Introduction

Status of Important Prey Fishes

in the U.S. Waters of Lake Ontario, 2005

The U.S. Geological Survey (USGS) and New York State Department of Environmental Conservation (NYSDEC) have cooperatively assessed Lake Ontario prey fishes each year since 1978. Bottom trawling has been conducted during spring to assess alewife *Alosa pseudoharengus*, summer to assess rainbow smelt *Osmerus mordax*, and autumn to assess slimy sculpin *Cottus cognatus*. Timing of the surveys was selected to correspond with the season when bottom trawl catches of the target species peaked during May to October trawling conducted in 1972 (Owens et al. 2003). Twelve transects were established at roughly 25-km (15.5 mile) intervals along the U.S. shoreline (Figure 1). Bottom trawling was generally conducted at all transects to assess alewife, at all transects except Fair Haven to assess rainbow smelt, and at 6 transects to assess slimy sculpin. Although each of the three surveys targets one species of fish, catches of non-target fishes are also tracked and they provide information on ecologically important changes in the fish community such as resurgence of once abundant native species (e.g. deepwater sculpin *Myoxocephalus thompsoni*) or increasing abundance of invasive species (e.g. round goby *Neogobius melanostomus*).

At each transect, trawl hauls were usually made at 10-m depth intervals through the range of depths occupied by the target species. Fixed station sampling designs, such as ours, are commonly used for assessing fish populations in the Great Lakes and in northern Europe (ICES 2004). The underlying assumption is that changes in relative abundance at the fixed stations are representative of changes in the whole population. Mean abundance from fixed station surveys will not be biased if the fish are randomly distributed. We have always assumed that the fish are randomly distributed in the geographic area in which a transect is located and, because we have numerous transects spaced at regular intervals around the shore, that our abundance indices are unbiased. However, we did not initiate acoustic sampling to test the assumption of random distribution within geographic areas until 2004 when we began an acoustic evaluation of fish distribution during the alewife assessment (see Status of Alewife, below). If the fish are not randomly distributed within geographic areas, mean abundance will be biased, although if the non-random pattern of fish distribution persists through time, the differences in mean abundance between years will be unbiased (Warren in ICES 1992). Although random sampling is preferable for estimating precision, the systematic, fixed-station sampling that we employ in Lake Ontario will often be optimal for getting the most precise estimate of relative abundance even though the variance of the estimated relative abundance will be biased (ICES 2004).

Two vessels participated in prey fish surveys during 1978-1982, the 19.8-m (65 ft), steel hull R/V *Kaho* (USGS) and the 12.8-m (42 ft), fiberglass hull R/V *Seth Green* (NYSDEC). During 1983-1985, all assessment trawling was conducted by the *Kaho* (the fiberglass *Seth Green* was permanently retired in fall 1982). In 1985, the NYSDEC accepted delivery of a new R/V *Seth Green* and this 14-m (46 ft), steel hull vessel participated with the *Kaho* in prey fish surveys during 1986-2002 and in 2004

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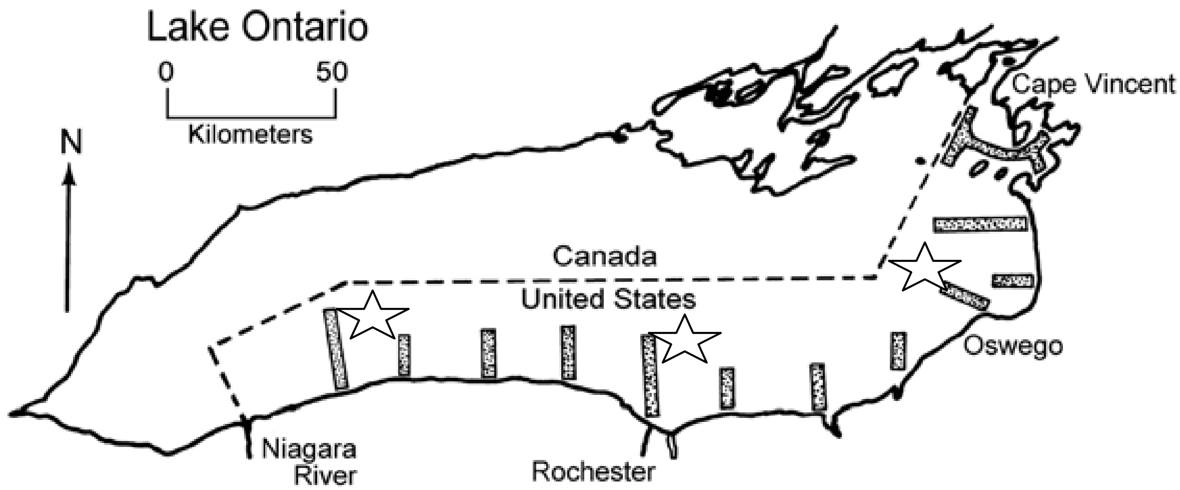

Figure 1. − Lake Ontario showing 12 transects sampled with bottom trawls. Transect names, from west to east, are: Olcott, Thirty Mile Pt., Oak Orchard, Hamlin, Rochester, Smoky Pt., Sodus, Fair Haven, Oswego, Mexico Bay, Southwick, and Cape Vincent. The six transects sampled during the slimy sculpin assessment are adjacent to the stars.

Because of personnel shortages within the NYSDEC, only the *Kaho* was used to assess prey fish stocks in 2003. Intercalibration studies determined that, for alewife and rainbow smelt, the fishing power of the *Kaho* did not differ from that of either the fiberglass or steel *Seth Green* (O'Gorman et al. 2005, see Status of Rainbow Smelt below). Intercalibration studies were not conducted for slimy sculpin because the *Kaho* was the only vessel used to assess slimy sculpin in fall.

A bottom trawl with a 12-m (39 ft) headrope and flat, rectangular trawl doors were used to assess alewife and rainbow smelt until 1997 when fouling by zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*, respectively, hereafter referred to collectively as dreissenids) forced a change to a 3-in-1 bottom trawl with a 18-m (59 ft) headrope and slotted, cambered V-doors. We made a series of paired tows to determine calibration factors for the two gears to allow comparison of alewife and rainbow smelt catches made by the new gear with those made by our traditional trawling gear. However, up until 2004, we continued to use the traditional trawling gear to assess slimy sculpin in areas where dreissenid density was sufficiently low (mainly in deep water) to allow us to trawl unimpeded. In 2004, the 18-m (headrope) trawl was used to assess slimy sculpin because increased dreissenid density in deeper water had greatly reduced not only the number of depths at which we could tow a trawl but also the amount of time we could tow at most depths. Few slimy sculpin were caught in 2004, however, indicating that the 18-m (headrope) trawl, which does not ride hard on the bottom, was not suitable for assessing benthic sculpin. In 2005, to increase bottom contact, a tickler chain was added to the 18-m (headrope) trawl for the slimy sculpin assessment (see Status of Sculpins and Round Goby below).

In 2005, the number of trawl hauls made for assessment of alewife, rainbow smelt, and slimy sculpin totaled 263 ─ 113 during April 19 - May 3, 91 during June 1 - June 10, and 59 during October 11 - 28. The number of trawl tows made to assess alewife was about 10% greater than the long-term average and was similar to that in 2004. Trawling effort during the rainbow smelt assessment was similar to that in recent years whereas effort during the slimy sculpin assessment was about 40% higher than that in most recent years. In addition to the three assessments of major prey species, we conducted the first assessment of the profundal fish community in mid-lake with bottom trawls and gillnets.

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Status of Alewife in the U.S. Waters of Lake Ontario, 2005

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Abstract

In 2005, we continued our review of the alewife Alosa pseudoharengus assessment, concentrating on the sampling plan, estimation procedure, and sample allocation. We decided to continue using a fixed sampling design and a stratified random estimator for calculating indices of mean alewife density in the U.S. waters of Lake Ontario. Implementing informed allocation of sampling effort in 2006 should improve precision of the indices. Two years of acoustic sampling during the alewife assessment demonstrated that the proportion of alewife-strength targets near bottom, in the path of the trawl, differs between years and likely results in some sampling error. However, to date, acoustics has not identified other potentially larger sources of error. The numerical index of abundance for adult alewife (age-2 and older) in 2005 was about 30% lower than that in 2004 and 57% lower than the long term mean. The weight index of abundance was 17% lower than that in 2004 and 49% lower than the long term mean. The numerical abundance index for age-1 alewife in 2005 was 37% lower than the numerical index in spring 2004 and 60% below the long term mean. Our alewife recruitment model suggests that, at age 1, the 2005 year class will be the largest since the 1998 year class (i.e. the numerical abundance index for age-1 alewife in 2006 will be higher than in any year since 1999) and, if true, the strong year class will propel abundance of adult alewife higher in 2007 and 2008.

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Progress on Review of Survey Analysis and Design

An independent peer review of the USGS-NYSDEC bottom trawling assessments of prey fishes (primarily alewife) conducted in fall 2003 concluded that the assessments provided reliable indices of trends in relative abundance and suggested a number of strategies for improving assessment data analysis and design (New York Sea Grant 2004, 2005). In response to this review, we began a re-analysis of the alewife assessment during 2004. The reviewers also suggested using acoustics to examine fish distribution during the alewife assessment to determine whether fish are concentrated near bottom and homogenously distributed in the area between transects. We initiated acoustic sampling during the 2004 alewife assessment and continued it in 2005 (see below). We also extended sampling to greater depths (170 m or 558 ft) but have not, as yet, incorporated catches made there into the index calculations.

Data Analysis

In 2004, we began our review of the alewife assessment by examining all aspects of the data analysis. The review of the data analysis is described in O'Gorman et al. 2005 and is repeated briefly here. We began by building and verifying an electronic file of all trawl catches made during the alewife assessment since its 1978 inception. Next, we revisited the validity of using fishing power correction factors (FPC) to account for changes in survey vessels and gear, redefined the sampling frame and strata, and revised rules for adding structural zeroes. Finally, we recalculated alewife abundance indices and compared the new indices to the old indices by use of the Spearman rank correlation. The recalculated alewife abundance indices for numbers and weight mirrored the historical indices for yearlings ($P < 0.0001$, $r = 0.98$) and adults ($P < 0.0001$, $r > 0.95$).

Survey Design

In 2005, we continued our review of the alewife assessment, concentrating on examining all aspects of the survey design. In considering what might be done to improve the design of the Lake Ontario alewife assessment, we examined three critical elements of survey design: 1) what sampling plan is used; 2) what estimation procedure is used; and 3) how the samples are allocated.

The sampling plan

Sampling plans can differ in the manner used to determine which sites are sampled. There are numerous ways to determine sampling sites, but nearly all are modifications of three basic approaches – fixed sites (i.e. the same sites are visited each sampling period), sites chosen at random each sampling period from within the entire sampling frame, or sites chosen at random within two or more strata that compose the sampling frame. To any of these plans, a rule can be added to incorporate additional samples based on results of completed sampling; this is called adaptive sampling. For example, we might follow the rule that any time we catch more than 50 alewife in a 10-min trawl tow, we will conduct an additional tow nearby (at a site that was not originally scheduled to be sampled).

We evaluated numerous sampling plans and decided to continue conducting the Lake Ontario alewife assessment using a "fixed site" sampling plan. An important advantage of fixed sites in a bottom trawl survey is that by visiting sites that are known to be trawlable, the chances of damaging the gear on rocks or debris is greatly reduced. Moreover, compared to other types of sampling plans, the logistics of fixed site surveys are simpler and the costs can be anticipated more accurately. Finally, continuing with the fixed site plan maintains continuity of the alewife assessment and makes future interpretation of the data easier.

The estimation procedure

Procedures for estimating mean density and its variance can be divided into two broad groups, design-based and model-based. Many "standard" designs, such as stratified random sampling, have design-based estimates associated with them which have well known statistical properties. There is no design-based estimator for a fixed site design, although it is common to apply a design-based estimator as if a fixed design were in fact random, just as we have done historically for the alewife assessment

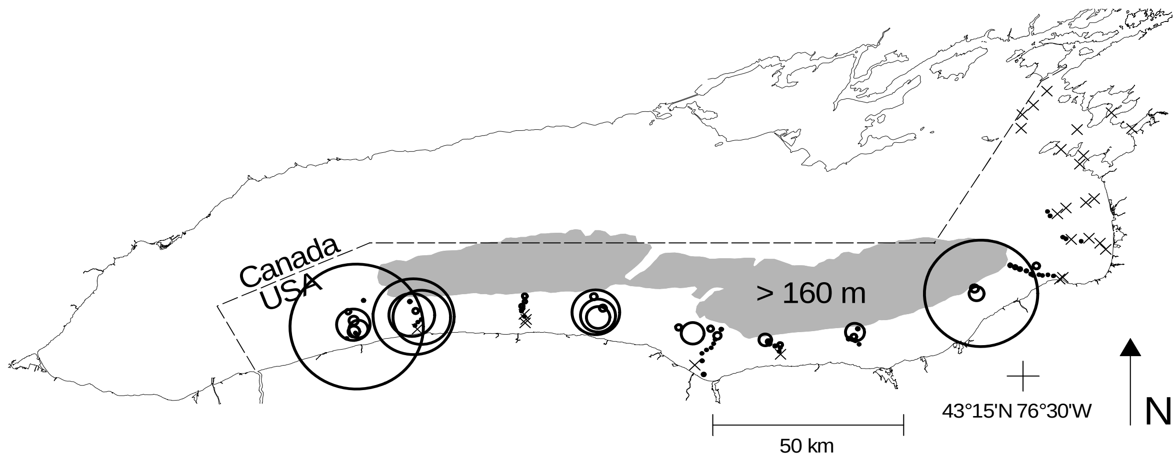

Figure 1. − Adult alewife density in U.S. waters of Lake Ontario, late April – early May, 2003. Circle size represents relative size of trawl catch, ranging from 0.01 to 650 kg per 10-min tow, Xs represent trawl samples with zero catch. Sample space includes area from shore to international boundary (dashed line) excluding waters greater than 160 m (525 ft, shaded area). 1kg =2.2 lb

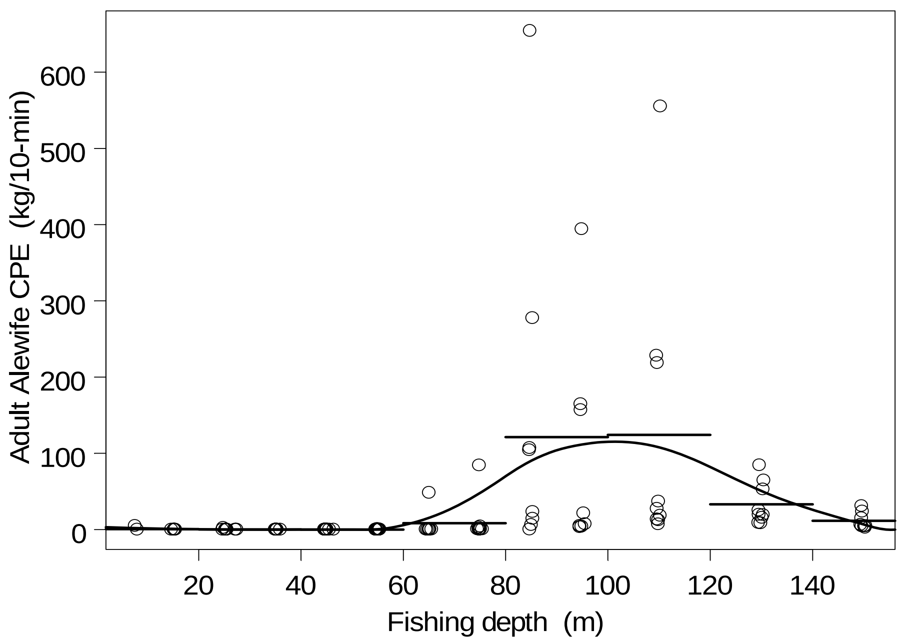

Figure 2. − Relation between adult alewife density and bottom depth in U.S. waters of Lake Ontario, late April - early May, 2003. Points represent observed values, lines indicate predicted values (horizontal line segments for the design-based estimator and curve for the model-based estimator). 1kg =2.2 lb and 1m = 3.28 ft.

To evaluate which estimation procedure would be best for the alewife assessment, we compared the precision of design-based and model-based estimates of adult alewife density calculated from catches of adult alewife in 2003 (Figure 1, Adams and O'Gorman 2005). For the design-based approach, mean alewife density was estimated based on the assumption that the fixed survey was, in fact, a stratified random survey, with eight, 20-m (66 ft) depth zones from 0 to 160 m (0 to 525 ft) as strata and the fixed sampling stations as random samples (the same assumption and stratification scheme currently used to calculate alewife abundance indices). Relative mean density and its variance were estimated using standard methods (Table 1, Cochran 1977). We also calculated bias-corrected bootstrap confidence intervals (Table 1). The sample means for each stratum are shown in Figure 2. Predictions of adult alewife density were made across a grid (at one minute intervals of latitude and longitude) within the sampling frame (U.S. waters shallower than 160 m [525 ft]; Figure 3).

For the model-based approach, we first considered using geostatistics, because it can yield more precise estimates by taking into account spatial correlation. But, geostatistical estimators require that samples be approximately evenly spaced, and that is not the case for the Lake Ontario survey, where samples along a transect are close together (< 1 km / 0.6 miles), and samples between transects are far apart (~ 25 km / 15.5 miles). So, instead of geostatistics we considered another model-based estimator, a generalized additive model (GAM). Mean alewife density was calculated based on the assumption that the relation between alewife density and bottom depth could be described by a smooth line (Figure 2). Predictions were made across a grid within the sampling frame (Figure 3). Mean alewife density was calculated as the mean of these predictions, and precision was estimated using bootstrap re-sampling (Manly 1997). The model-based approach did not yield a substantially more precise estimate of mean alewife density than did the design-based approach (Table 1).

There are both advantages and disadvantages to using the GAM approach. The advantage of the GAM approach is that it is more flexible in terms of sampling design, allowing for any allocation of sampling effort. This advantage was particularly appealing when we were considering incorporating adaptive sampling in the survey. However, after exploring this further, we decided that the gains in precision from using adaptive sampling would not outweigh the difficulty in implementing such a complex survey, and that equal or greater gains in precision could be made by simply modifying the existing survey to incorporate informed allocation of sampling effort (see below). The GAM approach also requires us to assume that alewife biomass is simply a smooth function of bottom depth (i.e. that the model is "correct"). Finally, the properties of the GAM estimates are not well known, and the smooth line function can be inaccurate at the edges of the sampling frame, potentially over- or underestimating alewife biomass at the minimum and maximum depths sampled.

Table 1. − Estimates of mean adult alewife density (kg/10-min) using different estimation methods. Precision is reported as standard error (SE), relative standard error (RSE = 100% * { SE / mean}), and 95% confidence intervals (CI). Bias-corrected bootstrap estimates of precision are also reported. 1kg =2.2 lb

		Precision - Cochran			Precision - Bootstrap		
Estimation	Mean	SE	RSE	95% CI	SE	RSE	95% CI
Design-based	27	6.6	25%	(14, 40)	6.5	24%	(17, 45)
Model-based	27	-	-	- -	6.4	24%	(17, 43)

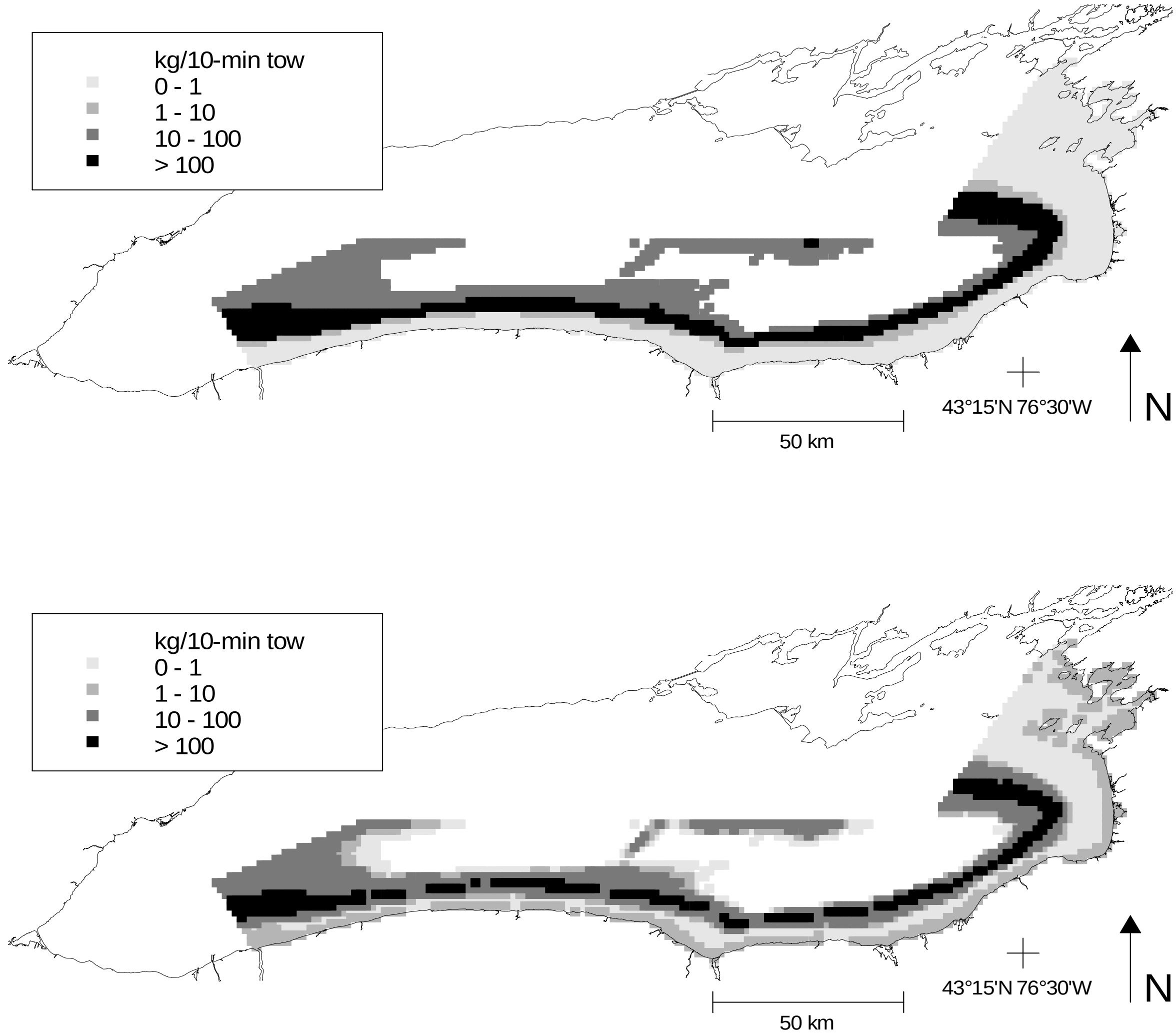

Figure 3. − Map of adult alewife density in U.S. waters of Lake Ontario during late April - early May, 2003 based on design-based (top) and model-based (bottom) estimators. 1kg =2.2 lb

Because the GAM approach did not improve precision and because the disadvantages of the GAM approach outweighed the advantages, we decided to continue using a fixed sampling design and a stratified random estimator for calculating an index of mean alewife density in the U.S. waters of Lake Ontario. The advantage of the stratified random approach is that its estimator has well-known and well-behaved properties (unbiased estimate of mean and variance). The stratified random approach does, however, require us to assume that densities at the fixed sites are representative of the entire sample fame. We believe this assumption is justified because the alewife assessment covers a broad range of bottom depths and has widespread spatial coverage of U.S. waters. Nonetheless, if densities at the fixed sites are not representative of the entire sampling frame, the mean will still be an accurate gauge of inter-annual changes in density, although the index and the variance will be biased. The stratified random approach requires that the allocation of sampling effort be carefully controlled, and this is easily accomplished with a fixed site design.

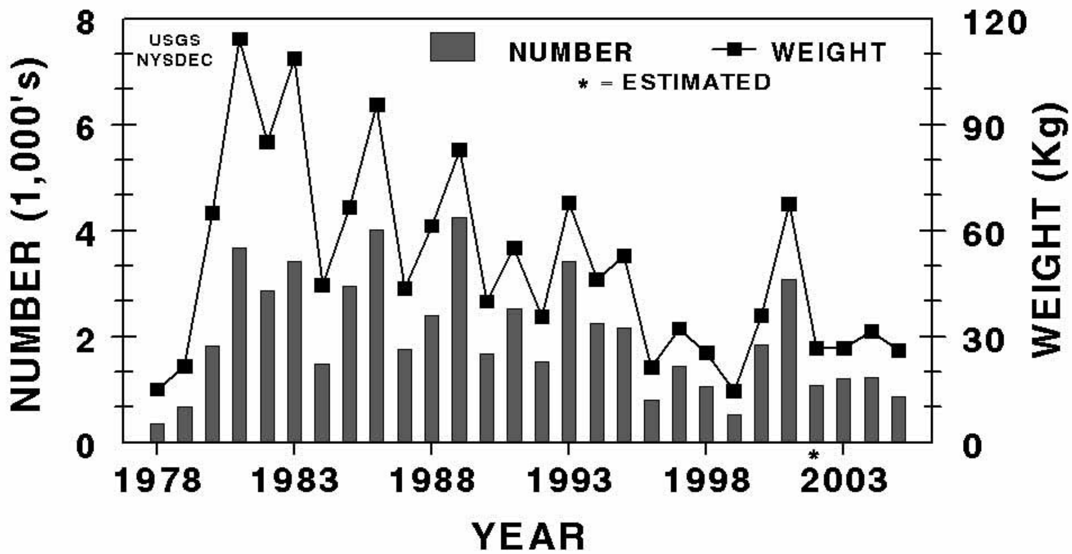

Figure 4. − Stratified mean catch of adult alewife (age-2 and older) with bottom trawls in U.S. waters of Lake Ontario shoreward of the 160-m (525 ft) bottom contour in late April - early May, 1978-2005. Mean catch in 2001 was estimated from bottom trawl catches in June 2001. For weight indices, 1kg =2.2 lb.

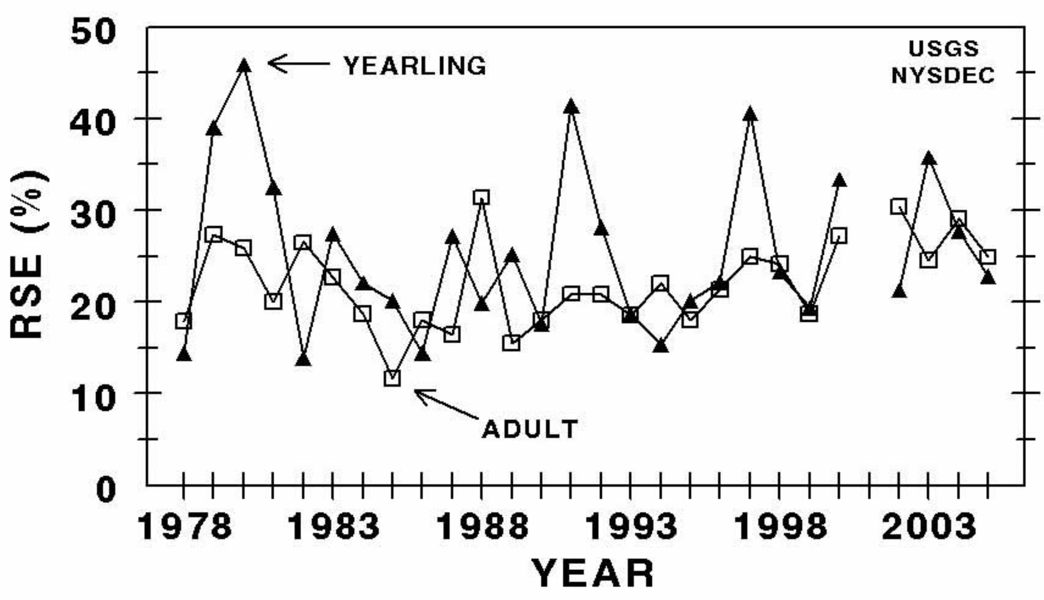

Figure 5. – Relative standard error (RSE) for yearling and adult alewife abundance indices in U.S. waters of Lake Ontario, 1978-2005. The RSE (RSE = 100% *{ standard error of the index / the index }) is a measure of variability in abundance indices.

Table 2. − Allocation of bottom trawl tows (number and percentage) by bottom depth for estimation of alewife density in U.S. waters of Lake Ontario. Average allocations are given for 1978-1993 and 1994-2005; planned allocation is given for 2006. 1m = 3.28 ft.

Depth	Allocation of tows					
(m)	1978-1993		1994-2005		2006	
0 - 60	63	55%	39	39%	14	15%
60 - 120	41	35%	43	45%	46	48%
120 - 180	11	10%	16	16%	36	37%
Total	115		99		96	

Informed allocation

In order to get the most precise estimates using a stratified random estimator, sampling effort should be allocated optimally (Cochran 1977), placing more sampling effort in those depth strata with high alewife densities. If we knew in advance of the survey which depth strata would have peak alewife densities, we could implement an optimal allocation sampling plan that would yield substantial gains in precision. For example, with results of the 2003 alewife survey in hand, we estimated that if we had used the optimal allocation, the error in the mean density index would have been reduced 38% (from SE = 6.5 and RSE = 24% to SE = 4.0 and RSE = 15%). However, it is impossible to know **in advance of the survey** which depth strata will have the greatest alewife density, because the depth distribution of alewives in Lake Ontario varies from one spring to the next (O'Gorman et al. 2000).

Although we do not know what the exact depth distribution of alewife will be in spring 2006, we expect that it will be roughly similar to that in 2005, with few alewife shoreward of the 60-m (197 ft) bottom contour and density peaking lakeward of the 60-m contour. We are certain that increasing effort in those depth strata near, or at, the density peak will result in increased precision and that decreasing effort in those depth strata far from the peak will have a trivial effect on precision. Thus, we concluded that the best chance for improving precision was to base this year's plan on the previous year's observations (i.e., the sampling allocation of the 2006 survey will be based on the depth distribution of alewife observed during the 2005 survey). We tested the performance of this informed allocation approach on past paired years of data, and found that the error in the index of mean density was reduced by 10-30%. The planned allocation for 2006 shifts sampling effort from shallower water (< 60 m or 197 ft) to deeper waters (> 60 m or 197 ft) (Table 2). A similar, but smaller, shift in allocation was made in 1994-2005. Since the 1994 shift in alewife depth distribution (O'Gorman et al. 2000), few alewife have been present shoreward of the 60-m bottom contour in spring. The 2006 sampling scheme will use a random draw to determine which fixed sites are sampled in shallow waters and require additional fixed sites in deeper waters. Following completion of the 2006 alewife assessment, we will conduct a retrospective analysis to determine how much the precision of the density estimates were improved as a result of this new allocation procedure.

Acoustic Evaluation of Fish Distribution in Spring

In 2004, we began our acoustic evaluation of fish distribution during the alewife assessment, by hydroacoustic sampling from the *Seth Green* along four parallel tracks running perpendicular to shore, to the 160-m (525 ft) bottom contour, off Rochester, NY on April 21 while the *Kaho* was bottom trawling (see Figure 1 in the Introduction for transect locations). The area sampled with hydroacoustics corresponded to the area sampled with bottom trawls. In 2005, we conducted a hydroacoustic evaluation of fish distribution along two bottom trawling transects as well as in two areas between adjacent bottom trawling transects. Hydroacoustic sampling was focused on depths > 50 m (164 ft) because bottom trawl catches and 2004 hydroacoustic data indicated that few alewife were at bottom depths < 50 m (164 ft). On April 20, 2005 we sampled perpendicular to shore along the Hamlin and Rochester transects by running a ft).

Hamlin transect and also the area between the zigzag course, parallel to shore, mostly between the 70 and 150-m bottom contours (230 to 492 On April 25, 2005 we sampled perpendicular to shore along the Sodus transect and also the area between the Sodus and Oswego transects by running a zigzag course, parallel to shore, mostly between the 50 and 150-m bottom contours (164 to 492 ft). On both days, a modest amount of time was spent sampling over bottom depths > 150 m (492 ft).

In 2004 and 2005, acoustic data were collected with a Biosonics DT-X 120 kHz split-beam echosounder, and analyzed with SonarData Echoview software. We examined the distribution of acoustic targets in the -45 to -35 dB range, corresponding to the expected range of alewife, based on previous experience in Lake Ontario and target strength studies by Warner et al. (2002). Target strengths of other fishes, notably adult rainbow smelt, overlap those of alewife and thus an unknown portion of the -45 to -35 dB targets are not alewife. Estimates of targets were stratified vertically along the path of the acoustic track into three layers – 1) within 3 m (10 ft) of bottom; 2) 3 to 10 m (10 to 33 ft) above bottom; and 3) > 10 m (33 ft) above bottom. In 2005, estimates of targets were also stratified horizontally into three zones defined by bottom depth − 1) 50 to 100 m (164 to 328 ft); 2) 100 to 150 m (328 to 492 ft); and 3) 150 to 200 m (492 to 656 ft). Maximum vertical opening of our bottom trawl was 3.25 to 3.75 m (10 to 12 ft) at those depths where alewives were abundant.

In 2004, acoustic sampling failed to detect large numbers of fish with target strengths corresponding to that of alewife above the zone sampled with the bottom trawl and where acoustics detected near bottom concentrations of fish with signal strengths similar to alewife, bottom trawl catches were dominated by rainbow smelt or alewife. In 2005, the acoustic data again generally agreed with bottom trawling results. Alewife-size targets within 3 m of bottom were more abundant in the Sodus-Oswego area than in the Hamlin-Rochester area and bottom trawl catches of alewife were indeed larger in the Sodus-Oswego area. Along-shore distribution of near-bottom targets showed a degree of homogeneity within the two areas, as numerical index since 1999. Age-2 fish (2003 year class) made up 34% of the adult alewife well as differences between them. Although these data are limited, they suggest that variability in fish density occurs on a geographic scale similar to that of the spacing of the bottom trawling transects and that fish density along a transect can be expected to be representative of that in the general area in which the transect is located. The distribution of the highest proportion of alewife-sized targets unavailable to the bottom trawl (above 3 m / 10 ft off bottom) varied, but in contrast to 2004 they were generally found at greater bottom depths, beyond 100 m (328 ft). Also in contrast to 2004, the off-bottom targets were larger, suggesting that larger fish species account for at least some (and perhaps all) of these targets. A proper interpretation is not possible without supporting evidence from midwater trawls.

In summary, two years of acoustic sampling during the alewife assessment demonstrated that, as suspected, the proportion of alewife-strength targets near bottom, in the path of the trawl, differs between years and likely results in some sampling error. However, to date, acoustics has not identified other potentially larger sources of error, i.e. no dense concentrations of alewife-strength targets were found at shallow bottom depths where bottom trawls indicated that alewife were absent and differences among lake areas in acoustically measured density of alewife-strength targets were reflected in density of alewife measured by bottom trawl. The presence of alewife-strength targets beyond the historical sampling frame suggests that recently implemented bottom trawling at depths > 160 m (525 ft) should be continued and expanded to additional sites and we fully intend to do so. We also intend to continue evaluating fish distribution during the alewife assessment with acoustics in 2006.

Status of Alewife

In April-May 2005, the numerical index of abundance for adult alewife (age-2 and older) in U.S. waters of Lake Ontario was about 30% lower than that in 2004 whereas the weight index of abundance was 17% lower than that in 2004 (Figure 4). The 2005 numerical index was 57% lower than the long term mean, 80% below the record high of 1989, and the smallest catch, age-4 fish made up 27%, and age-3 and age-6 fish made up 14% and 13%. About 9% of the adults were age-7 fish from the strong 1998 year class. The 2005 weight index for adult alewife was 49% lower than the long term mean, 77% below the record high of 1981, and similar to the 2002-2003 weight indices.

We use the relative standard error (RSE; RSE = 100% * { standard error of the index / the index }) as a measure of variability in abundance indices. In 2005, the RSE of the 2005 adult abundance indices was 25%, which was above the long term mean (22%) (Figure 5). Change point analysis revealed that a marginally significant (P = 0.08) shift in RSEs occurred in 2000. The RSEs averaged 21% during 1978-1999 but 27% thereafter, and the means for the two time periods were significantly different (ANOVA, P = 0.006). We suspect that the recent increase in RSEs was due to an increasing discrepancy between sampling effort and alewife distribution and that with implementation of informed allocation of sampling effort in 2006, the RSE will decline sharply.

The numerical abundance index for age-1 alewife (2004 year class) in U.S. waters in spring 2005 was 37% lower than the numerical index in spring 2004 and 60% below the long term average (Figure 6). Although yearling alewife are not fully recruited to our sampling gear, we consider the yearling abundance index a rough indicator of year class strength because the indices are correlated with the catch rates of the same year class at age 2 (Spearman rank correlation, n = 27, r = 0.60, P = 0.0001). The weak 2004 year class, 9th smallest out of 28 at age 1 in 2005, apparently will not provide sufficient age-2 recruits in 2006 to propel adult abundance above the level recorded in spring 2005. The RSE of the 2005 yearling abundance index (23%) was below the long term average (26%) (Figure 5). Change point analysis detected no significant change through time in the RSEs of the numerical abundance indices for age-1 alewife.

Our index of adult alewife condition is the wet weight of a 165-mm (6.5-in) alewife predicted from annual length-weight regressions. The predicted weight in fall 2005 was similar to that in fall 2004 and in both years it was higher than at any time since 1980 (Figure 7). Elevated condition in two consecutive falls suggests that the alewife population was not expanding to a level at which it would depress food resources, and that the relatively small alewife population in 2004-2005 was more in balance with Lake Ontario's productive capacity than in any of the previous 23 years.

Strength of alewife year classes at age 1 is positively linked to nearshore water temperatures during May-July and negatively linked to the number of days nearshore water is < 4° C (39° F) during the first winter after hatch (an index of winter duration) (O'Gorman et al. 2004). May-July water temperatures in 2005 were the 6th warmest of the last 30 springs (1976-2005) indicating favorable conditions for reproduction. Moreover, the duration of winter is apparently going to be shorter than average indicating favorable conditions for survival of juveniles. Year class strength is also influenced by the abundance of spawners in a curvilinear manner – weak year classes are produced by extremely large and very small spawning stocks whereas strong year classes are produced by spawning stocks of intermediate size. The spawning stock in spring 2005, although smaller than in 22 of the previous 27 springs, was of intermediate size. Because all three factors known to influence alewife year class strength were favorable during 2005-2006, we anticipate that, at age 1, the 2005 year class will be the largest since the 1998 year class (i.e. the numerical abundance index for age-1 alewife in 2006 will be higher than in any year since 1999).

The prognosis is good for the Lake Ontario alewife population returning to the early 1990s intermediate levels of abundance but poor for remaining at an intermediate level. In recent years, the population was able to rebound to intermediate abundance levels in 2000-2001 only because of the unusually large 1998 year class. But at an intermediate abundance level, adult condition declined and the population quickly returned to a low level. The process of food web disruption, mediated by exotic species, in concert with reductions in phosphorus concentration, appears to have eroded lower trophic level support for the Lake Ontario

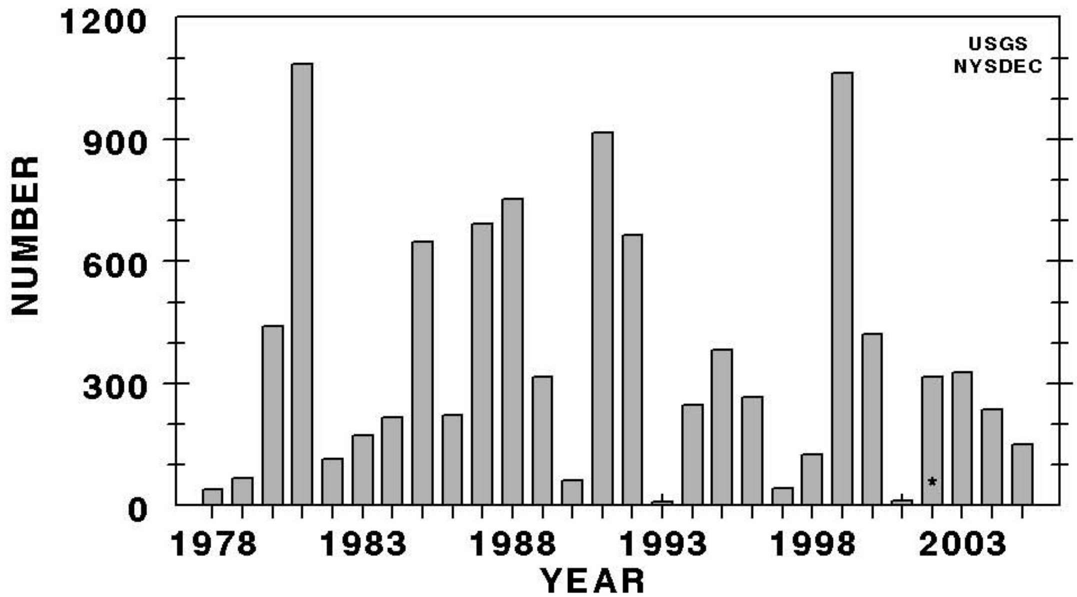

Figure 6. – Stratified mean catch of yearling alewife with bottom trawls in U.S. waters of Lake Ontario shoreward of the 160-m (525 ft) bottom contour in late April-early May, 1978-2005. Mean catch in 2001 (*) was estimated from bottom trawl catches in June 2001.

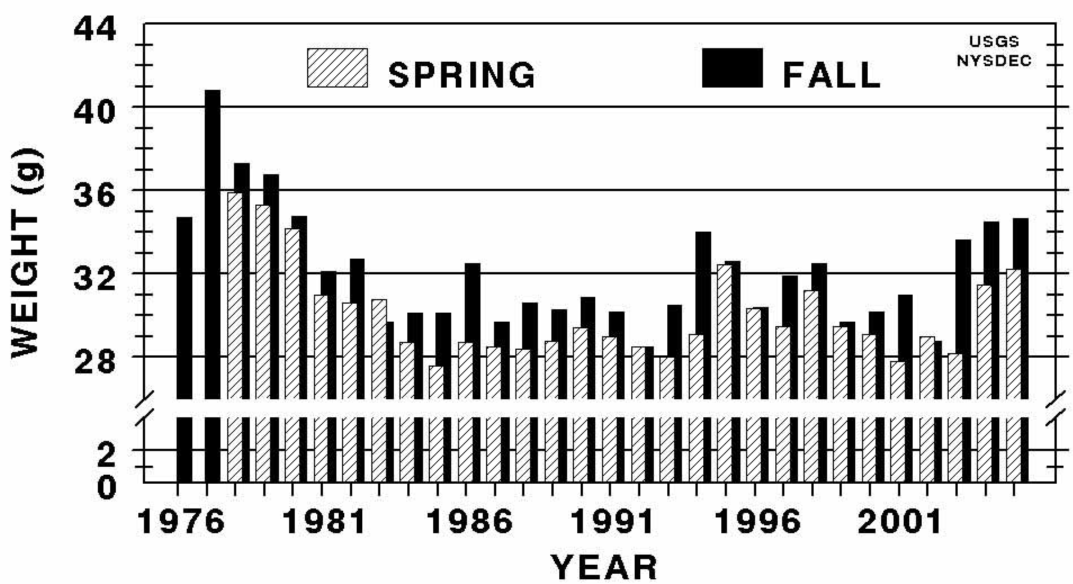

Figure 7. – Wet weight of a 165-mm (6.5 in) alewife (predicted from annual length-weight regressions) in spring and fall, Lake Ontario, 1976-2005. 1 gram = 0.035 ounce.

alewife population to below that of the early 1990s. With poor to average reproductive success during 2000-2003, the population has been stable at a low level and adult condition has improved. In the short term, we expect indices of adult alewife abundance to decline below 2005 levels in 2006 as recruitment of age-2 fish from the weak 2004 year class fails to exceed losses of older fish to mortality. In the longer term, assuming the model prediction of a strong 2005 year class is correct, we expect a repeat of the population dynamic that occurred in 2000-2002 when the strong 1998 year class recruited to the adult portion of the stock (Figure 4) – adult abundance should increase sharply in 2007 and 2008 as the 2005 fish recruit and then collapse to a low level by 2009 as adult abundance once again exceeds the lake's carrying capacity.

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Status of Rainbow Smelt in the U.S. Waters of Lake Ontario, 2005

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Abstract

We began a re-analysis of our rainbow smelt Osmerus mordax *bottom trawl assessments, conducted annually since 1978. Based on analyses of side-by-side comparison tows conducted in 1980 and 1985-1989, we did not detect a difference in rainbow smelt catches between the R/V* Kaho *and the fiberglass- or steel-hulled R/V* Seth Green. *Preliminary results also indicate no difference in rainbow smelt catches between the 12-m (39 ft, headrope) Yankee trawl and the 18-m (59 ft, headrope) 3-in-1 bottom trawl, but we are still evaluating changes in gear effectiveness with depth. Abundance indices for age-1 and older rainbow smelt in 2005 were lower than those recorded in 2004, and were generally similar to indices recorded in 2001 and 2002. An unusually large catch of yearling rainbow smelt in 2004 (2003 year class) followed by a relatively small catch of age-1 fish in 2005 (2004 year class) appears to signal a resumption of the alternating pattern in year class strength that had been intact during 1984-2000. Larger and older rainbow smelt remain scarce in Lake Ontario, but the population has demonstrated considerable resiliency by rebounding from an extremely low level of spawner abundance in 2003, which suggests that a prolonged population collapse is unlikely.*

Progress on Review of Survey Design and Analysis

Indices of rainbow smelt *Osmerus mordax* abundance are stratified, weighted mean catch-per-tow. Eleven of the twelve transects sampled on the alewife assessment are sampled on the rainbow smelt assessment (only Fair Haven is not sampled, see Figure 1 in the Introduction). Whereas the sampling frame for alewife extends from shore to the 160-m (525 ft) bottom contour in U.S. waters, the sampling frame for rainbow smelt extends from shore to the 140-m (459 ft) bottom contour in U.S. waters because historically few smelt were found at depths >140 m (459 ft). The rainbow smelt sampling frame was divided into six strata by depth and geographic area where catches were homogenous.

Beginning in 2000, we modified our stratification scheme for calculating rainbow smelt abundance indices and re-allocated sampling effort to account for the shift in distribution of smelt to deeper water (O'Gorman et al. 2000). During 1978-1999, because catches made at depths ≥70 m (230 ft) were uniformly low, the area between the 70-m (230 ft) and 140-m (459 ft) bottom contours was considered one stratum and few trawl tows were made there. After the distribution shift, however, catches at depths ≥70 m (230 ft) were neither low nor homogenous. Therefore, sampling effort at depths ≥70 m (230 ft) was increased and the single ≥70-m (230 ft) stratum was divided into three strata (60 to 79 m [197 to 259 ft], 80 to 99 m [262 to 325 ft], and 100 to 139 m [328 to 456 ft]) in which catches were homogenous.

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An independent peer review of the USGS-NYSDEC bottom trawling assessments of prey fishes (primarily alewife) conducted in fall 2003 found that the assessments provided reliable indices of trends in relative abundance and suggested a number of strategies for improving assessment design and data analysis (New York Sea Grant 2005). In response to this review, we completed a thorough re-analysis of the alewife assessment in 2004-2005 (O'Gorman et al. 2005) and we initiated a similar re-analysis of the rainbow smelt assessment in 2005. Using archived data from comparison tows, we reviewed rainbow smelt (all sizes combined) catches to determine if we need to implement correction factors to account for potential differences in fishing power between: 1) the R/V *Kaho* and the fiberglass-hulled R/V *Seth Green* which was retired permanently in fall 1982, 2) the R/V *Kaho* and the steel-hulled R/V *Seth Green* which has been in use since 1986, and 3) the 12-m (39 ft, headrope) Yankee bottom trawl used on the rainbow smelt assessment until 1996 and the 18-m (59 ft, headrope) 3-in-1 bottom trawl adopted on the rainbow smelt assessment in 1997 after biofouling by dreissenid mussels made use of the 12-m (39 ft) Yankee trawl problematic and impractical.

We performed some preliminary analyses to evaluate potential differences in rainbow smelt catches between vessels and gears. First, we graphically examined the data to look for obvious differences in paired catches and evaluated possible relationships between catch differences and depth by creating bubble plots with the size of the bubble scaled according to depth. We also performed paired t-tests on log-transformed catch data to evaluate differences between the two catches on paired tows.

To compare catches between the R/V *Kaho* and the fiberglass-hulled R/V *Seth Green*, a series of 18 side-by-side comparison tows were conducted during April-June 1980 at depths ranging from 23 to 75 m (75 to 246 ft). Eight trawl tows were conducted at depths <50 m (164 ft) and 10 were conducted at depths ≥50 m (164 ft). We did not detect a difference in rainbow smelt catches between the two vessels based on paired t-tests of log-transformed rainbow smelt catches (P = 0.12). Although the number of comparison trawls was low, these are the only data available to evaluate relative fishing power of the two vessels. Results of the analysis indicate that we do not need to use a correction factor to combine historic rainbow smelt catches from these two vessels. Similar results were found in the re-analysis of the alewife assessment (O'Gorman et al. 2005).

To compare catches of the R/V *Kaho* and the steel-hulled R/V *Seth Green*, a total of 56 side-by-side comparison tows were conducted during April-July, 1985-1989 at depths ranging from 8 to 95 m (26 to 312 ft). The number of trawl tows within each 10-m (33 ft) depth increment from 0 to 95 m (0 to 312 ft) ranged from 1-10. We did not detect a difference in rainbow smelt catches between the two vessels based on paired t-tests of log-transformed rainbow smelt catches (P = 0.16), indicating that we do not need to use a correction factor to combine rainbow smelt catches from these two vessels. Similar results were found in the re-analysis of the alewife assessment (O'Gorman et al. 2005).

To compare catches of rainbow smelt using the 12-m (39 ft) Yankee trawl used through 1996 and the 18-m (59 ft) 3-in-1 trawl used starting in 1997, we conducted 97 side-by-side comparison tows during April-June 1995-1998 at depths ranging from 8 to 154 m (26 to 505 ft) Forty-nine tows were conducted with the 12-m (39 ft) trawl on the R/V *Kaho* and the 18-m (59 ft) trawl on the R/V *Seth Green* and 48 tows were made with the opposite configuration of vessels and gears. The number of trawl tows within each 10-m (33 ft) depth increment from 0 to 150 m (0 to 492 ft) ranged from 2-11. We did not detect a difference in rainbow smelt catches between the two trawling gears based on paired t-tests of log-transformed catches (P = 0.23), indicating that we do not need to use a correction factor to account for the change in trawling gear. However, based on our graphical evaluation we saw some evidence that catch differences between the two gears became more pronounced at greater depths. Similar evidence of catch differences between gears was observed during evaluation of the alewife assessment, and re-analysis of those data resulted in a fishing power correction factor being applied to alewife

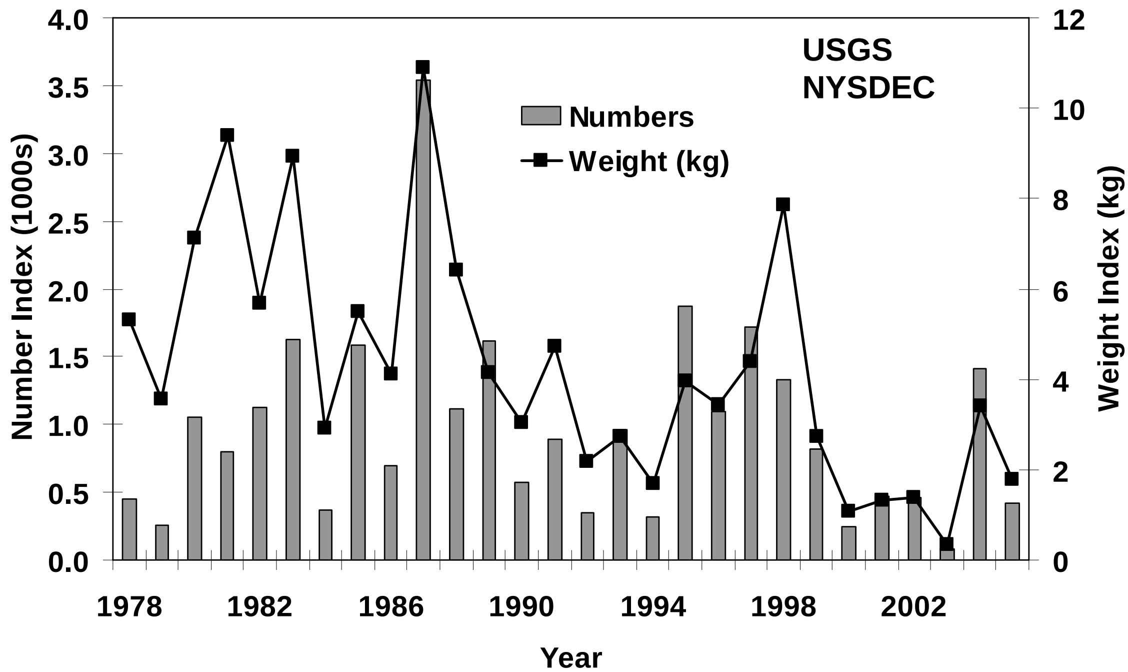

Figure 1. − Stratified mean catch of age-1 and older rainbow smelt with bottom trawls in U.S. waters of Lake Ontario shoreward of the 140-m (459 ft) bottom contour in late May-early June, 1978-2005. For the weight index, 1 kg = 2.2 lb.

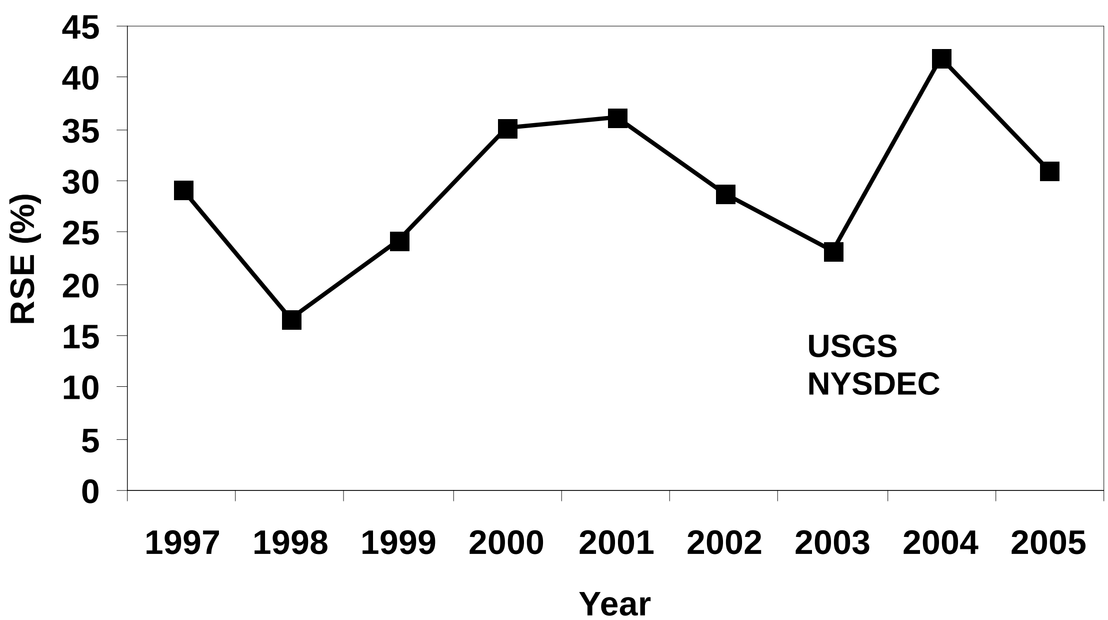

Figure 2. − Relative standard error (RSE) for age-1 and older rainbow smelt abundance indices in U.S. waters of Lake Ontario, 1997-2005. The RSE (RSE = 100{standard error of the index / the index}) is a measure of variability in the abundance index.*

PROVISIONAL DATA NOT TO BE CITED

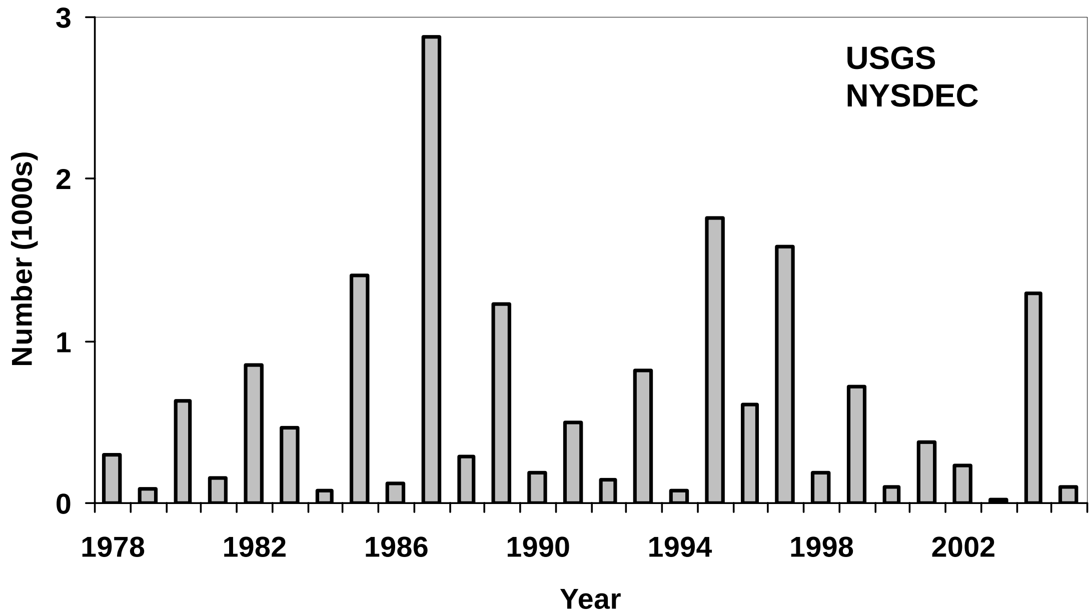

Figure 3. − Stratified mean catch of age-1 rainbow smelt with bottom trawls in U.S. waters of Lake Ontario shoreward of the 140-m (459 ft) bottom contour in late May-early June, 1978-2005. All estimates are age-based.

catches at depths >91.5 m to account for the increased effectiveness of the 18-m (59 ft) 3-in-1 trawl at those depths (O'Gorman et al. 2005). In 2006, we plan to further investigate the change in gear effectiveness with depth by using a decision rule to evaluate the appropriateness of applying a fishing power correction factor to rainbow smelt catches made at the deeper bottom depths.

Status of Rainbow Smelt

Number and weight indices for rainbow smelt were lower in 2005 than in 2004, when the abundance indices were the highest since 1998 (Figure 1). In 2005, the numerical index was 3.4% lower, and the weight index 1.9% lower than in 2004, but both indices were generally similar to values observed in 2001 and 2002 (Figure 1). Relative standard error (RSE, RSE = 100% * {standard error of the index / the index}) of the rainbow smelt abundance index has ranged from 17 to 41% during 1997-2005, the time period following the gear change to the 18-m (59 ft) 3-in-1 trawl (Figure 2). In 2006, we intend to reconstruct and quality check the entire historic rainbow smelt database, after which we will be able to calculate RSEs for the complete time series. We will also re-evaluate the current stratification scheme and number of trawl tows conducted on the rainbow smelt assessment to reduce the level of variability in our population indices.

In 2005 we allocated time and effort to evaluating the methods used in our long-term rainbow smelt aging program, a program which is unique among the Great Lakes. This included developing methods to train new personnel in estimating rainbow smelt ages from sectioned pectoral fin rays, determining smelt ages from fin rays collected on assessments in 2003-2005 while instituting new measures for quality control, and initiating a study to compare the precision and efficiency of using otoliths and fin rays to age smelt. From these efforts, we will produce a standard operating procedure for aging rainbow smelt with fin rays which will be used within the Lake Ontario Biological Station (LOBS) and which will also be available as an instructional tool for other scientists and managers interested in instituting a smelt aging program.

Rainbow smelt year classes generally alternate between strong and weak in Lake Ontario apparently due to cannibalism, primarily by yearling smelt on young-of-year (Figure 3). The alternating pattern was interrupted by two successive weak year classes in 1982-1983 and again in 2001-2002. However, an unusually large catch of yearling rainbow smelt in 2004 (2003 year class) followed by a relatively small catch of yearlings in 2005 (2004 year class) appears to signal a resumption of the alternating pattern in year class strength that had been intact during 1984-2000.

The relative and absolute abundance of large rainbow smelt (≥150-mm or ≥5.9 in) remained low in 2005. Large rainbow smelt made up less than 3% of the population during 1989-2004 (range: 0.1 to 2.8%) and in 2005 they made up about 0.1% of the population. The stratified mean catch per tow of large rainbow smelt ranged from 1 to 14 during 1989-2004 and was only 1 in 2005. In contrast, during 1978-1983, large rainbow smelt were 10 to 26% of the population and mean catch per tow ranged from 55 to 205. The paucity of large rainbow smelt during 1989-2005 was likely due to heavy predation and, more recently, weak year classes in 1999-2002.

We forecast that rainbow smelt abundance indices will be slightly higher for yearlings and all age groups combined in 2006. Any rise in rainbow smelt abundance will probably be short lived without a relaxation of predation pressure. Rainbow smelt have demonstrated considerable resiliency by rebounding from an extremely low level of spawner abundance which suggests that a prolonged population collapse is unlikely.

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Status of Sculpins and Round Goby in the

U.S. Waters of Lake Ontario, 2005

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Abstract

In 2004, after dreissenid mussels precluded towing with the 12-m (39 ft, headrope) Yankee trawl historically used to assess the slimy sculpin Cottus cognatus *population, we used the 18-m (59 ft, headrope) 3-in-1 bottom trawl, but results were inconsistent. In October 2005 we added a tickler chain to the footrope of the 18-m (59 ft) 3-in-1 bottom trawl, which allowed us to both add tows at shallower depths and tow for longer amounts of time at deeper depths without biofouling. Although 2005 catches were generally lower than historic catches, we were able to successfully complete the population assessment for the first time since 1995, and we will begin a new time series to monitor and index slimy sculpin populations. In standard assessment and targeted sampling in 2005, we caught 17 deepwater sculpin* Myoxocephalus thompsonii *(46 - 157-mm, 1.8 - 6.2 in) at depths ranging from 110 to 175 m (361 - 574 ft). For the first time, young, small deepwater sculpin were numerically dominant, indicating that conditions for survival of young deepwater sculpin are favorable. Since our first collection of round goby* Neogobius melanostomus *in 2002, the population has expanded both numerically and spatially. In southern Lake Ontario, round gobies begin to move offshore during the breakdown of the thermocline in mid October and by late April are widely distributed among depths ≤ 150 m (492 ft). Round gobies move back inshore as water temperatures increase, and are generally located at depths shallower than the intersection of the bottom and the thermocline while the lake is stratified from June through September. Given the potential importance of the round goby as a member of offshore and nearshore fish communities in Lake Ontario, we developed a preliminary index to track round goby abundance in upcoming years.*

Status of Sculpins

Slimy Sculpin

In 1996, we lost our ability to index the slimy sculpin *Cottus cognatus* population at depths <70 m (230 ft) along the south shore of Lake Ontario because density of zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*; hereafter collectively referred to as dreissenids) had risen to a level that made sampling with our 12-m (39 ft) Yankee trawl problematic. Large quantities of dreissenids collected in the net during trawling, , hindering catch sorting, sometimes preventing winching the catch onto the deck, and pontentially altering the fishing power of the net. We continued to use the 12-m (39 ft) Yankee trawl to assess sculpins at depths >70 m (230 ft) during 1997-2003 although tow times at depths <100 m (328 ft) were continually reduced as

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the dreissenid population expanded into deeper water. By 2003, in southwestern Lake Ontario, we were unable to trawl at depths <80 m (262 ft) and the standard 10-min tow time had to be reduced to 5-min or less at depths of 85 m (279 ft) and 95 m (312 ft). We were also forced to reduce tow time at two depths in southeastern Lake Ontario.

The continual reductions in effort directed at slimy sculpin assessment due to fouling of the 12-m (39 ft) Yankee trawl, prompted us to use the 18-m (59 ft) 3-in-1 bottom trawl to assess slimy sculpin in 2004. The 18-m (59 ft) 3-in-1 trawl catches few dreissenids and has been successfully used to assess alewife and rainbow smelt since 1997. In 2004, few slimy sculpin were captured in southwestern Lake Ontario, so few in fact that we suspected the net was in poor or intermittent contact with the bottom. In central Lake Ontario, catches of slimy sculpin were about 1% of previous years, whereas in the southeast, catches were about 50% of previous years. Overall, our general impression was that the 18-m (59 ft) 3-in-1 trawl performed inconsistently, but that with some modification it could be a useful tool for assessing sculpins and other small, demersal fishes on the dreissenid-infested bottom.

In summer 2005 we evaluated the effects of adding a tickler chain to the 18-m (59 ft) 3-in-1 trawl as a method to increase slimy sculpin catches. A tickler chain is a common trawl modification used in commercial fisheries, and consists of a chain attached to the net in such a manner that it drags along bottom in front of the footrope, causing benthic animals to move up off of the sea floor so they can be more easily swept into the trawl net. We evaluated three options: 1) current trawl design with no tickler device, 2) a tickler rope with chain droppers, and 3) a tickler chain. Both the tickler rope and tickler chain were attached to the footrope with rope so as to drag along the bottom 1.8 m (6 ft) in front of the footrope. To compare the three options, we fished one 10-min tow with each footrope/tickler configuration at each of five depths (65, 75, 85, 95, and 110 m / 214, 246, 279, 312, and 361 ft) off Oswego, NY. Due to time and budget constraints, it was not feasible for us to conduct this comparison in more than one lake area. We assessed the current trawl design (no tickler) on 4 August, the tickler rope on 9 August, and the tickler chain on 12 August 2005.

Catches of slimy sculpin were minimal with no tickler device and the tickler rope with chain droppers (0.8 and 6.2 sculpins per 10-min tow, respectively), and would be insufficient to conduct a population assessment (Table 1). When the tickler chain was used, slimy sculpin catches averaged 135.4 per 10-min tow, significantly higher than both other methods (ANOVA, $P < 0.01$). We concluded that, of the three options tested, the tickler chain would provide the best opportunity for us to catch an adequate number of slimy sculpins to do a population assessment and we implemented this method on the slimy sculpin assessment in October 2005.

Table 1 Numbers of slimy sculpin caught per 10-min tow of an 18-m (59 ft) 3-in-1 bottom trawl without and with tickler modifications at five depths in Lake Ontario off of Oswego, NY, August 2005. For depth, 1 m = 3.28 ft.

	Depth (m)				
Gear	65	75	85	95	110
No tickler device	1	2	0	0	1
Tickler rope	0	9	1	0	21
Tickler chain	213	175	35	158	96

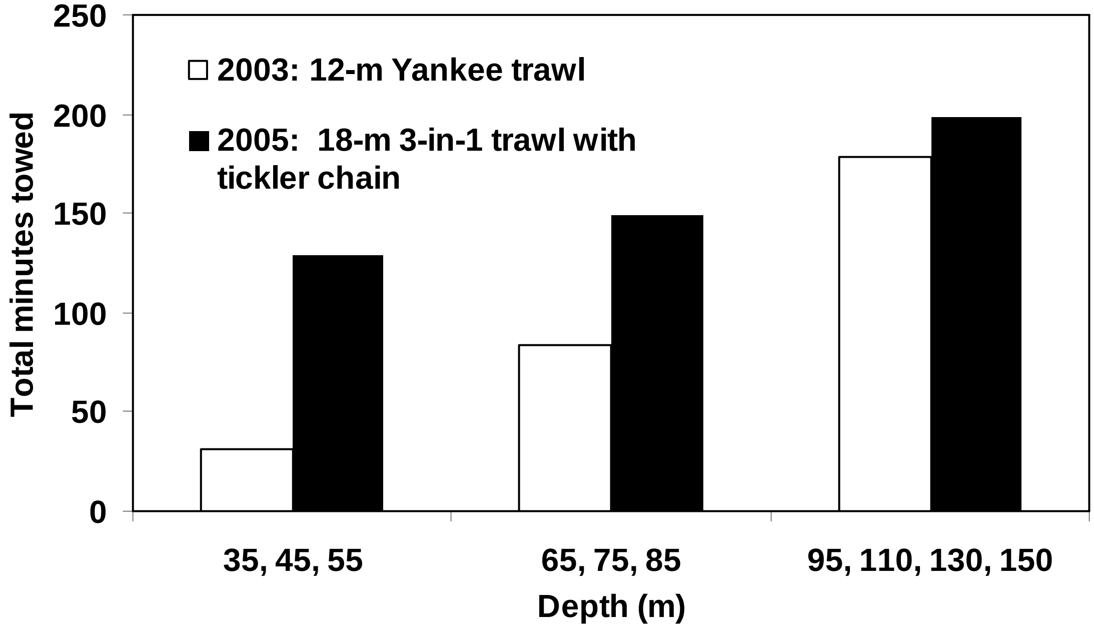

Figure 1. - Total number of minutes towed in three depth ranges during the slimy sculpin assessments in October 2005 (with tickler chain attached to the 18-m [59 ft] trawl) and 2003 (the last year of using the 12-m [39 ft] Yankee trawl), Lake Ontario. For depth, 1 m = 3.28 ft.

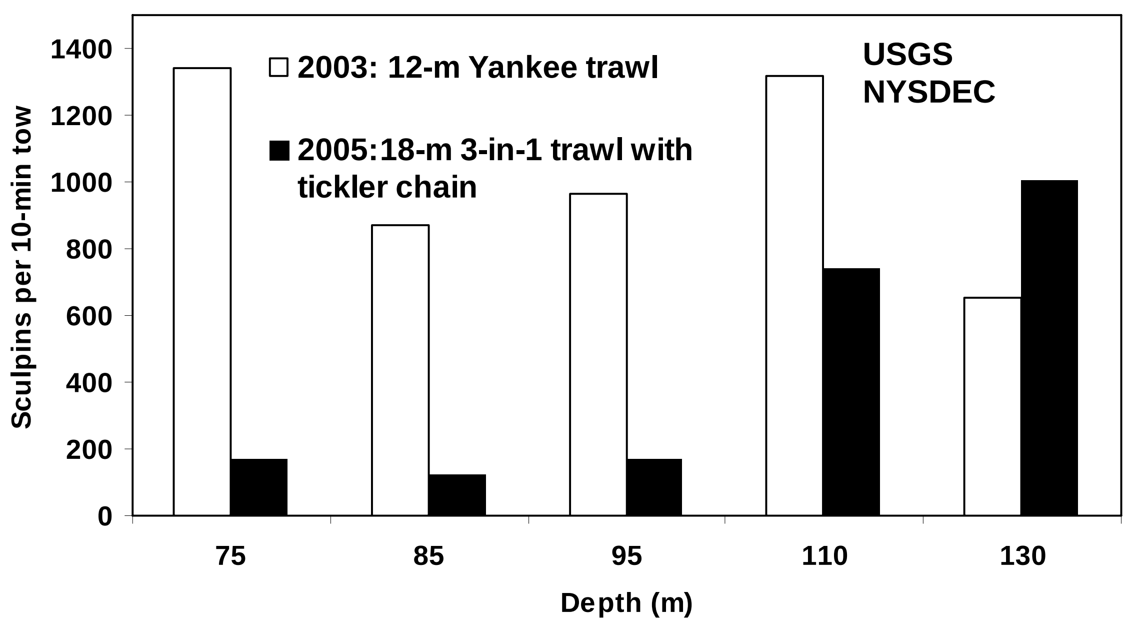

Figure 2. - Numbers of slimy sculpins caught per 10-min tow on sculpin assessments in 2005 (with tickler chain attached to the 18-m [59 ft] 3-in-1 trawl) and 2003 (the last year of using the 12-m [39 ft] Yankee trawl), in October in southern waters of Lake Ontario. Depths <75 m (246 ft) were fished in 2005, but generally were not fished in 2003 due to biofouling by dreissenid mussels. For depth, 1 m = 3.28 ft.

The slimy sculpin assessment is conducted at six transects among three lake areas (western, central, and eastern) in southern Lake Ontario (see Introduction; Figure 1). With the addition of the tickler chain to our 18-m (59 ft) 3-in-1 trawl, we were able to increase the number of tows completed in 2005 compared to 2003, the last year we used the 12-m (39 ft) Yankee trawl. We conducted a total of 59 tows in 2005 versus only 44 in 2003. Of these 59 tows, 26 were conducted at depths <75 m (246 ft), as opposed to only 13 in 2003. Our total towing time also increased substantially in 2005, because we were able to both add tows at shallower depths and tow for longer amounts of time at deeper depths without biofouling from dreissenid mussels. At depths of 35, 45, and 55 m (115, 148, and 180 ft), our effort was over four times greater in 2005 than in 2003, and at depths of 65, 75, and 85 m (214, 246, and 279 ft) our effort was nearly two times greater in 2005 than in 2003 (Figure 1).

Mean slimy sculpin catches were generally lower in 2005 than in 2003 (Figure 2), and this pattern was true among all three lake areas. However, our catches were adequate to conduct a population assessment in an efficient, timely, and safe manner. Smaller catches in 2005 are likely due mostly to the change in gear (i.e. the 18-m [59 ft] 3-in-1 trawl with tickler chain is less effective at catching slimy sculpins than the 12-m [39 ft] Yankee trawl) and not to a sharp drop in the number of slimy sculpins. Based on the successful completion of the 2005 slimy sculpin assessment, we intend to begin a new time series to monitor and index slimy sculpin populations using the 18-m (59 ft) 3-in-1 trawl with the tickler chain attachment. In the future, we may conduct comparison tows and develop correction factors to allow current and future sculpin catches to be compared to historic catches with the 12-m (39 ft) Yankee trawl, and catches of all species to be compared between the 18-m (59 ft) 3-in-1 trawl with and without the tickler chain, but these direct comparisons cannot be made at this time.

The slimy sculpin length-frequency distribution in 2005 was characterized by a larger proportion of mid-size individuals (70 – 80 mm, 2.8-3.1 in) and a lower proportion of small individuals (<50 mm, 2.0 in) compared to previous years (Figure 3). In 1990, before dreissenid mussels were established in the lake, slimy sculpin were distributed among a broad range of length groups, forming a left-skewed distribution with a peak at about 80 mm (3.1 in). However, in 2003 and 2005, length-frequency distributions were more symmetric and had a higher degree of kurtosis because a high proportion of individuals occurred in a more narrow range of length groups. The peak of the distribution shifted from the 70 – 74-mm (2.8 – 2.9 in) length group in 2003 to the 75 – 79-mm (3.0 – 3.1 in) length group in 2005 (Figure 3).

Among lake areas, slimy sculpin in the southwest were generally larger, and length appeared to be consistent among depths (Figure 4). The larger size of slimy sculpin in the southwest area of the lake has been hypothesized to be density-dependent, as historically slimy sculpin were much more abundant in the southeastern area of the lake (Owens and Noguchi 1998). A pattern of increasing slimy sculpin size with increasing depth was previously observed in central and southeastern areas, but was not evaluated in the southwestern area (Owens and Weber 1995). Based on 2005 catches, it appears that the positive correlation between size and depth still exists for the central and eastern areas (Figure 4), but is less clear due to the low catch of slimy sculpins < 50 mm (2.0 in) in 2005. The absence of small slimy sculpins in the catch may indicate poor sculpin recruitment in recent years; however, we caution that differences between the size structure of the population in 2005 and that in previous years may be

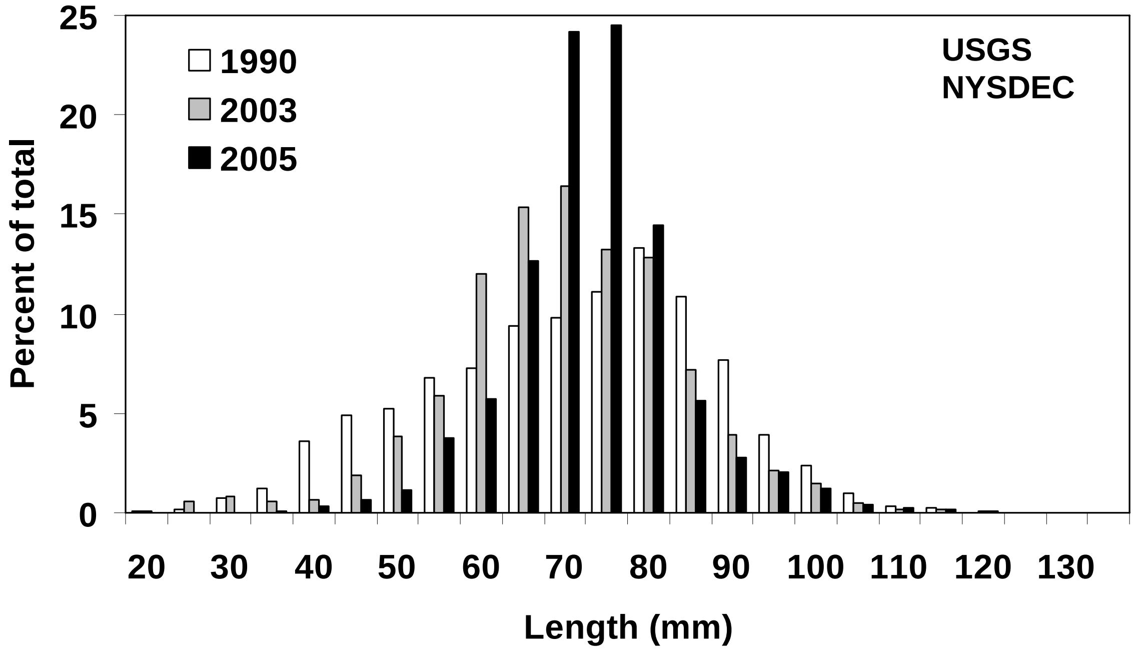

Figure 3. - Length-frequency distribution (as percent of expanded catch) of slimy sculpins in U.S. waters of Lake Ontario in October of three years: 1990, prior to dreissenid invasion; 2003, the last year that the 12-m (39 ft) Yankee bottom trawl was used; and 2005, the first year that the 18-m (59 ft) 3-in-1 bottom trawl with tickler chain attachment was used. For length, 25.4 mm = 1 in.

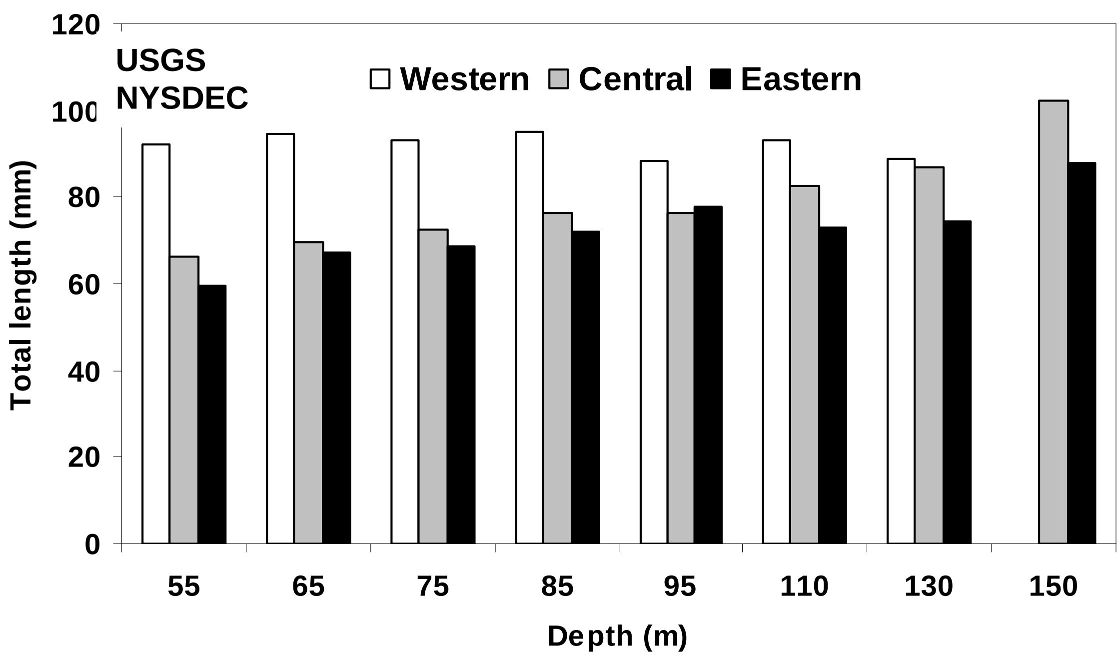

Figure 4. - Mean total length of slimy sculpins at various depths in three geographic areas of southern Lake Ontario in October 2005. For length, 25.4 mm = 1 in, and for depth, 1 m = 3.28 ft.

due, in whole or part, to the change in gear from the 12-m (39 ft) Yankee trawl to the 18-m (59 ft) 3-in-1 trawl with tickler chain attachment. Additional assessment of the slimy sculpin population with the new trawlconfiguration is required before apparent changes in the length-frequency distribution can be reliably interpreted.

Deepwater Sculpin

Deepwater sculpins *Myoxocephalus thompsonii* were abundant in Lake Ontario in the 1920's and at least common into the 1940's. By the mid 1960's, they were rare and thereafter, some considered the population extirpated. Prior to 1998, the last documented catch of deepwater sculpin in U.S. waters of Lake Ontario occurred in 1942, and none were collected during exploratory trawling in 1964 and 1972, or any annual fish population assessments conducted by the USGS and NYSDEC during 1978-1997.

During 1998-2000, we caught five deepwater sculpin (mean ± standard deviation, 120 ± 24 mm, 4.7 ± 0.9 in) at depths of 110 – 150 m (361 - 492 ft), two while conducting long-term assessment trawling, and three while conducting short-term assessment trawling that targeted deepwater prey fishes in mid lake along the international boundary. After 2000, we did not conduct targeted trawling until summer 2005 (see Midlake Assessment below), and during 2001-2004, we caught only one deepwater sculpin during annual assessments [147 mm (5.8 in), collected in 2004 at 170 m (558 ft)]. In 2005, however, catches increased sharply, with 17 deepwater sculpin caught in U.S. waters at depths ranging from 110 – 175 m (361 - 574 ft). Twelve deepwater sculpin (46 – 157 mm, 1.8 - 6.2 in) were caught during standard assessments (8 in April, 1 in July, 3 in October) and the other five were caught during the targeted midlake assessment. Most individuals were caught in southwestern U.S. waters, two individuals were caught in central waters, and one individual in southeastern waters. For the first time, young, small sculpin were numerically dominant--14 individuals averaged 68 ± 12 mm (2.7 ± 0.5 in, one small individual was not measured) and 2 larger fish averaged 155 ± 3 mm (6.1 ± 0.1 in). Young fish could have originated from reproduction by the small in-lake population, from downstream drift of planktonic larvae from Lake Huron, or both. Nonetheless, the presence of juveniles is a clear sign that conditions for survival of young deepwater sculpin are favorable, perhaps because of reduced abundance of alewife, which have been linked to depression of deepwater sculpin in Lake Michigan (Madenjian et al. 2005), and benthic piscivores, burbot *Lota lota* and lake trout *Salvelinus namaycush.*

Status of Round Goby

Round gobies *Neogobius melanostomus,* first detected in the Great Lakes Basin in the St. Clair River between Lakes Huron and Erie in 1990, were likely introduced with ballast water (Jude et al. 1992). After round gobies established populations in the Lake Huron-Lake Erie corridor, MacInnis and Corkum (2000a, b) predicted that life history characteristics of round gobies (i.e., early age at maturity, fast growth, and repeated spawning over an extended period) would facilitate the invasion of this species across the Great Lakes. Round gobies probably moved downstream into Lake Ontario through the Welland Canal; they were first reported in southwestern Lake Ontario in 1998 near the Canal's entrance (Owens et al. 2003). In their native range, round gobies are generally found inshore (<20 m, 66 ft) on rock, sand, and shell substrate, but move offshore to depths up to 60 m (197 ft) to overwinter (Miller 1986). In the Great Lakes, Weimer and Keppner (2000) state that round gobies "are believed to move offshore in late fall through winter" in Lake Erie, and offshore presence of round goby has been recently documented to depths of 73 m (240 ft) in October and November in Lake Huron (Schaeffer et al. 2005). Based on round goby catches in our standard assessment trawl tows during 2002-2005, it appears that in southern Lake Ontario, round gobies begin to move offshore during the breakdown of the thermocline in mid October and by late April are widely distributed among depths ≤ 150 m (492 ft). Round gobies then move back inshore as water temperatures increase, and are generally located at depths shallower than the intersection of the thermocline and the bottom while the lake is stratified from June through September.

Our first collection of round gobies in the open lake was four years after they were first reported from Lake Ontario and we caught two individuals in April 2002 at 55 m (180 ft) at Olcott, 37 km (23 mi) east of the Welland Canal. In subsequent years, the round goby population in the offshore waters of Lake Ontario has expanded both numerically and spatially. Our most consistent catches of round goby have occurred at the western-most transect (Olcott) in late April, where we caught increasing numbers of round gobies over a broader depth range during 2002-2005 (Table 2). In 2005, we caught round gobies at all eight depths fished from 45 to 130 m (148 – 427 ft) with the peak catch occurring at 75 m (246 ft, Table 2). Average catch of round goby catch per 10-min tow at Olcott rose from 0.4 in 2002, to 8 in 2003, 70 in 2004, and reached 358 in 2005.

Round goby abundance in southern Lake Ontario currently declines from west to east, (Table 3) and this pattern will likely continue until population expansion is complete. The farthest east we have caught round gobies in April is Smoky Point (east of Rochester), where round gobies were when shallower depths were fished on the present in low numbers in both 2004 and 2005 (4 and 5 individuals, respectively). Among sites sampled in April, maximum depth of capture was 150 m (492 ft). We did not catch round gobies in trawl tows made at 175 m (574 ft) in southwestern Lake Ontario in 2004 or 2005.

Catches of round goby have been lower and more variable after April, but generally catches in other months reflect the same patterns of higher round goby abundance in western areas, and increasing abundance through time. At the western end of the lake in late May - early June, round goby catch per 10-min tow increased from 0.2 in 2004 to 124.6 in 2005. Our catches of round goby in late May - early June indicate that round goby have either moved inshore or are in the process of moving inshore as water temperature increases and thermal stratification occurs. In 2004 only a few individuals were collected, and all were at depths ≤15 m (49 ft), while in 2005 round gobies were caught to depths of 85 m (279 ft), likely indicating that thermal stratification was not complete at the time of sampling. In west-central and central Lake Ontario, round gobies were absent from catches until 2005, when they were present in low numbers at depths ≤15 m (49 ft). To date, we have not caught any round gobies at transects east of Rochester in late May - early June.

In late July - early August, when thermal stratification is well established, it appears that round goby are located primarlity at depths shallower than the intersection of the thermocline and the bottom. During this time period, we have only caught round gobies in small numbers at shallower depths on the western end of the lake. However, sampling during this time is targeted to areas deeper than the intersection of the thermocline and the bottom, decreasing the likelihood of round goby capture. In 2004,

Table 2. - Numbers of round gobies caught per 10-min tow of an 18-m (59 ft) 3-in-1 bottom trawl at various depths in southwestern Lake Ontario near Olcott, NY, April 2002-2005 (dashes indicate that a particular depth was not fished that year). No round gobies were collected at this site prior to 2002. For depth, 1 m = 3.28 ft

	Year			
Depth (m)	2002	2003	2004	2005
35	--	0	0	--
45	--	--	0	37
55	2	0	0	195
65	0	0	0	612
75	0	0	282	1,401
85	0	14	248	401
95	0	6	121	358
110	--	28	38	145
130	--	22	6	69
150	--	0	0	0
TOTAL	2	70	695	3,218
AVERAGE	0.4	8	70	358

Table 3. - Numbers of round gobies caught per 10-min tow of an 18-m (59 ft) 3-in-1 bottom trawl in three geographic areas of southern Lake Ontario during late April, 2002-2005. In each lake area, trawls are fished along two transects located perpendicular to shore. To date, no round gobies have been collected at any transects east of the central geographic area during late April – early May.

	Geographic Area		
	Western	West-central	Central
2002	0.2	0	0
2003	5.7	0.9	0.2
2004	34.4	1.3	0.2
2005	205.1	34.8	1.7

western end of the lake to target alewife for bioenergetic samples, numerous round gobies were caught to 35 m (115 ft), including a catch of 3,410 goby per 10-min tow at 15 m (49 ft). To date, we have not caught any round gobies in central or eastern lake areas in late July to early August.

By October, round gobies were again more widely distributed among depths, indicating offshore movement after breakdown of the thermocline. Although round goby have been documented to occur offshore during fall in Lake Huron (Schaeffer et al. 2005), prior to 2005 we did not catch any round gobies on our October slimy sculpin assessment. However, this may be linked to gear difficulties and limited sampling in 2003-2004 as described above. In October 2005, we caught large numbers of round goby (Table 4), and based on the bathymetric distribution, it appeared that they were in the process of moving from inshore summer habitat out to deeper waters to overwinter. Catches were highest in the southwest where we caught round gobies at depths to 85 m (279 ft, Table 4). At one transect in the western lake area (Olcott), catches of round goby peaked at 16,334 gobies per 10 min tow at 55 m (180 ft) and exceeded 9,000 gobies per 10-min tow at 45 and 65 m (148 and 214 ft); these are by far our highest catches to date during any of our standard asssessments.

Table 4. - Numbers of round gobies caught per 10-min tow of an 18-m (59 ft) 3-in-1 bottom trawl equipped with a tickler chain in three geographic areas of southern Lake Ontario during October 2005 (dashes indicate that a depth was not fished). No round gobies were caught during the October slimy sculpin assessment before 2005. Round gobies caught in the eastern area were the first occurrence of the species in any standard trawl assessments in this area. For depth, 1 m = 3.28 ft.

	Geographic Area		
Depth (m)	Western	Central	Eastern [a]
25	--	--	4
35	3,132	169	0
45	6,257	224	0
55	9,760	187	3
65	5,256	2	0
75	32	0	0
85	2	0	0
95	0	0	0
110	0	0	0
130	0	0	0

[a] Two trawl tows were made at each depth in the western and central areas, and one trawl tow was made at each depth in the eastern area.

Round gobies were present at lower densities in the central area of the south shore, and for the first time during any assessments, we caught round goby in the southeast (Table 4). It is possible that both the appearance and high catch of round gobies in October were related to the use of the tickler chain on the 18-m (59 ft) 3-in-1 trawl during the 2005 assessment. This modification designed to increase the catch of benthic fishes.

Based on our observations to date on the seasonal and bathymetric distribution of round goby in southern Lake Ontario to date, it appears that this species will inhabit profundal waters for at least six months of the year (October through April) and is capable of colonizing to depths of at least 150 m (492 ft). About 72% of Lake Ontario is ≤130 m (427 ft) deep and about 82% is ≤150 m (492 ft) deep, so in any given year round gobies will use most of the available lake bottom and will be part of, and link, profundal and nearshore food webs. The seasonal migrations of the benthic round goby in the Great Lakes appears similar to that of an earlier exotic invader, the pelagic alewife, whose migrations from profundal overwintering grounds to littoral summer spawning grounds negative affected both profundal and nearshore fish communities (O'Gorman and Stewart 1999). Unfortunately, the round goby appears to have a potential similar to that of the alewife for disruption of native fish communities in Lake Ontario.

Given the potential importance of the round goby as a member of offshore and nearshore fish communities in Lake Ontario, we have developed a preliminary index to track its' future abundance. For now we have chosen to build our index from catches during the late April – early May alewife assessment. Two facts prompted this decision: 1) round gobies have been consistently present in April trawl tows since 2002, four years after they were first detected in Lake Ontario, and 2) during April round gobies are most widely distributed across a broad depth range. The round goby number and biomass indices were calculated in the same manner as those for alewife, a depth-stratified weighted mean. Given the uneven spatial distribution of round gobies along the southern shore of the lake, the relative standard error of the indices are currently very high. Nontheless, the indices capture the important pattern of a population in a state of exponential increase (Figure 5). We will continue to calculate the indices and evaluate better ways to index the round goby population in the future, given uncertainties about its' ultimate seasonal and spatial distribution in the offshore waters of Lake Ontario. At sites where the round goby population is established, such as in the southwest, it is still expanding exponentially and individuals are using a greater range of depths each year. As round goby colonization continues eastward, we expect this pattern to continue until the round goby population stabilizes.

It is important to note that the depths fished on the April assessment in 2002-2005 were selected to target alewives and not investigate the bathymetric distribution of round gobies. In anticipation of continuing to index round goby population from April catches, we will be evaluating adding tows to the April 2006 alewife assessment to better index round goby abundance and distribution. Starting in 2006, we also will begin to collect length-frequency and other biological data on round gobies in conjunction with either, or both, the late April – early May and October assessments.

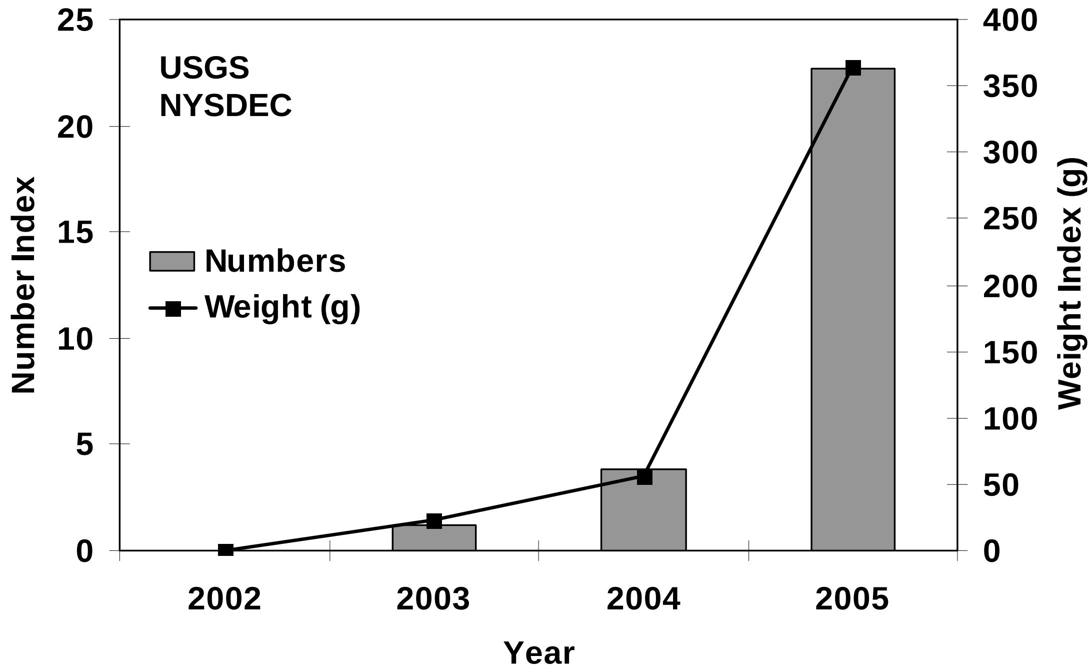

Figure 5. - Preliminary indices of round goby abundance and weight in U.S. waters of Lake Ontario in April 2002-2005 (no round gobies were caught prior to 2002). Indices are calculated as a stratified mean in the same manner as the alewife indices. For weight index, 454 g = 1 lb.

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Mid-Lake Assessment In The U.S. Waters Of Lake Ontario, 2005

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Introduction

In late June 2005 the USGS R/V Kaho conducted an exploratory survey of the deep water area (>150 m, 492 ft) on the U.S. side of the international boundary of Lake Ontario (abyss). There were two main objectives: 1) develop and evaluate sampling techniques for assessing the mid-lake profundal fish community; and 2) assess the fish community composition in mid-lake, an area not sampled during annual surveys. The logistics of sampling great depths in mid-lake are problematic because large amounts of time are needed to travel to sites located well offshore and to set and retrieve gear at extreme bottom depths.

Methods

During June 23-29, 2005 we fished gillnets and trawls on bottom in mid-lake at four locations spaced relatively equidistant along the international boundary off Thirty Mile Pt, Rochester, Sodus, and Oswego (Figure 1). At each location, two gillnets were set overnight at the approximate site of the trawl hauls. Gillnets consisted of ten, 15.2 x 2.4 m (50 x 8 ft) panels of 38 to 152 mm (1.5 to 6 in) stretch mesh in 12.8 mm (0.5 in) increments. A trawl net reel was used to lift gillnets instead of our usual bandolier-type gillnet lifter because we had to use extraordinarily long anchor lines.

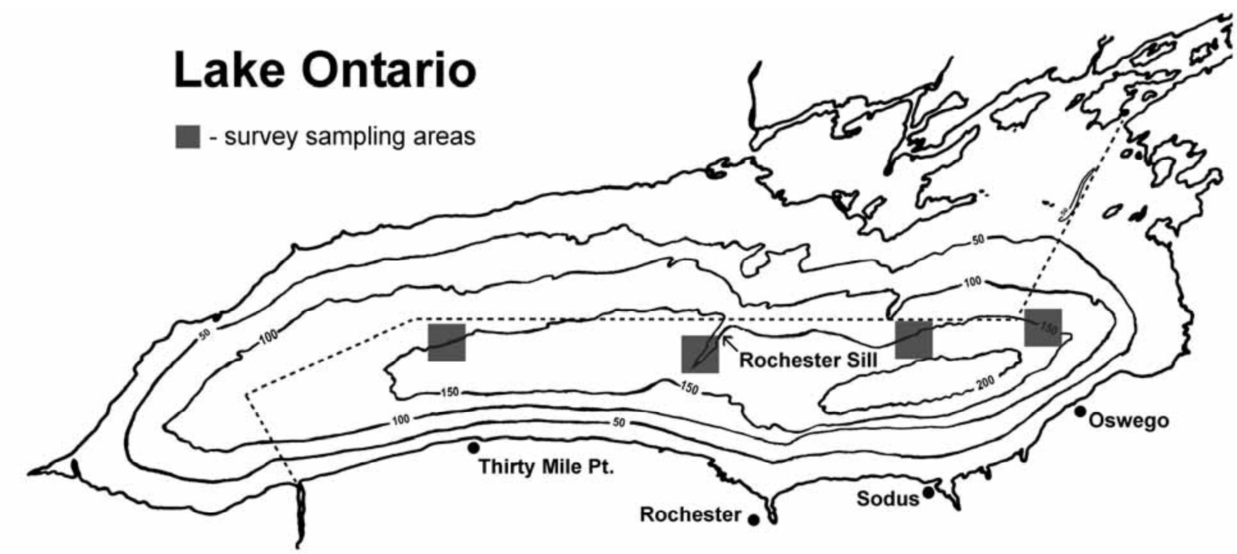

Figure 1. Lake Ontario showing 4 areas sampled with bottom trawls and gillnets during the mid-lake assessment in 2005. Depth contours in meters (1 m = 3.28 ft).

Table 1. Description of sampling during the mid-lake assessment in 2005.

Site	Date Sampled June 2005	Gillnet Depths (m/ft)	Bottom Trawl Depths (m/ft)	Tow Time (min)	Trawl Warp Ratio
Oswego	23	190/625	160/525	10	2:1
		210/695	180/590	10	2:1
			225/740	10	2:1
Rochester	25	150/495	155/510	20	2:1
		164/540	165/545	20	2:1
			180/590	20	2:1
Thirty Mile	26 & 27	158/520	170/560	20	2:1
Pt.		175/580	160/525	2*	3:1
			150/495	20	3:1
			177/580	20	3:1
Rochester	28	None	150/495	12.5**	3:1
Sodus	29	156/515	None		
		166/550			

* trawl dug into bottom, aborted
** trawl snagged bottom, destroyed

We used the same 18-m (59 ft. headrope) 3-in-1 bottom trawl used for all other USGS standard trawling surveys conducted in Lake Ontario (O'Gorman et al. 2005). Initial towing time of 10 min was later increased to 20 min in an effort to increase catches and utilize time more efficiently. In an effort to reduce time shooting and retrieving the trawl warp, the ratio of warp length to water depth was initially reduced from 3:1 to 2:1, a ratio thought sufficient to get the trawl on bottom. Repeated trawl hauls with no fish indicated poor or no contact with the bottom; therefore, the 2:1 warp to depth ratio was changed to 3:1 (Table 1).

Results and Discussion

Using gillnets to sample the fish community in mid-lake proved to be ineffective. The only fish caught were a few alewives (*Alosa pseudoharengus*), obviously entangled at mid-depths as the net was retrieved. Fish of the size likely to be ensnared in gillnets (i.e. deepwater ciscoes, *Coregonus spp.*) were either absent or in low abundance and unlikely to be caught with the limited effort expended. In hindsight, sacrificing a net reel to retrieve gillnets proved of less value than storing an extra trawl which ultimately was needed to continue the survey after destroying the only net onboard.

Only two rainbow smelt (*Osmerus mordax*) were caught with the trawl when fished with the 2:1 ratio of warp length to water depth. Switching to a 3:1 ratio resulted in an immediate increase in the catch, however only two complete 20 minute tows were made before the net hung up on the bottom at Rochester and was destroyed. Overall, a total of 58 slimy sculpin (*Cottus cognatus*), 29 rainbow smelt, 32 alewife, and 5 deepwater sculpins (*Myoxocephalus thompsoni*) were caught in all of the trawl tows combined. The small numbers of fish caught with the bottom trawl in mid-lake generally reflects the low fish density that we normally see at great depths on our annual bottom trawl assessments conducted on the south side of the abyss. A total catch of five deepwater sculpins from widely separated locations (Rochester and Thirty Mile Point) confirms the existence of a widely dispersed, low density population in mid Lake Ontario. Due to time and budget constraints there are no plans to continue this survey in the future.

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