Diet and growth analysis of juvenile fish and adult sport fish*

766 yellow perch, round goby, alewife, spottail shiner and rainbow smelt stomachs from June – October 2010 samples have been analyzed. All fish < 80 mm total length were classified as small, while fish larger than 80 mm were classified as large. Mean length for fish in these size groups is detailed in Table 1. Prey items of yellow perch and round goby were relatively similar, with chironomids being the most or second most frequently consumed prey for both fish (Table 2). Yellow perch consumed higher numbers of cladoceran and copepod zooplankton, but 81% of small round gobies consumed copepods compared to 75% of small yellow perch. The largest difference in prey consumption between the two fish species was for Dreissenid mussels; they were consumed by 42% and 65% of small and large round goby, respectively, but by less than 5% of yellow perch.

A total of 89 lake trout stomachs collected by the Illinois Department of Natural Resources during 2009 and 2010 were analyzed for prey counts and lengths. 42 stomachs contained no prey items. Alewife was the most common prey, followed by round goby and unidentified fish. Three stomachs contained *Mysis*.

*Job 101.3: Data analysis and reporting*

Data was entered and checked into Access databases. SAS statistical software was used to analyze data and generate reports for inclusion in this report.

**<u>Study 102:</u> Quantify nearshore zooplankton abundance and taxonomic composition**

*Job 102.1: Sample zooplankton*

A total of 50, 46, and 46 zooplankton samples were collected from DR, M2 and S2, respectively. Replicate samples were collected at the 3, 5 and 7 m sites.

*Job 102.2: Id and count zooplankton*

Mean annual zooplankton densities were low in 2011 and did not differ among locations. Annual mean density (ind/L), including rotifers, was 7.1 ± 9.4 at DR, 5.6 ± 8.7 at M2 and 8.0 ± 14.0 at S2. In general, densities were highest during August and October and lowest in June across all locations (Figure 5). Mean densities did not differ greatly across sample depths, with the exception of October (Figure 6); densities at the 3 m DR site and the 5m site at S2 were higher than the other depths.

Bosminidae, calanoid copepods, copepod nauplii and rotifers were the most common zooplankton taxa collected. However, there were seasonal variations in composition and abundance patterns among the three locations. Bosminidae did not appear in noticeable numbers at the two north locations until August; however, Bosminidae density at DR in October was the highest seen throughout the years (Figure 5). Rotifer densities followed the same trends at DR and M2, with peaks in August and October, while S2 did not exhibit the September decline seen at the other two locations. Cyclopoid copepod density was above 1 ind/L only during October at DR and calanoid copepod density only climbed above 1 ind/L in October at both DR and M2. Densities of dreissenid veligers were low compared to years past; with monthly mean densities below 10 ind/L (Table 3). Veliger densities at S2 were generally higher compared to those at DR and M2.

*Job 102.3: Data analysis and reporting*

Data were entered and checked in Access databases. Data were analyzed with SAS software for inclusion in this report.

**<u>Study 103:</u> Estimate relative abundance and taxonomic composition of benthic invertebrates**

*Job 103.1: Sample in soft sediments*

We collected a total of 67 benthic cores and 67 petite ponar grabs in the 2011 field season.

*Job 103.2: Sample on rocky substrates*

Dead River is a very sandy location, and no rocks were ever observed on SCUBA dives. Thus there are no samples from rocky substrates for this location. A total of 21 rocks were collected at M2. Rocks were never observed at the 3 meter sites at M2 and S2. Boat problems and limited divers lead to no rocks being collected at S2 during 2011.

*Job 103.3: Id and count invertebrates*

Total annual invertebrate density for core and ponar samples did not differ amongst the three locations and ranged from 1269 ± 2201 ind/$m^2$ at M2 to 1469 ± 3407 ind/$m^2$ at S2. Total densities at DR and S2 were highest in September and October, while total density at M2 remained relatively stable June through October. Oligochaetes and nematodes were the dominant taxa at S2, while Chironomids and Dreissenids were most abundant at DR, and Oligochaetes and Dreissenids predominated at M2 (Figure 7). Very low densities of amphipods were collected at M2 and S2 and none were found at DR. (Figure 7).

When looking at patterns by water depth, DR and M2 had the highest annual mean invertebrate densities in samples collected at 7 m and the lowest densities in 3 m samples (Table 4). On the other hand, invertebrate densities at S2 were highest at 3 m and lowest at 7 m.

Seventeen taxa were identified on M2 rocks. Chironomid larvae, *Dreissena bugensis* and nematoda were the most abundant taxa on the hard substrate at M2 (Table 5). *Echinogammarus, Gammarus* and *Hyalella* amphipods were collected on rocks, but no *Diporeia*. Several Ephemeroptera mayflies and hydroids were also collected, which are rarely found in the ponar and core samples.

*Job 103.4: Data analysis and reporting*

Data from benthic cores and rock collections were entered and checked in Access databases. Analysis was run using SAS software and compiled for this report.

**<u>Study 104:</u> Explore multivariate patterns in nearshore fishes and prey communities**

*Job 104.1: Explore multivariate patterns*

Water temperatures from our profile sampling indicated a relatively warm year, with peak surface temperatures > 24°C. Highest recorded water temperatures occurred during late July to mid-August at all three locations (Figure 8). Water temperature differences among site depths were relatively minor at all three locations. The largest differences between same date surface and bottom temperatures occurred at DR during June through early August and at S2 on July 21. Total gill net CPE by date and location was positively correlated with mean bottom temperature (Pearson's $r= 0.49$, $p< 0.02$). Individual species CPEs had no significant correlations with bottom temperature, the exception being yellow perch, which showed a positive relationship with bottom temperature (Pearson's $r=0.48$, $p< 0.02$).

ANOSIM analysis of eight benthic taxa categories indicated no significant differences in taxa composition by number across all three locations (global $R=0.42$, $P >0.10$) and months (global $R=0.17$, $P > 0.2$) (Figure 9a). The community at M2 was most similar across all months, with 63% similarity. There were some minor differences exhibited in the MDS plot for DR in June and August and S2 in June; these samples had no native mollusks and lower chironomid proportion compared to the others.

The fish community also did not differ between locations during 2011 unlike patterns seen in previous years. The MDS plot shows all locations and months in a mostly randomly distributed pattern (Figure 9b). Similarity analysis indicated that the fish community was 65% similar throughout the year at DR and M2 and 55% similar at S2. Differences between all pairs of sites were less than 56%.

*Job 104.2: Impact of round goby on yellow perch*

Annual mean CPE of round goby and yellow perch was very similar among locations, although round goby were less abundant at DR (Figure 2). However, round goby and yellow perch CPE varied seasonally. Round goby CPE at M2 and S2 was highest in June and slowly declined through the sampling season. Yellow perch CPE peaked in June and July at S2 and July at M2, while yellow perch CPE at the northernmost site, DR, was highest in August and September, demonstrating an abundance shift through the season from south to north (Figure 3).

A variety of multivariate tests were run on 7 broad prey taxa (Cladocera, Chironomids, Copepods, Amphipods, Dreissenid, Veligers, and other invertebrates) in diets of our five most abundant juvenile fish species to look for potential diet similarities/overlap. Fish species were initially further classified by size into small (TL>80 mm) and large (TL ≥ 80 mm) categories, however initial results did not show large differences between these size groups and results that follow are presented by coding both these groups by species only.

Within fish species, average diet similarity was lowest for rainbow smelt at 53%, while alewife, spottail shiner, round goby and yellow perch all had intra-species diet similarity of > 67% during June through October. Across all locations, a two way crossed ANOSIM indicated that diets differed moderately between fish species (global R=0.48) and between months (global R=0.26). The largest diet differences occurred between round goby and alewife, rainbow smelt and round goby, and yellow perch and alewife (pairwise r's > 0.5). Simper analysis indicated that yellow perch, spottail shiner and round goby diets were 64-66% similar. These results are reflected in the MDS plot, with the majority of alewife and rainbow smelt tending to group together on the right hand side and all other species clustering together on the left side (Figure 10a). There are some yellow perch in the middle between these two groups.

Although all fish consumed large numbers of chironomid larvae throughout the year, alewife and rainbow smelt consumed noticeably less than the other fish (Figure 10 b), while they consumed larger proportions of Cladoceran zooplankton (Figure 10c). Dreissenid consumption was highest in round goby and reflected the minor separation between round goby and yellow perch and spottail shiner diets (Figure 10d).

*Job 104.3: Report preparation*

Data were further processed to include in Primer-E analyses. Visual representations of multivariate community analyses were generated to include in this report.

## Discussion

After our fourth full year of sampling three locations with different habitat characteristics, it appears that mechanisms influencing fish assemblages may operate at small, localized spatial scales (i.e. <20 km). Clearly, temporal changes in the abundance of fish also occur. Qualitative differences in abiotic and biotic conditions that could influence fish growth and survival have been observed between our sampling locations. Species composition of fish and benthic invertebrates did not differ among locations in 2011, compared to differences among locations in 2008 -2010. Water temperature did vary among locations in early summer months, and showed larger differences between surface and bottom temperatures at DR compared to the other two locations. S2 is a mosaic of sand, pebbles, and intermittent cobble overlying clay and has a much armored shoreline. M2 is the most structurally complex of the three locations, with sand, gravel, pebble, cobble and boulder substrate. Fine sand is the predominant substrate at the DR location. Continued monitoring is needed to build a long term data set to help determine the impact these differences may have on community composition and fish growth and survival in the Illinois nearshore waters of Lake Michigan.

There is a large data gap on fish older than YOY but younger than spawning adults, and for fish communities on rocky habitats (Keast 1977; Vanderploeg et al. 2002). Within lakes, different fish assemblages are found among habitat types (Pratt and Smokorowski 2003). Using identical sampling gear (small-mesh gill nets) at the three locations we did find that the fish community showed different seasonal patterns at each of our locations. Dead River is the most featureless of our locations, with fine sandy substrate and no shoreline structures. Dead River is also generally colder than the other sites and subject to more frequent upwelling events. It thus makes sense that alewife and rainbow smelt, which are pelagic and prefer cool water, were more abundant at this location than at the other locations. Alewife densities were also highest here at DR in August and September, while catches at the other locations were very low during these months. Spottail shiners have previously been noted to spawn in water depths < 5m over sand in Lake Michigan during late June – September (Wells and House 1974). Our data also suggest this habitat type preference: spottail shiner numbers were highest overall at DR and lowest at the 7 m sites for all locations.

Yellow perch were relatively abundant at all three sampling locations during 2011, but their abundance by month varied amongst all three locations. Yellow perch were abundant at the two southern locations during June and July, but then catches declined. As water temperatures warmed and stabilized at DR, numbers of yellow perch peaked in August and September. The temperature regime at M2 likely makes this site a transition area between the relatively stable temperatures at S2 and the more variable temperatures at DR (frequent bottom temperature declines) as seen in July and August numbers. Yellow perch may have been tracking not only favorable temperatures, but also prey resources. Numbers of chironomid larvae, a preferred food source were highest at M2 during early summer when perch were present, but declined in September and October. Conversely, chironomid densities at DR were highest in July, September and October.

Analyses of fish diets for five species showed many prey items in common and diets of round goby, yellow perch and spottail shiners were most similar to each other. Although round gobies consumed more Dreissenids than the other fish, they also ate large numbers of other benthic items (chironomids and amphipods) and zooplankton, which are important prey for juvenile yellow perch. If abundance of benthic organisms, such as *Diporeia*, and zooplankton further declines, the round goby would be at a competitive advantage because of their ability to consume Dreissenid mussels. Yellow perch would likely be impacted more than spottail shiner because both yellow perch and round goby were most abundant at the rockier sites whereas spottail shiners were more common in sandy locations. Additional years of data collection will give us further insight into the competitive interactions of these species in Lake Michigan. We will also be able to compare stomach contents of fish to zooplankton composition and benthic invertebrate assemblages and determine if diet shifts occur because of changes in food preference or shifts in food availability. For example, Keast and Eadie (1985) determined that differences in growth of juvenile largemouth bass in the same system were due to differences in diet caused by prey availability.

There is a limited understanding of the importance of various factors affecting fish communities in nearshore waters of Lake Michigan. Since the arrival of the invasive zebra mussel, quagga mussel, and round goby, we are not sure to what extent these organisms displaced native fish to less suitable habitats, affected abundance of preferred prey of native fish, and impacted growth of native fish species. Our data shows that these invasive species were primary contributors to community differences within our study area. While populations of alewife have declined, round goby have expanded into the north sampling area in recent years. Yellow perch growth has been declining compared to that in the late 1990s and young round gobies consume many of the same zooplankton and benthic species as juvenile yellow perch.

Identifying and understanding ecological constraints placed on yellow perch year-class strength and growth is critical for harvest regulations and habitat protection. Similarly, understanding alewife dynamics is important because these planktivores are the primary food source of stocked salmonids in Lake Michigan (Stewart et al. 1981). Information on alewife abundances and growth will indicate appropriate salmonid stocking levels, and may be useful to predict negative interactions between yellow perch and alewife. Extending our knowledge on other species such as spottail shiners, bloaters *Coregonus hoyi*, Cyprinids, round goby, and rainbow smelt will provide additional information on the prey base for adult sport fishes, and a more complete picture of competitive interactions within the nearshore fish assemblage. Overall understanding of how abundance, composition, growth and competition within the nearshore fish communities relate to habitat, food availability, and temperature will be very beneficial to managers as they work to set angler harvest limits, salmonid stocking quotas, and preferred areas for habitat protections and/or restoration.

**Conclusions**

Current management strategies for Lake Michigan focus on nearshore waters as contiguous units despite many habitat differences exhibited in this study at three different habitat types. Therefore, it is important to continue to investigate how ecological conditions vary temporally and within smaller spatial scales in the nearshore zone, and effects these differences (e.g., temperature, food resources, and habitat structure) may have on growth, survival, and species composition of the entire nearshore fish assemblage.

## Literature cited


Barton, D.R., R.A. Johnson, L. Campbell, J. Petruniak, M. Patterson. Effects of round gobies (*Neogobius melanostomus*) on Dreissenid mussels and other invertebrates in Eastern Lake Erie, 2002-2004. Journal of Great Lakes Research 31(Suppl. 2): 252-261.

Chrzastowski, M.J. and C.B. Trask. 1995. Nearshore geology and geologic processes along the Illinois shore of Lake Michigan from Waukegan Harbor to Wilmette Harbor. Final Report to U.S. Army Corps of Engineers. ILGS Open File Series 1995-10.

Confer, J. L., E. L. Mills, and L. O. Bryan. 1990. Influence of prey abundance on species size and selection by young yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 47:882-887.

Creque, S.M., and S.J. Czesny. 2012. Diet overlap of non-native alewife with native yellow perch and spottail shiner in nearshore waters of southwestern Lake Michigan, 2000-2007. Ecology of Freshwater Fish 21:207-221.

Creque, S.M., S.J. Czesny, B.C. Ruebush, and M.J. Weber. 2007. Growth and survival of nearshore fishes in Lake Michigan. Illinois Natural History Survey Technical Report (49), Champaign, IL, 64 p.

Danehy, R.J., N.H. Ringler, and J.E. Gannon. 1991. Influence of nearshore structure on growth and diets of yellow perch (Perca flavescens) and white perch (Morone Americana) in Mexico Bay, Lake Ontario. Journal of Great Lakes Research 17: 183-193.

Hrabik, T.R., M.P Carey and M.S. Webster. 2001. Interactions between young-of-the-year exotic rainbow smelt and native yellow perch in a northern temperate lake. Transactions of the American Fisheries Society. 130: 568-582.

Janssen, J. Berg, M.B. Berg, and S.J. Lozano. 2005. Submerged terra incognita: Lake Michigan's abundant but unknown rocky zones. Pp. 113-139 *In* T. Edsall and M. Munawar, editors. State of Lake Michigan: Ecology, Health and Management. Ecovision World Monograph Series.

Janssen, J. and M. Luebke. 2004. Preference for rocky habitat by young-of-the-year yellow perch and alewives. Journal of Great Lakes Research 30: 93-99.

Keast, A. 1977. Diet overlaps and feeding relationships between the year classes in the yellow perch (*Perca flavescens*). Environmental Biology of Fish 2: 53-70.

Keast, A., and J.A. Eadie. 1985. Growth dispensation in year-0 largemouth bass: the influence of diet. Transactions of the American Fisheries Society 114: 204-213.

Kuhns, L.A., and M.B. Berg. 1999. Benthic invertebrate community responses to round goby (*Neogobius melanostomus*) and zebra mussels (*Dreissena polymorpha*) invasion in southern Lake Michigan. Journal of Great Lakes Research 25: 910-917.

Madenjian, C. P., R. O'Gorman, D.B. Bunnell, R.L. Argyle, E.F. Roseman, D.M. Warner, J.D. Stockwell, and M.A. Stapanian. 2008. Adverse effects of alewives on Laurentian Great Lakes Fish Communities. North American Journal of Fisheries Management 28: 263-282.

Miller, T., L. B. Crowder, and F. P. Binkowski. 1990. Effects of changes in the zooplankton assemblage on growth of bloater and implications for recruitment success. Transactions of the American Fisheries Society 119:483-491.

Miller, T. J., L. B. Crowder, J. A. Rice, and E. A. Marschall. 1988. Larval size and recruitment mechanisms in fishes: toward a conceptual framework. Canadian Journal of Fisheries and Aquatic Sciences 45:1657-1670.

Nalepa T. F., D. J. Hartson, D. L. Fanslow, G. A. Lang, and S. J. Lozano. 1998. Declines in benthic macroinvertebrate populations in southern Lake Michigan, 1980-1993. Canadian Journal of Fisheries and Aquatic Sciences 55: 2402-2413.

Persson, L. 1983. Food consumption and competition between age classes in a perch *Perca fluviatilits* population in a shallow eutrophic lake. Oikos 40: 197-207.

Pothoven, S.A., T.F. Nalepa, and S.B. Brandt. 2000. Age-0 and age-1 yellow perch diet in Southeastern Lake Michigan. Journal of Great Lakes Research 26:235-239.

Pratt, T. C., and K.E. Smokorowski. 2003. Fish habitat management implications of the summer habitat use by littoral fishes in a north temperate, mesotrophic lake. Canadian Journal of Fisheries and Aquatic Sciences 60: 286-300.

Stewart, D. J., J. F. Kitchell, and L. B. Crowder. 1981. Forage fishes and their salmonid predators in Lake Michigan. Transactions of the American Fisheries Society 110:751-763.

Vadeboncouer, Y., M.J. Vander Zanden, D.M. Lodge. 2002. Putting the lake back together: reintegrating benthic pathways into lake food web models. Bioscience 52: 44-54.

Vanderploeg, H.A., T.F. Nalepa, D.J. Jude, E.L. Mills, K.T. Holeck, J.R. Liebig, I.A. Grigorovich, and H. Ojaveer. 2002. Dispersal and emerging ecological impacts of Ponto-Caspian species in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 59: 1209-1228.

Wells, L. and R. House. 1974. Life history of the spottail shiner in southeastern Lake Michigan, the Kalamazoo River, and western Lake Erie. Bureau of Sport Fisheries and Wildlife (U.S.) Research Report 78.

Winnell, M.H. and D. J. Jude. 1987. Benthic community structure and composition among rocky habitats in the Great Lakes and Keuka Lake, New York. Journal of Great Lakes Research 13: 3-17.

**Table 1. Mean length ± 1 s.d. of fish captured in small mesh gill nets during June – October 2010 whose stomachs were processed for diet analysis. Fish classified as small were ≤ 80 mm TL, fish classified as large were between 80 and 150 mm TL.**

| Fish | Size class | Mean length (mm) | # of stomachs |
|---|---|---|---|
| Yellow perch | Small | 67 ± 8 | 139 |
| Yellow perch | Large | 103 ± 21 | 165 |
| Alewife | Small | 71 ± 4 | 28 |
| Alewife | Large | 118 ± 21 | 90 |
| Rainbow smelt | Large | 120 ± 21 | 28 |
| Spottail shiner | Small | 68 ± 7 | 13 |
| Spottail shiner | Large | 100 ± 13 | 111 |
| Round goby | Small | 66 ± 8 | 121 |
| Round goby | Large | 94 ± 10 | 55 |

**Table 2. Frequency of occurrence of diets items in fish stomachs with prey present from 2010 sample collection.**

| Fish | Size class | Amphipod | Chironomid | Cladocera | Copepod | Dreissenid | Invertebrate | Veliger |
|---|---|---|---|---|---|---|---|---|
| Yellow perch | Small | 4 | 70 | 68 | 75 | 1 | 59 | 4 |
| Yellow perch | Large | 9 | 89 | 42 | 45 | 4 | 59 | 2 |
| Alewife | Small | 0 | 46 | 100 | 96 | 0 | 11 | 7 |
| Alewife | Large | 0 | 81 | 94 | 88 | 2 | 28 | 29 |
| Rainbow smelt | Large | 0 | 89 | 46 | 11 | 0 | 64 | 0 |
| Spottail shiner | Small | 8 | 69 | 54 | 31 | 8 | 23 | 0 |
| Spottail shiner | Large | 2 | 91 | 37 | 10 | 19 | 41 | 3 |
| Round goby | Small | 38 | 93 | 47 | 81 | 42 | 65 | 3 |
| Round goby | Large | 33 | 89 | 38 | 56 | 65 | 73 | 7 |

**Table 3. Dreissenid veliger density (ind/L ± 1 s.d.) collected at three locations in southwestern Lake Michigan during June – October 2011. Number in parentheses is sample number.**

| Month | DR | M2 | S2 |
|---|---|---|---|
| June | 0.9 ± 1.2 (12) | 0.7 ± 0.8 (11) | 7.7 ± 11.1 (10) |
| July | 1.1 ± 2.0 (12) | 0.3 ± 0.3 (12) | 0.4 ± 0.4 (12) |
| August | 7.2 ± 9.1 (14) | 0.8 ± 0.4 (6) | |
| September | 1.1 ± 0.7 (6) | 0.1 ± 0.1 (6) | 5.2 ± 5.5 (12) |
| October | 2.2 ± 2.1 (6) | 5.6 ± 7.7 (12) | 9.7 ± 18.4 (12) |

**Table 4. Annual mean total benthic invertebrate density (#/$m^2$) ± 1 standard deviation in core and ponar samples at each location by depth for June – October sampling in 2011. Number in parentheses equals the number of samples collected.**

| Site depth/Location | DR | M2 | S2 | All locations combined |
|---|---|---|---|---|
| 3 m | 422 ± 661 (17) | 695 ± 985 (16) | 2867 ± 5532 (13) | 1208 ± 3124 (46) |
| 5 m | 1044 ± 1977 (17) | 856 ± 1317 (13) | 812 ± 1159 (13) | 917 ± 1543 (43) |
| 7 m | 2849 ± 4372 (17) | 2241 ± 3288 (15) | 730 ± 1282 (13) | 2034 ± 3408 (45) |

**Table 5. Total number of organisms detected on rocks collected at M2 during the 2011 sampling season. There were 21 rocks collected.**

| General Category | Taxa | M2 |
|---|---|---|
| Amphipods | Amphipoda | 11 |
| | Echinogammarus | 41 |
| | Gammaridae | 27 |
| | Gammarus | 25 |
| | Hyalella Azteca | 71 |
| Midges | Chironomid larvae | 1019 |
| | Chironomid pupa | 6 |
| Non-native mussels | Pelecypoda | 5 |
| | Dreissena bugensis | 725 |
| | D. polymorpha | 1 |
| Gastropods | Gastropoda | 0 |
| Arachnid | Hydracarina | 50 |
| Misc. invertebrates | Hydroid | 6 |
| | Ostracoda | 4 |
| | Annelids | 1 |
| | Nematoda | 167 |
| | Oligochaetes | 87 |
| | Ephemeroptera | 15 |

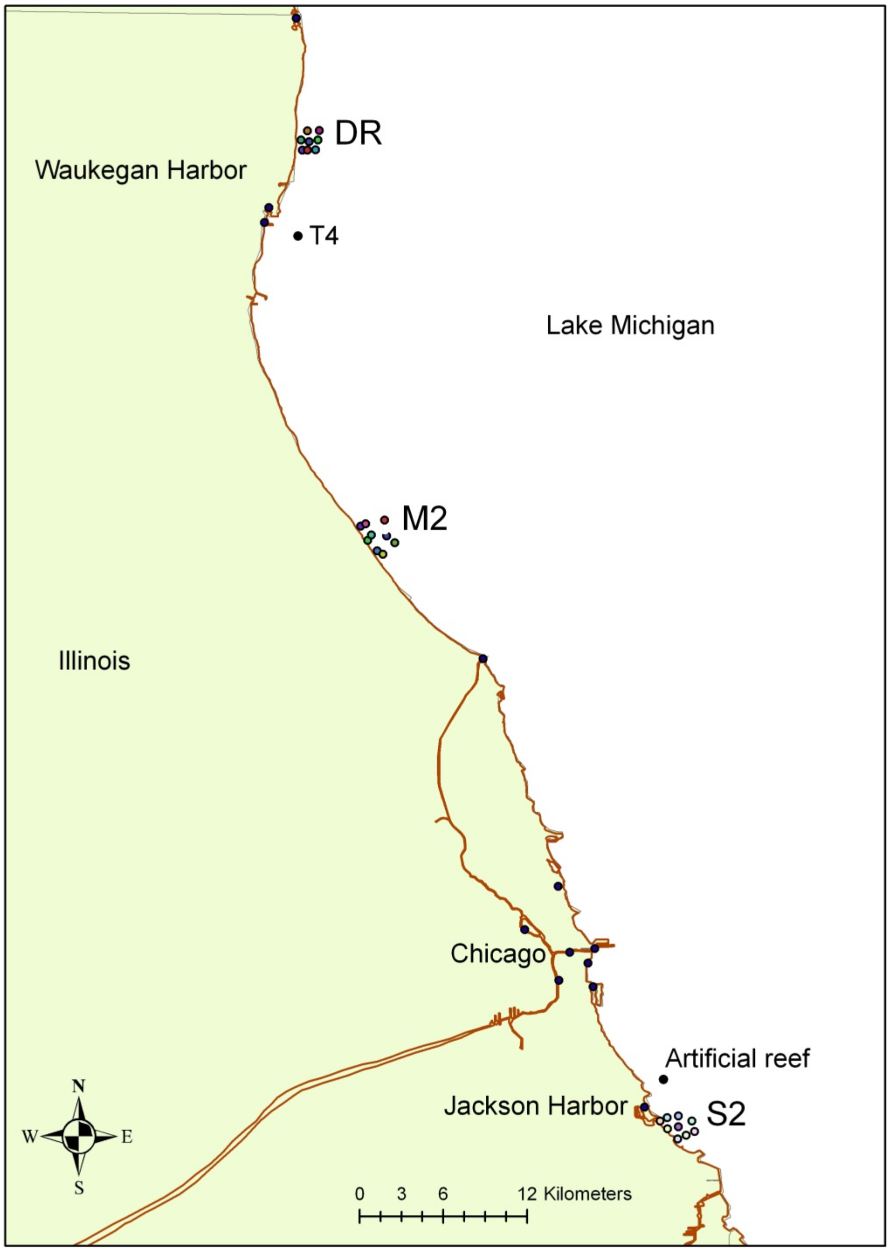



Figure 1. Map of sampling locations in the Illinois waters of Lake Michigan.

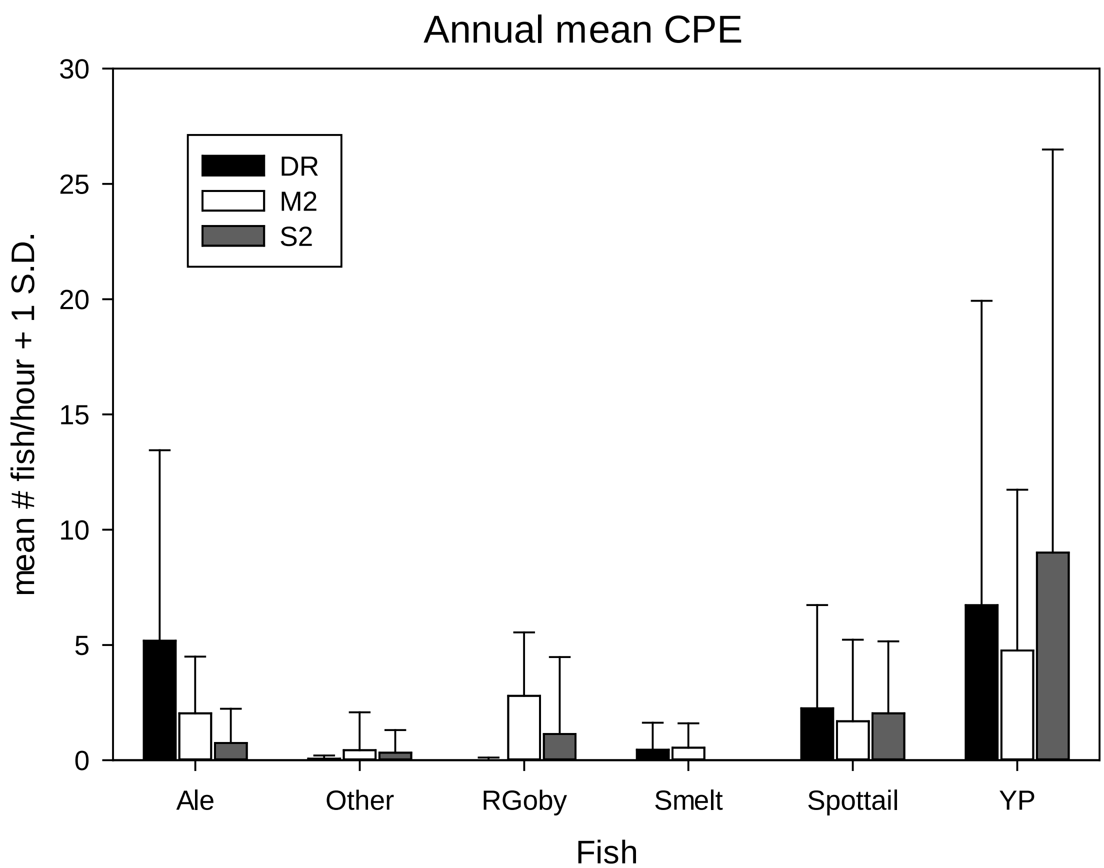



Figure 2. Mean annual CPE (number fish/hour + 1 standard deviation) from small-mesh gill netting during June-October, 2011 at three sampling locations in Illinois waters of Lake Michigan.

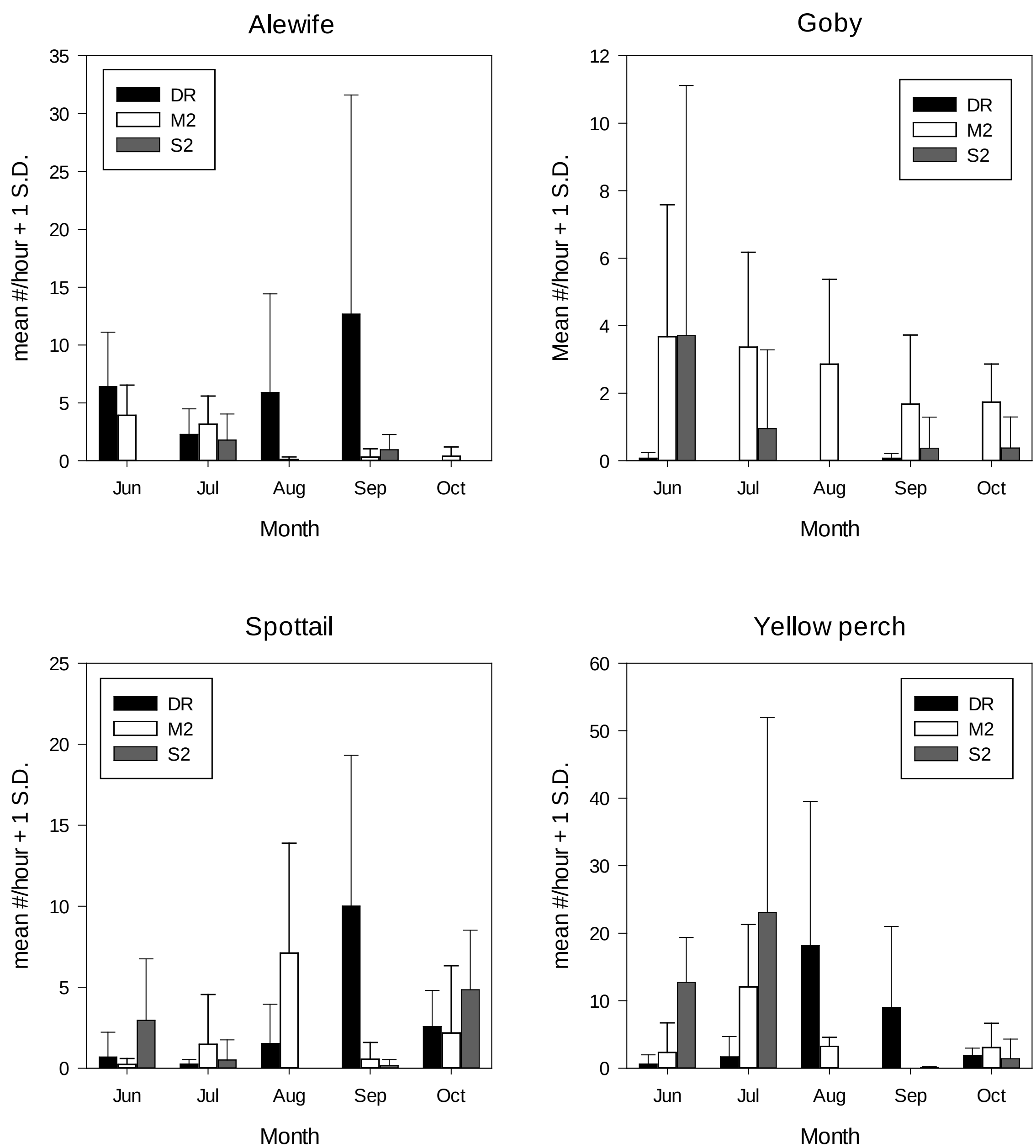



Figure 3. Mean monthly CPE (number of fish/hour + 1 standard deviation) of the most abundant fish collected in small mesh gill nets during June – October, 2011 at three locations in Illinois waters of Lake Michigan.

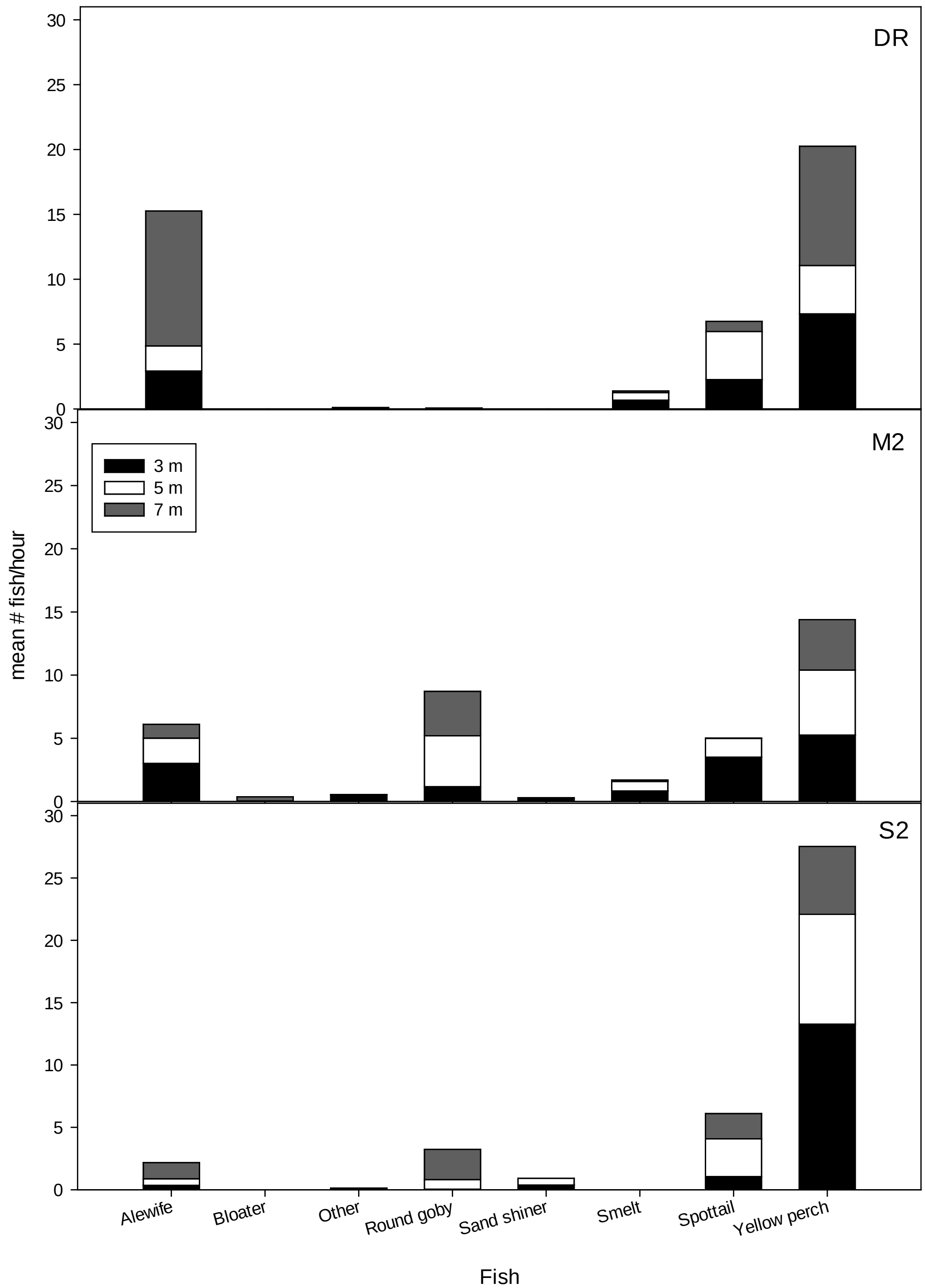



Figure 4. Annual mean number of fish per hour in small mesh gill nets set at three water depths (3, 5 and 7 meters) at each of three locations (DR, M2, and S2).

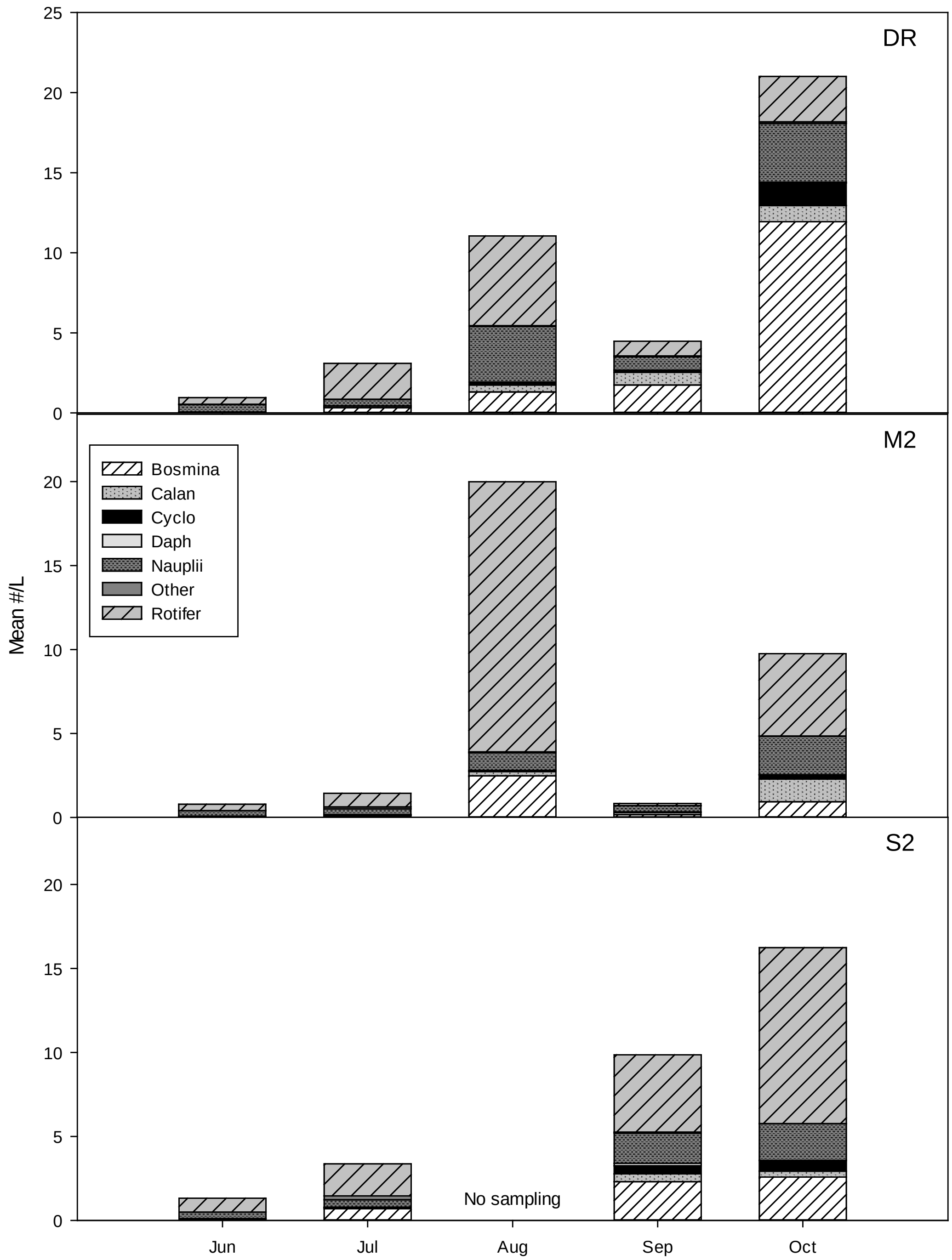



Figure 5. Monthly mean zooplankton density (#/L) for the most common taxa collected at three locations in Illinois waters of Lake Michigan during 2011.

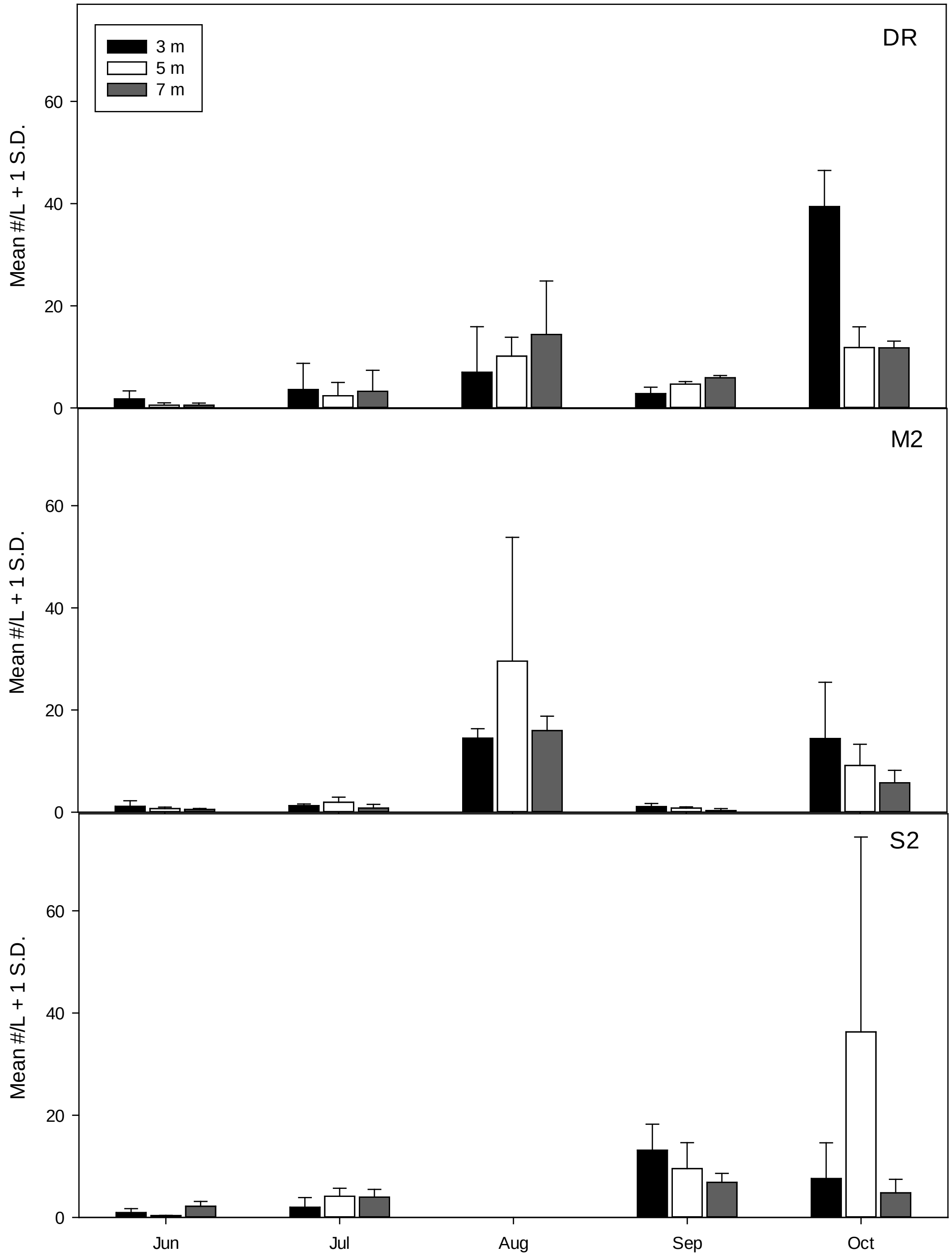



Figure 6. Monthly mean zooplankton density (#/L + 1 S.D.) by water depth at three nearshore locations in Illinois waters of Lake Michigan during 2011.

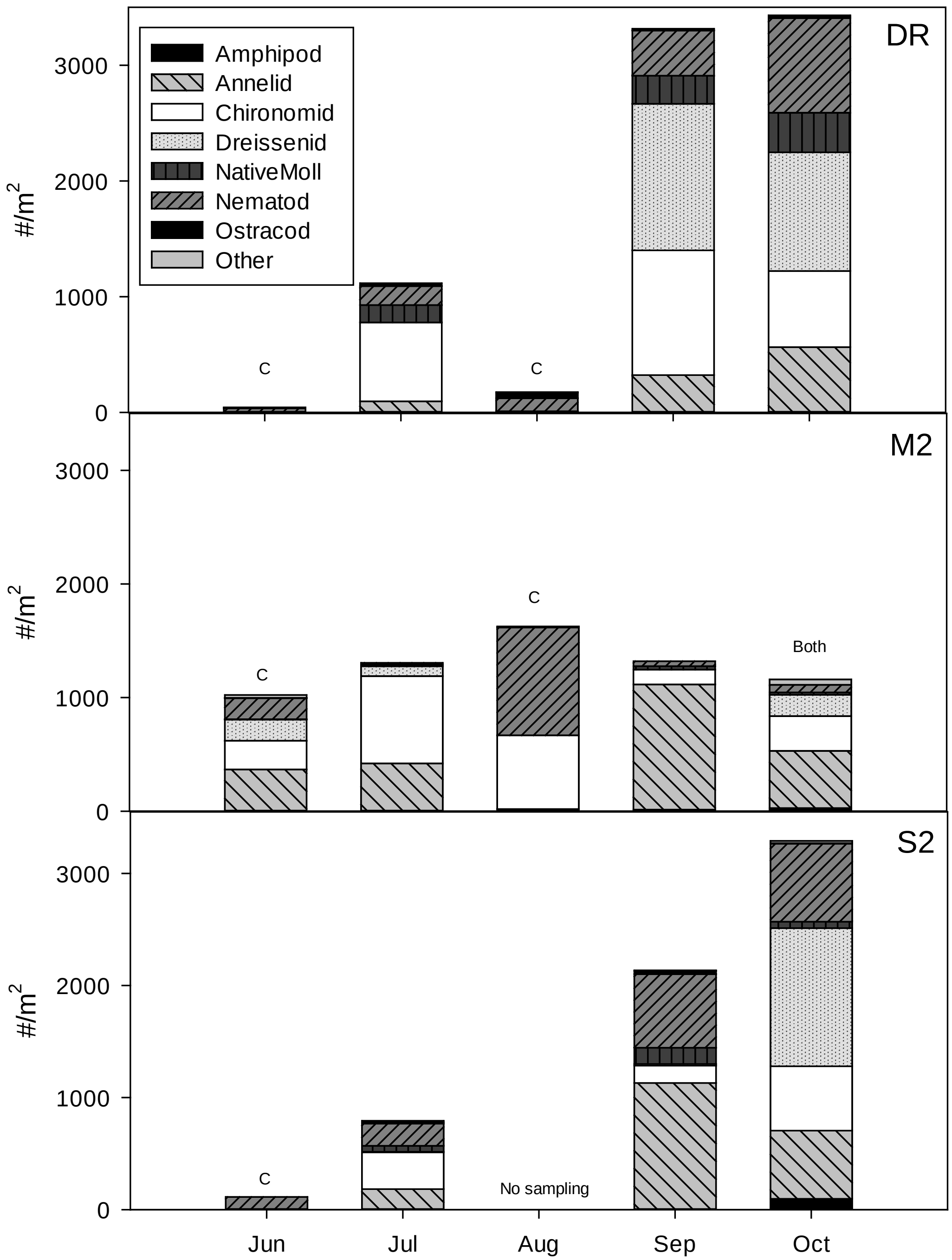



Figure 7. Monthly mean density (#/$m^2$) of the most common invertebrate taxa collected in benthic cores and ponar grabs during 2011 sampling. The letter “c” above a bar indicates those samples were collected using cores, while samples without a letter were collected with a ponar grab; “both” indicates a combination of cores and ponars were used for that sampling occasion.

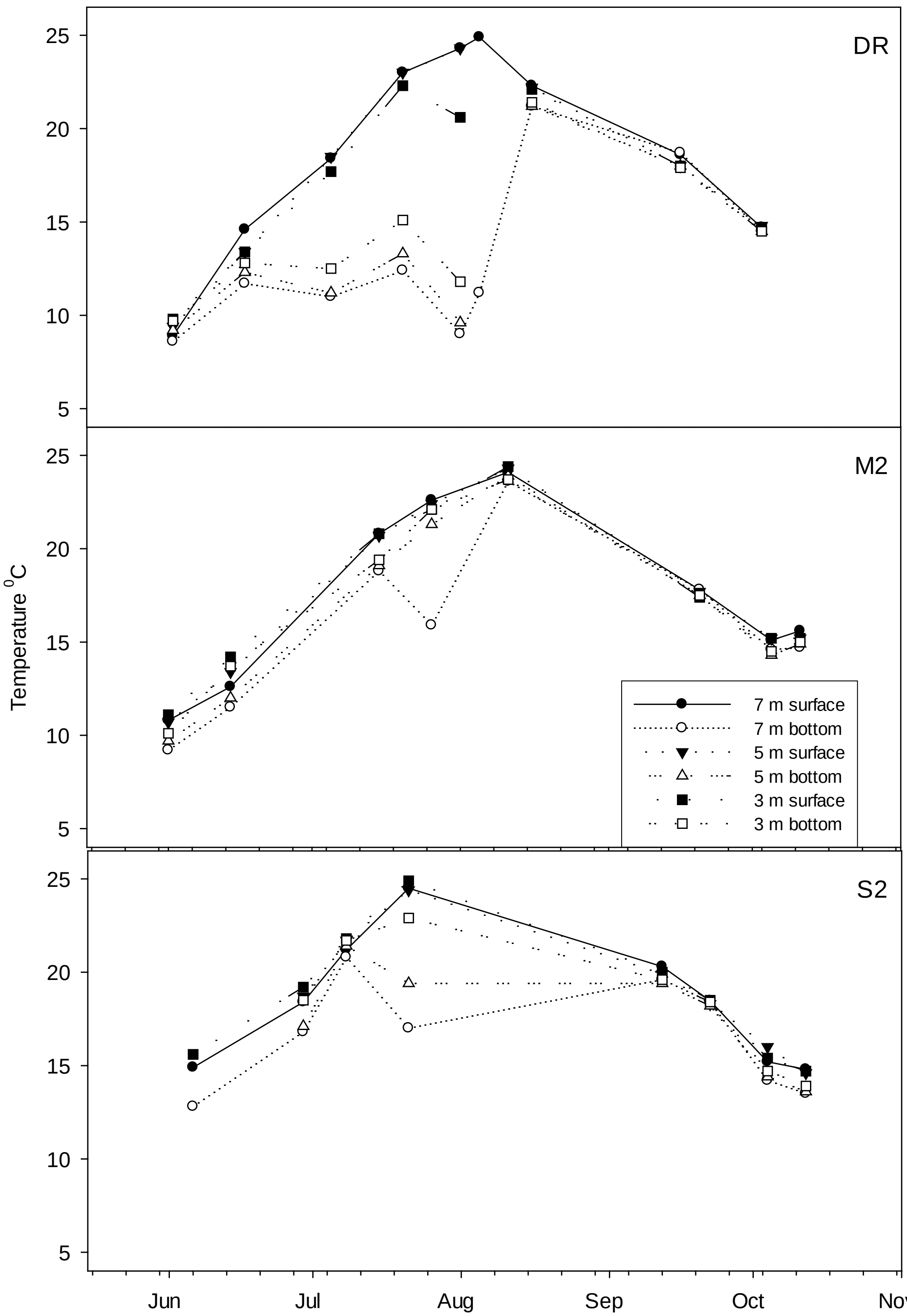
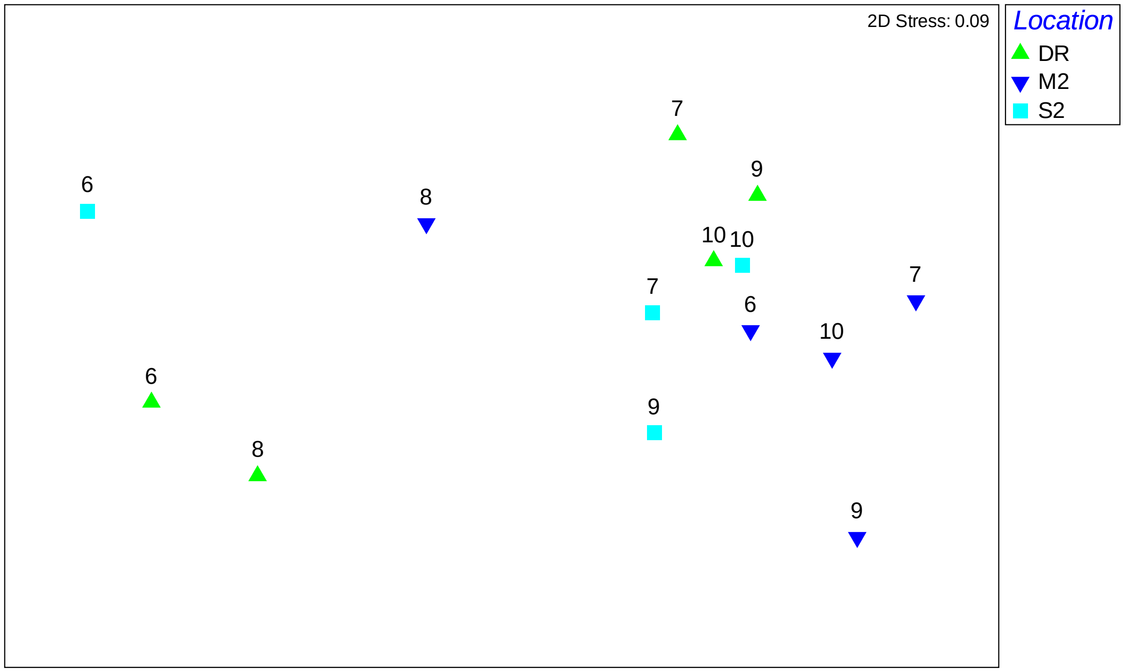



Figure 8. Surface and bottom water temperatures from profiles taken on each sample outing during 2011.

a.




b.

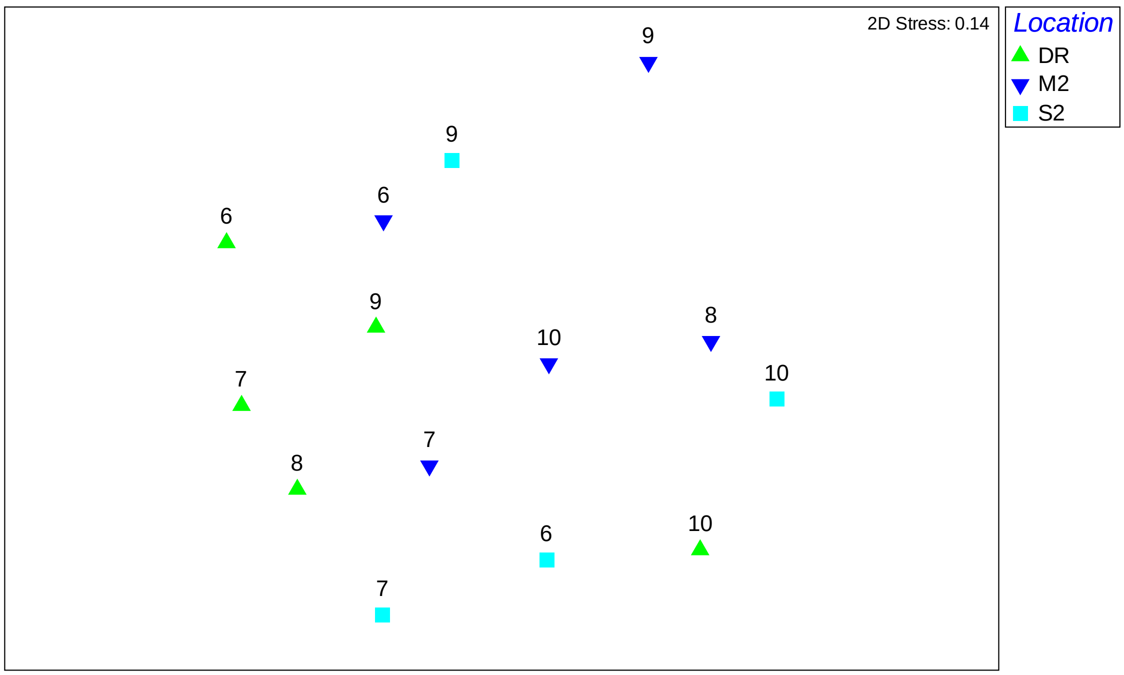



Figure 9. Mean a) benthic and b) fish composition (% by number) by location and month during 2011 sampling, illustrated in a non-metric multidimensional scaling plot. Text above symbols indicate month; symbols that are close together have greater similarity than symbols that are further apart.

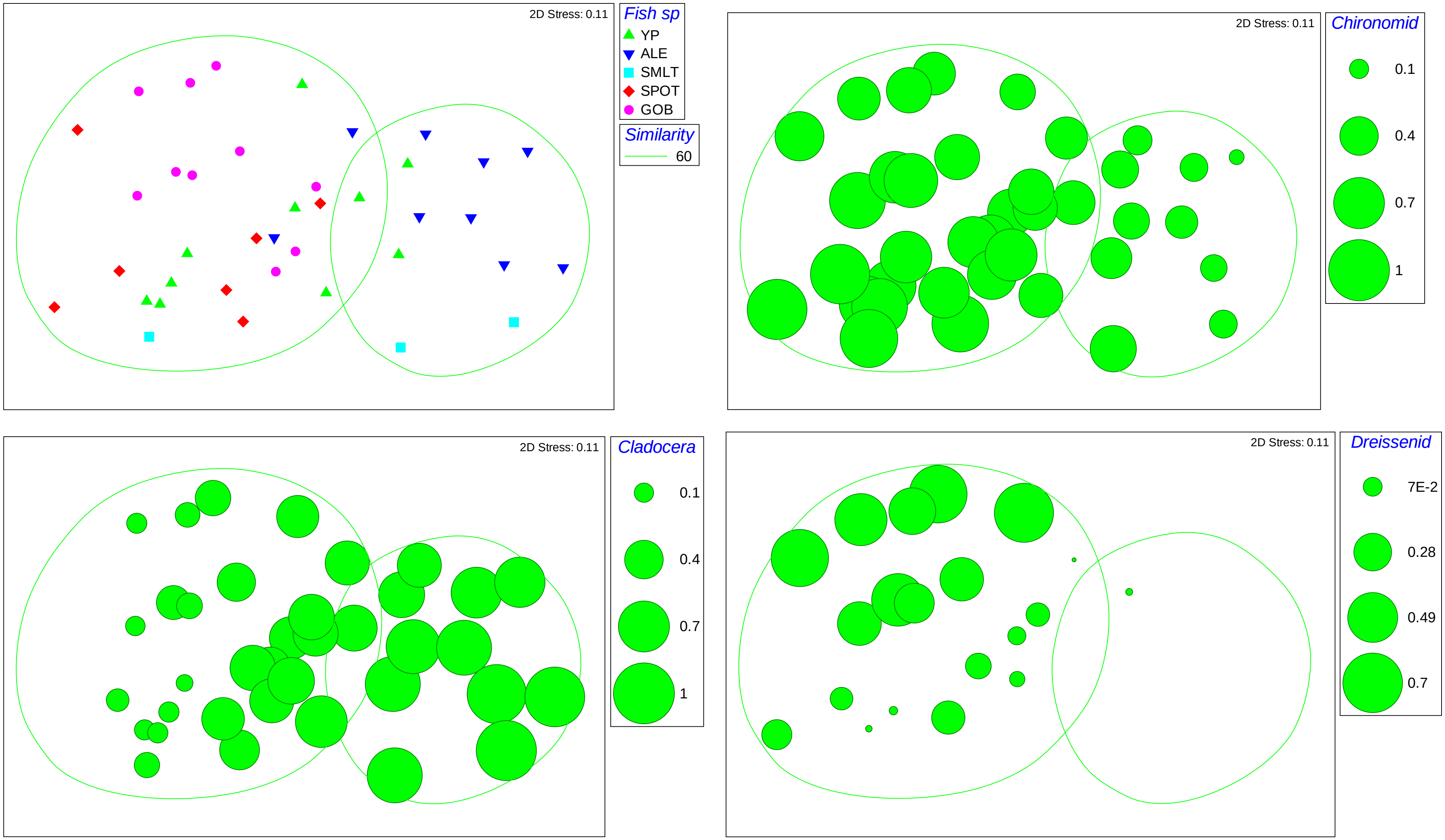



Figure 10. a) Similarity of diet composition (% by number) for five fish species collected in small-mesh gill nets during June - October 2010 displayed in a non-metric multidimensional scaling plot. The varying diameters of the superimposed circles reflect relative abundance of b) chironomid larvae, c) Cladoceran zooplankton and d) Dreissenid mussels in the fish diets .