Status and Trends of the Lake Huron Deepwater Demersal Fish Community, 2008[1]

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Abstract

The U.S.Geological Survey Great Lakes Science Center has conducted trawl surveys to assess annual changes in the deepwater demersal fish community of Lake Huron since 1973. Since 1992, surveys have been carried out using a 21 m wing trawl towed on-contour at depths ranging from 9 to 110 m on fixed transects. Sample sites include five ports in U.S. waters with less frequent sampling near Goderich, Ontario. The 2008 fall bottom trawl survey was carried out between October 24 and November 20, 2008 and sampled only the three northern U.S. ports at DeTour, Hammond Bay, and Alpena due to mechanical problems with the research vessel and prolonged periods of bad weather. Therefore, all data presented for 2008 are based on samples collected from these ports. Compared to previous years, alewife populations in Lake Huron remain at low levels after collapsing in 2004. Age-0 alewife density and biomass appears to have increased slightly but overall levels remain near the nadir observed in 2004. Density and biomass of adult and juvenile rainbow smelt showed a decrease from 2007 despite record-high abundance of juveniles observed in 2005, suggesting recruitment was low. Numbers of adult and juvenile bloater were low despite recent high year-classes. Abundances for most other prey species were similar to the low levels observed in 2005 - 2007. We captured one wild juvenile lake trout in 2008 representing the fifth consecutive year that wild lake trout were captured in the survey. Based on pairwise graphical comparisons and nonparametric correlation analyses, dynamics of prey abundance at the three northern ports followed lakewide trends since 1992. Density of benthic macroinvertebrates was at an all-time low in 2008 since sampling began in 2001. The decline in abundance was due to decreases in all taxonomic groups and a large reduction in recruitment of quagga mussels. Density of *Diporeia* at northern ports in 2008 was the lowest observed. Diporeia were found only at 73-m sites of three ports sampled in northern Lake Huron. While no lakewide estimate of prey biomass was calculated due to the limited spatial scope of the 2008 survey, existing data suggest prey biomass remains depressed. Prey available to salmonids during 2009 will likely be small alewives, small rainbow smelt and small bloaters. Predators in Lake Huron will continue to face potential prey shortages.

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Introduction

The Great Lakes Science Center (GLSC) has conducted annual bottom trawl surveys on Lake Huron since 1973. These surveys are used to examine relative abundance, size and age structure, and species composition of the prey fish community. Estimates of lake-wide (i.e., between 5- and 114-m depth contours) prey fish biomass available to the trawl are also generated. Sampling was conducted with a 12-m bottom trawl during 1973-1991, but in 1992 the gear was changed to a 21-m wing trawl to improve biomass estimates of pelagic prey species and to reduce apparent size selectivity. This report focuses on data collected during 1992-2008 using the 21-m wing trawl. Sampling was conducted annually during this time period, except during 2000 when sampling did not occur due to vessel navigation system breakdown. In 2008, only the three northern-most ports were sampled due to delays associated with mechanical problems with the research vessel and prolonged periods of bad weather.

Methods

Trawl sampling is performed annually at five ports in U.S. waters: DeTour, Hammond Bay, Alpena, Au Sable Point (Tawas), and Harbor Beach (Figure 1). In 2008, only DeTour, Hammond Bay, and Alpena were sampled. At each port, 10-minute on-contour trawl tows are made on approximate 9 m depth intervals at fixed transects from 9 to 110 m in depth. The 27, 37, 46, 55, 64, and 73 m depths are common to all ports, but the number of shallower and deeper tows varies among ports due to variation in bathymetry and bottom composition. Sampling also occurred at Goderich, Ontario during 1998, 1999, and 2003-2007 using the same trawling regime as U.S. ports (Figure 1).

Tow times and speeds were constant, but true time-on-bottom increases with depth, and catches C_i were standardized among tows using the formula:

$$C_i = N_i * \left(\frac{10}{t(0.004d + 0.8861)} \right)$$

where N_i is the number of fish of species *i* captured in a single tow, *t* is tow time (usually 10 minutes), and *d* is depth (m). Density (D_i) was calculated for each species by dividing C_i by area swept, expressed as number · Ha^{-1}.

Annual numeric density (A_i) was defined as mean number · Ha^{-1} of each species:

$$A = \frac{\sum_{i=1}^{n} D_i}{n}$$

where D_i is the density of species *i* from each trawl tow, and *n* is total number of tows performed.

Variability associated with *A* was estimated using Relative Standard Error (*RSE*):

$$RSE_{\mathrm{i}} = 100 \times \left(\frac{se}{A_i} \right)$$

where *se* represents the standard error of *A* (mean density). An RSE of 100% indicates the standard error was equal to the estimated mean.

For analysis of recruitment trends, mean density was apportioned into age-0 and adult fish based on length frequency data from all tows where a species was captured. We used 100 mm TL as a demarcation between juvenile and older fish for alewife, 90 mm for rainbow smelt, and 120 mm for bloater based on archived historical length at age data.

Swept area biomass estimates for Lakes Huron and Michigan (Madenjian et al. 2008) are now calculated in the same manner. In both lakes, only depth contours sampled by trawling (i.e., 5 to 114 m depth) are considered. The Lake Huron acoustic survey estimates lakewide biomass in deeper waters (see Schaeffer and O'Brien 2009). In this report, lakewide biomass B_i of each major prey fish species i was calculated from trawl biomass per tow:

$$B_i = \sum_{s=0}^{s=110} \frac{W_{is} a_s}{n}$$

where B_i is biomass of species i, W_{is} represents mean biomass ($kg \cdot ha^{-2}$) of each species within each depth stratum s, a_s represents the weighted area (ha^2) of individual strata s, and n represents the number of depth strata. W_i was derived for each species i by calculating its total weight within each depth stratum and dividing by area swept by the trawl. Because of the limited spatial scope of the 2008 data set, no lakewide biomass values were estimated for this year.

Because only the northern three ports (DeTour, Hammond Bay, and Alpena) were sampled in 2008, we were concerned that estimates of prey fish abundance at these ports may not be representative of lakewide trends. To assess the relationships between numeric abundance of prey fish collected at the three northern ports with lakewide abundance estimates, we used graphical biplots and nonparametric correlation analyses. We used Spearman's nonparametric rank correlation statistic to assess relationships between estimates of prey abundance at northern ports and lakewide estimates. These techniques allowed us to assess the strength of relationships between prey dynamics at northern ports with lakewide trends.

Benthic macroinvertebrate samples were collected at each U.S. port during 2001 through 2004 and all U.S. ports plus Goderich, ON in 2005-2007. As with the trawl sampling, only the northern three ports were sampled in 2008. Three replicate grabs were made with a Ponar dredge (484 cm^2 mouth) at 27 m, 46 m, and 73 m depths. Samples were washed onto 0.5 mm benthos sieves and preserved in 5% formalin. We calculated mean density of major invertebrate groups representing common prey types for fish.

The 2008 Survey

The 2008 survey was carried out during October 24 - November 20. Twenty-five of the forty-eight planned trawl tows were completed at DeTour, Hammond Bay, and Alpena, the northern-most ports. These ports include the deepest depths (91 and 110 m) in the survey. Trawling could not be carried out at the 46 m transect at Detour due to an obstruction on the lake bottom that damaged gear. Survey logistics and bad weather prevented sampling the southern ports at Au Sable Point, Harbor Beach, and Goderich, ON. The lake remained stratified during the 2008 survey with a deep (30-40 m) thermocline present.

A total of 10 fish species was collected in the survey (Appendix I). Common and scientific names of fishes are listed in Appendix I. Status and trends of common forage species are described below.

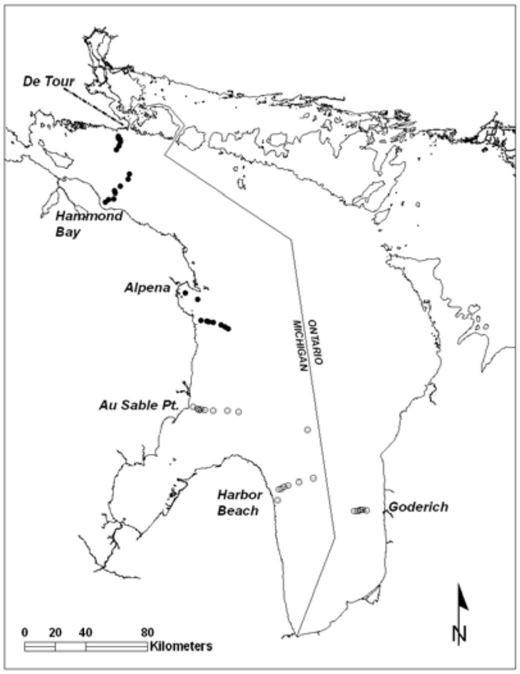

Figure 1. Sampling locations in Lake Huron, 2008. Circles indicate trawling sites; filled circles represent locations where trawling was conducted in 2008.

Abundance, size, and age structure

Alewife- Alewives were at low abundance in Lake Huron from 2003 – 2007 and did not increase at northern ports in 2008. Adult alewife density and biomass remained near the all-time low observed in 2004 (Figure 2). The RSE for adult alewife was about 60% in 2008 suggesting uneven distributions of adults. The RSE value increased to 75% in 2004 and 85% in 2005 because of patchy distributions in those years (Figure 2). Age-0 alewife abundance showed a slight increase at northern ports in 2008, but densities remain suppressed and near the all-time low for the time series (Figure 3).

The alewife population collapse occurred during 2002-2004. During 2002, alewives of all sizes and ages were abundant due to a series of strong year classes that occurred in 1998, 1999, 2001, and 2002. However, high mortality of all sizes during 2002-2004 caused almost complete mortality of the 2002 year class, and substantial reduction in the abundance of older fish. During 2003, the few remaining adults produced the largest year class in the time series (Figure 3), but age-0 alewives experienced almost complete mortality resulting in record-low densities during 2004.

Recent alewife size and age structure reflected these conditions. Since 2003, alewife size distribution has been dominated by fish less than 100 mm TL (i.e. age-0 fish; Figure 4), whereas age-1 through age-5 fish were rare (Roseman et al. 2008). Recent year-classes either failed to survive (2003) or were present at low densities (2004-2008). Trends observed in the lake-wide fisheries acoustic survey (Schaeffer and O'Brien 2009) follow those observed by the bottom trawl survey. In both surveys, alewives have been scarce and at unprecedented low population levels since 2004. Currently, only low numbers of small alewives are available to predators.

Pair-wise comparisons and correlation analyses showed statistically significant relationships for adult and YOY alewife abundance dynamics at northern ports compared with lakewide estimates (Appendix IIa, III).

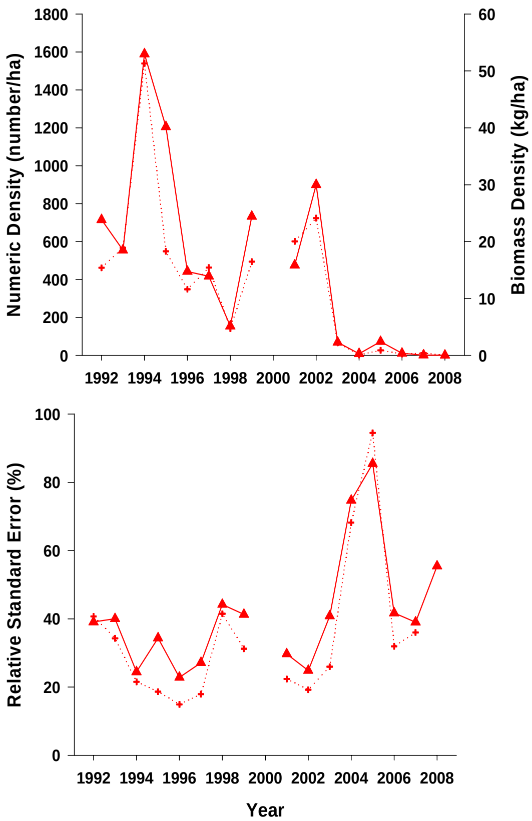

Figure 2. Density of adult alewives as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

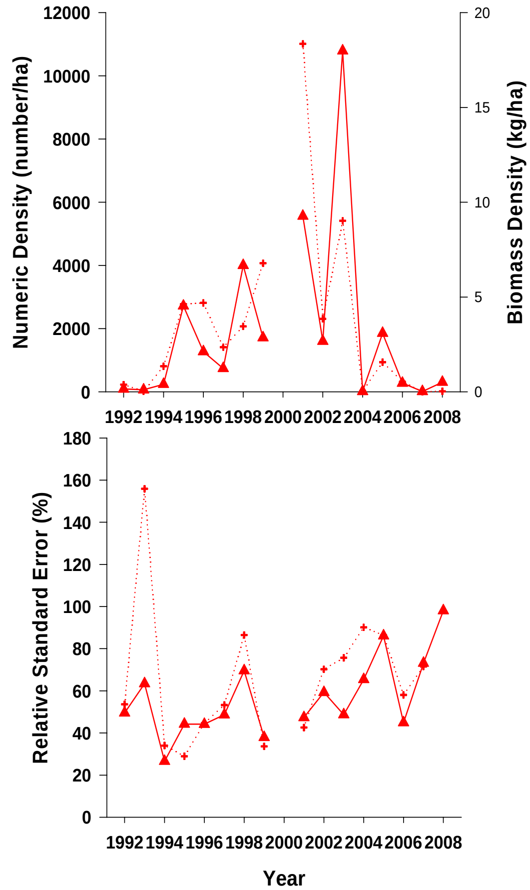

Figure 3. Density of age-0 alewives as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

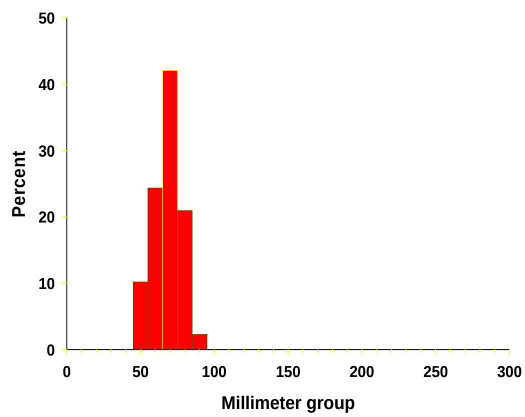

Figure 4. Size structure of northern Lake Huron alewives, 2008. Percentages less than 1% are not visible.

Rainbow smelt- Adult rainbow smelt density continued to decline in 2008 despite record high levels of age-0 rainbow smelt in 2005 (Figures 5 and 6). In 2005, age-0 biomass was the highest on record since 1992 representing a doubling in density over 2004 estimates, but age-0 biomass declined by 85% in 2006 and increased only slightly in 2007 (Figure 6) and these 2005 fish did not recruit to the adult stock. Values for 2008 based on samples collected in northern Lake Huron suggest development of a small rainbow smelt year-class and a lack of recruitment.

Similar to the previous three years (Roseman et al. 2008), the rainbow smelt population was dominated by age-0 fish in 2008 with less than 40% of the population larger than 100 mm (Figure 7). The low abundance of adult fish suggests that the large numbers of small rainbow smelt observed during 2005 - 2007 did not translate into recruitment of larger rainbow smelt. In fact, the combined biomass for all age classes of rainbow smelt decreased by about 50% from 2005 to 2006-2008 despite the record-high density of age-0 fish observed in 2005. Both the bottom trawl and acoustic surveys (Schaeffer and O'Brien 2009) were in agreement that there have been no substantive changes in adult rainbow smelt density or biomass in recent years, and that overall adult density and biomass remain low compared to previous levels in the 1980's and 1990's. Both surveys were also in agreement that the 2008 year class was exceptionally poor. The poor year-class strength observed in 2008 was also observed during the larval stage. Larval rainbow smelt collections in St. Martin Bay (northern Lake Huron) during spring 2008 were extremely low (T.P. O'Brien unpublished data) compared with larval abundance estimates from earlier surveys (2007; E.F. Roseman unpublished data; Brown 1994).

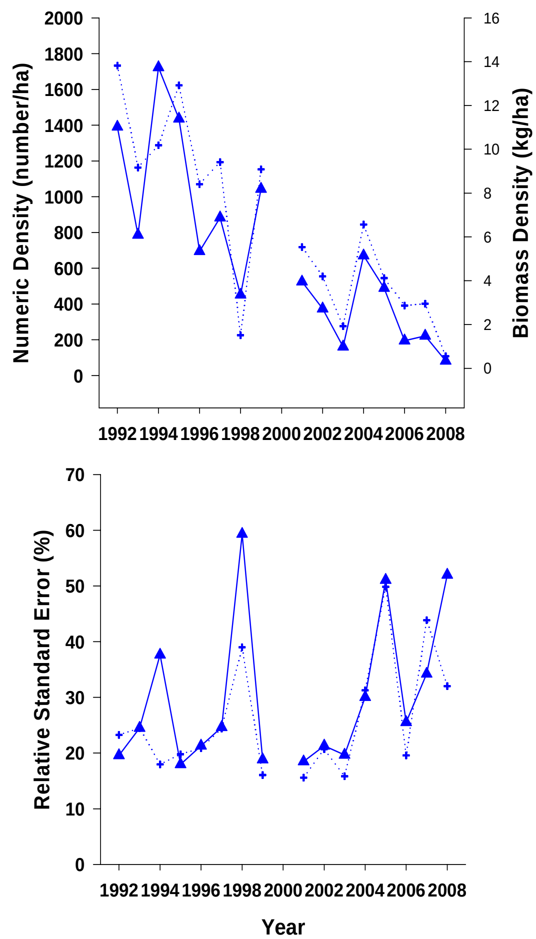

Figure 5. Density of adult rainbow smelt as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

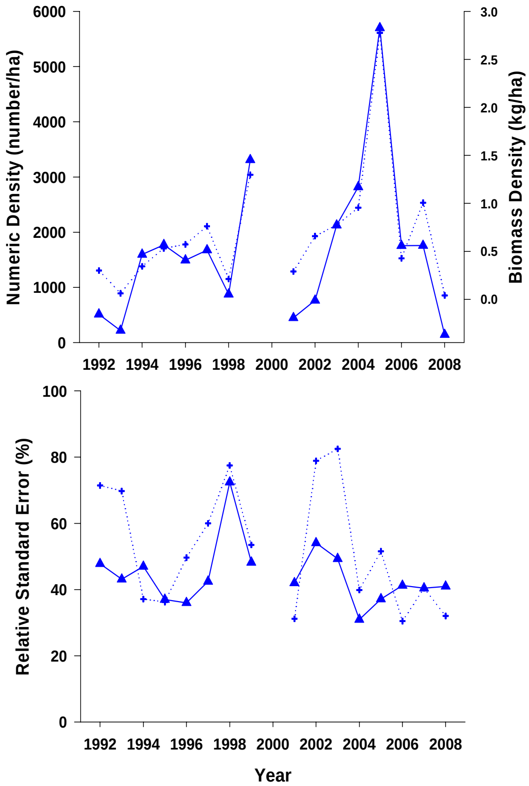

Figure 6. Density of juvenile rainbow smelt as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

Pair-wise comparisons and correlation analyses showed statistically significant relationships for adult and YOY rainbow smelt abundance dynamics at northern ports compared with lakewide estimates (Appendix IIa, III).

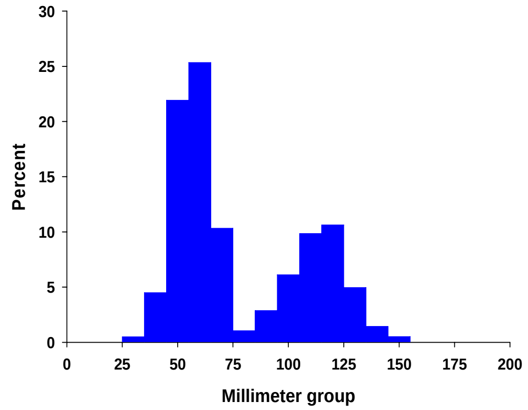

Figure 7. Length-frequency distribution of rainbow smelt collected in bottom trawls from three northern Lake Huron sites sampled during fall, 2008.

Bloater- Adult and juvenile bloater densities in northern Lake Huron were low compared to lakewide values from previous years (Figure 8 and 9). About 85% of bloaters captured during 2008 were less than 120 mm TL representing year-classes formed in 2007 and 2008. Abundance of larger bloater was low (Figure 10) compared to previous years. Juvenile bloaters are pelagic and generally not susceptible to bottom trawls, so true year class strength may not be apparent until they become fully recruited to the trawl at age-3 or older (Wells 1968).

High densities of juveniles observed during 2003-2007 may represent a conservative estimate of the strength of these year classes. Nonetheless, juvenile bloater densities rarely exceeded 5 fish ha^{-1} during 1992-2002, but densities increased to approximately 60 fish · ha^{-1} in 2003, 28 fish · ha^{-1} in 2004, 320 fish · ha^{-1} in 2005, and 105 fish · ha^{-1} in 2006, and a record high of over 800 fish · ha^{-1} in 2007 (Figure 9). In 2008, densities of adult and juvenile bloater were lower than observed since the alewife collapse in 2004.

RSE values for both adult and juvenile bloaters typically fluctuate between 30 and 50 %, however 2008 results were higher than most previous years (Figures 8 and 9). Although bloater catches can vary by an order of magnitude or more over time and by port, their distribution with depth typically varies little from year to year.

The bottom trawl and acoustic surveys (Schaeffer and O'Brien 2009) show poor agreement with respect to age-specific bloater densities. In 2005 and 2007 the bottom trawl survey caught large numbers of age-0 bloater, and this occurred at the southern ports that were not sampled in 2008. The acoustic survey found far fewer numbers of age-0 bloaters in those years (Schaeffer and O'Brien 2009). This year (2008), the southern ports were not sampled by bottom trawling, but the acoustic survey found exceptionally high densities of both age-0 bloaters and small adults that likely originated from 2005 or 2007 (Schaeffer and O'Brien 2009). Thus, the two surveys are in general agreement that bloaters are increasing and that it is a young population.

Pair-wise comparisons and correlation analyses showed statistically significant relationships for adult and juvenile bloaters abundance dynamics at northern ports compared with lakewide estimates, although the strength of the relationship for young bloaters was low (Appendix IIa, III).

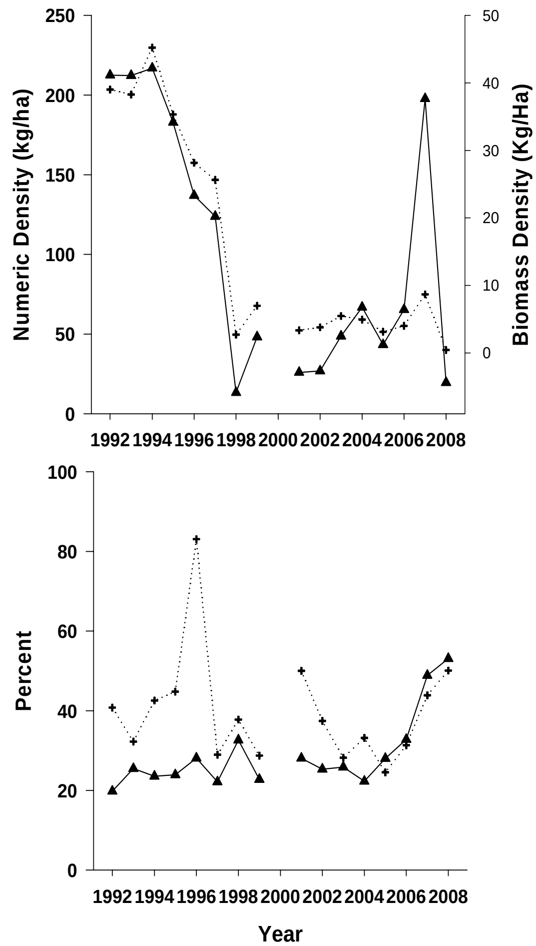

Figure 8. Density of adult bloaters as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

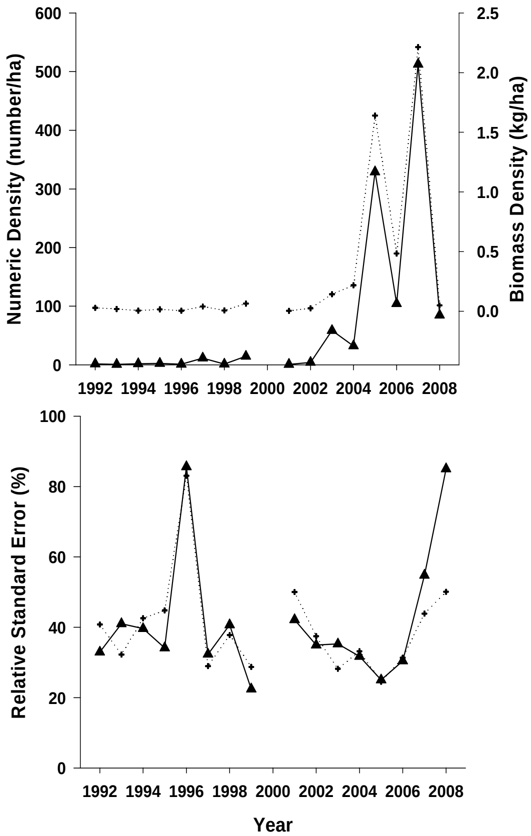

Figure 9. Density of juvenile bloaters as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

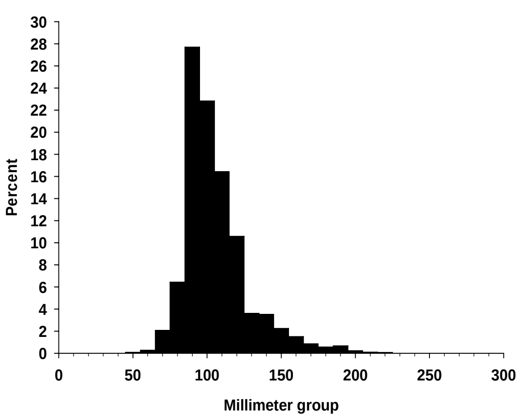

Figure 10. Length frequency distribution of bloaters collected in bottom trawls from Lake Huron, 2008.

Sculpins, sticklebacks, and troutperch- Sculpin abundance in Lake Huron has fluctuated widely since 1992 but has been depressed since 1998 (Figure 11). Deepwater sculpins comprise most of the total sculpin catch, while slimy sculpins are only a minor component of the deepwater fish community and were not collected in 2008. Deepwater sculpin abundance in northern Lake Huron was low in 2008 compared to previous years. RSE for deepwater sculpins remains at relatively high levels (40 to 60%). Based on recent offshore and northern sampling sites, deepwater sculpin distributions have become patchier during recent surveys, restricted to offshore and northern sample sites (O'Brien et al. in press). For both sculpin species, we found statistically significant relationships between abundance dynamics at northern ports and lakewide estimates (Appendix IIb, III).

Density and biomass of ninespine sticklebacks in northern Lake Huron were low and showed signs of continued decline as was observed in previous years (Figure 12). Ninespine stickleback abundance has varied considerably since 1992 and low densities have been observed previously (1992-94 and 1998-99). However, the recent trend since 2001 has been downward. Correlation analyses showed statistically significant relationships between ninespine stickleback abundance dynamics at northern ports and lakewide estimates (Appendix IIb, III).

Troutperch density and biomass also continue a five-year overall decline. None were collected in samples taken in northern Lake Huron during 2008

(Figure 13). Troutperch will not likely be an important alternative prey species in 2009. Correlation analyses showed statistically significant relationships between troutperch abundance dynamics at northern ports and lakewide estimates (Appendix IIb, III).

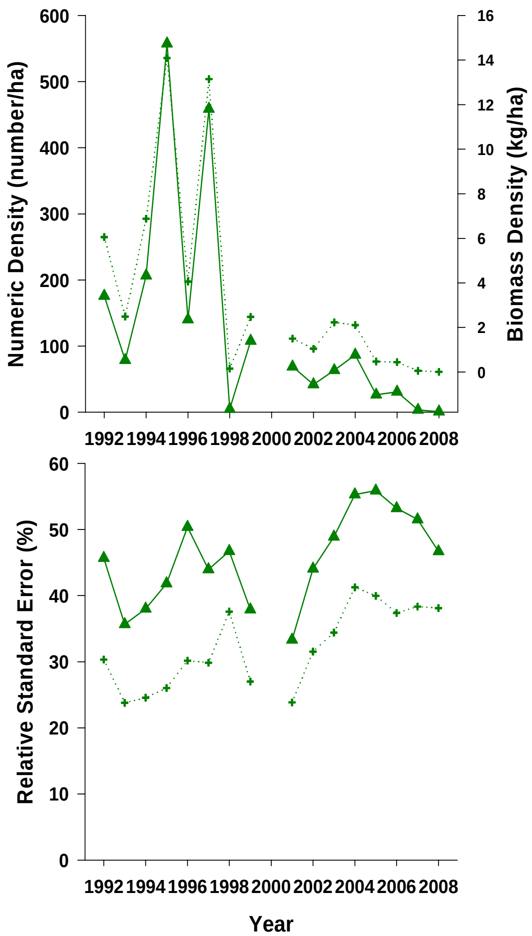

Figure 11. Density of deepwater sculpins as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

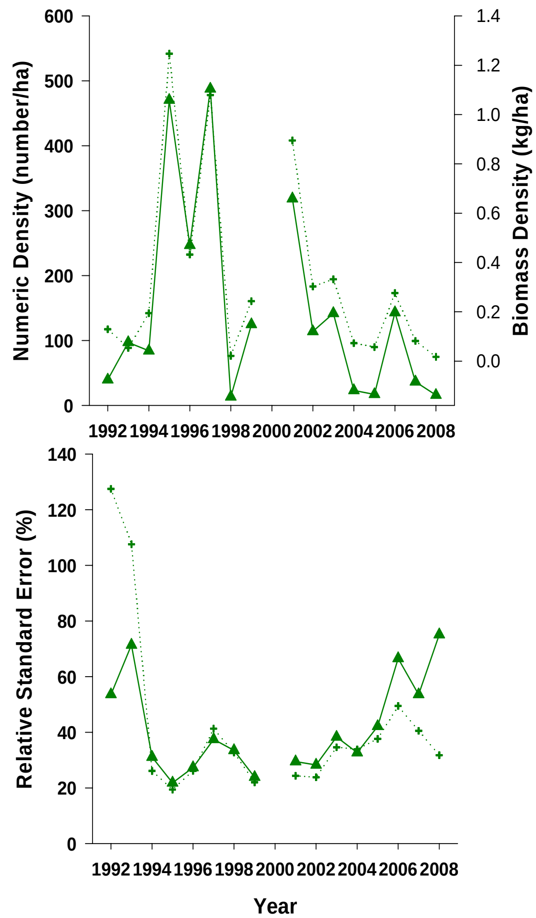

Figure 12. Density of ninespine sticklebacks as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

Round gobies- Round gobies were first collected in the trawl survey during 1997 and increased in abundance steadily until 2003 when their abundance declined in 2004 and has remained below 40 fish ha^{-1} in 2005-2007 (Figure 14). Round goby abundance traditionally has been highest at the southern ports not sampled in 2008. However, it is worth noting that we collected the first round goby at the Hammond Bay port in 2008 but found none at Alpena where the species was collected in previous years. Round gobies were collected at all ports except Hammond Bay and DeTour in 2007. Spearman's rank correlation analysis showed a strong statistically significant relationship between round goby abundance dynamics at northern ports and lakewide estimates, likely due to the influence of round goby dynamics at Alpena where the population proliferates (Appendix IIb, III).

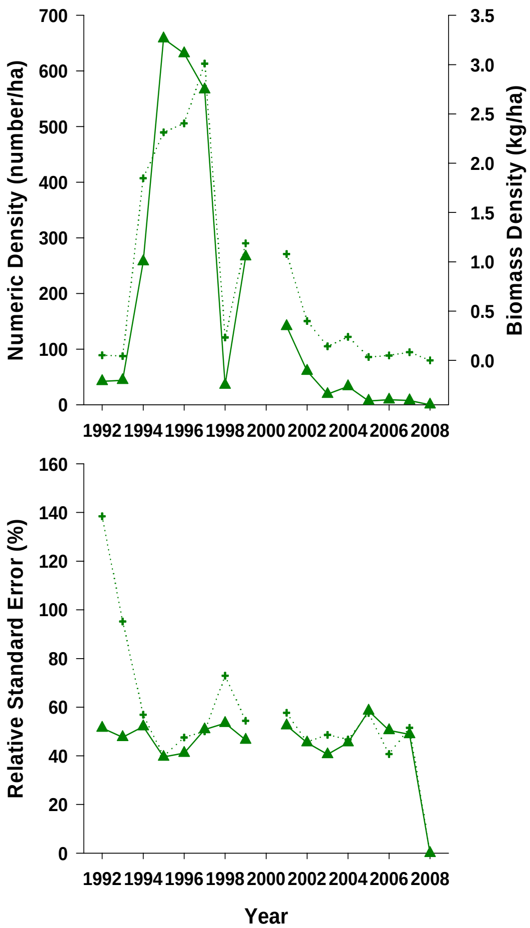

Figure 13. Density of troutperch as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

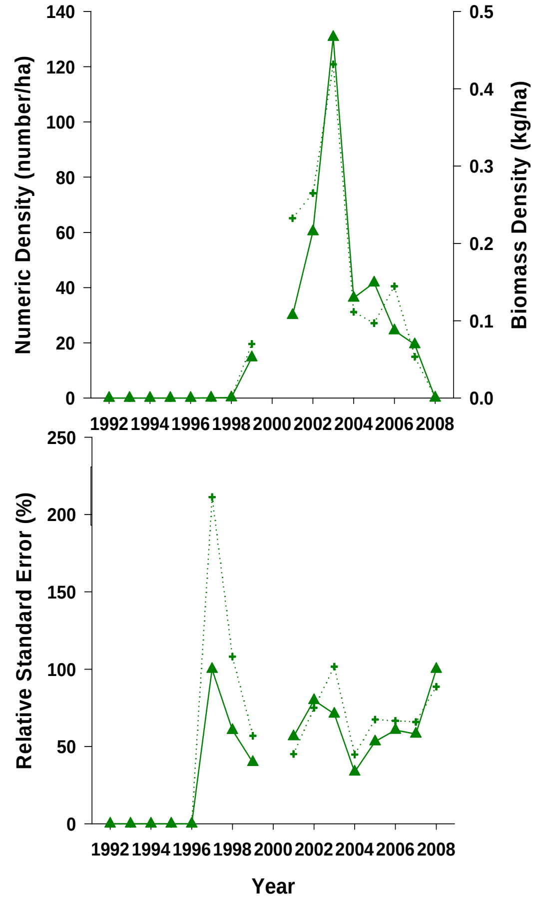

Figure 14. Density of round gobies as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2008. Only three northern ports were sampled in 2008.

Lake trout- Collection of wild juvenile lake trout continued in 2008. These fish were identified as naturally-spawned because they lacked fin clips and were smaller during October than the smallest hatchery lake trout stocked earlier that year. Overall lake-wide mean density of wild lake trout in northern Lake Huron was low at about 0.04 fish · ha^{-1} in 2008. Collections of stocked lake trout have declined in recent years (Figure 15).

Wild age-0 lake trout have been collected in mid-lake surveys of Six-

Fathom Bank (Desorcie and Bowen 2003) and collections in recent years indicate that widespread reproduction is occurring in the main basin (Riley et al. 2007). A majority of these wild fish were determined to be descendants of stocked Seneca strain fish (Roseman et al. In press). Correlation analyses showed strong statistically significant relationships between abundance dynamics at northern ports and lakewide estimates for wild and stocked lake trout (Appendix IIc, III).

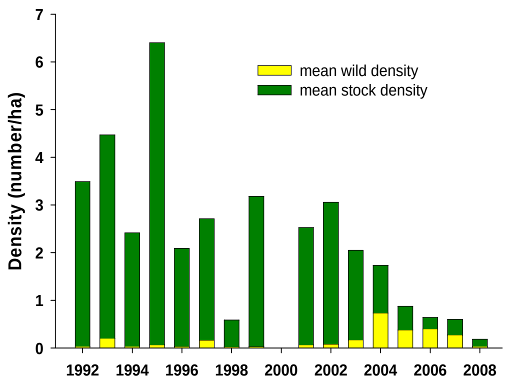

Figure 15. Density of wild and stocked lake trout collected in fall bottom trawls from Lake Huron 1992-2008. Only three northern ports were sampled in 2008.

Biomass Estimates- Because of the limited spatial scope of the 2008 survey, no lakewide biomass estimate was calculated for this year. Total main basin prey biomass for the area between 5 and 114 m increased from 32 kilotonnes in 2006 to 40 kilotonnes in 2007 (Figure 16) but remained far below levels observed when alewives dominated the forage fish community. The increase observed in 2007 was due to moderate increases in bloater and rainbow smelt. Biomass of other species did not change appreciably, indicating that no species has begun to replace lost alewife production, at least in the offshore environment. Based on the strong statistically significant correlation relationships between prey abundance at northern ports sampled in 2008 and lakewide estimates (Appendix IIa,IIb, III), we are confident that lakewide biomass remains low for all species.

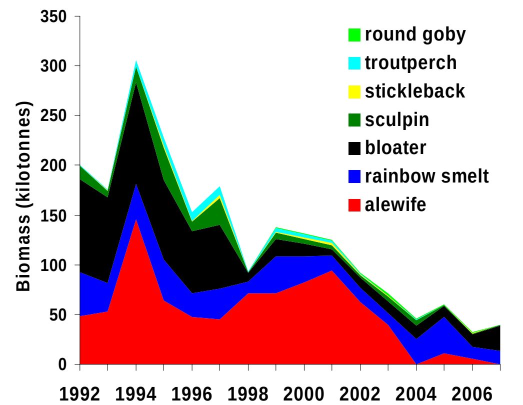

Figure 16. Prey fish community biomass (Kilotonnes) in main basin waters of Lake Huron, 1992-2007. No sampling occurred during 2000; biomass estimates for that year represent interpolated values.

Benthic Invertebrates- Density of benthic invertebrates was at an all-time low in 2008 due to decreases in densities of all major macroinvertebrate taxonomic groups (Figure 17). Density of *Diporeia* spp. has shown a continuing decline in abundance since sampling began in 2001 and densities in 2005 - 2008 were the lowest observed (Figure 18). Overall mean quagga mussel density decreased in 2008 and remains below the peak abundance observed in 2002 and 2003 (Figure 19).

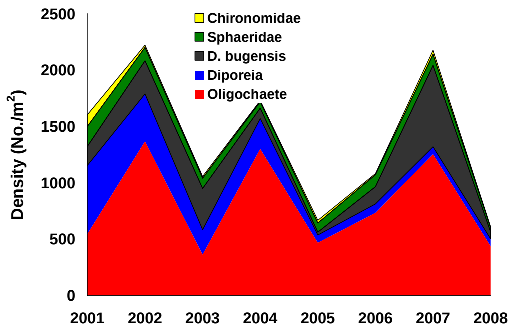

Figure 17. Mean density of benthic macroinvertebrates collected from five U.S. ports in western Lake Huron (2001-04), five U.S. ports plus Goderich, ON (2005-07), and three U.S. ports in northern Lake Huron (2008). Data include all depths pooled**.**

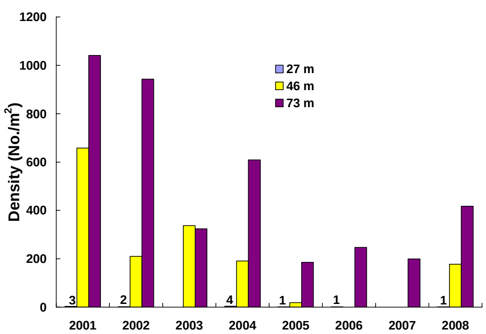

Figure 18. Mean density of *Diporeia* spp. at 27 m, 46 m, and 73 m depth strata determined from collections at five U.S. ports in western Lake Huron (2001-04) and five U.S. ports plus Goderich, ON (2005-07).

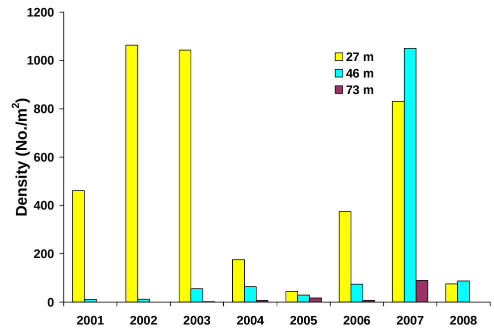

Figure 19. Mean density of quagga mussels *Dreissena bugensis* at three depth strata as determined from samples collected from five U.S. ports in western Lake Huron (2001-04), five U.S. ports plus Goderich, ON (2005-07), and three U.S. ports in northern Lake Huron (2008).

Discussion

The availability of prey fish in Lake Huron remains in a depressed state since the collapse of the deepwater demersal fish community in the lake (Riley et al. 2008) in 2004. Alewife density remains near the all-time low for the time series observed in 2004 and the existing population remains dominated by small fish. Abundance of juvenile and adult rainbow smelt was also reduced despite recent record high year-class in 2005. While a reduction in the abundance of an exotic species is consistent with fish community objectives for Lake Huron (DesJardine et al. 1995), prey availability and sustainability of the Chinook salmon *Oncorhynchus tshawytscha* sport fishery remain as concerns for fisheries managers and stakeholders.

Prey availability for piscivores will likely be low during 2009 because no species has replaced alewife in either numbers or biomass. While density of bloaters nearly doubled and rainbow smelt increased by about 15% between 2006 and 2007, overall prey biomass remained low compared to previous years (1992-2001) and showed only a slight increase in 2007. Catches from northern Lake Huron during 2008 suggest small alewives may have increased slightly over the record low levels seen since 2004, but abundance of other forage species was depressed.

While this survey is designed to provide indices of forage abundance, collections are also useful in monitoring young age-classes of lake trout. Relatively high catches of wild juvenile lake trout in bottom trawls during 2004–2006 suggest that natural reproduction by lake trout had increased and occurred throughout the Michigan waters of the main basin. Increased catches of wild juvenile lake trout in the USGS fall bottom trawl survey were coincident with a drastic decline in alewife abundance, but data were insufficient to determine what mechanism may be responsible for increased natural reproduction by lake trout (Riley et al. 2007). Only one wild age-0 lake trout was collected during 2008 and the overall trend in lake trout density has been downward since 2003 when the demersal forage fish community collapsed (Riley et al. 2008). Depressed forage fish abundance will likely be a deterrent to lake trout recovery efforts in Lake Huron.

Densities of benthic invertebrates collected during fall have been variable since collections began in 2001 but typically follow the declining trends reported in other studies (McNickle et al. 2006, Nalepa et al. 2003, 2005). Most notable is the decline of *Diporeia*, an important forage item for demersal fishes such as rainbow smelt (Gordon 1961), deepwater sculpin (O'Brien et al. in press), juvenile lake trout (Roseman et al. in press), and lake whitefish (Pothoven and Nalepa 2006). This decline is coincident with declines in alewives and expansion of quagga mussel distributions toward deeper waters of the lake.

Lack of collections from the entire southern portion of the lake prevents us from making calculations of lakewide forage fish abundances and eliminates the possibility of assessing abundance of some species collected mainly in the southern part of the lake. For example, abundances of round gobies (Schaeffer et al. 2005) and emerald shiners (Schaeffer et al. 2008a, b, 2009) are typically higher in the southern part of the lake. Despite this shortcoming, the declining trend in forage fish abundance observed in previous years appears to be continuing. Further, we found strong statistically significant relationships between numeric prey abundance estimates at northern ports and lakewide estimates (Appendix IIa, IIb, III). This suggests that lakewide trends in forage fish abundance are mirrored at northern ports and also stresses the importance of northern ports for species such as slimy and deepwater sculpins that are collected almost exclusively in the north.

The continued depression of forage species biomass in the northern main basin of Lake Huron suggests that predators will continue to face potential prey shortages during 2009. Rainbow smelt and juvenile bloaters will likely be the only common pelagic prey and predation on these may limit their recruitment and reduce the possibility of future strong year-classes. Rainbow smelt and bloater are utilized as prey of salmonids (Diana 1990, Rybicki and Clapp 1996, Madenjian et al. 1998), but there are likely to be low numbers of large-sized prey items needed to sustain growth of large salmonids, especially adult lake trout (Martin 1966, Madenjian et al. 1998). Managers and anglers should expect slow growth of salmonids in 2009.

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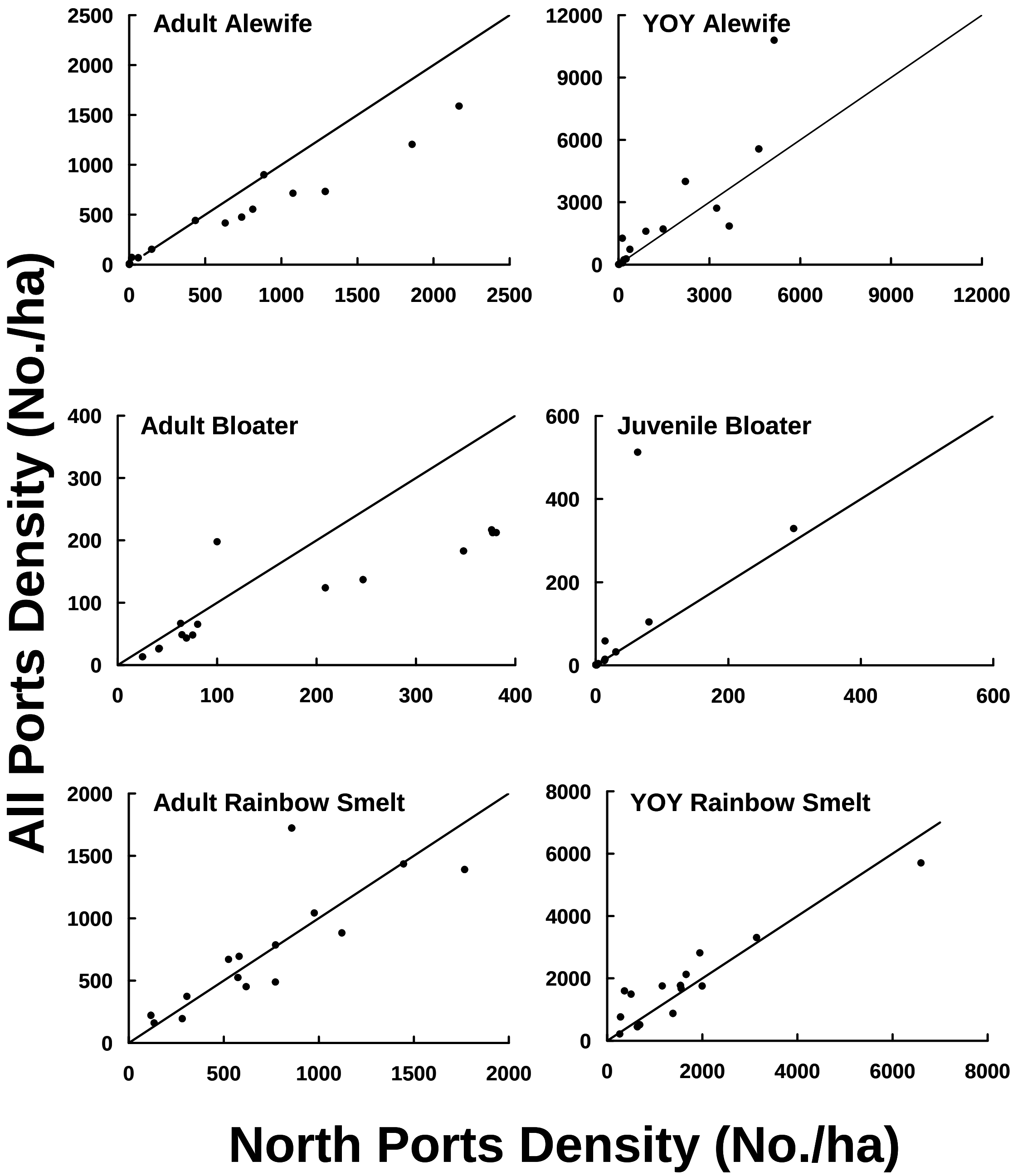
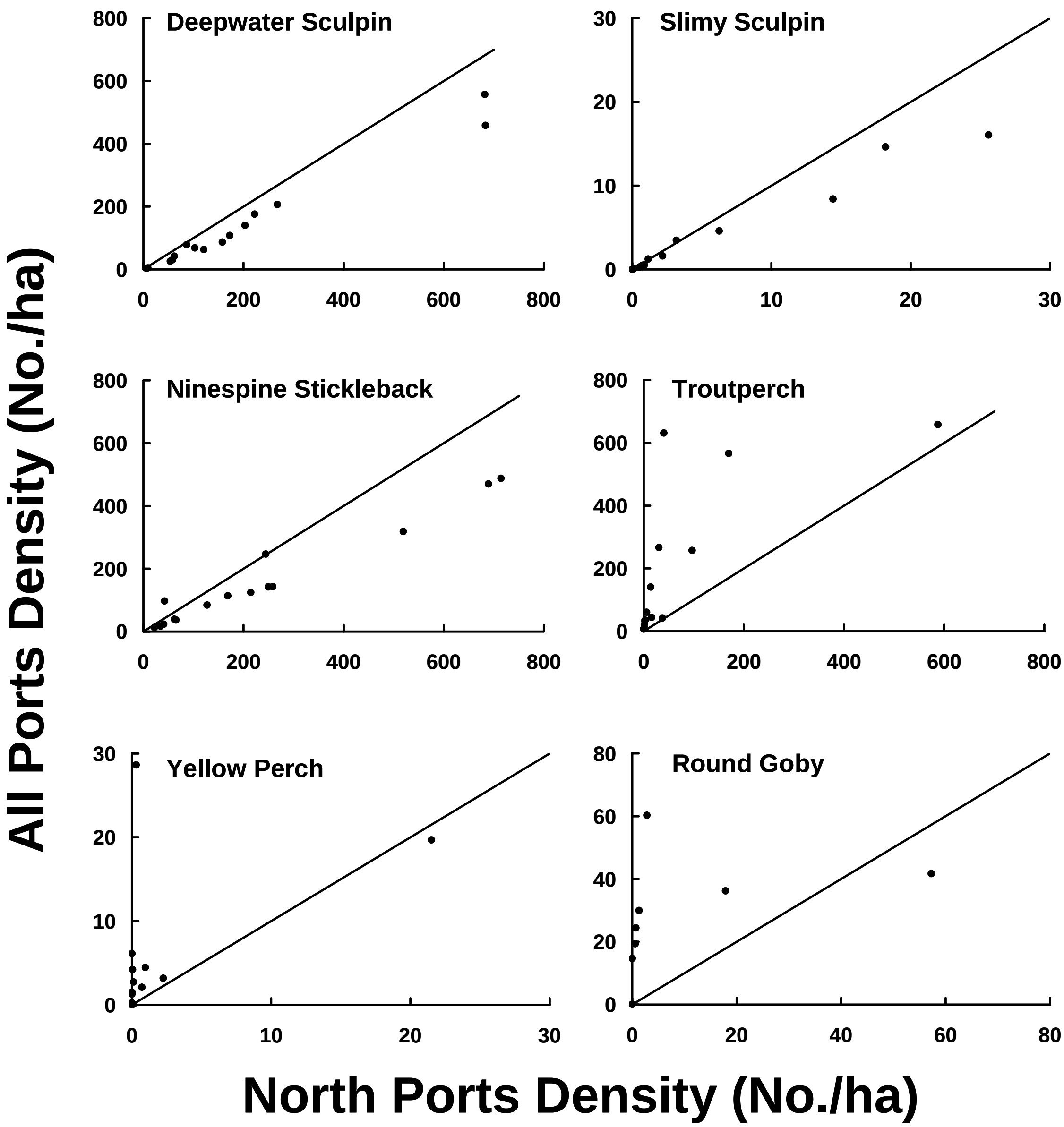
Appendix I. List of species (common and scientific names) and mean densities (number/ha) collected during the 2008 fall bottom trawl survey at three ports in northern Lake Huron.

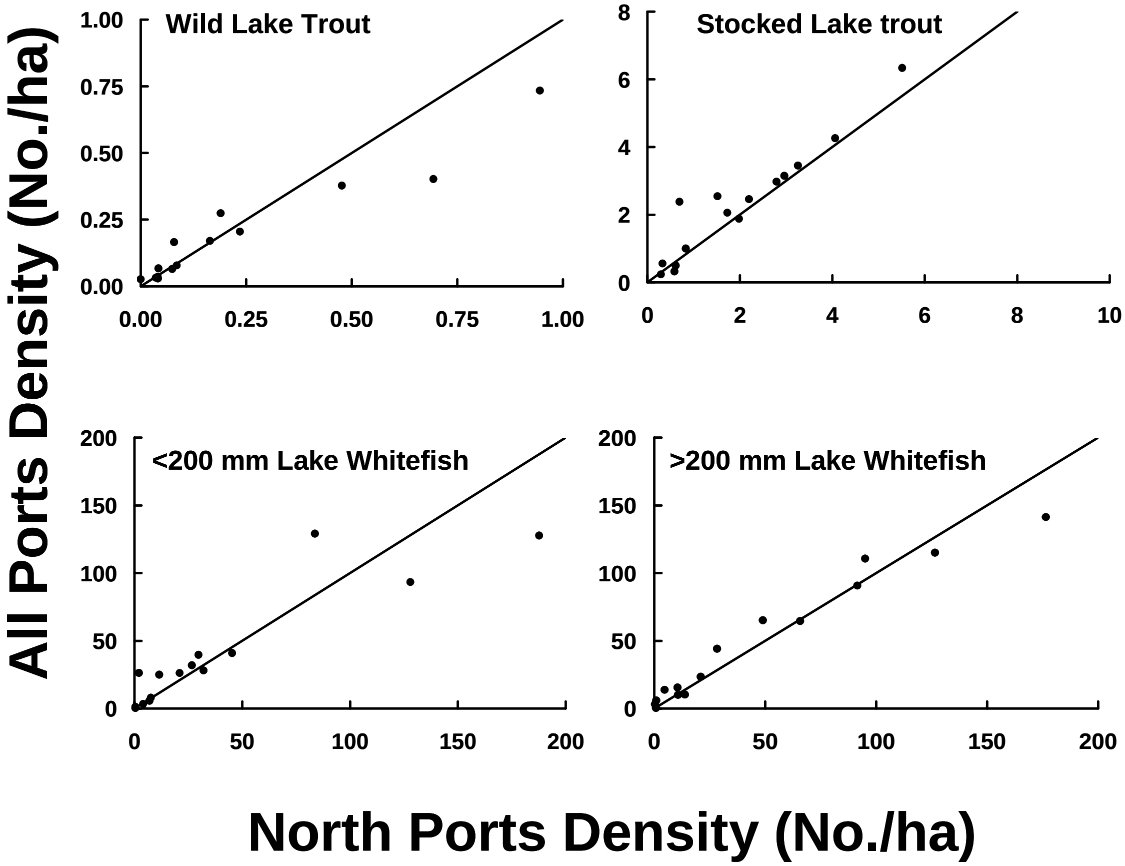
Common name	**Scientific name**	**Density (No./ha)**
Alewife	*Alosa pseudoharengus*	304.13
Rainbow smelt	*Osmerus mordax*	224.99
Bloater chub	*Coregonus hoyi*	104.36
Ninespine stickleback	*Pungitius pungitius*	15.86
Deepwater sculpin	*Myoxocephalus thompsonii*	0.78
Lake whitefish	*Coregonus clupeaformis*	0.60
Lake trout	*Salvelinus namaycush*	0.19
Threespine stickleback	*Gasterosteus aculeatus*	0.10
Round goby	*Apollonia melanostoma*	0.05
Sea lamprey	*Petromyzon marinus*	0.05



Appendix IIa. Relationships between numeric density estimates derived from all ports compared to estimates from the three northern ports (DeTour, Hammond Bay, Alpena) for adult and young of year (YOY) alewives, bloater, and rainbow smelt, 1992 – 2007. Axis scales differ across panels. Horizontal lines indicate a 1:1 relationship.



Appendix IIb. Relationships between numeric density estimates derived from all ports compared to estimates from the three northern ports (DeTour, Hammond Bay, Alpena) for deepwater sculpin, slimy sculpin, ninespine stickleback, troutperch, and yellow perch, 1992 – 2007, and round goby 1997-2007. Axis scales differ across panels. Horizontal lines indicate a 1:1 relationship.



Appendix IIc. Relationships between numeric density estimates derived from all ports compared to estimates from the three northern ports (DeTour, Hammond Bay, Alpena) for wild lake trout, stocked lake trout, small (<200 mm) lake whitefish, and large (>200 mm) lake whitefish, 1992 – 2007. Axis scales differ across panels. Horizontal lines indicate a 1:1 relationship.

Appendix III. Spearman's rank correlation statistics assessing the relationships between density of fish species at northern ports (DeTour, Hammond Bay, and Alpena) with lakewide estimates from 1992 - 2007. Round goby estimates based on 1997-2007 only.

Species	Spearman's Rank Correlation (r_s)	p-value
Adult Alewife	0.978	<0.0001
YOY Alewife	0.946	<0.0001
Adult Bloater	0.921	<0.0001
Juvenile Bloater	0.975	<0.0001
Adult Rainbow Smelt	0.889	<0.0001
YOY Rainbow Smelt	0.846	<0.0001
Deepwater Sculpin	0.982	<0.0001
Slimy Sculpin	0.998	<0.0001
Ninespine Stickleback	0.964	<0.0001
Troutperch	0.932	<0.0001
Yellow Perch	0.654	0.0081
Round Goby	0.926	0.0001
<200 mm Lake Whitefish	0.925	<0.0001
>200 mm Lake Whitefish	0.964	<0.0001
Wild Lake Trout	0.966	<0.0001
Stocked Lake Trout	0.936	<0.0001