Assessment of wetland habitat use by juvenile fishes, with a focus on rock bass *Ambloplites rupestris* within the St. Clair River delta, Michigan, USA

By

Maureen A. Lynch

A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Science
(Natural Resources and Environment)
at the University of Michigan
April 2013

Faculty advisors:
Professor James Diana, Chair
Professor Bobbi Low
Professor Michael Wiley

Abstract

Juvenile fish are an essential link to adult populations, and often inhabit distinct environments from larvae and adults. I sampled fish at nine sites within the St. Clair River delta in an effort to 1) describe the juvenile fish community, 2) determine the use of bay habitats as nursery grounds, and 3) assess the short-term growth of rock bass *Ambloplites rupestris*. Fish were collected monthly from May through August and in October of both 2011 and 2012 using hoop nets and minnow traps in shallow areas along the Middle Channel and its connected bays. Catch per unit effort (CPUE) was highest in the channel sites and in October, with emerald shiner *Notropis atherinoides* and other cyprinids dominating overall catch. When these taxa were removed to evaluate only young-of-the-year (YOY) fishes, rock bass accounted for almost 50% of the overall catch and were cosmopolitan throughout the system. CPUE and rare species richness for YOY fishes were greater at bay sites than channel sites, and YOY fish species richness was correlated with vegetation species richness, which was also higher in bay sites. Growth of YOY rock bass was assessed using RNA:DNA ratios, which were highest in the bay sites, as well as in late summer, indicating that these nursery grounds may allow faster growth, and that growth fluctuates seasonally. While community associations varied by site and month throughout the summer, bay habitats consistently had higher abundance and diversity of YOY fish, indicating that these habitats may be critical nursery grounds and should be highlighted as conservation and restoration priorities.

Acknowledgments

This project was funded by Michigan Sea Grant and the Great Lakes Restoration Initiative (USEPA – GLRI, NA10NMF4630409). Many people helped me in the process of this thesis, most notably my advisor Dr. Jim Diana, and my committee members Dr. Bobbi Low and Dr. Mike Wiley. My field assistants were essential in my sampling efforts and without them, my data would not have been collected: Chelsea Crane, Dan Fingas, Kristin Fisher, Nate Gainer, Maggie Grundler, Joe Krieger, Chris Li, Dani Drekich McGarry, Jenny Pfaff, Matthew Snyder, and Zack Stepan. I was allowed to use lab space and time on equipment from Dr. Brad Cardinale, Dr. Dave Jude, and Dr. Don Zak. I would not have completed my field seasons and thesis work without the help and support of my classmates and friends at SNRE, Barb Diana, Janet and Dan Drekich, the fine mechanics at Colony Marine and Expert Marine, and the friendly boaters on the Middle Channel who gave us mechanical help and towed us to shore or gave me a lift on multiple occasions.

Table of Contents

Introduction

Fish communities in the Great Lakes are recreationally, commercially, and ecologically important. Past studies have examined these communities and documented changes to individual species and large assemblages as a whole (Leslie and Timmins 1991, Danzmann et al. 1992, Nichols et al. 2003, Dobiesz et al. 2005). Some focused on anthropogenic influences on habitat (Höök et al. 2001, Jacobus and Webb 2005, Webb 2008, Goforth and Carman 2009, Trebitz et al. 2009a) and others documented the habitat and microhabitat used by fish communities (Brazner and Beals 1997, Jacobus and Ivan 2005, Trebitz et al. 2009b, Brown and Bozak 2010, Lapointe et al. 2010). Fish community structure can vary by season and location, with a complex system of interactions influencing the distribution of taxa.

While the Great Lakes are relatively well studied, there is much that can still be explored, especially at local scales. Human effects on the Great Lakes have made changes to fish ecology that are large and basin-wide, as well as on smaller scales. Shoreline development, land-use change, shoreline and channel modification, fishing, invasive species introductions, and stocking have all impacted, and continue to impact, multiple aspects of fish ecology in the Great Lakes system. Therefore, it is imperative that researchers continue to examine the changing fish communities to better inform both regulatory decisions and conservation efforts. By studying fish community dynamics and interactions with the biotic and abiotic environment, we can estimate needs for habitat restoration and conservation more accurately.

Habitat associations of fish are often species- or group-specific and vary temporally. Seasonal changes in habitat use have been linked to environmental factors such as changes in the vegetation diversity and density, water temperature, and water depth. Habitat fragmentation, either natural or anthropogenic, can have large and detrimental impacts on the ability of fish to move throughout the system (Jacobus and Ivan 2005, Jacobus and Webb 2005). High degrees of natural or anthropogenic environmental disturbance also tend to reduce fish communities to more resilient taxa, both in wetland and open water environments (Trebitz et al. 2009b). However, differences in community structure and microhabitat use may decrease in late summer and early fall, because many habitat associations are linked to spawning, larval, and juvenile behaviors which primarily occur in spring and summer. Therefore, both wetland and shallow offshore areas may provide suitable habitat for multiple fish taxa at different times of the year (Lapointe et al. 2010).

Habitat use is critically important to the ecology of fishes. Many taxa are associated with specific habitats at different life stages. In many species, adults migrate upstream to shallow areas of streams and rivers to spawn. After larvae hatch they are dispersed by river currents, and juveniles may move away from their spawning site to nursery grounds with greater protection and food sources. Therefore, both physical connectivity of habitats and selection of quality habitat are important to year class formation and individual survival (Brazner and Beals 1997, Henning et al. 2007, Brown and Bozek 2010). Due to their size and early development, individuals at these stages are particularly vulnerable to predation, starvation, and environmental stressors.

The nursery period is often defined as the time between swim-up and the first winter for a juvenile fish. As these early stages have high rates of mortality, rapid growth and predator avoidance increase first winter survival for YOY (Murry and Farrell 2007). Thus, defining biotic, abiotic, and landscape factors that combine to create nursery habitat is important for environmental conservation and fisheries management (Dantas et al. 2012). However, characteristics of optimal nursery habitat vary by taxa. Murry and Farrell (2007) found that YOY muskellunge *Esox masquinongy* were most often associated with moderate levels of macrophyte density, but the type of vegetation that they preferred changed during summer. For these predatory fishes, prey fish availability was also a critical component of nursery grounds. Dantas et al. (2012) found that seasonal fluctuations of chemical characteristics, such as salinity and dissolved oxygen, were critical determinants of catfish *Cathorops* sp. nursery grounds in an estuary, and Roseman et al. (2005) described turbidity and vegetation cover in shallow water habitats to be important elements of walleye *Sander vitreus* nurseries.

Nursery grounds may not be used by all species, or for the entire nursery period. Nannini et al. (2012) found that the relative abundance of larval taxa varied across channel and backwater habitats in the Illinois River. Centrarchids, clupeids, and cyprinids were among those families more commonly associated with backwater nursery grounds, while moronids and catostomids were more abundant in the main channel habitats. Shallow backwater habitats have longer water residence time and relatively warm water compared to channel habitats, which allow for a greater abundance and diversity of invertebrate prey, as well as providing slower currents than the main channel. Channel sites may be utilized by species that are fluvial specialists and have specific life history traits (Nannini et al. 2012). Thus, while estuarine, wetland, or otherwise protected environments may be preferentially used by some species in early life stages, the importance of other habitat types such as open-water areas to other YOY species should not be ignored.

Selection of nursery ground habitat by fishes may also vary greatly with time. Shifts in vegetation or invertebrate and prey fish assemblages can result in YOY nursery habitat associations that vary throughout the summer and early fall (Dantas et al. 2012). YOY yellow perch *Perca flavescens* changed habitat preferences during summer, moving from areas with complex woody structures to those with less complex cobble substrate in late summer in part due to increasing predator densities in woody substrate (Brown and Bozek 2010). Lapointe et al. (2010) found that early summer months had distinct assemblages and higher species richness at inshore compared to offshore sites in the Detroit River, but these distinctions were not significant in late summer. They attributed this primarily to macrophyte growth becoming more uniform between inshore and offshore locations as summer progressed.

Nursery habitats not only provide food sources and protection from predation, but also are areas that promote individual fish growth. Rapid growth of juvenile fish before their first winter greatly increases overwinter survival rates (Garvey et al. 1998). High growth rates have been recorded in YOY fishes in late spring and early summer in nursery grounds, and fish growth has been used as an indicator of nursery habitat quality (Vasconcelos et al. 2009). However, seasonal or episodic increases in temperature and decreases in water level in shallow areas have also been related to slower growth rates (Glémet and Rodríguez 2007).

Traditional growth analyses have used easily measured physical characteristics such as length and weight, as well as more time-intensive measures such as growth ring analyses of otoliths and scales. Recently, molecular methods have proved to be a reliable and accurate measure of short-term growth, both in lab experiments and in the field. Measuring the ratio of cellular RNA to DNA (R/D ratio) in individual fish provides an analog for growth over a period of days rather than weeks or months as with traditional metrics (Buckley et al. 1999). Cellular DNA concentrations remain relatively constant, but RNA concentrations vary as the cell divides. This is a relative metric and does not measure actual growth rates: higher R/D ratios indicate higher growth rates. The R/D ratio can reflect differences in feeding rates and body condition on a scale of one to three days and is a highly sensitive measure (Buckley et al. 1999, Smith and Buckley 2003).

This short-term measure can be used to connect habitat use to growth rate, as a fish will most likely have been in the same habitat for a period of several days prior to collection. Long-term metrics of growth from changes in body weight or otolith rings may be influenced by multiple habitats that a fish had used during a more extended time period, and would thus be less accurate. Given the connectivity of wetland systems, and the potential for fish movement among habitat types, these short-term growth rates are essential to drawing conclusions about habitat and growth.

This study focuses on juvenile fish in the St. Clair River delta. The entire area is classified as an Area of Concern (AOC) by the US-Canada Great Lakes Water Quality Agreement, in part due to fish and wildlife habitat loss throughout the river as well as water and sediment contamination, degradation of aesthetics, and reproductive deformities in birds and wildlife. Most of these Beneficial Use Impairments (BUIs) are due to heavy agricultural and industrial inputs in the upper reaches of the river. The AOC includes the entire St. Clair River from Lake Huron to Lake St. Clair (Ensman 2008). Because of these BUIs, the St. Clair River has recently been the focus of restoration and conservation projects. The river and its delta wetlands are considered important spawning grounds, nursery areas, and year-round habitat for many fish common to the Huron-Erie Corridor. Protection and restoration of these areas may be beneficial for multiple fish and wildlife taxa.

The objectives of this study were to:

1. Assess the juvenile fish community and to document seasonal changes at various sites in the wetlands fringing the Middle Channel of the St. Clair River, as well as in its connected bays.
2. Determine whether YOY fish use areas within the St. Clair River delta as nursery habitats.
3. Assess temporal and spatial differences in short-term growth of rock bass (chosen for their prevalence in the system) from different locations within the St. Clair River delta.

My hypotheses were:

1. Greater abundance and species richness of juvenile fish would be found in bay sites compared to channel sites, and abundance would be highest in mid-summer.
2. Greater abundance and diversity of YOY fish would be found in bay sites, indicating their role as nursery grounds. These sites would have higher vegetation cover and diversity than the channel sites.
3. Rock bass growth would be highest in the bay nursery grounds and lowest in the channel sites.

Methods

Study sites were chosen along the Middle Channel of the St. Clair River delta (*Figure 1*). The river splits into three major channels near Algonac, MI: the North, Middle, and South channels. Commercial shipping traffic runs through the South Channel, as does the US-Canada border, while the North and Middle channels are used primarily for recreational boat traffic. A total of nine locations were chosen along the Middle Channel itself and in the bays adjacent to the channel: Fisher and Goose bays to the northwest, and Little and Big Muscamoot bays to the southeast. Four sites were situated along the channel itself (C1-C4) and five were placed in bays along the delta margin (B1-B5) *(Figure 2)*. It should be noted that all sites were in shallow areas at the margins of the Middle Channel, or near where small distributaries from the Middle Channel enter the bays. For this report, the terms “channel sites” and “bay sites” will be used to describe these locations.

Channel sites differed markedly from bay sites. Much of the shoreline along the channel was highly modified with seawalls, docks, housing, and by dredging and fill. At most channel sites, there was only a narrow area of shallow shelf on either side of the channel, which quickly dropped to approximately 6 to 12 meters deep with a strong current moving southwest towards the lake, and frequent wave disturbance from boat traffic. Bay sites had a greater area of shallow water and slower currents than channel sites. Several of these bay sites were oriented such that they faced either the lake or a large bay and were thus exposed to direct wind and wave action.

Sites were chosen to be approximately one meter deep to accommodate sampling gear. Sites were chosen in areas that had some amount of emergent vegetation and were not directly connected to seawalls or docks, however it was difficult to find channel sites without these features nearby.

Generally, common reed *Phragmites australis* and hardstem bulrush *Schoenoplectus acutus* dominated the shoreline vegetation in the channel and bay sites. Bay sites, however, were more likely to have common cattail *Typha latifolia*, spikestem squarerush *Eleocharis quadrangulata*, common threesquare *Schoenoplectus pungens* and tape grass *Vallisneria americana* throughout the summer.

Hoop nets and minnow traps were used to collect juvenile fish, each set in duplicate at each of the nine sites. Hoop nets had 5 hoops, each 1m in diameter, 2 throats, and a 15m long by 1m deep lead. Both the net and lead had were made of 3mm uncoated nylon mesh. Nets were set so that the opening of the net was parallel to the shoreline, with the lead stretched between the first hoop and the shoreline or edge of dense vegetation. Nets were not set if water depth was too shallow to submerge both throats of the net.

Minnow traps had 2 openings, 3mm metal mesh, and were baited with approximately 50g of dry dog food. Five minnow traps were attached along a rope at 3m intervals to make a gang, for a total length of 12m between the first and fifth trap. Gangs were set in a straight line, but not necessarily perpendicular to the shoreline.

Field samples were collected monthly May through August, and October in both 2011 and 2012. Collections were made at the 9 distinct sites, and sampling effort at each site consisted of 2 replicate hoop nets and minnow trap gangs, set for 2 consecutive 24-hour periods. This resulted in a total of four net-nights and four trap-nights at each site per month. Effort was standardized so that one gang-night and one trap-night were each considered one unit of effort, for a combined total of eight units of effort per site per month. After each set, fish were removed, identified to species, and counted. Subsamples of each species were measured for total length in whole centimeters. Fish were then returned to the water alive. From these data, species richness, CPUE, and rare species richness were calculated for further analyses.

Vegetation transects were measured at each replicate site once per month. In 2011 and 2012, one transect was measured parallel to the location of each hoop net. Plant composition in 10 quadrats, $1m^2$ each, was measured along a 20m transect (a length equivalent to the length of the lead and net). Submerged and emergent vegetation were identified to species and percent cover of each species was visually estimated to the nearest 5% in each quadrat. In 2012 a piece of rebar was placed at the vegetation edge in May at each site, and a second 20m transect was measured from this point each month in an effort to estimate the vegetation change throughout the season. This was not entirely successful, because at some sites common reed grew in so thickly that the rebar could not be found even one month later. Data from these latter transects were used as descriptions of site habitats rather than for statistical analyses.

Samples for R/D analysis were taken May through August of 2012. Rock bass were chosen for this study based on their abundance and prevalence at all sites during the 2011 season. When available, a maximum of 10 rock bass were taken from hoop nets at each site. Individuals were removed only from hoop nets so as to eliminate the feeding effect from baited minnow traps. Individuals were removed at the same time as normal sampling and euthanized by severing the spinal column with a sterile scalpel.

Approximately 50mg of white muscle tissue was taken from each fish and preserved in RNAlater. If possible, dependent on fish size, a replicate 50mg sample was taken and preserved in a separate microcentrifuge tube. This procedure was kept as sterile as possible, with sterile scalpels used for each fish, and all other tools cleaned with RNase-Erase and 90% ethanol between fish. All fish samples were kept on ice for the duration of field sampling on the day that they were collected, stored at -2C for no more than 8 days, and later transferred to -30C until processing. All samples were processed within four months of the collection date.

Molecular analysis was performed on a BioTek Synergy H Microplate Reader. Methods were modified slightly from Roberts (2010), using the fluorescent nucleic acid dye RiboGreen to tag samples and standards. Standards of RNA from bovine pancreas and DNA from calf thymus were diluted in 1x TE buffer to concentrations of 0.033-2μg/mL and 0.051-10.107μg/mL, respectively. Two standard curves of fluorescence were calculated to estimate concentrations of both RNA and DNA in fish tissue samples.

For sample analysis, two subsamples (10mg each) were taken from each 50mg fish tissue sample. After nucleic acid extraction, each subsample was aliquoted into two wells of a 96-well plate. Thus, a fish with one tissue sample taken in the field had four replicate fluorescence readings, and a fish that had two samples taken in the field had eight replicate fluorescence readings. For both standards and samples, fluorescence was read at 485nm for excitation and 528nm for emission with a 3x3 area scan. Average values for the scan were reported in relative fluorescence units (RFU). Blanks of DI water and TE buffer were used to calibrate fluorescence readings for each plate.

Sample fluorescence was read once, after which RNase was added to each well. After incubation, the plate was read again. The initial reading represented total fluorescence from RNA and DNA combined, and the final reading represented fluorescence from only DNA, as all RNA should have been digested following addition of RNase. An average value for all blanks in each plate was subtracted from all sample fluorescence readings on each plate, and fluorescence values were averaged per fish. Using standard curves, the final reading was used to calculate DNA concentration, and the difference between final and initial reading was used to calculate RNA concentration. Average R/D ratios were calculated for each fish.

Two statistical models were used to analyze data. Mixed model analyses of variance (ANOVA) were used to determine significant differences across sites, classifications of channel site or bay site, years, and months for natural log-transformed CPUE and square root-transformed species richness. A canonical correlation analysis (CCA) was used to determine correlations between habitat and fish variables. Habitat variables included species richness of vegetation, average vegetation cover along the transects, straight-line distance to the channel, straight-line distance from the divergence of the Middle Channel from the North Channel, and the previously used characteristics of year, month, site, and channel site or bay site classification. Fish variables included natural log-transformed CPUE, square root-transformed species richness, presence of rock bass, abundance of emerald shiner, abundance of spotfin shiner, rare species richness, and length-adjusted R/D ratios. Alpha was set at α=0.05 for all analyses. Statistical analyses were performed using SAS v9.3 statistical software.

Results

Over the course of 10 months and 610 net-nights, 40,106 fish were collected and identified, encompassing 28 species (*Table 1*). Emerald shiner was the most abundant species, with almost 27,000 individuals collected. Spotfin shiner was second in abundance, with over 3,200 collected. Rare species were defined as those representing less than 1% of the total catch, and of these 19 species, 16 were in abundances of less than 50 individuals. Of the rare species, largemouth bass was most abundant, with 167 individuals. It should be noted that this terminology does not imply that these species are rare in the ecosystem, rather that they were rare in my samples of the fish community.

Fish species composition varied greatly across sites and months. Relative abundance of emerald shiner ranged from 0 to 0.97, while spotfin shiner ranged from 0 to 0.78. However, while mean emerald shiner abundance was 0.52, the mean spotfin shiner abundance was only 0.0900. Of 83 averaged units of effort per site per month, emerald shiner was the most or second most abundant species 67 times, while spotfin shiner held these places only 27 times. Rock bass was the most or second most abundant species 26 of 83 times. Fish species richness also varied by month and site, with the highest values in October (ANOVA, p=0.01) *(Figure 3)*. Bay sites had higher fish species richness (CCA, p=0.014) and higher relative proportion of spotfin shiner than channel sites, however bay sites further downstream were more similar to the channel sites than to upstream bay sites, with a large proportion of emerald shiner. Emerald shiner were most abundant in areas of low vegetation cover (CCA, p=0.017), closer to the channel (CCA, p=0.0095), and downstream (CCA, p=0.0489). Vegetation species richness was positively correlated with overall fish species richness (CCA, p=0.0081), and rare fish species richness (CCA, p=0.0329).

CPUE was significantly higher in channel sites compared to bay sites (ANOVA, p=0.0221), but again varied by month (ANOVA, p=0.001). Differences in CPUE between the channel and bay sites were most pronounced in May, June, and August. October had significantly higher CPUE than all other months (ANOVA, p<0.001), while CPUE in June was significantly higher than July (ANOVA, p=0.0056) (*Figure 4*). For the 610 units of effort, CPUE ranged from 0 to 1521, with 9 of the 10 highest values occurring in October and 7 of those 10 values in bay sites. However, 84% of all net-nights had CPUE values of less than 100.

Emergent vegetation in the delta was dominated by hardstem bulrush and reached maximum coverage in June, July, or August at all sites. Very few living shoots were seen in May, and most of what was recorded in that month was dead hardstem bulrush shoots from the previous season. Transects measured from the water's edge provided a more detailed look at vegetation at each site, because transects parallel to the nets were often in less vegetated areas as a result of shallow water levels close to the vegetation edge. While hardstem bulrush dominated the study area overall, bay sites showed more diversity than channel sites. Six species of emergent vegetation were found throughout the sampling period, and bay sites had greater species richness than channel sites (*Table 2*).

The percent vegetation cover varied across sites throughout the season with growth of thick hardstem bulrush stands heavily influencing overall percentages. Percent vegetation cover was averaged along the length of each transect. Three of the four highest values of average percent cover were recorded at C1, where dense stands of hardstem bulrush grew throughout the season, ranging from 18.4% to 42.3% average cover. Average tape grass coverage of 28.5% at B4 in July was the third highest value. The lowest average coverage was 0%, found at C3 and C4 in October, and B1 in May. In May, all sites except C1 had coverage of less than 5%, and sites C2 and B5 continued to have coverage of less than 5% in June. As summer progressed, cover increased at all sites (CCA, p=0.0369), as did vegetation species richness (CCA, p=0.0069). Increased vegetation cover was also significantly correlated with increased distance from the channel (CCA, p=0.0253).

In order to assess YOY fish communities, species that may have included multiple year classes were removed from the analyses. Approximate age determination in the field was made by body length. However, the ages of some species such as emerald shiner were not easily distinguished by this metric, and these taxa made up a large proportion of the total catch. After all cyprinids, round goby, and brook silverside were removed from the analysis, total catch was reduced to 2229 individuals with a CPUE of 3.65 and species richness of 19. Eleven species were categorized as rare, accounting for less than 1% of the total YOY catch, and 17 of the YOY species had been listed as rare in the entire fish community. Rock bass made up almost half of the catch, and banded killifish were the next most abundant, representing 15% of the catch (*Table 3)*.

Bay sites had higher YOY CPUE (CCA, p=0.0234) and rare species richness (CCA, p=0.0354) than channel sites, and upstream sites had higher species richness (CCA, p=0.0039) and rare species richness (CCA, p=0.0340) than downstream sites. As with the overall fish community, CPUE for YOY fish was highest in October (ANOVA, p<0.01) *(Figure 5)*, but in contrast, YOY species richness was significantly higher in July and August than in May and June (ANOVA, p<0.004) *(Figure 6)*. Also in contrast to the whole fish community, YOY CPUE, species richness, and rare fish species richness were all also significantly lower in 2012 than in 2011 (CCA, p=0.0261, 0.0153, 0.0375).

R/D ratios were standardized to fish lengths, and analyzed for 107 rock bass, and standardized to fish length. Growth (defined by higher ratios of RNA to DNA) was highest in bay sites (ANOVA, p<0.02) *(Figure 7)* and August had significantly higher values than all other months (ANOVA, p<0.0006). Of the 25 highest R/D ratios, 72% were from bay sites, and the majority of those were in July and August. The exceptions to this pattern were samples taken in May at sites C4 and C2. Channel sites made up 65% of the 25 lowest ratios, and the exceptions to this were samples taken in bay sites in June. High growth rates were also associated with high fish species richness (ANOVA, p<0.001) and rare fish species richness (ANOVA, p=0.0087). However, rock bass growth significantly declined with increased rock bass density (ANOVA, p=0.0471).

Discussion

Overall, the fish community examined in this study was influenced by season, location, and environmental factors. I conclude that:

1. Overall fish abundance and diversity varied across site locations as the summer progressed, with highest abundances found in early fall at channel sites. Species diversity was highest in bay sites, although this difference became less significant in late summer as vegetation became more uniform between bay and channel sites.
2. YOY fishes were in greater abundance and diversity in bay sites compared to channel sites, and were associated with greater emergent vegetation diversity. Higher abundances of YOY fishes were found at downstream sites, but lower diversity and fewer rare species occurred there. Bay sites seem to act as nursery grounds, but the nature and timing of this function may be seasonal and species-specific.
3. Relative growth of rock bass was highest in late summer in the bay sites, again leading to the conclusion that bay sites serve as better nursery grounds than channel sites. Growth may increase in these habitats due to food sources associated with emergent vegetation density and diversity.

The fish community in the St. Clair River varied across the study sites and through the season. Cyprinids, specifically emerald shiner, dominated large CPUE values at the channel sites, and catches and diversity were highest in October. High catches in the channel sites were contrary to what I expected, as well as contrary to previous studies of larval and juvenile fish in the St. Clair River that recorded large CPUE values in bay areas (Leslie and Timmins 1991). Bay sites had higher species richness, albeit lower CPUE values than channel sites. These sites may therefore provide habitat for a larger variety of fish, and provide refuge from colder temperatures, high flow velocity, and decreased macrophyte cover in the channel sites. For these reasons, channel habitats have been previously described as a “soft barrier” for juvenile and small fish movement, and these barriers may create a greater degree of habitat patchiness (Leslie and Timmins 1991).

Bay sites had greater diversity of vegetation species, but had lower overall cover than the channel sites. High fish species richness values in bays may be attributed to these habitat qualities, which corresponds to results shown in Brown and Bozek (2010) and Jacobus and Ivan (2005) who found that greater fish diversity was correlated to physically complex, sheltered habitats. This also corresponds to previous studies that indicated that juvenile fishes preferred habitats with moderate levels of macrophyte density, rather than high levels (Brazner and Beals 1997, Murry and Farrell 2007).

Fish species richness was significantly higher in May and June in bay sites, while there was a less pronounced difference between bay sites and channel sites later in the summer. As vegetation stands increased throughout the summer across all sites in the study area, bay sites became more similar to channel sites in terms of habitat complexity, and some taxa may have moved into channel sites because of this habitat homogenization. Lapointe et al. (2010) saw a similar pattern in the Detroit River, in which inshore and offshore habitats were less similar in early summer than in late summer.

The pattern of high CPUE in channel sites may be a result of cyprinid species dominating the assemblages. Emerald shiner made up 66% of all fish caught in the study, and were cosmopolitan across the study site and time period. However, there was also a wide range in their relative abundance, which indicates that large schools of these fish affected CPUE values. When schools were encountered, CPUE and relative abundance would be very high compared to sampling efforts when schools were not present. Given that emerald shiner and other *Notropis* spp. are mid-water feeders and often inhabit larger and deeper water bodies than some other species found in this study, such as rock bass (Page and Burr 2011), it follows that more individuals of *Notropis* spp. would be found in channel sites, as well as farther downstream, closer to the lake. These taxa would be fluvial specialists as classified by Nannini et al. (2012), compared to rock bass and other centrarchids that were found more in the bay sites than in the channel sites. However, Nannini et al. (2012) reported cyprinids as a whole in higher abundance in bay sites rather than rivers. Contrary to that, I found cyprinids in large numbers in both bay and channel sites, and their relative proportion in channel sites impacted overall CPUE values.

Because of the high abundance of cyprinids, certain taxa had to be removed from the data set to assess YOY fish community in particular. Field classification of juvenile fish was approximated by length, so taxa with relatively small maximum size, such as cyprinids, likely had multiple age classes in each catch. Therefore, all eight cyprinid species were removed from analysis, as well as brook silverside and round goby, which likely also had multiple age classes within the sample.

When I analyzed only YOY fishes, total abundance and CPUE significantly decreased, and rock bass accounted for almost 50% of the catch. CPUE and species richness for YOY fishes were both higher in bay sites than channel sites, which was in line with the predictions for this study, as well as other published studies (Leslie and Timmins 1991, Jacobus and Ivan 2005, Nannini et al. 2012). As with the overall fish community, YOY CPUE was highest in October, but YOY species richness was highest in July and August. This indicates that hatch dates are staggered throughout the spring and summer, resulting in the largest abundance of species and YOY fishes accumulating in late summer and early fall. While downstream sites had higher CPUE of YOY fishes than upstream sites, they had lower YOY species richness and rare species richness, which again indicates that these sites may be more suitable for fluvial specialists, while bay sites are used by a wider variety of YOY species. As noted previously, rare species richness does not indicate rarity in the ecosystem as a whole, but that these species made up a relatively small proportion of my overall catch from the bay and channel sites.

Greater diversity, and rare species abundance of YOY fishes in bay sites indicate that these areas are used as nursery grounds. Higher vegetation diversity provides a more complex physical habitat in bays compared to channels, which provides protection from predation as well as algal and invertebrate food sources associated with nursery grounds (Nannini et al. 2005).

I conclude from these data that YOY fishes used bay areas during the nursery period, and that moderate macrophyte density and high macrophyte diversity provided preferred habitat for these fishes. The abiotic and biotic factors that categorize nursery grounds changed over the season, and thus the optimal nursery ground may be time- and species-specific, as seem with smallmouth bass that stayed in nursery areas with woody habitat structure in early summer, and then moved to rocky, cobble substrate to reduce predation risk in late summer (Brown and Bozek 2010).

Another element of assessing nursery habitat is to examine whether or not fish have different growth rates. The data show that length-adjusted R/D ratios were higher in bay habitats than in channel sites, and the highest growth was recorded in August. While other species have been shown to have rapid growth rates in early development (Vasconcelos et al. 2009) and early summer (Glémet and Rodríguez 2007), rock bass in this system displayed a different pattern. This may be in part due to relatively low water levels and high water temperatures in 2012, as these were shown by Glémet and Rodríguez (2007) to slow growth rates in yellow perch.

R/D ratios were negatively affected by increased rock bass density at a given site, which may indicate density-dependent effects of competition or resource limitation. However, R/D values increased with abundance and diversity of the fish community, which may indicate that the density of other species did not influence growth. However, it may simply indicate that higher abundance and diversity was found in sites with higher habitat quality and food sources for growth. Given these two results, the relationship between community structure and rock bass growth is unclear.

Rock bass growth increased throughout the summer and peaked in August, which was later than peak vegetation cover at most sites. This indicates that there may be a time lag between when vegetation grows in and when associated invertebrate prey would be dense enough for rock bass feeding and subsequent growth to increase, or that other factors such as water temperature are affecting growth. The nursery grounds do provide habitat suitable for increased growth of rock bass compared to channel sites, which may be a result of higher quality food sources.

More work is needed in order to fully understand interactions at the species and community levels in the St. Clair River. As all sampling was passive there could be bias with sampling gear and site selection. Sites were selected opportunistically in the summer of 2011, and were not changed for 2012. A more targeted approach, with the help of the data presented here, may provide a more diverse or representative suite of sites to be sampled in the future. There may also be flows of energy, nutrients, and fish from the lake to the bay sites which are unaccounted for, while most of the flow to channel sites would be riverine.

R/D analysis could also be improved, mainly by increasing sample size. While each YOY rock bass collected in hoop nets in 2012 was sampled, each site had sample sizes ranging from zero to ten per month. In order to more effectively analyze this data, a larger sample size might display more clear trends. There may also be issues with temperature associated with the R/D analysis. Laboratory studies have found that slight increases in temperature of 1-2 degrees can change R/D values of fish otherwise under equal conditions (Buckley et al. 1999). Given the nature of this fieldwork, samples were collected throughout the day, and individual fish were exposed to a range of ambient water temperatures prior to collection. This, however, is hard to avoid or rectify in a field study.

The results from this study provide a view of the juvenile fish community in the St. Clair River delta that can be used as a reference point for future assessments of community dynamics as well as for conservation and management. Effective management requires not only a solid understanding of community structure and habitat use at all life stages, but also monitoring for changes in these characteristics. This is crucial for identifying areas and habitat types to conserve or restore, as well as for measuring the success of these projects. In this study, bay sites proved important as nursery grounds for YOY fish, but shallow wetlands along the edge of the main channel, especially downstream, were also important for the fish community as a whole. Thus restoration and conservation efforts should not only focus on backwater bays, but should also include these shallow habitats as well. In order to manage fish populations effectively, we must understand the dynamics of the fish community and this study provides valuable information to that end.

Figures and Tables

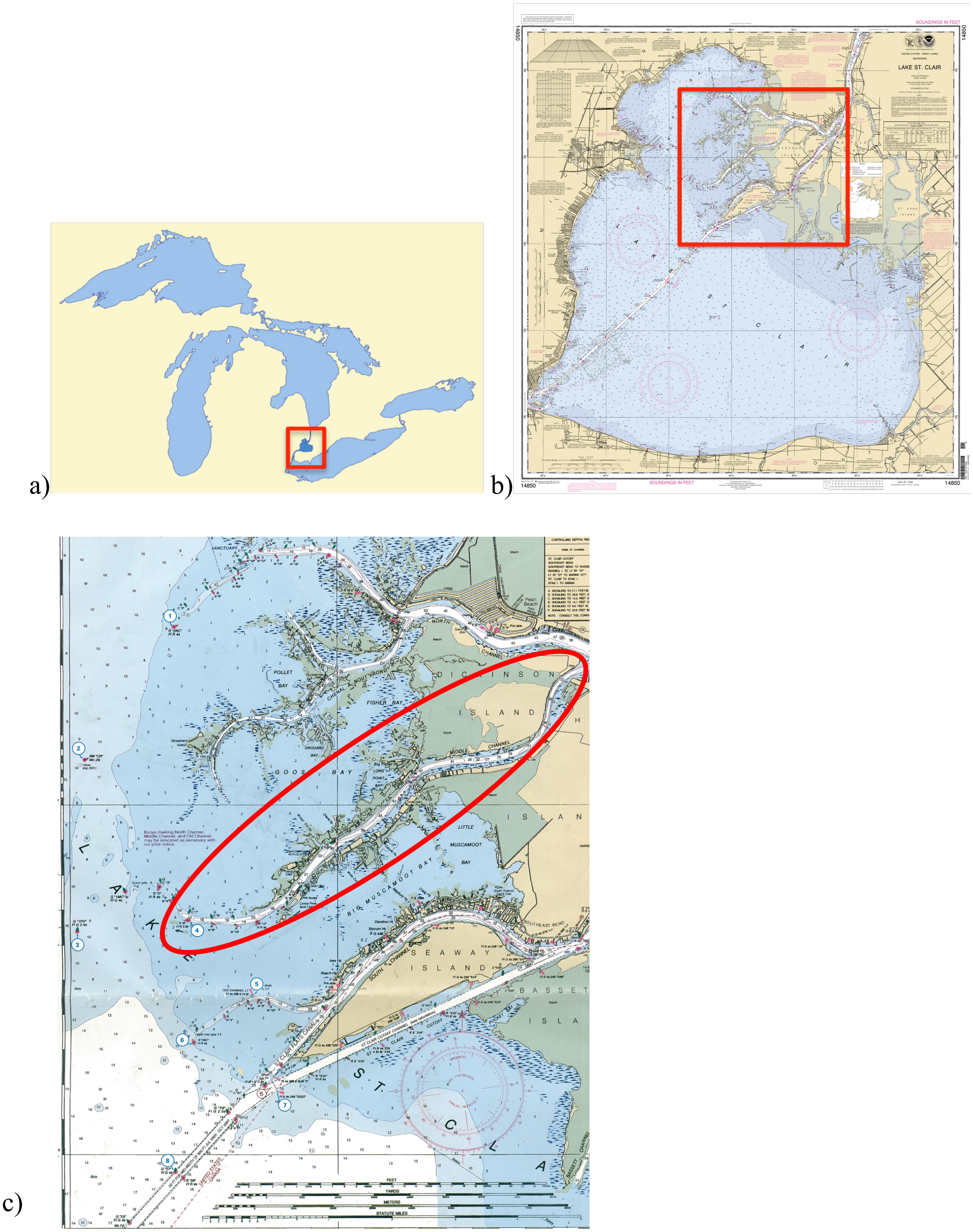

Figure 1 The location of the a) Lake St. Clair, b) the St. Clair River delta, and c) the Middle Channel. Charts from www.lakestclair.net

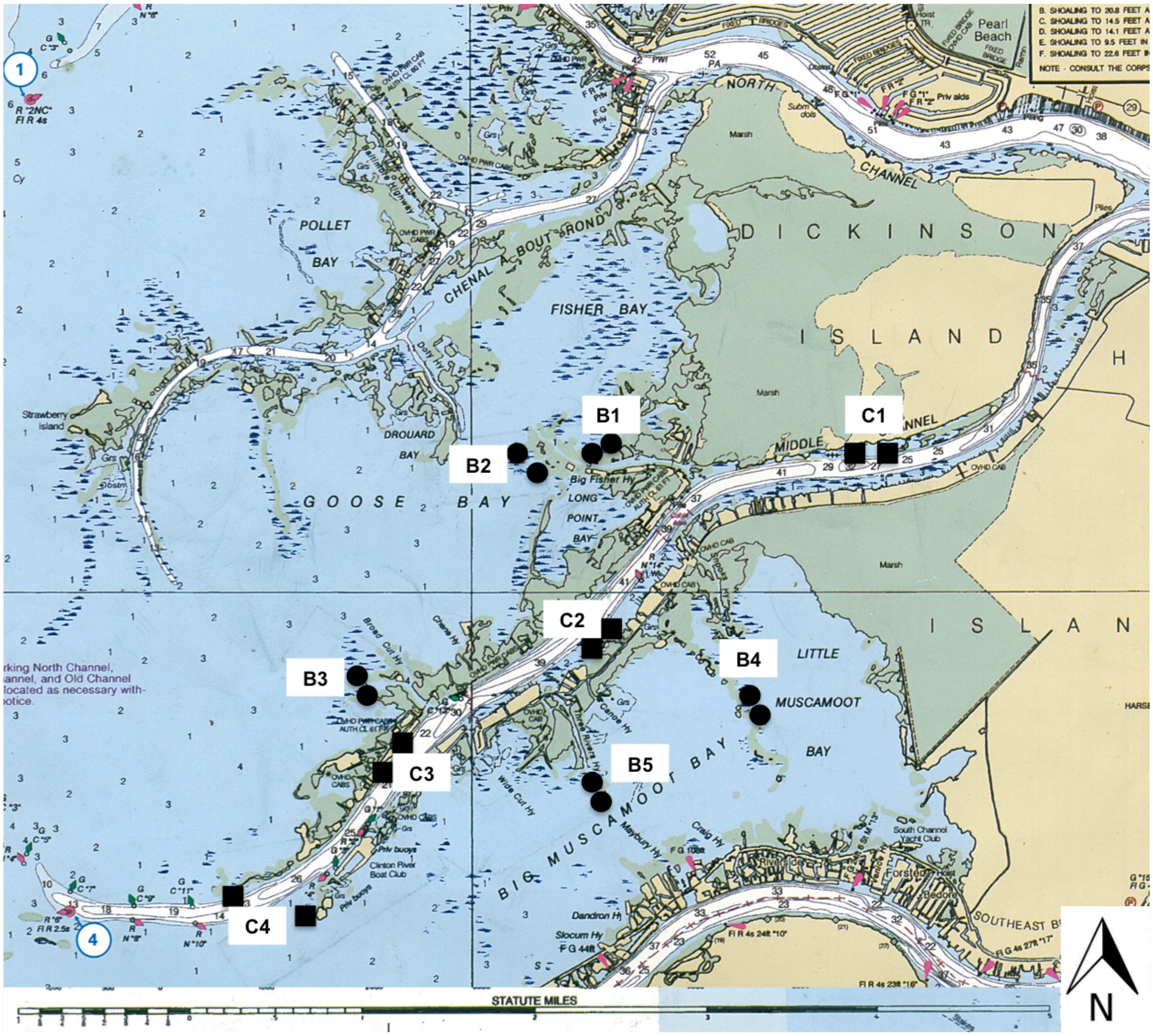

Figure 2 Sampling site locations within the St. Clair River delta. Bay sites are labeled with circles B1-B5 and channel sites are labeled with squares C1-C4. Replicate locations are shown for each site.

Table 1 Total abundance and relative proportion of all species collected. Asterisks indicate rare species (less than 1% of the total catch)

Common Name	Scientific Name	Total Abundance	Relative Proportion
Brindled Madtom*	*Noturus miurus*	1	<0.0001
Fathead Minnow*	*Pimephales promelas*	1	<0.0001
Johnny Darter*	*Etheostoma nigrum*	1	<0.0001
Lake Chub*	*Couesius plumbeus*	1	<0.0001
Three-Spined Stickleback*	*Gasterosteus aculeatus*	1	<0.0001
Trout-Perch*	*Percopsis omiscomaycus*	1	<0.0001
Black Bullhead*	*Ameiurus melas*	2	<0.0001
Bluegill*	*Lepomis macrochirus*	2	<0.0001
Longnose Gar*	*Lepisosteus osseus*	2	<0.0001
Green Sunfish*	*Lepomis cyanellus*	4	0.0001
Bowfin*	*Amia calva*	6	0.0001
Pumpkinseed*	*Lepomis gibbosus*	8	0.0002
Brown Bullhead*	*Ameiurus nebulosus*	37	0.0009
Muskellunge*	*Esox masquinongy*	38	0.0009
Yellow Perch*	*Perca flavescens*	47	0.0011
Tadpole Madtom*	*Noturus gyrinus*	49	0.0012
Smallmouth Bass*	*Micropterus dolomieu*	62	0.0015
Brook Silverside*	*Labidesthes sicculus*	85	0.0021
Largemouth Bass*	*Micropterus salmoides*	167	0.0041
Banded Killifish	*Fundulus diaphanus*	411	0.0101
Round Goby	*Neogobius melanostomus*	435	0.0107
Bluntnose Minnow	*Pimephales notatus*	1042	0.0256
Rock Bass	*Ambloplites rupestris*	1348	0.0331
Spottail Shiner	*Notropis hudsonius*	1380	0.0339
Sand Shiner	*Notropis stramineus*	1702	0.0418
Blacknose Shiner	*Notropis heterolepis*	3154	0.0774
Spotfin Shiner	*Cyprinella spiloptera*	3225	0.0792
Emerald Shiner	*Notropis atherinoides*	26935	0.6611

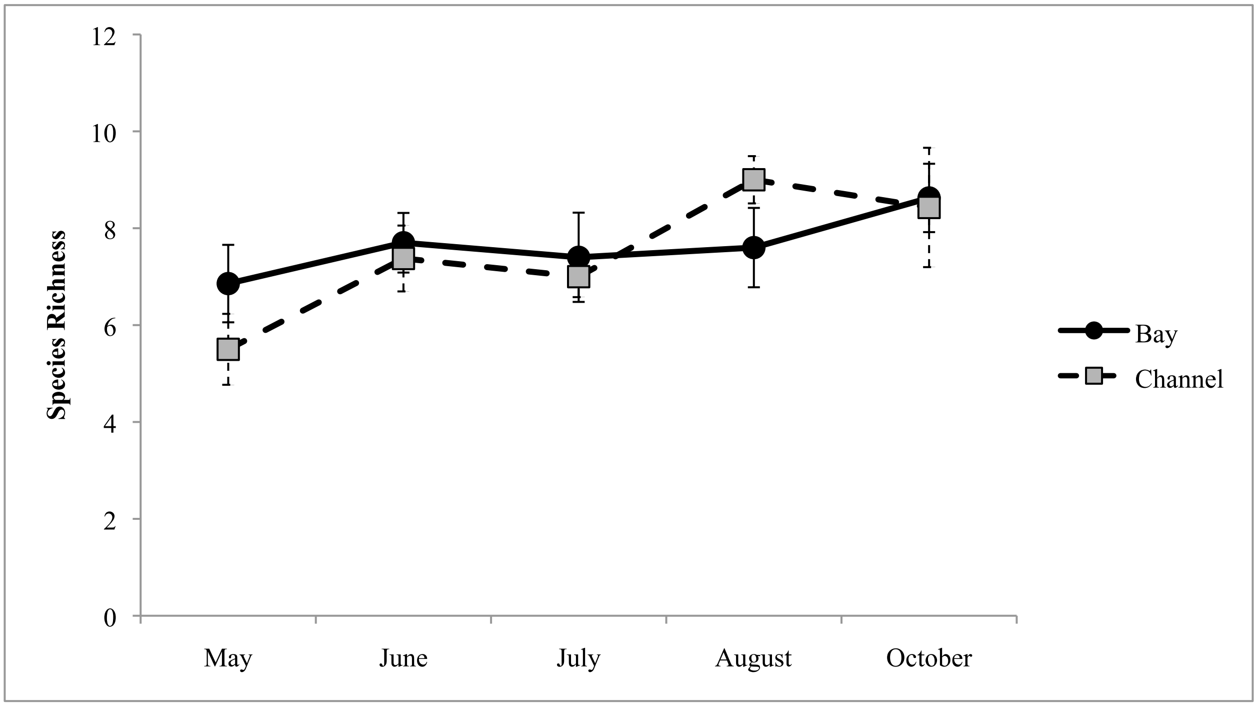

Figure 3 Species richness per month for all fish collected. Values are averages, with whiskers representing standard error. Bay sites are represented by solid circles and lines, while channel sites are represented by gray squares with dashed lines.

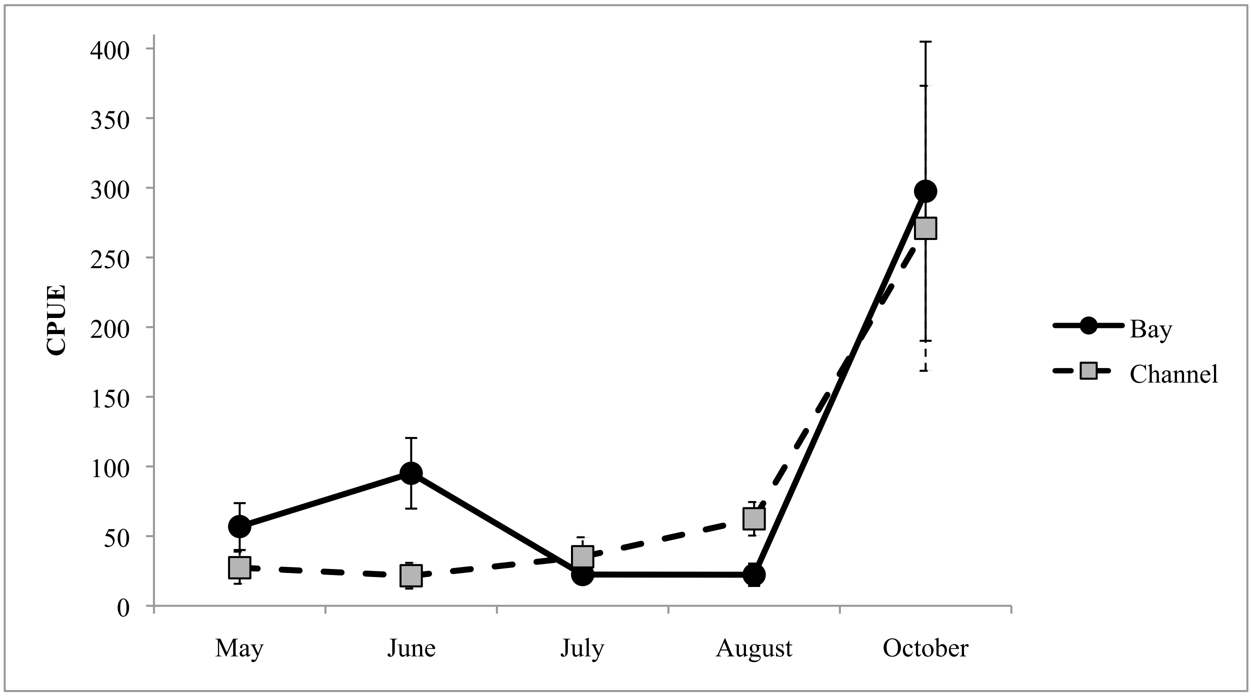

Figure 4 CPUE per month for all fish collected. Representation as in *Figure 3*.

Table 2 Dominant vegetation and species richness for each site, compiled for all months.

	Dominant Vegetation Species		**Vegetation Species Richness**
Site	**Common Name**	**Scientific Name**	
B1	Hardstem Bulrush	*Schoenoplectus acutus*	4
B2	Hardstem Bulrush	*Schoenoplectus acutus*	4
B3	Hardstem Bulrush	*Schoenoplectus acutus*	3
B4	Tape Grass	*Vallisneria americana*	4
B5	Common Cattail	*Typha latifolia*	4
C1	Hardstem Bulrush	*Schoenoplectus acutus*	1
C2	Hardstem Bulrush	*Schoenoplectus acutus*	3
C3	Hardstem Bulrush	*Schoenoplectus acutus*	3
C4	Hardstem Bulrush	*Schoenoplectus acutus*	1

Table 3 Total abundance and relative proportion of all YOY species caught in 2011-2012. Double asterisks indicate rare species (less than 1% of total YOY catch); single asterisks indicate species that were considered rare in the entire community (see *Table 1)*.

Common Name	**Scientific Name**	**Total Abundance**	**Relative Proportion**
Brindled Madtom**	*Noturus miurus*	1	0.0004
Johnny Darter**	*Etheostoma nigrum*	1	0.0004
Lake Chub**	*Couesius plumbeus*	1	0.0004
Three-Spined Stickleback**	*Gasterosteus aculeatus*	1	0.0004
Trout-Perch**	*Percopsis omiscomaycus*	1	0.0004
Black Bullhead**	*Ameiurus melas*	2	0.0007
Bluegill**	*Lepomis macrochirus*	2	0.0007
Longnose Gar**	*Lepisosteus osseus*	2	0.0007
Green Sunfish**	*Lepomis cyanellus*	4	0.0015
Bowfin**	*Amia calva*	6	0.0022
Pumpkinseed**	*Lepomis gibbosus*	8	0.0030
Brown Bullhead*	*Ameiurus nebulosus*	37	0.0137
Muskellunge*	*Esox masquinongy*	38	0.0140
Yellow Perch*	*Perca flavescens*	47	0.0174
Tadpole Madtom*	*Noturus gyrinus*	49	0.0181
Smallmouth Bass*	*Micropterus dolomieu*	62	0.0229
Largemouth Bass*	*Micropterus salmoides*	167	0.0617
Banded Killifish	*Fundulus diaphanus*	411	0.1518
Rock Bass	*Ambloplites rupestris*	1348	0.4978

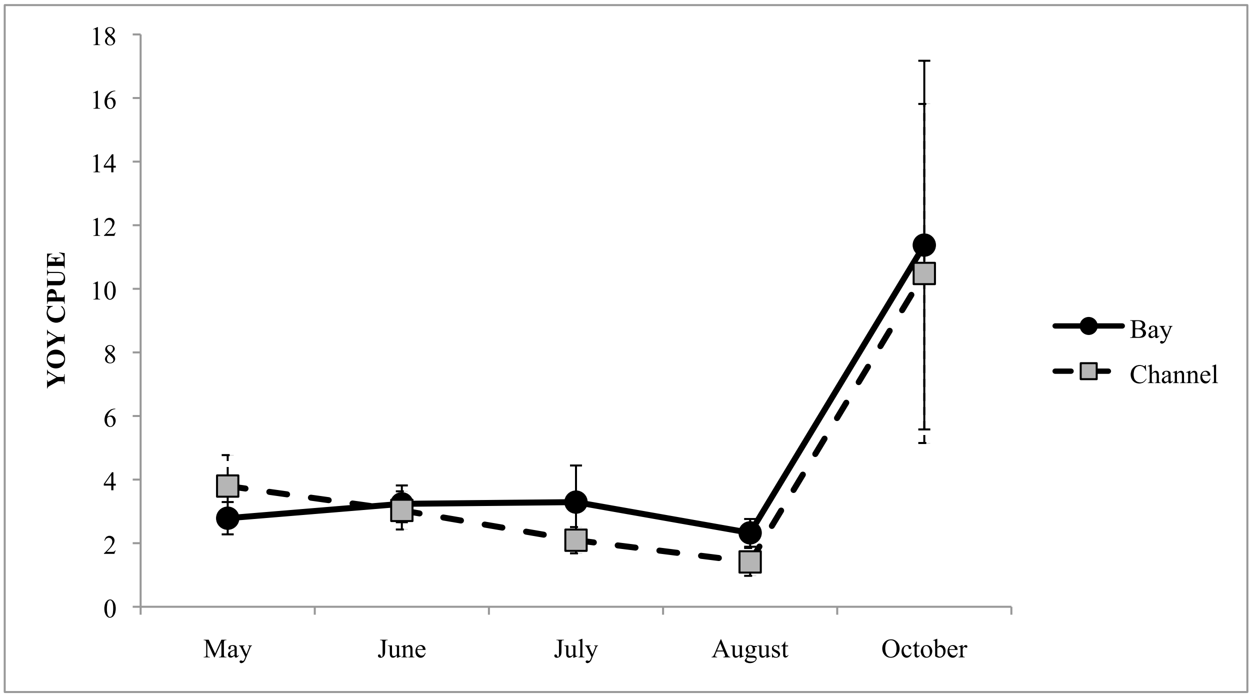

Figure 5 CPUE per month for all YOY fish collected. Representation as in *Figure 3*.

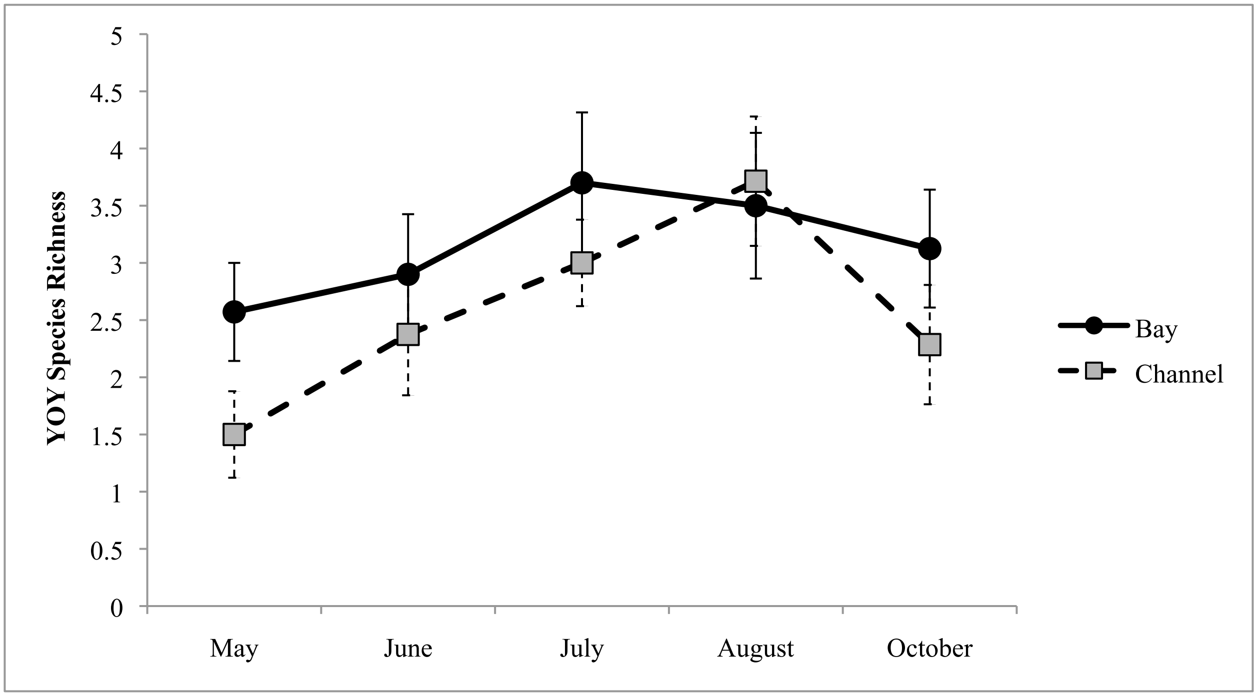

Figure 6 Species richness per month for all YOY fish collected. Representation as in *Figure 3*.

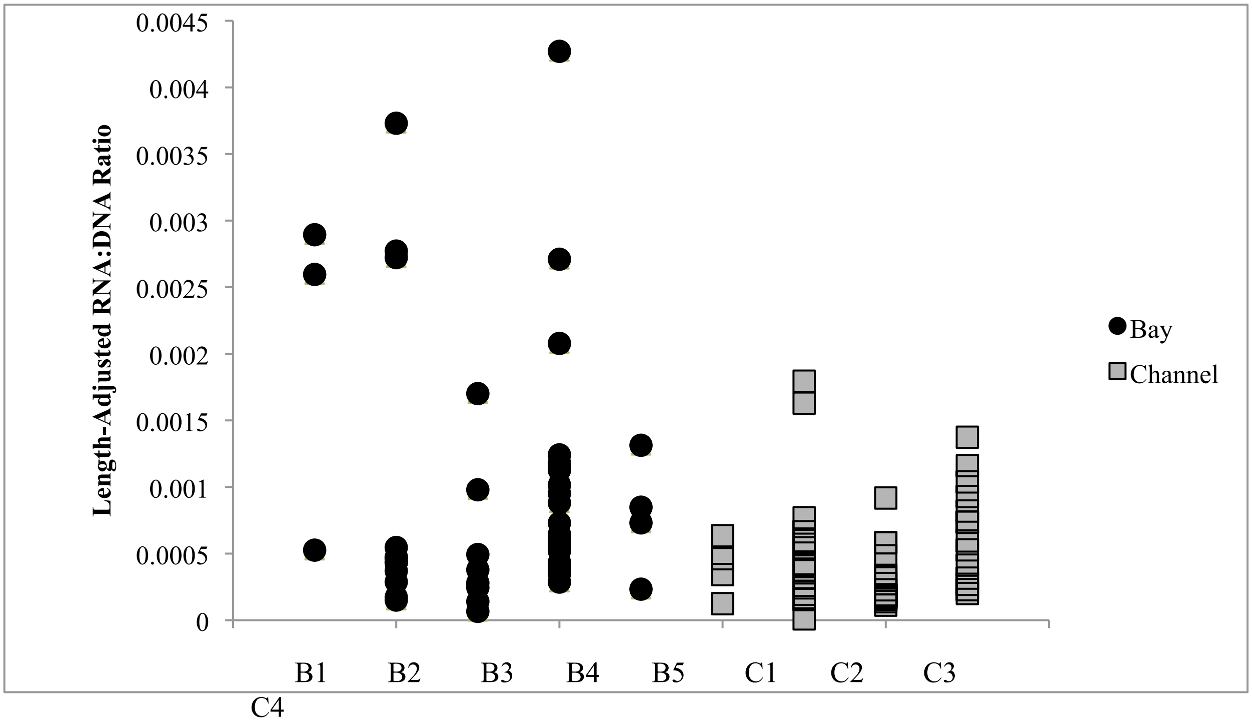

Figure 7 R/D ratios by site, compiled across months. Bay sites are represented by solid circles, while channel sites are represented by gray squares.

Literature Cited

Brazner, J. C. and E. W. Beals. 1997. Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: A multivariate analysis of abiotic and biotic forcing factors. Canadian Journal of Fisheries and Aquatic Sciences 54:1743-1761.

Brown, P. J. and M. A. Bozak. 2010. Habitat selection and abundance of young-of-the-year smallmouth bass in north temperate lakes. Transactions of the American Fisheries Society 139:1247-1260.

Buckley, L., E. Caldarone, and T-L. Ong. 1999. RNA-DNA ratio and other nucleic acid-based indicators for growth and condition of marine fishes. Hydrobiologia 401:265-277.

Dantas, D. V., M. Barletta, A. R. A. Lima, J. dA. A. Ramos, M. R. da Costa, and U. Saint-Paul. 2012. Nursery habitat shifts in an estuarine ecosystem: Patterns of use by sympatric catfish species. Estuaries and Coasts 35:587-602.

Danzmann, R. G., D. S. MacLennan, D. G. Hector, P. D. N. Hebert, and J. Kolasa. 1992. Community structure of Lake St. Clair fishes based upon catchability studies from 1977 to 1988. Journal of Great Lakes Research 18:11-21.

Dobiesz, N. E., D. A. McLeish, R. L. Eshenroder, J. R. Bence, L. C. Mohr, M. P. Ebener, T. F. Naepa, A. P. Woldt, J. E. Johnson, R. L. Argyle, and J. C. Makarewicz. 2005. Ecology of the Lake Huron fish community, 1970-1999. Canadian Journal of Fisheries and Aquatic Sciences 62:1432-1450.

Ensman, L.A. 2008. The Michigan Department of Environmental Quality Biennial Remedial Action Plan Update for the St. Clair River Area of Concern. Michigan Department of Environmental Quality. Lansing, MI.

Garvey, J. E., R. A. Wright, and R. A. Stein. 1998. Overwinter growth and survival of age-0 largemouth bass (*Micropterus salmoides*): revisiting the role of body size. Canadian Journal of Fisheries and Aquatic Sciences 55:2414-2424.

Glémet, H. and M. A. Rodríguez. 2007. Short-term growth (RNA/DNA ratio) of yellow perch (*Perca flavescens*) in relation to environmental influences and spatio-temporal variation in a shallow fluvial lake. Canadian Journal of Fisheries and Aquatic Sciences 64:1646-1655.

Goforth, R. R., and S. M. Carman. 2009. Multiscale relationships between Great Lakes nearshore fish communities and anthropogenic shoreline factors. Journal of Great Lakes Research 25:215-223.

Henning, J. A., R. E. Gresswell, and I. A. Fleming. 2007. Use of seasonal freshwater wetlands by fishes in a temperate river floodplain. Journal of Fish Biology 71:476-492.

Höök, T., N. M. Eagan, and P. W. Webb. 2001. Habitat and human influences on larval fish assemblages in northern Lake Huron coastal marsh bays. Wetlands 21:218-291.

Jacobus, J. and L. N. Ivan. 2005. Evaluating the effects of habitat patchiness on small fish assemblages in a Great Lakes coastal marsh. Journal of Great Lakes Research 31:466-481.

Jacobus, J. and P. Webb. 2005. Using fish distributions and behavior in patchy habitats to evaluate potential effects of fragmentation on small marsh fishes: A case study. Journal of Great Lakes Research 31(supp1):197-211.

Lapointe, N.W.R., L. D. Corkum, and N. E. Mandrak. 2010. Macrohabitat associations of fishes in shallow waters of the Detroit River. Journal of Fish Biology 76:446-466.

Leslie, J.K, and C. A. Timmins. 1991. Distribution and abundance of young fish in the St. Clair River and associated waters, Ontario. Hydrobiologia 219:125-134.

Murry, B.A. and J. M. Farrell. 2007. Quantification of native muskellunge nursery habitat: influence of body size, fish community composition, and vegetation structure. Environmental Biology of Fishes 79:37-47.

Nannini, M.A., J. Goodrich, J. M. Dettmers, D. A. Soluk, and D. H. Wahl. 2012. Larval and early juvenile fish dynamics in main channel and backwater lake habitats of the Illinois River ecosystem. Ecology of Freshwater Fish 21:599-509.

Nichols, S.J., G. Kennedy, E. Crawford, J. Allen, J. French III, G. Black, M. Bluoin, J. Hickey, S. Chernyák, R. Haas, and M. Thomas. 2003. Assessment of lake sturgeon (*Acipenser fulvescens*) spawning efforts in the lower St. Clair River, Michigan. Journal of Great Lakes Research 29:383-391.

Page, L.M. and B. M. Burr. 2011. Peterson Field Guide to Freshwater Fishes of North America North of Mexico Second Ed. Houghton Mifflin Harcourt, New York.

Roberts, J.J. 2010. The ecological consequences of hypoxia for yellow perch (*Perca flavescens*) in Lake Erie. PhD Dissertation. The University of Michigan, Ann Arbor.

Roseman, E.F., W. W. Taylor, D. B. Hayes, J. T. Tyson, and R. C. Haas. 2005. Spatial patterns emphasize the importance of coastal zones as nursery areas for larval walleye in western Lake Erie. Journal of Great Lakes Research 31(suppl 1):28-44.

Smith, T.R. and L. J. Buckley. 2003. RNA-DNA ratio in scales from juvenile cod provides a nonlethal measure of feeding condition. Transactions of the American Fisheries Society 132:9-17.

Trebitz, A.S., J. C. Brazner, N. P. Danz, M. S. Pearson, G. S. Peterson, D. K. Tanner, D. L. Taylor, C. W. West, and T. P. Hollenhorst. 2009a. Geographic, anthropogenic, and habitat influences on Great lakes coastal wetland fish assemblages. Canadian Journal of Fisheries and Aquatic Sciences 66:1328-1342.

Trebitz, A.S., J. C. Brazner, M. S. Pearson, G. S. Peterson, D. K. Tanner, and D. L. Taylor. 2009b. Patterns in habitat and fish assemblages within Great Lakes coastal wetland and implications for sampling design. Canadian Journal of Fisheries and Aquatic Sciences 66:1343-1354.

Vasconcelos, R.P., P. Reis-Santos, V. Ronseca, M. Ruano, S. Tanner, M. J. Costa, and H. N. Cabral. 2009. Juvenile fish condition in estuarine nurseries along the Portuguese coast. Estuarine, Coastal and Shelf Science 82:128-138.

Webb, P. 2008. The impact of changes in water level and human development on forage fish assemblages in the Great lakes costal marshes. Journal of Great Lakes Research 34:615-630.