ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Growth and survival rate of nearshore fishes in Lake Michigan, 2012

Sara M. Creque and Sergiusz J. Czesny

INHS Technical Report

Prepared for Illinois Department of Natural Resources, Division of Fisheries

Issue Date: November 15, 2013

Sponsor: Division of Fisheries, Illinois Department of Natural Resources
Grant/Contract No: Federal Aid Project F-138-R-16

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, 2012

August 1, 2012 – June 30, 2013

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-16

____________________ ________________________

Sergiusz J. Czesny
Principal Investigator

Associate Director for Research

November 2013

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 2012 field season and marks the fifth 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 2013 is ongoing and lab processing is not complete. As such, a complete reporting of data collected during the 2012 sampling season is presented, covering data from Segments 15 and 16. 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.

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

1. Mean annual catch per unit effort (CPE) ranged from 10 fish/hour at M2 to 30 fish/hour at M2. Total CPE did not significantly differ due to location, month or depth.

2. Alewife and yellow perch were the most abundant taxa at DR by an order of magnitude. Alewife, round goby and yellow perch were all caught in similar numbers at M2. Yellow perch was the most abundant at S2.

3. Length data indicated that age-0 yellow perch made up the majority of yellow perch captured at all locations in August-October.

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

1. Mean annual crustacean zooplankton density was less than 6 individuals/L for all three locations and did not differ by location or month.

2. Copepod nauplii were the most abundant crustacean zooplankton at DR and M2, while Bosmina was the most abundant taxa in S2 samples.

3. Annual mean veliger density was highest at DR and highest mean annual rotifer density occurred at S2.

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

1. Mean annual benthic invertebrate densities (excluding Dreissenid mussels) ranged from 1148 – 1910 ind/m^2 at DR and M2 respectively and were highly variable amongst samples.

2. The most common taxa collected at all three locations were Chironomids, Dreissenids, Annelids and nematods.

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

1. Multivariate analysis of community data over 2008-2012 indicated that there were differences in species composition amongst locations for both the benthic invertebrate and fish communities.

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.

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. In general, species diversity tends to increase with increasing habitat complexity (Keast and Eadie 1985; Danehy et al. 1991; Pratt and Smokorowksi 2003). The Illinois waters of Lake Michigan are a mosaic of sandy substrates to the north, moving to rockier habitat in the middle and mixed substrates to the south (Creque et al. 2010) providing a variety of available habitats.

Although there are a large number of studies on pelagic productivity, few focus on the littoral zone (Vadeboncouer et al. 2002) despite its importance as spawning and nursery habitat for many sport and prey fish species. In addition, 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. This is especially critical with the many recent ecological changes in the nearshore region brought on by the arrival of invasive species and human induced habitat and water quality changes.

Ecological changes caused by invasive species can affect diet and competitive interactions of Lake Michigan fish. For example, 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 (Confer et al. 1990 and Miller et al. 1990). 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). 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). 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). Round goby < 70 mm consume a variety of benthic invertebrates, very similar to small yellow perch and other native fish (Vanderploeg et al. 2002).

Abundance and growth trends of invasive species such as alewife and round goby are very important to understand because of the large role they now play in the Lake Michigan food web. Alewives are the dominant prey of stocked chinook salmon (Rybicki and Clapp 1996; Warner et al. 2008), which provide a very important sport fishery, and their importance as prey seems to be increasing in recent years (Jacobs et al. 2013). Round goby are also beginning to show up in diets of large predators such as the native lake trout. One of the native species of biggest concern in the nearshore zone is yellow perch, a very popular sport fish in Lake Michigan. Yellow perch experienced a precipitous decline in the early 1990s and abundance and harvest was greatly reduced lake wide (Madenjian et al. 2002; Marsden and Robillard 2004). Despite harvest regulations and an increase in spawning stock, recruitment has remained relatively low (Wilberg et al. 2005, Redman et al. 2011). Both plankton and benthic resources have declined since the high yellow perch abundances of the 1980s (Dettmers et al. 2003, Nalepa et al. 2006, Redman et al. 2011). 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. Therefore, monitoring changes in distribution, abundance and growth of yellow perch in relation to biotic and abiotic factors is extremely important.

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 16 marks the fifth 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 2-3 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.

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.

<u>Study 102:</u> 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. *Dreissenid* veligers and rotifers 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 zooplankton, benthic invertebrate and small mesh gill net fish data to give an indication of community patterns across locations during 2008-2012. Data were square root transformed, and analysis was performed in Primer-E multivariate software using cluster, non-metric multidimensional scaling (NMDS) and ANOSIM tests.

Job 104.2: Explore impact of round goby on yellow perch

Trends of round goby and yellow perch abundance and spatial overlap during 2008-2012 were analyzed using SIMPER and NMDS plots in Primer-E software.

Job 104.3: Report preparation

Data were further processed to include in Primer-E analyses. Multivariate analyses of 2008-2012 zooplankton, benthic invertebrate and fish community data were included in this report.

Results

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 2012 sampling season (June – October) which includes data collected in Segment 15 and Segment 16. Differences in number of samples collected at the three locations result from occasional weather related cancellations of sample outings, equipment issues, and boat repairs.

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

Job 101.1: Quantify abundance and composition of juvenile fish community

During 2012 sampling, yellow perch, alewife, round goby and spottail shiner were collected in small mesh gill nets at all three locations. An additional 5 species, including rainbow smelt, bloater and coho salmon, which were not found anywhere else, were collected at DR (Table 1). Longnose dace were collected only at M2 and smallmouth and largemouth-bass were found in nets only at S2. Mean annual total CPE was 30 + 31 fish/hour at DR, 10 + 8 fish/hour at M2 and 17 + 30 fish/hour at S2 (Figure 2). A total of 24 nets were set at DR June - October, 15 at S2 June-September and 10 at M2 June-August. Weather was a factor in the limited number of nets set in fall. There was high variability in individual net set's CPE and the annual total CPE did not significantly differ between locations ($F=0.86$, $P>0.4$, $df=48$). Alewife and yellow perch CPEs differed by less than 1 fish/hour and together accounted for 96% of CPE at DR. Alewife, round goby and yellow perch were caught in very similar numbers at M2 (2.6-

4.3 fish/hour) and accounted for 99% of CPE (Figure 2). Yellow perch (9.5 fish/hour) was the most common species captured at S2, accounting for 57% of annual CPE.

Total CPE in June was similar at all three locations, while CPE in July was four times higher at DR (Figure 3). CPE at S2 peaked in August. General linear model analysis of total CPE with factors of Location and month was not significant (F=1.83, P<0.8, df=48). Depth of nets was also not a significant factor for total CPE.

For the 4 most abundant fish species, general linear models were run with month, location and their interaction as factors on CPE. Results should be treated with caution as only DR has data for all months. CPE of alewife in July at DR was 43.4 ± 25.3, three times higher than any other month/location combination (Figure 4); the overall model for alewife was significant (F=3.97, df=48, P>0.001, P>0.002), with the interaction of month and location being the significant factor. The interaction factor was also significant for yellow perch (F=3.73, df=48, P>0.001, P>0.003), which had high CPE in August-October at DR and at S2 in August. Round goby CPE on the other hand differed significantly amongst locations 9F=4.25, df=48, P>0.001, P>0.001), being higher at M2 and S2 than DR in all months. The model for spottail shiner was not significant, catches were highest at DR in October when there was no data for the 2 other locations (Figure 4).

Job 101.2: Diet analysis of juvenile nearshore fish

Data on fish lengths taken in the field and during lab processing were similar across locations during summer and indicate age 1+ fish (Figure 5). During Fall, DR had a small number of perch in age 1+ size classes, but the majority of yellow perch caught at all three locations were likely age-0 based on length. Length data for alewife and spottail shiners indicate that fish caught at S2 in the fall were age-0 while those captured at DR and M2 contained older age classes as well.

Sex ratios of yellow perch were within 6% at DR and S2, but were more strongly skewed towards females at M2 (Table 2). Catches of alewife were dominated by males at all three locations. Male gobies were slightly higher at M2, while females were slightly higher at S2.

Diet processing for fish collected in 2012 is underway and data will be presented in a future report.

Job 101.3: Data analysis and report preparation

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

Study 102: Quantify nearshore zooplankton abundance and taxonomic composition

Job 102.1: Sample zooplankton

A total of 37, 14, and 22 zooplankton samples were collected at DR, M2, and S2 respectively during the 2012 field season. Samples were not collected during October at S2 and during September and October at M2 due to weather and boat repair issues.

Job 102.2: Id and count zooplankton

Mean annual crustacean zooplankton ranged between 4.4 ± 3.9 #/L (S2) to 5.5 ± 4.9 #/L (DR) and was not significantly different amongst locations (F=0.33, df=72, P>0.72). Seasonal patterns of zooplankton density varied by location. Crustacean zooplankton density was lowest at DR during August, while density was highest in August at M2 (Figure 6). June density at S2 was 6- 8 times lower than that at DR and M2. Crustacean zooplankton community was dominated by *Bosmina*, copepod nauplii and calanoid copepods.

When looking at the historical time series of crustacean zooplankton collected at 7- 10 m for DR and S2, densities in 2012 were similar to those in 2009-2010 and higher than in 2011, but lower than in 1999 and 2002-2005 (Figure 7).

Densities of Dreissenid veligers and rotifers were higher than crustacean densities at all locations (Figure 8). Overall, dreissenid veliger densities were highest at DR and lowest at M2. June had the highest seasonal densities for both DR and M2 locations, while densities in Chicago were highest during June and July. Rotifer densities were the highest of all zooplankton taxa collected, with annual means ranging from 13.6 ± 12.8 #/L at DR to 17.6 ± 16.0 #/L at S2. Seasonal patterns in rotifer density varied between all three locations.

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.

Study 103: Estimate relative abundance and taxonomic composition of benthic invertebrates in three different habitat areas

Job 103.1: Sample benthic invertebrates in soft sediments

Ponar grabs at DR and a combination of ponar grabs and benthic cores taken by SCUBA divers at M2 and S2 were used to collect sediment to sample benthic invertebrates. In sandy substrates, a total of 33, 16, and 43 samples at DR, M2 and S2 respectively were collected during 2012.

Job 103.2: Sample benthic invertebrates on rocky substrates

Sixteen core samples and 2 ponar grabs were used to collect data from rocky/gravelly substrate at the 5 and 7 m sites at M2 during 2012. In addition, during June 8 small rocks were collected at S2 and 12 at M2, with 8 more rocks collected at M2 during July.

Job 103.3: Identify and enumerate benthic invertebrates

Data for all core and ponar samples was standardized to give density in $\#/m^2$ and combined for analysis. Non-dreissenid total density ranged from 1148 ± 1291 $\#/m^2$ at DR to 1910 ± 2605 $\#/m^2$ at M2, and as evident by the large standard deviations, variability in counts between individual samples was very high. Non-dreissenid total density significantly differed by month and interaction of month and location (F=3.32, df=107, P>0.001), as visible in Figure 9, with spikes in density in July at M2 and August at S2. Non-dreissenid densities also differed significantly by depth (F=3.99, df=107, P> 0.001). Mean annual densities at 3 m were the lowest, with the exception of S2 (Table 3).

Dreissenid densities were highly variable across locations, seasons and even within replicate samples, likely owning to the dominance of extremely small juvenile mussels whose distribution is apparently quite patchy and seasonal (Table 4; Figure 10). Dreissenids were extremely rare or not found in 3 m samples at DR and M2, while the opposite trend occurred at S2, with highest densities at the 3m site (almost all in August) and few at the 5 and 7 m sites. Very few Dreissenids were collected at M2 regardless of depth.

When looking at all taxa collected, Dreissenids made up the largest percentage of species composition at DR and S2, 41 and 38% respectively, while Chironomid larvae accounted for 51% of organisms collected by number at M2 but less than 16% at the other 2 locations. Annelids, dominated by Oligochaetes, were common at all three locations, as were nematodes to a varying degree seasonally (Figure 9). Native mollusks were really only a major contribution to species composition at DR. No *Diporeia* were collected and other amphipods accounted for less than 1% by number at all 3 locations. This continues the shift we have seen in the benthic community since 2006, with a steep decline in *Diporeia* and a complete takeover of quagga mussels in place of zebra mussels (Figure 11).

Job 103.4: Data analysis and report preparation

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

Study 104: 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

Longer-term community analysis was run for zooplankton, invertebrate and fish data collected during 2008-2012. Analysis of similarity test on fish species caught during this time period indicated that the fish community did not differ amongst years (Global R=0.03, p>0.2), but was moderately dissimilar between locations (Global R=0.251, P<0.01). Pairwise testing showed that the fish communities at S2 and M2 are very similar (r=0.06), but that DR is moderately different from fish caught at both M2 and S2 (r=0.34 and 0.33 respectively). Non-metric multidimensional scaling analysis gave a visual picture of these patterns, with DR samples clustering together on the top left portion of the graph and M2 and S2 samples overlapping on the bottom portion (Figure 13). The benthic invertebrate data showed even stronger dissimilarities amongst locations (global R=0.493, P<0.01), with differences between DR and M2 being very high (r=0.71), moderate to high between DR and S2 (r=0.54) and relatively similar invertebrate communities at S2 and M2 (r=0.19) (Figure 14). Year was also a significant factor in explaining dissimilarities in the benthic invertebrate community, although the overall level was low (Global R=0.22, P<0.01). Years with moderate dissimilarity were 2008 with 2011 and 2012, and 2009 and 2011. Zooplankton communities were similar across all years (global R=0.06, P>0.8) and locations (global R=0.102, P<0.03), as evident in the MDS analysis, with samples from all three locations being scattered throughout the plot (Figure 15).

Job 104.2: Explore impact of round goby on yellow perch

The Highland Park and Chicago area appear to provide good habitat for both yellow perch and round goby (Figure 16). Although not as abundant as at the rockier locations, numbers of round goby caught at the Waukegan area location have slowly been increasing since 2008.

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

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). Our study sites cover a range of physical habitat types, both in terms of substrate and temperature regime. DR has fine sand as the predominant substrate and is subject to frequent cold water upwellings. M2 is the most structurally complex of the three locations, with sand, gravel, pebble, cobble and boulder substrate. S2 is a mosaic of sand, pebbles, and intermittent cobble overlying clay and has a much armored shoreline and rarely experiences the dramatic changes in mid-summer temperatures compared to the north sites. Therefore we would expect to find varying fish and possibly prey communities within the Illinois waters of Lake Michigan on varying spatial and temporal scales.

Using identical sampling gear (small-mesh gill nets) at the three locations we did find differences in the nearshore fish community. During 2012 sampling, alewife was most abundant at DR and rainbow smelt, coho salmon and brown trout, all pelagic species that prefer cool water, were only collected at DR. Smallmouth and largemouth bass, which prefer structure and cool/warmer water temperatures, were only captured in nets at S2. For the most abundant species across all three locations, individual CPEs of alewife, yellow perch and round goby significantly differed by location and usually had interactions with varying seasonal patterns.

Small-mesh gill net catches during 2012 showed much more positive signs for yellow perch compared to those in 2011, when less than 10 age-0 yellow perch were caught across all locations and months. Although overall catch rates were similar in 2011 and 2012, during August-October 2012, the majority (84% of 1,026 perch measured) of yellow perch caught were age-0 based on size. In Illinois waters, recruitment of age-0 yellow perch during 1989-2007 was generally better in warmer years with higher levels of zooplankton available for young fish (Redman et al. 2011). Crustacean zooplankton densities during June and July 2012 were generally higher than those found during 2011, early June & July temperatures were also warmer in 2012. The importance of zooplankton is a concern because of the very low nearshore zooplankton abundances we have observed since 1999, especially compared to pre-Dreissenid densities (Dettmers et al. 2003) and the potential for other species competing for this limited resource.

Another major prey resource decline has occurred with the collapse of *Diporeia* amphipods in Illinois waters since , as occurred earlier on the eastern side of Lake Michigan (Nalepa et al. 1998; Madenjian et al. 2002). Loss of *Diporeia* as prey is thought to have contributed to the decline in condition of alewife (Madenjian et al. 2003). It could also have a severe impact on age-0 yellow perch as diet data from 2000-2007 showed both YOY and age-1 perch in Illinois waters switched primarily to amphipods during October, an important last period of growth before overwintering (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 other species of amphipods decline.

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.

Madenjian et al. 2012 and Jacobs et al. 2013 both call for additional data collection to provide insights into annual & across lake changes in habitat use, prey abundance and distribution and predator prey dynamics to determine mechanisms influencing bottom–up and top-down impacts on alewife and other prey fish species. This project is helping to fulfill that need in the Illinois nearshore waters of Lake Michigan.

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. 2005. 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. , K. M. Stainbrook, D.C Glover, S.J. Czesny, and J.M. Dettmers. 2010. Mapping bottom substrate in Illinois waters of Lake Michigan: linking substrate and biology. Journal of Great Lakes Research 36:780-789.

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.

Dettmers, J.M., M.J. Raffenburg, and A.K. Weis. 2003. Exploring zooplankton changes in southern Lake Michigan: implications for yellow perch recruitment. Journal of Great Lakes Research. 36:780-789.

Jacobs, G.R., C.P. Madenjian, D.B. Bunnell, D.M. Warner, and R.M. Claramunt. 2013. Chinook salmon foraging patterns in a changing Lake Michigan. Transactions of the American Fisheries Society 142:362-372.

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.

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., D.B. Bunnell, T.J. Desorcie, M.A. Chriscinske, M.J. Kostich, and J.V. Adams. 2012. Status and trends of prey fish populations in Lake Michigan, 2011. Great Lakes Fishery Commission, Lake Michigan Committee, Ann Arbor, MI.

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.

Madenjian, C.P., J.D. Holuszko, and T.J. Desorcie. 2003. Growth and condition on alewives in Lake Michigan, 1984-2001. Transactions of the American Fisheries Society. 132: 1104-1116.

Madenjian, C.P. G.L. Fahnestiel, T.H. Johengen, T.F. Nalepa, H.A. Vanderploeg, G.W. Fleischer, P.J. Schneeberger, D.M. Benjamin, E.B. Smith, J.R. Bence, E.S. Rutherford, D.S. Lavis, D.M.

Robertson, D.J. Jude, and M.P. Ebner. 2002. Dynamics of the Lake Michigan food web, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences. 59: 736-753.

Marsden, J.E. and S.R. Robillard. 2004. Decline of yellow perch in southwestern Lake Michigan, 1987-1997. North American Journal of Fisheries Management 24:952-966.

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.

Nalepa, T.F., D.L. Fanslow, A.J. Foley III, G.A. Lang, B.J. Eadie, and M.A. Quigley. 2006. Continued disappearance of the benthic amphipod Diporeia spp. in Lake Michigan: is there evidence for food limitation? Canadian Journal of Fisheries and Aquatic Sciences 63: 872-890.

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.

Pothoven, S.A., T.F. Nalepa, P.J. Schneeberger, S.B. Brandt. 2001. Changes in diet and body condition of Lake Whitefish in Southern Lake Michigan associated with changes in benthos. North American Journal of Fisheries Management 21:876-883.

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.

Redman, R.A., S.J. Czesny, J.M. Dettmers, M.J. Weber, D. Makauskas. 2011. Old tales in recent context: current perspective on yellow perch recruitment in Lake Michigan. Transactions of the American Fisheries Society. 140:1277-1289.

Rybicki, R.W., and D.F. Clapp. 1996. Diet of Chinook salmon in eastern Lake Michigan 1991-1993. Michigan Department of Natural Resources, Research Report 2027, Ann Arbor.

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.

Warner, D.M., C.S. Kiley, R.M. Claramunt, D.F. Clapp. 2008. The influence of alewife year-class strength on prey selection and abundance of age-1 Chinook salmon in Lake Michigan. Transactions of the American Fisheries Society 137:1683-1700.

Wilberg, M.J., J.R. Bence, B.T. Eggold, D. Makauskas, and D.F. Clapp. 2005. Yellow perch dynamics in southwestern Lake Michigan during 1986-2002. North American Journal of Fisheries Management 25:1130-1152.

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. Species caught in small mesh gill nets during 2012 indicated by shaded boxes for each location. Species are listed in decreasing order by overall abundance during this time period.

	DR	M2	S2
Yellow perch	■	■	■
Alewife	■	■	■
Round goby	■	■	■
Spottail shiner	■	■	■
Rainbow smelt	■		
Bloater	■		
Sand shiner			■
Smallmouth bass			■
Longnose dace		■	
Gizzard shad	■		■
Largemouth bass			■
Coho salmon	■		
Brown trout	■		

Table 2. Sex ratios of YOY GN fish collected during 2012 in nearshore Illinois waters of Lake Michigan.

Location	Gender	YEP	ALE	SPT	GOB
DR	% Male	49	59	46	-
	% Female	43	36	48	-
	% Unknown	8	5	6	-
M2	% Male	33	70	75	49
	% Female	65	27	25	40
	% Unknown	1	3	0	11
S2	% Male	42	53	33	41
	% Female	48	34	17	47
	% Unknown	10	13	50	13

Table 3. Total non-dreissenid benthic invertebrate mean density (#/m2 ± 1 s.d.) results by depth and location during 2012 sampling in southwestern Lake Michigan. Number in parentheses in total column indicates number of samples.

Location/depth	3 m	5 m	7 m	Total
DR	300 ± 357	917 ± 490	2225 ± 1687	1148 ± 1291 (33)
M2	1096 ± 1068	2714 ± 3766	1922 ± 3178	1910 ± 2605 (32)
S2	1361 ± 2250	1082 ± 1383	2467 ± 4627	1637 ± 3055 (43)

Table 4. Dreissenid mean density (#/m2 ± 1 s.d.) results by depth and location during 2012 sampling in southwestern Lake Michigan. Number in parentheses in total column indicates number of samples.

Location/depth	3 m	5 m	7 m	Total
DR	4 ± 13	1028 ± 2821	1359 ± 2237	797 ± 2096 (33)
M2	0	47 ± 143	50 ± 88	32 ± 97 (32)
S2	2663 ± 7329	67 ± 166	16 ± 32	1016 ± 4564 (43)

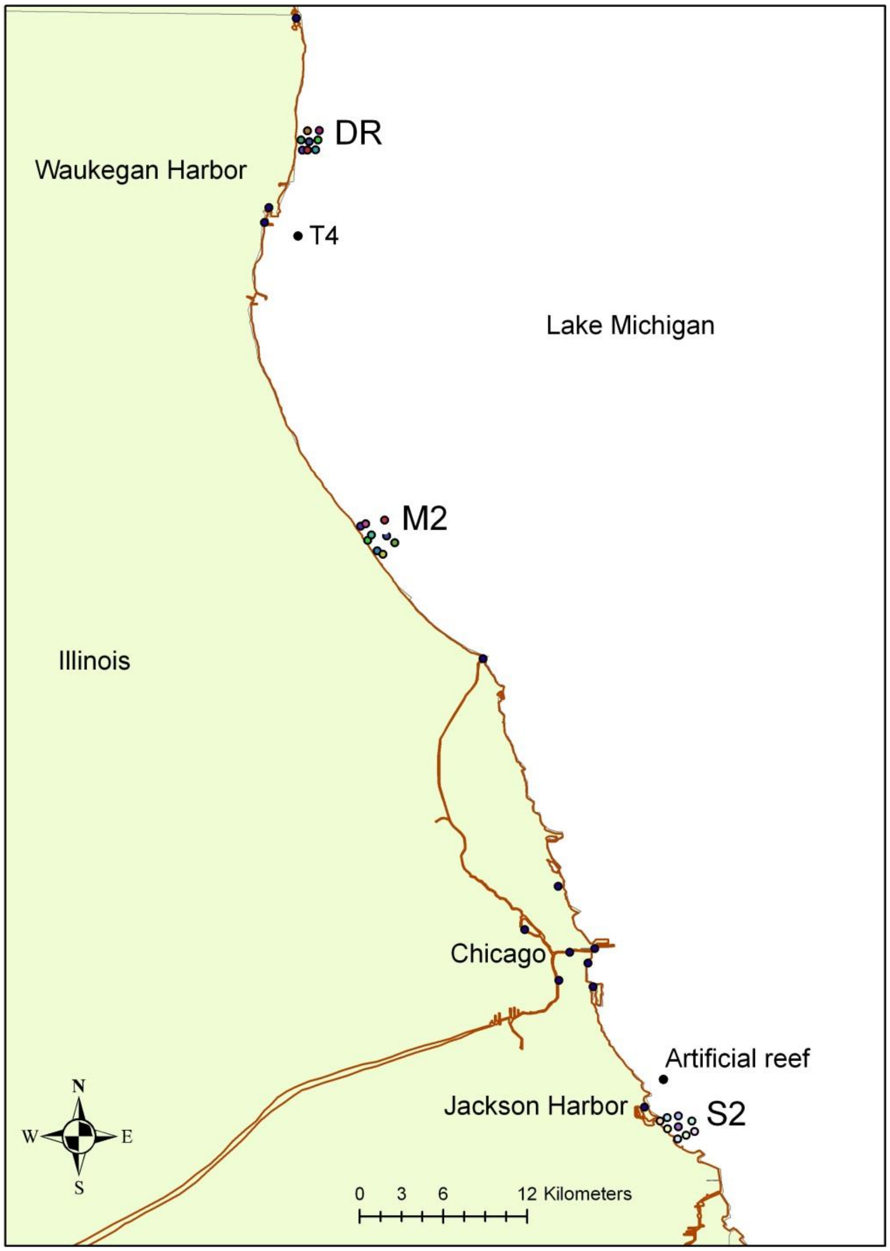

Figure 1. Map of nearshore sampling locations in southwestern Lake Michigan.

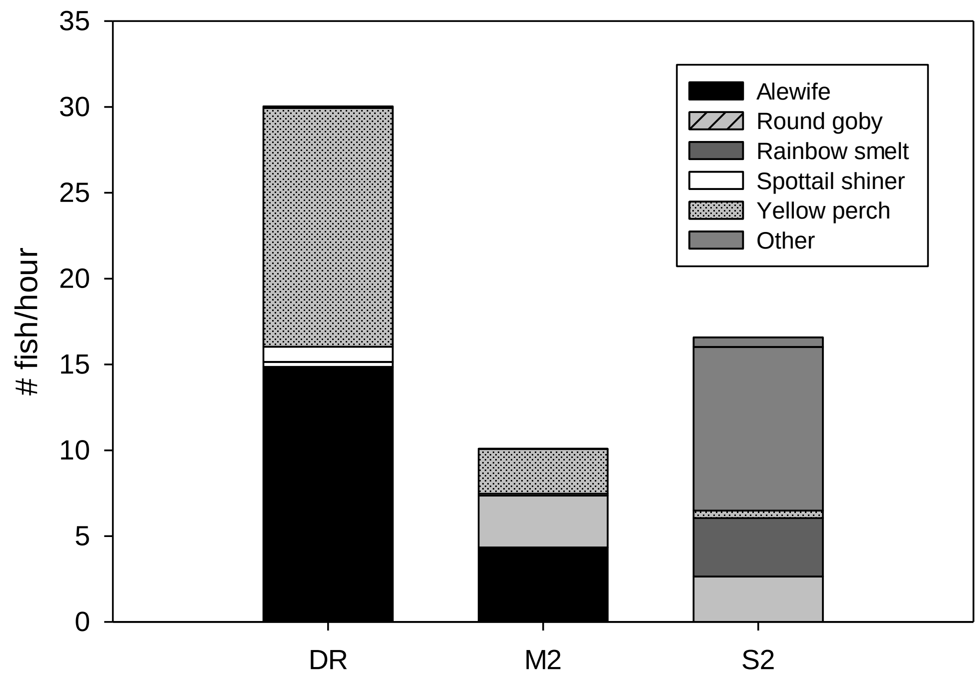

Figure 2. Annual mean CPE (# fish/hour) and community composition of fish sampled in small mesh gill nets at three locations in nearshore Lake Michigan during 2012.

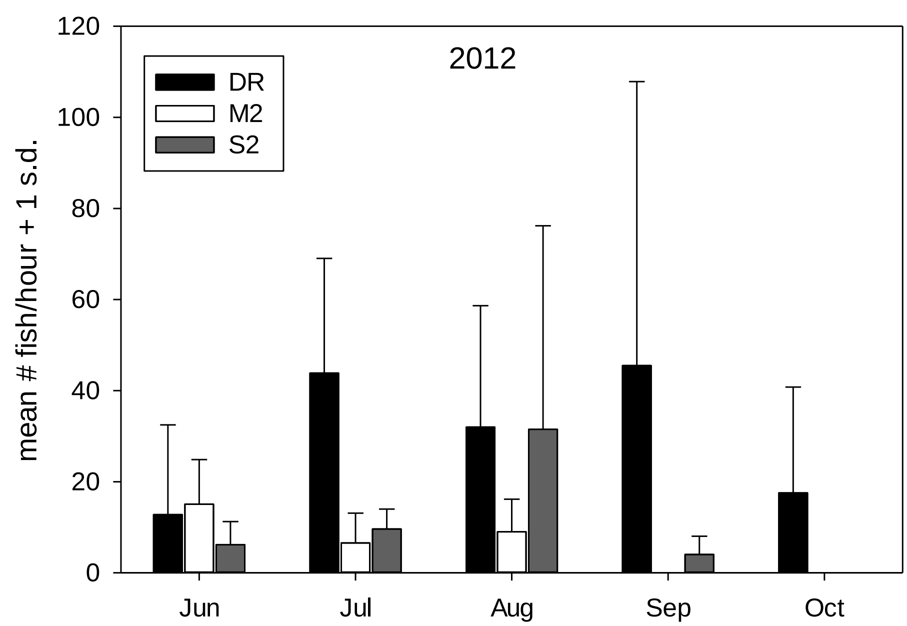

Figure 3. Monthly mean total CPE (# fish/hour + 1 s.d.) of fish sampled in small mesh gill nets at three locations in nearshore Lake Michigan during 2012.

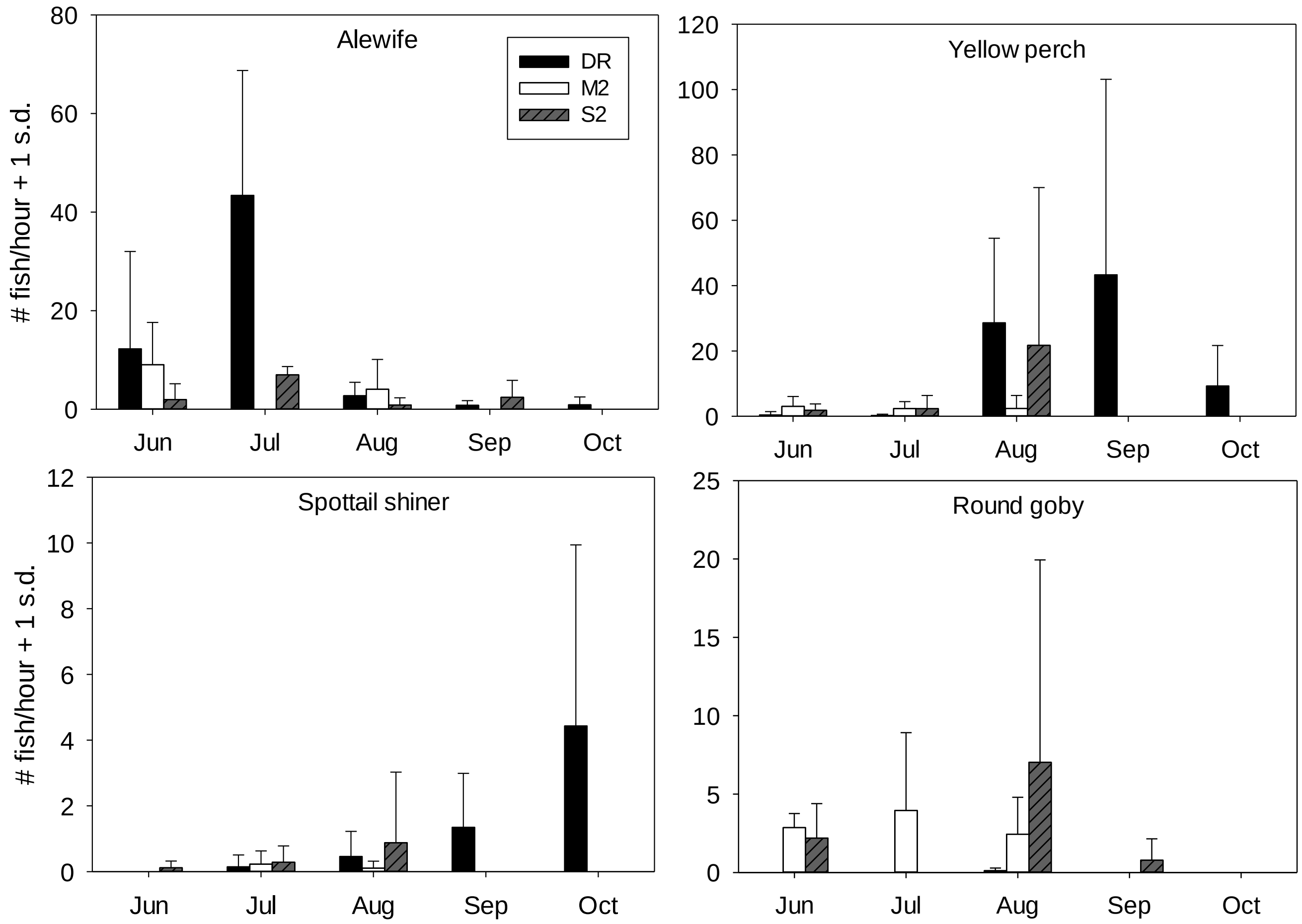

Figure 4. Mean monthly CPE + 1 s.d. for the four most abundant fish species caught in small mesh gill nets in nearshore Illinois waters of Lake Michigan during 2012.

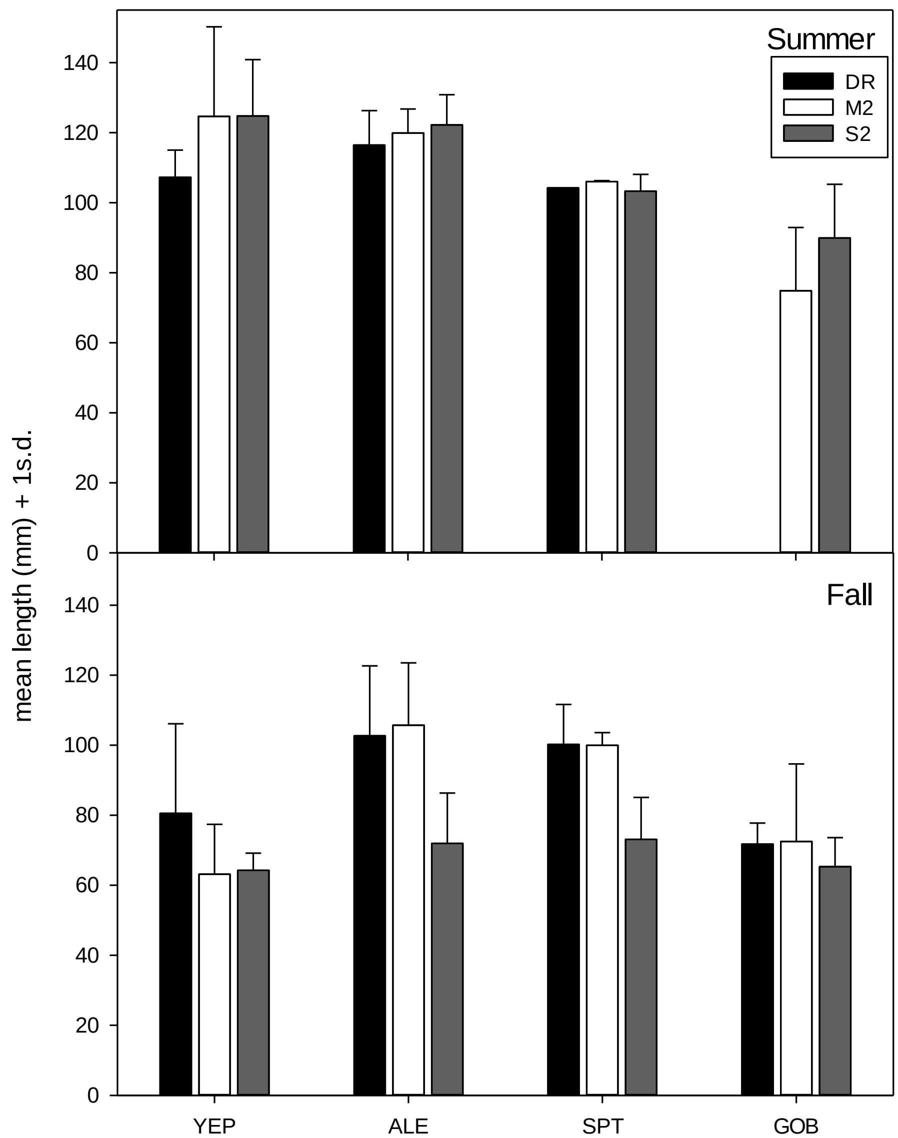

Figure 5. Mean total length (mm + 1 s.d.) of fish caught in small mesh gill nets during 2012 and measured either in the field or lab. Summer includes June and July, Fall includes August and September (and October for DR).

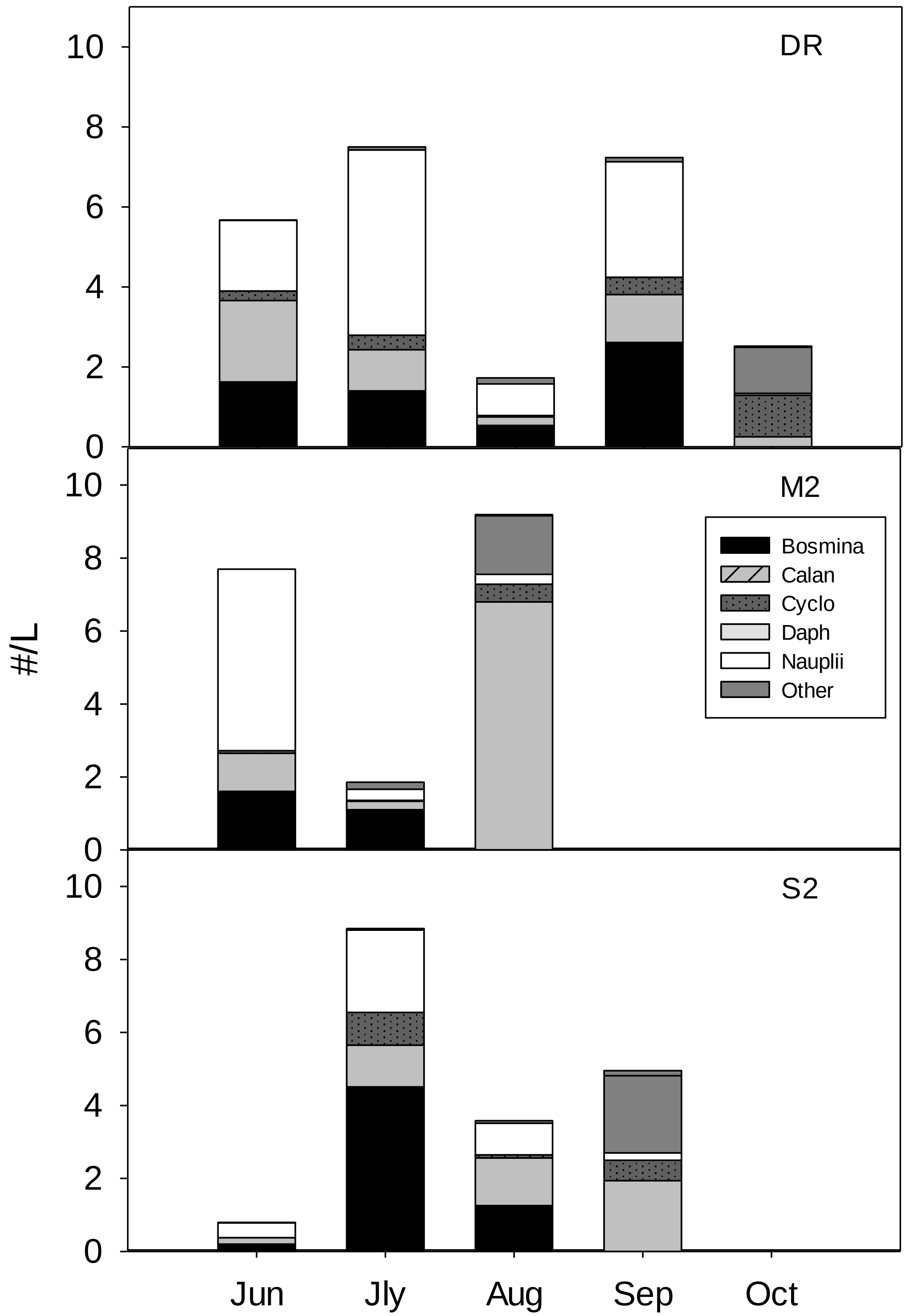

Figure 6. Monthly mean crustacean zooplankton density (#/L) and community composition from samples collected during 2012 in Illinois nearshore waters of Lake Michigan.

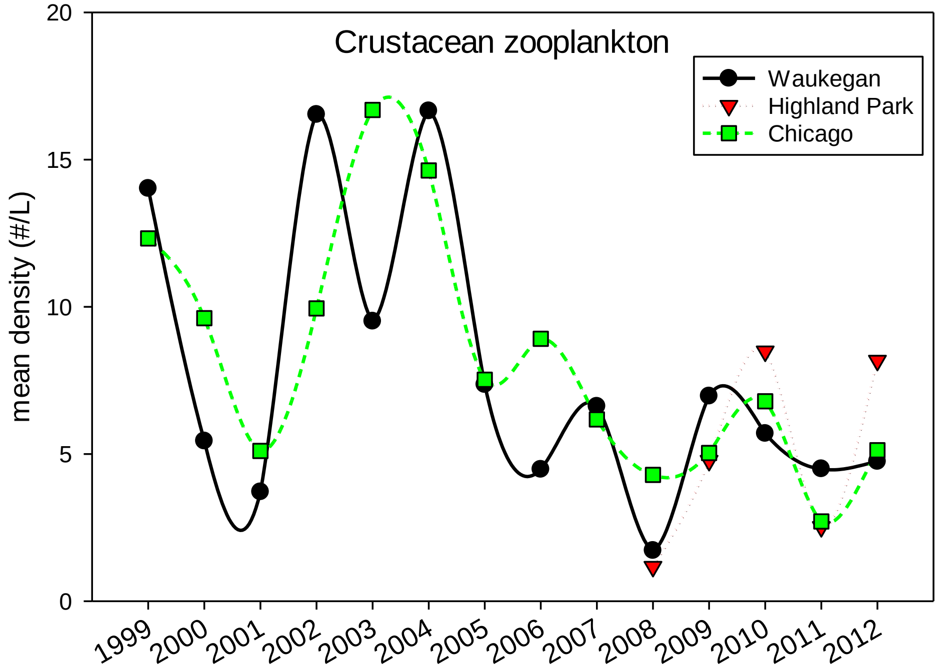

Figure 7. Long-term time series of mean annual crustacean zooplankton density (#/L) collected at 7 - 10 m water depths during 1999-2012 in Illinois nearshore waters of Lake Michigan.

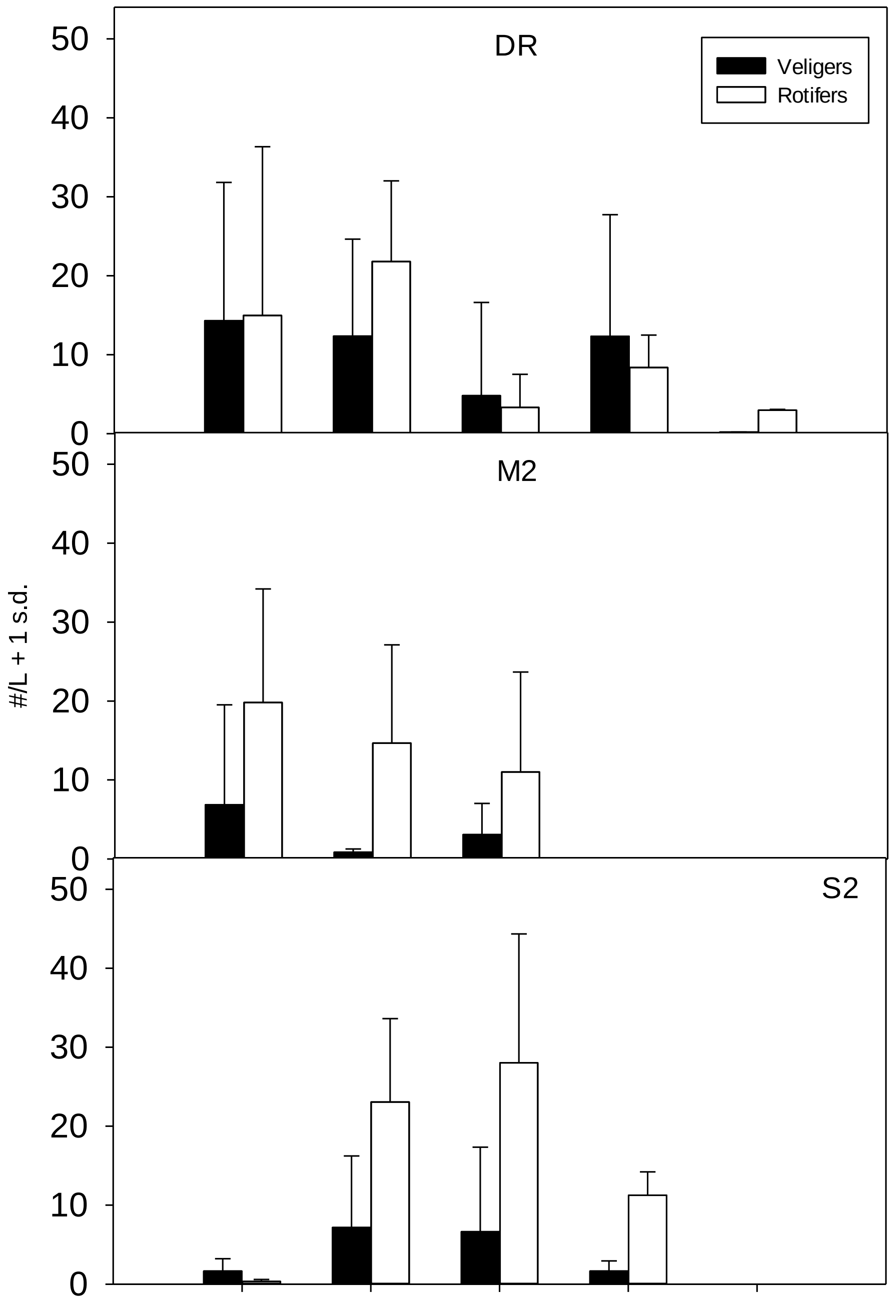

Figure 8. Monthly mean dreissenid veliger and rotifer micro-zooplankton density (#/L + 1 s.d.) from samples collected during 2012 in Illinois nearshore waters of Lake Michigan.

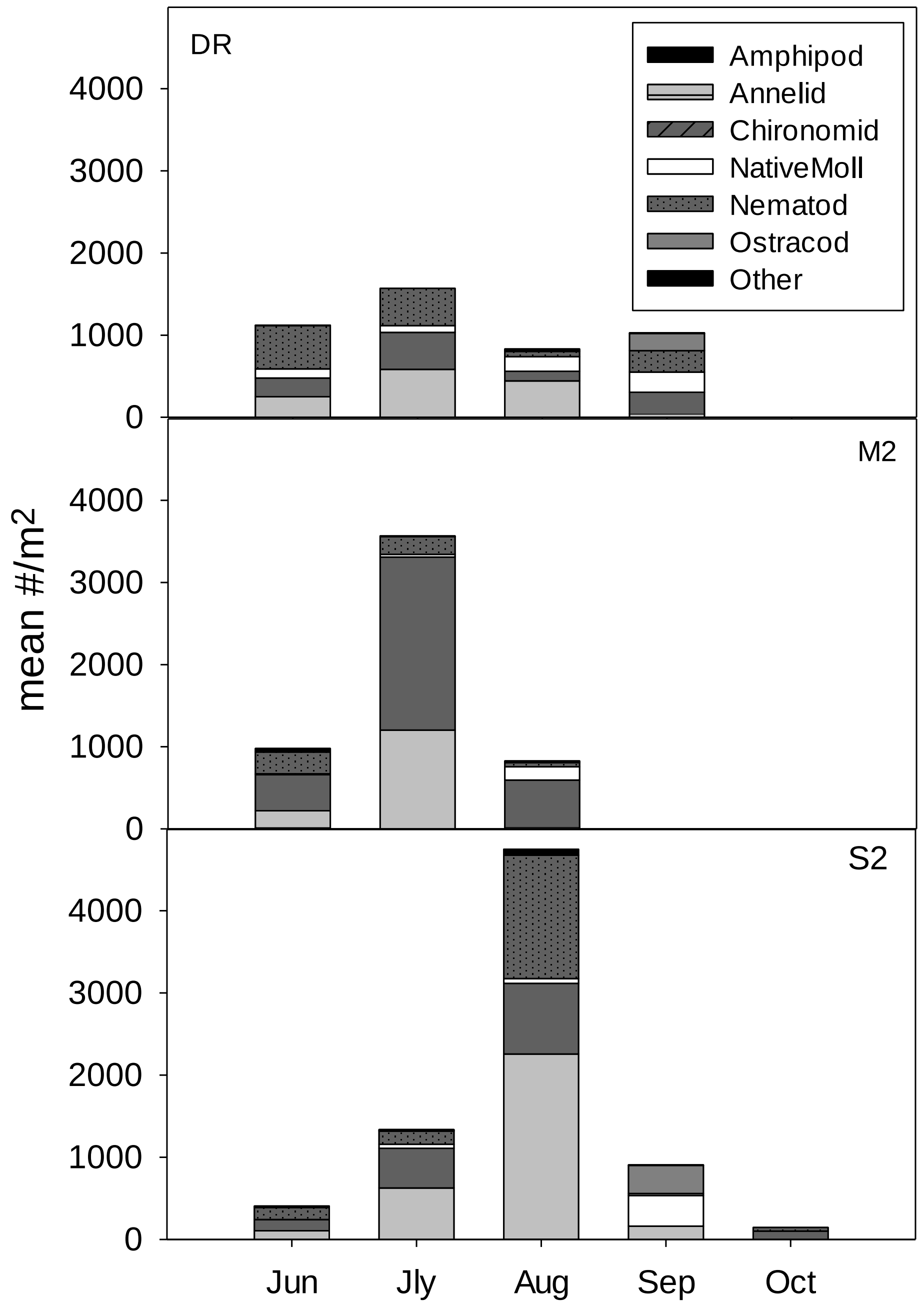

Figure 9. Mean monthly density (#/m2 + 1 s.d.) and community composition of non-Dreissenid invertebrates collected with ponar grabs or benthic core samplers during 2012 in Illinois nearshore waters of Lake Michigan.

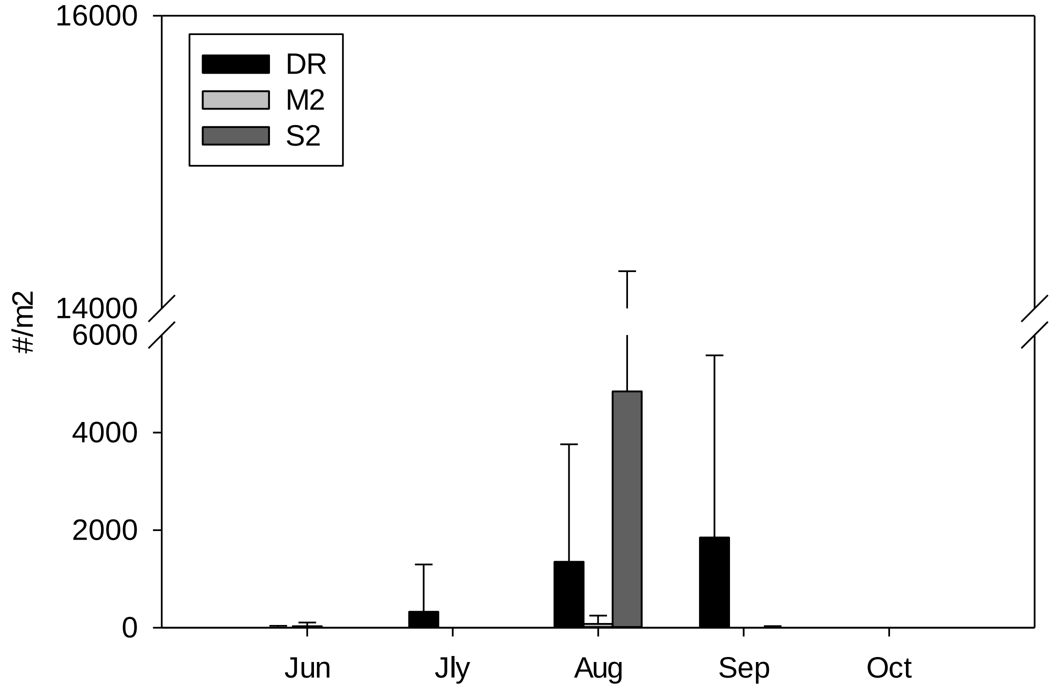

Figure 10. Mean monthly density (#/m2 + 1 s.d.) of Dreissenid mussels collected with ponar grabs or benthic core samplers during 2012 in Illinois nearshore waters of Lake Michigan.

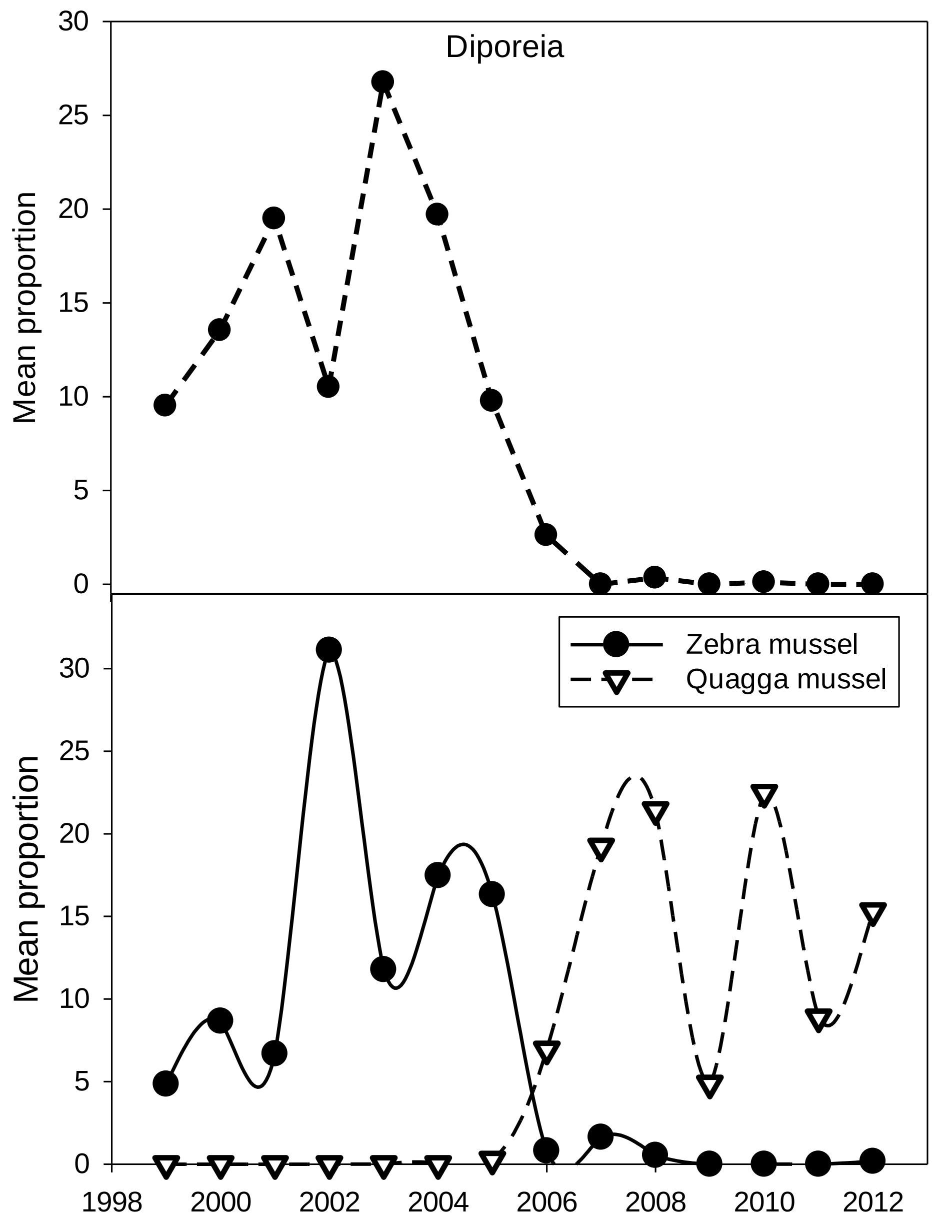

Figure 11. Long-term time series of mean proportion by number of Diporeia amphipods and Dreissenid mussels in benthic samples averaged over 2 locations (DR and S2) in 1999-2007 and 3 locations in 2008-2012 (DR, M2, S2).

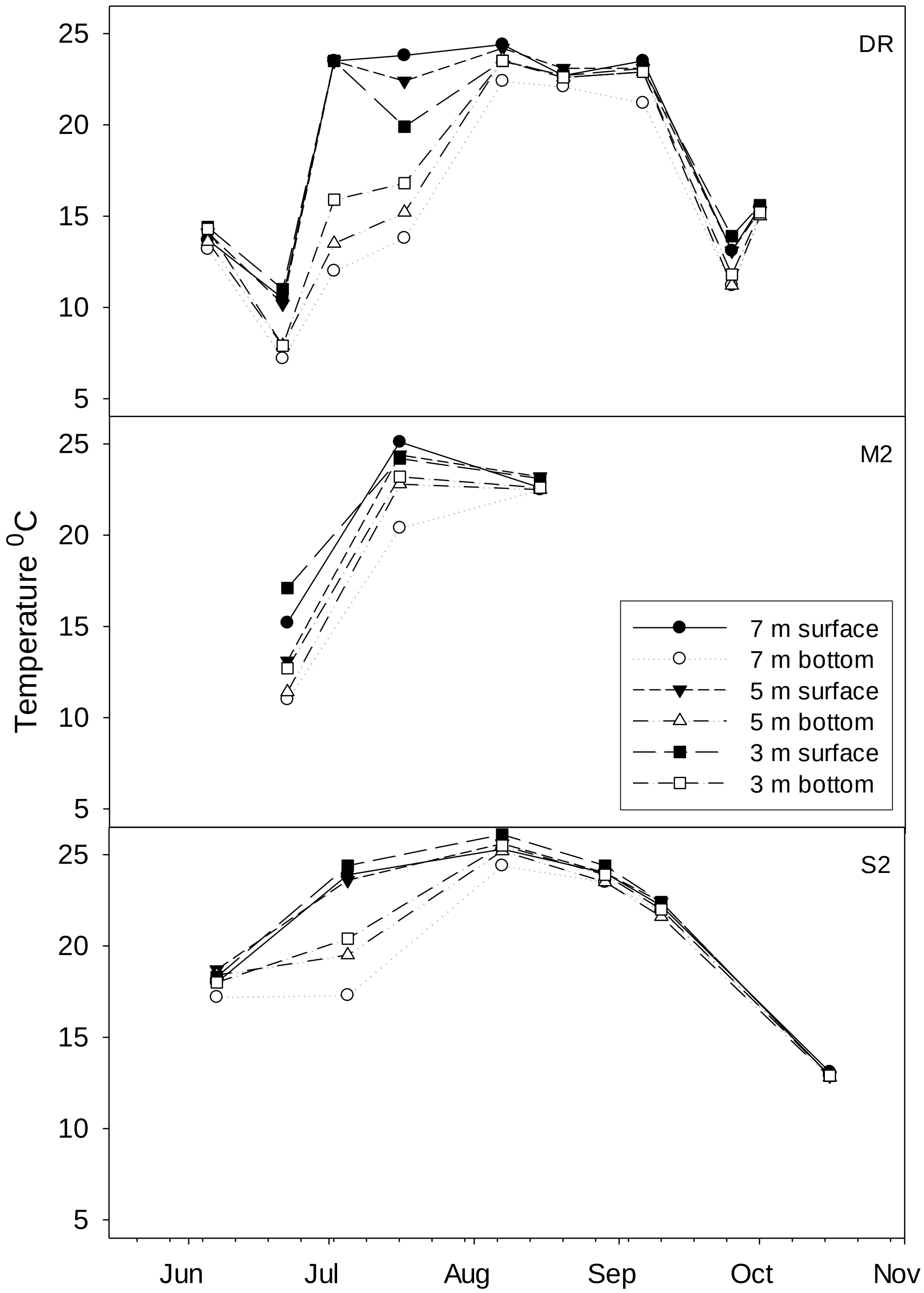

Figure 12. Surface and bottom temperatures recorded on each sampling event using a YSI meter.

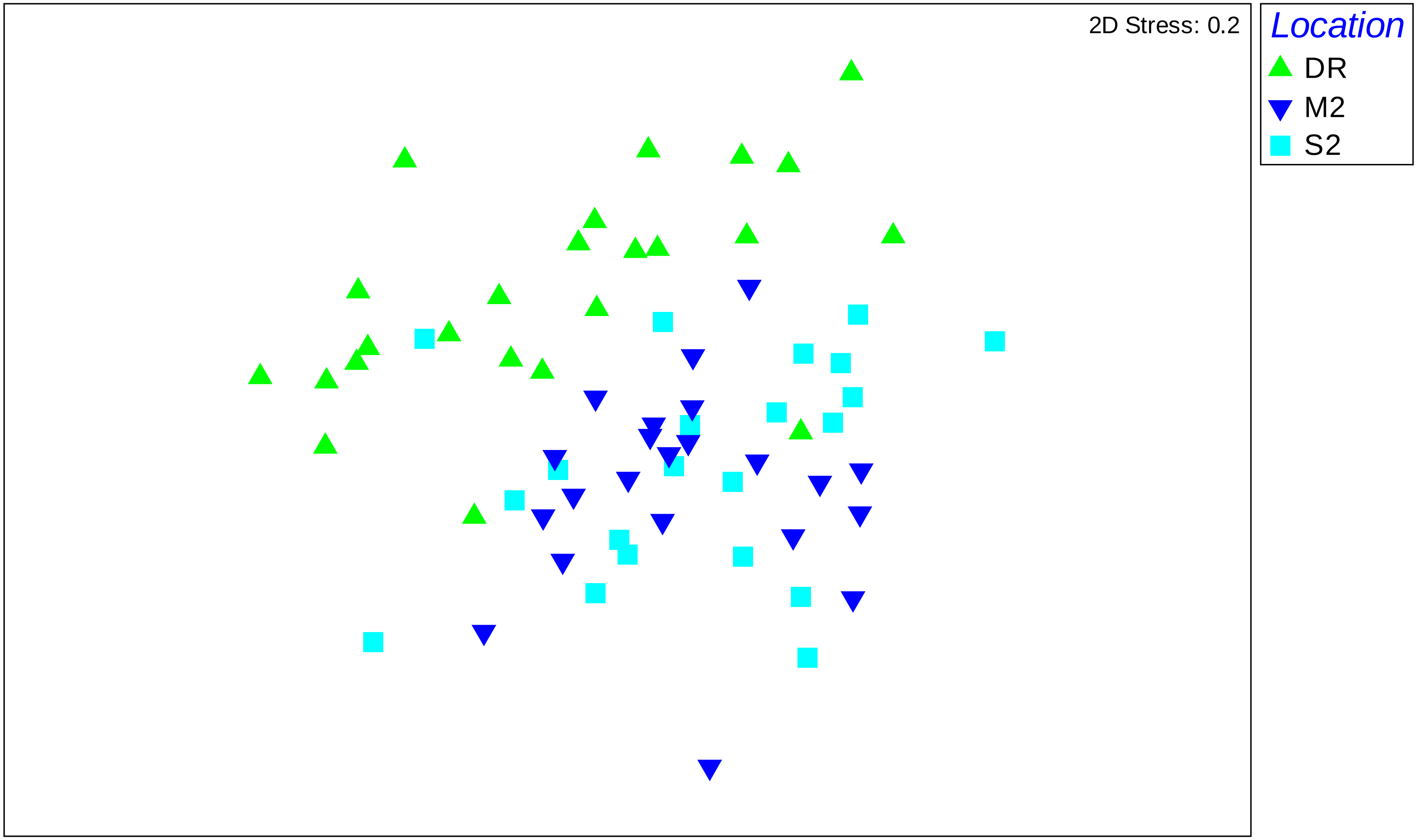

Figure 13. Non-metric multidimensional scaling plot of mean fish composition (% by number) by location, month during 2008-2012 small mesh gill net sampling. Symbols that are close together have greater similarity than symbols that are further apart.

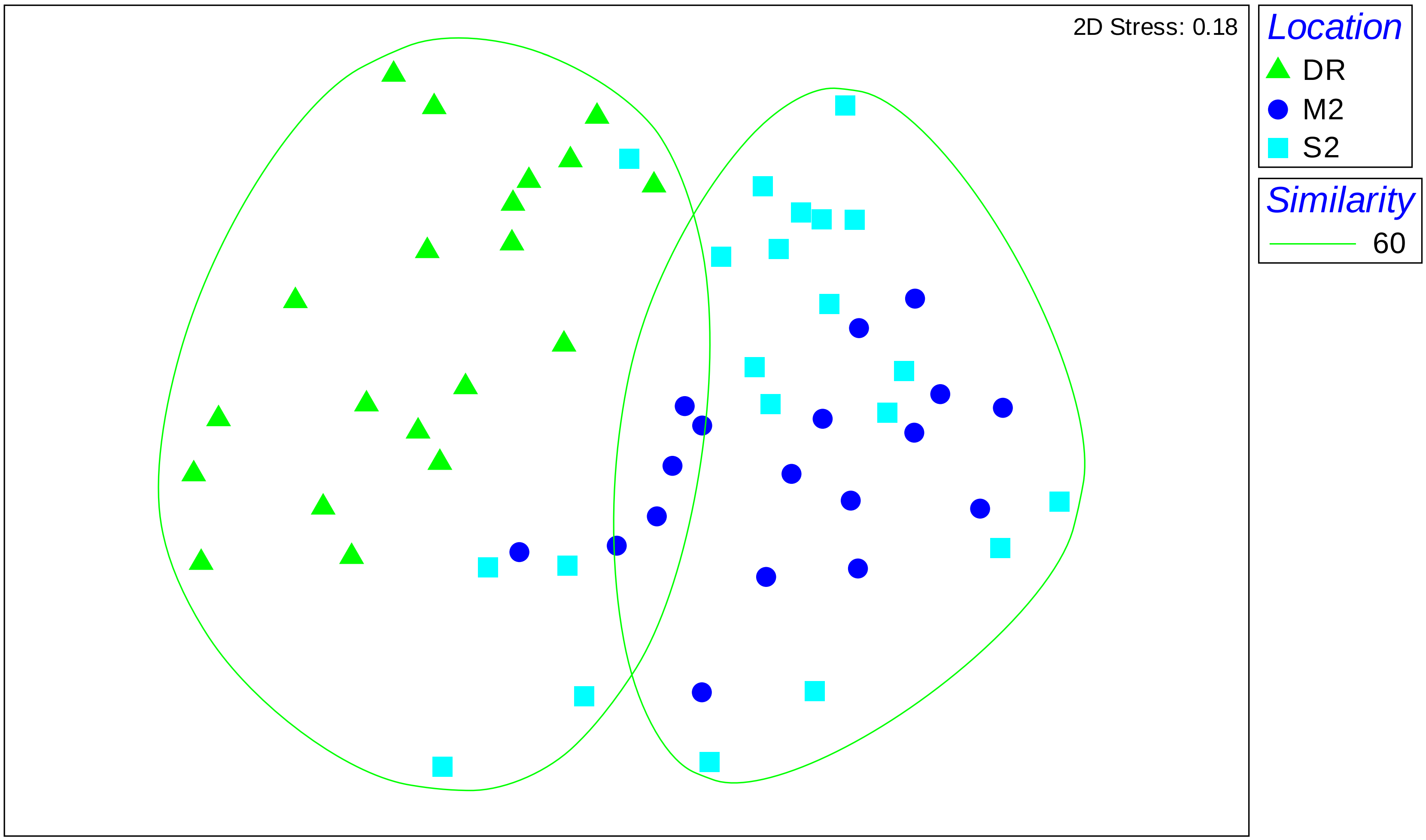

Figure 14. Non-metric multidimensional scaling plot of mean invertebrate species composition (% by number) by location and month during 2008-2012 sampling. Symbols that are close together have greater similarity than symbols that are further apart.

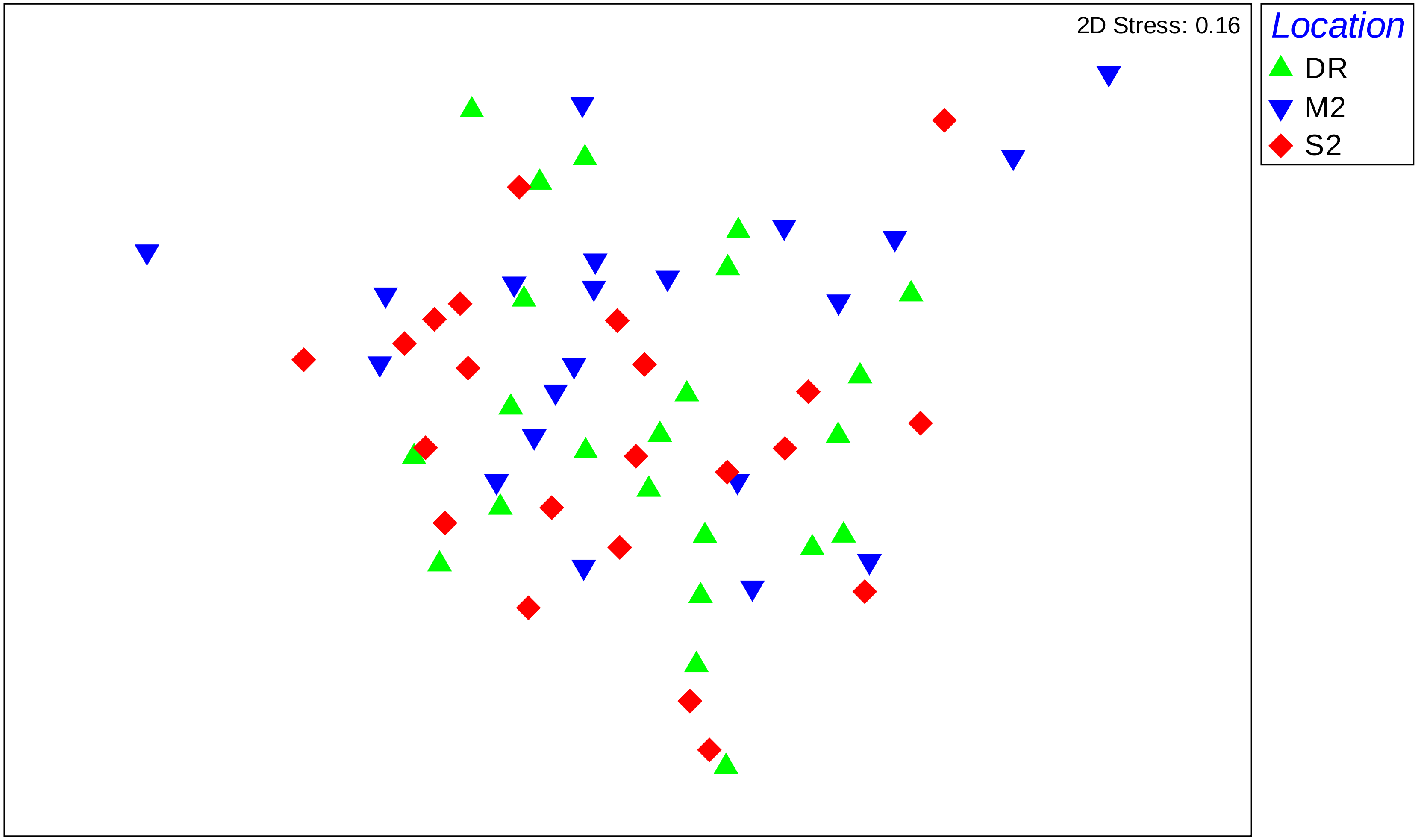

Figure 15. Non-metric multidimensional scaling plot of mean zooplankton composition (% by number) by location and month during 2008-2012 sampling. Symbols that are close together have greater similarity than symbols that are further apart.

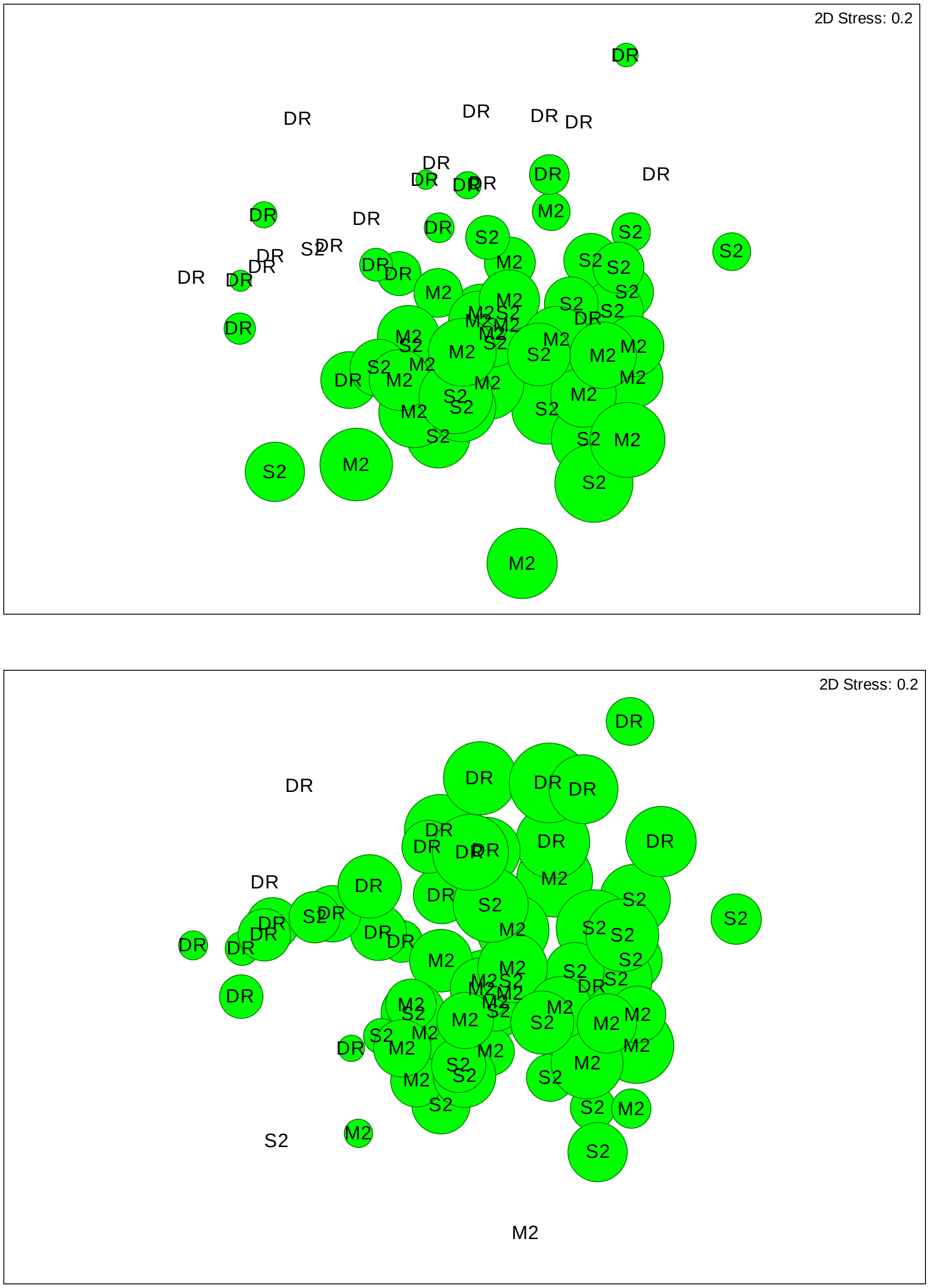

Figure 16. Similarity of fish species composition (% by number) across the three sampling locations during June - October 2008-2012. The varying circle diameter reflects relative abundance of round goby (top panel) and yellow perch (bottom panel).