Oneida Lake and its Fishery in 2008

New York Federal Aid in Sport Fish Restoration
Study 1
F-56-R

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Table of Contents

Introduction 2

Oneida Lake in 2008 3

- Limnology 3
- Fish community changes 9
- Walleye 13
- Yellow perch 20
- White perch 23
- Smallmouth bass 24
- Open water forage fish 25
- Sturgeon 26
- Cormorants 26
- Nearshore sampling 27

Recommendations for management and future research directions 30

Literature Cited 33

Appendix 1: Standard methods 38

Appendix 2: Standard data tables 41

Appendix 3: Scientific publications on Oneida Lake in 2008-09 49

Introduction

Oneida Lake is the largest lake by area within the borders of New York State. It also receives the most angler days per year of any lake in New York State outside the Great Lakes (Connelly et al. 1997). Traditionally, Oneida Lake anglers target walleye *Sander vitreus* and yellow perch *Perca flavescens*, but the black bass (smallmouth bass *Micropterus dolomieu* and largemouth bass *M. salmoides*) fishery, including tournament fishing, is increasing in popularity. The walleye population is managed using annual stockings of walleye larvae soon after hatching, almost complete removal of double-crested cormorants *Phalacrocorax auritus* from the lake, and angling regulations that have been imposed and relaxed with the goals of retaining both a high walleye yield and a yellow perch population consisting of larger fish attractive to anglers (Forney 1980). Angling regulations are based on intensive monitoring of the walleye and yellow perch populations and predicted future walleye recruitment. Oneida Lake has been the focus of research activities at the Cornell Biological Field Station (CBFS) since its beginning in 1956, 53 years ago. These activities are an important part of the collaboration between Cornell's Department of Natural Resources and New York State Department of Environmental Conservation's Bureau of Fisheries (NYSDEC). Research and monitoring on Oneida Lake is designed to encompass a range of trophic levels, from nutrients to fish and anglers, and these data are used to improve our understanding of the interactions between the ecosystem and the fishery in Oneida Lake. This report provides a summary of the standard monitoring data for 2008, along with an appendix with standardized methods for data collection and standard data tables. Several of the data sets are also available on the web at the Cornell University Mann Library's site eCommons (http://ecommons.library.cornell.edu/) and through the Knowledge Network for Biocomplexity (http://knb.ecoinformatics.org/index.jsp) (Rudstam and Mills 2008a-e, Rudstam and Jackson 2008a, b).

Collection of data to maintain the long-term database and directed studies aimed at understanding the effects of ecosystem change on the fish populations were continued in 2008 by the Department of Natural Resources of Cornell University as part of the activities of CBFS. Funding was provided by NYSDEC through the Federal Aid in Sport Fish Restoration Program and from the CBFS endowment. Cormorant management and studies are supported by a grant from the USDA Animal and Plant Health Inspection Services National Wildlife Research Center (APHIS-NWRC).

Oneida Lake in 2008

Limnology

Ice covered Oneida Lake for six days in December 2007 (12/19-12/25), from January 2 to January 9, 2008, and from Jan 22 to the day of ice break-up on April 1, 2008 for a total of 83 ice days during the winter of 2008 (10 days shorter than the average ice duration 1975-2008, Appendix Table A1). This was followed by an average year for water temperature in the 2000-2008 period, with temperatures at 2 m depth (June-August) averaging 22.5 ^{o}C (72.5 ^{o}F). But temperature in the summer of 2008 was still 0.8 ^{o}C (1.4 ^{o}F) above the average observed in 1968-2007. Summer temperatures in Oneida Lake have increased in the last three decades (Fig. 1, Table 1).

Water clarity in 2008 was among the highest on record, with a mean annual Secchi depth of 4.2 m and mean chlorophyll-*a* concentration of 3.8 µg/L (Fig. 2, Appendix Table A1). This continues the period of high water clarity and low chlorophyll-*a* concentrations that has been the norm since 1992, the year when zebra mussels (*Dreissena polymorpha*) became abundant in Oneida Lake (Zhu et al. 2006). Maximum Secchi disk depth recorded during 2008 was 7.6 m (during the spring clear water phase on June 10, 2008). Total phosphorus (TP) concentration, the limiting nutrient for algal growth in Oneida Lake, was slightly lower than most years since 2000, but not as low as in the 1995-1999 period. Although there is a significant decreasing trend in TP for the whole data series, this decreasing trend appears to have ended and TP has stabilized at levels between 20 and 30 µg/L (22 µg/L in 2008, Fig. 2). These are levels that are expected for mesotrophic lakes (Wetzel 2001, p283). Zooplankton biomass for 2008 is not yet available.

Of note is that quagga mussels (*Dreissena rostriformis bugensis*) are now abundant in the lake. This zebra mussel congener has been in the lake at least since 2005. Dr. Chris Mayer at the University of Toledo is checking species identification of a sample of small mussels collected in 2003 using genetic analysis, which may help us determine year of arrival. We expected this species to invade Oneida Lake as it has been found in nearby Onondaga Lake for several years. Quagga mussels have replaced zebra mussels in many systems including the Great Lakes (Mills et al. 1999, Watkins et al. 2007). Because this species can colonize softer bottoms than zebra mussels, we expect this invasion will lead to increased mussel biomass in Oneida Lake, which in turn should lead to further increases in water clarity. Currently, few dreissenid mussels occur on the softer sediments present at depth over 10 m.

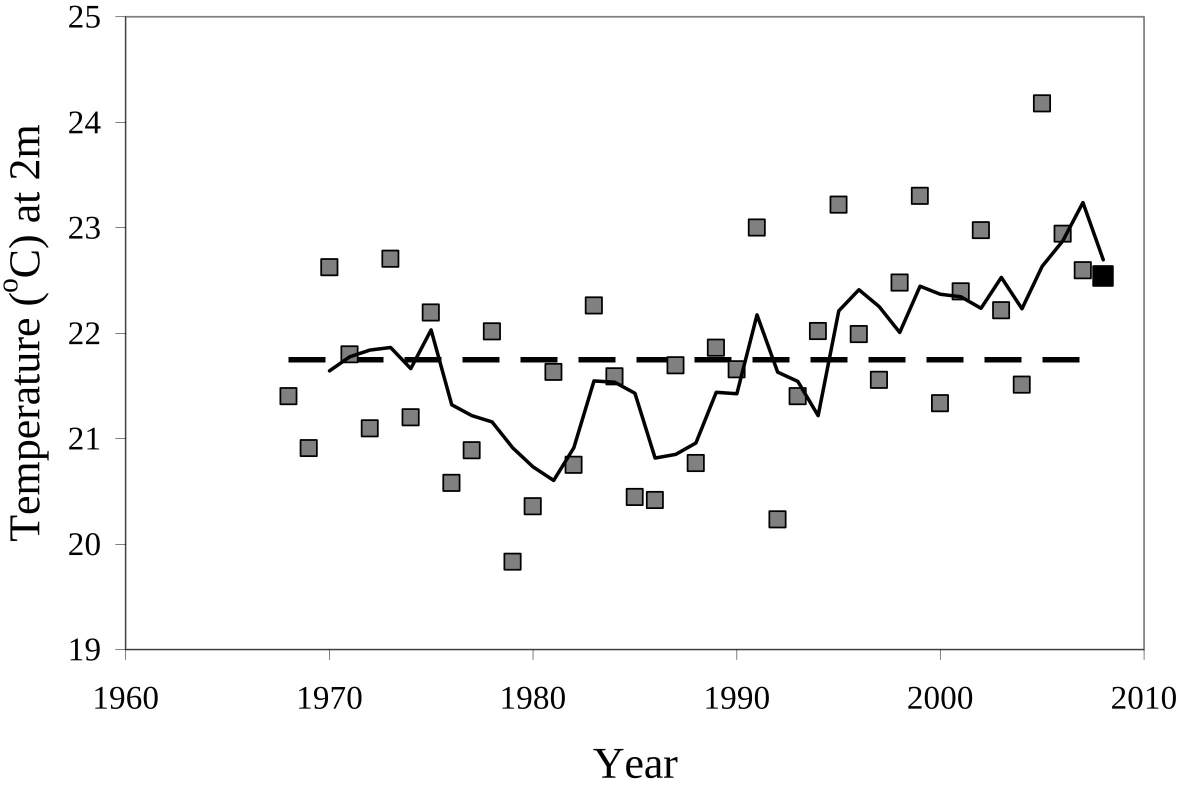


Figure 1. Average daily water temperature at 2 m depth at the Shackelton Point station from June 1 to August 31. Dashed line is the average temperature for 1968 to 2007, solid line is the 3-point moving average. The 2008 value is a solid square.

With over 30 years of limnological data from Oneida Lake, an analysis of the time trends and the relationships among lower trophic level indicators can be informative (Tables 1, 2 and 3). Climate warming trends since 1975 are evident in an increase in summer water temperature of 0.6^{o}C/decade and a decrease in ice duration of 9.6 days/decade. However, the spring ice break-up date in 2008 is only a day earlier than the average for the period 1975-2007. Interestingly, both the first day of complete ice cover and the ice break-up dates have not changed significantly since 1975. The main effect of climate warming is more frequent ice break-ups and longer periods of open water during the winter, particularly at the beginning of the ice season. Other significant time trends include increased water clarity, decreased chlorophyll-*a* concentrations, decreased TP, and decreased SRP concentrations (Table 1, Fig. 2). These trends are due to decreased nutrient loading to the lake and abundant zebra mussels since 1992 (Idrisi et al. 2001, Zhu et al. 2006). More importantly, the decline in phytoplankton biomass (as indexed by chlorophyll-*a*) did not result in a decline in total zooplankton or in *Daphnia* biomass. Total zooplankton biomass has actually increased significantly with time. It is surprising that zooplankton biomass did not decline with decreased phytoplankton biomass as we also have a large biomass of filtering mussels on the bottom of the lake. Part of the explanation is a compensatory increase in algal productivity (production per unit biomass) due to higher water clarity after the zebra mussel invasion (Idrisi et al. 2001).

Correlations among lower trophic level indicators reveal a strong negative correlation between water clarity measured as Secchi disk depth and phytoplankton abundance measured as chlorophyll-*a* concentrations (Table 2). Chlorophyll-*a* level explains 71 % of the variation in Secchi depth among years. This indicates that water clarity in Oneida Lake is mainly determined by the amount of phytoplankton biomass and not by periodic resuspension of bottom sediments (although sediment loads from streams do affect certain areas of the lake). The higher water clarity causes increased depth distribution of submerged aquatic vegetation (Zhu et al. 2006). Light environment suitable for macrophyte growth is now predicted to be 43 % of Oneida Lake's bottom area, an increase from 26% of the bottom in the 1960s (Fitzgerald et al. submitted). This could increase to 62% of the bottom if water clarity increases further and macrophytes are found down to the maximum depth tolerated by most vascular plants (9m, Wetzel 2001). The diversity of plant species has also increased as both light-limited and light-tolerant species are now present in the lake (Zhu et al. 2006). Grazing by zebra mussels has both direct effects on the ecosystem through decreased algal production and indirect effects resulting from increased water clarity. Increased water clarity increases benthic primary production (Cecala et al. 2008). Dreissenid mussels also redirect pelagic production to the benthic subsystem. We call this process "benthification" (Mills et al. 2003, Zhu et al. 2006, Mayer et al. submitted).

Predicting chlorophyll-*a* levels is particularly interesting as chlorophyll-*a* represents an index of the biomass of one of the major primary producers in the lake, the phytoplankton. Although the correlation between chlorophyll-*a* and TP is highly significant (Table 2, N=34, P<0.001), only 27% of the variation in chlorophyll-*a* can be explained by average summer TP. Zebra mussel biomass was the best single predictor of chlorophyll-*a* (Table 2, excluding Secchi depth which is a consequence of lower chlorophyll-*a* levels, not a predictor of chlorophyll-*a* levels). Using the Akaike Information Criteria to determine the best model given the data (Burnham and Anderson 2002), we found that the best model included a positive effect of TP and a negative effect of summer temperature, zebra mussel biomass and *Daphnia* biomass (Table 3). This model explained 58% of the variation in mean annual chlorophyll-*a* concentration. The three top models all included zebra mussels, *Daphnia* and temperature, but differed in the inclusion of total zooplankton and TP. The positive effect of TP and negative effects of the major grazers were expected, but the results suggest that phytoplankton biomass in Oneida Lake is regulated more by grazing than by nutrient levels. The negative effect of temperature is difficult to explain (we expected a positive effect because blue-green algal blooms are typically more pronounced in warmer temperature (Reynolds 2006). This may be an effect of correlations between warmer summer temperatures and the arrival of zebra mussels, although the negative effect of temperature on blue-green algae biomass is evident also in the years 1997-2007 (Siefert, pers. obs). Several studies are ongoing for explaining the phytoplankton – grazing dynamics in Oneida Lake (Hairston and Gyllström, Department of Ecology and Evolutionary Biology; Siefert and Mills, CBFS).

To summarize the limnology section of this report, 2008 was a year with higher water clarity and lower phytoplankton abundance than any year with the exception of 1995. Water temperatures continue to be above average and ice duration below average for the data series. Phytoplankton biomass is controlled primarily by grazing, and we expect the expansion of the quagga mussel will further increase grazing rates. Therefore we expect further increase in water clarity and in the area of lake bottom covered by submerged macrophytes in the future.

Table 1. Time trends in Oneida Lake lower trophic level indicators. The mean and range are based on data collected since 1975. R^2, P and N are related to the significance of a linear trend between 1975 and 2008. Significance levels are based on standard linear regressions using JMP 7.11. Also given is the value for the year 2008. Limnological variables are averages of weekly whole water column samples from May through October (Appendix Table A1). Trend indicates direction (+ or -) over time. First freeze day for 2001 when the lake did not completely freeze over was set to Feb 1 for this analysis (61 days after Dec 1). The dreissenid mussel trend is only calculated from 1992-2007, after the mussels arrived to the lake. Densities prior to 1992 were considered to be 0.

Variable	Abbreviation	2008	Mean	Range	Trend	R^2	P	N
Ice Duration (days)	IceDur	83	93	58-121	-	0.167	**0.018**	33
First freeze (# days after Dec 1)	Freeze	19	26	3-54	+	0.077	0.124	32
Ice break-up (day-of-year)	Thaw	92	92	62-109	0	0.001	0.853	34
Temperature Jun-Aug (C)	Temp	22.5	21.8	19.8-24.2	+	0.363	**0.0002**	34
Total Phosphorus (µg/L)	TP	22.3	30.4	14.7-64.7	-	0.360	**0.0002**	34
Soluble Reactive Phosphorus (µg/L)	SRP	8.8	10.5	1.8-29.0	-	0.137	**0.034**	33
Chlorophyll-*a* (µg/L)	Chl-a	3.8	7.5	3.2-12.7	-	0.474	**<.0001**	34
Secchi disk depth (m)	Secchi	4.2	3.1	2.1-4.7	+	0.428	**<.0001**	34
Daphnia biomass(µg/L)	Daph	NA	130.3	42.2-231.0	+	0.059	0.171	33
Total zoo-plankton (µg/L)	Zoop	NA	236.1	101.8-389.4	+	0.140	**0.035**	32
Dreissenid mussel biomass (g/m2)	ZM	NA	27.3	11-55	0	0.04	0.53	15

Table 2. Pearson correlation coefficient for pair wise correlations among lower trophic level indicators in Oneida Lake. Bold values indicate significant correlations (samples sizes are 32 to 34 depending on the parameter, $P<0.05$). Abbreviations are explained in Table 1.

	Freeze	Thaw	Temp	TP	SRP	Chl-a	Secchi	Daph	Zoop	ZM
IceDur	**-0.670**	**0.523**	-0.244	0.323	0.182	0.211	-0.116	-0.060	0.058	-0.152
Freeze		-0.081	0.079	-0.248	-0.210	-0.255	0.160	0.095	-0198	0.228
Thaw			-0.113	0.069	0.108	-0.176	0.242	0.192	0.050	**0.373**
Temp				**-0.480**	-0.199	**-0.559**	**0.540**	-0.147	0.184	**0.531**
TP					**0.828**	**0.530**	**-0.438**	-0.002	-0.128	**-0.477**
SRP						0.216	-0.197	0.117	0.060	-0.307
Chl-a							**-0.845**	-0.310	-0.071	**-0.655**
Secchi								0.324	0.123	**0.641**
Daph									**0.833**	0.211
Zoop										0.303

Table 3. Model selection for prediction of chlorophyll-*a* concentrations in Oneida Lake. Predictor variables included were total phosphorus (TP), temperature in June-August (Temp), *Daphnia* biomass (Daph), total zooplankton biomass (Zoop), and zebra mussel biomass (ZM). All models with a Δ AIC (Akaike Information Criteria) less than 5.0 are presented. The evidence ratio (w_i) is the probability that a model is the best model given the data and the candidate models. The evidence ratios sum to 1.

Model	AIC	Δ AIC	w_i
ZM, TP, Daph, Temp	37.7	0	0.247
ZM, Daph, Temp	38.3	0.6	0.183
ZM, TP, Daph, Temp, Zoop	38.6	0.9	0.157
ZM, Daph, Temp, Zoop	39.7	2.0	0.091
TP, Daph, Temp	39.8	2.1	0.086
ZM, Daph, TP	40.3	2.6	0.067
ZM, Temp	41.2	3.5	0.043
TP, Daph, Temp, Zoop	41.4	3.7	0.039
ZM, TP, Daph, Zoop	41.4	3.7	0.039
ZM, TP	42.0	4.3	0.029
ZM	42.7	5.0	0.020

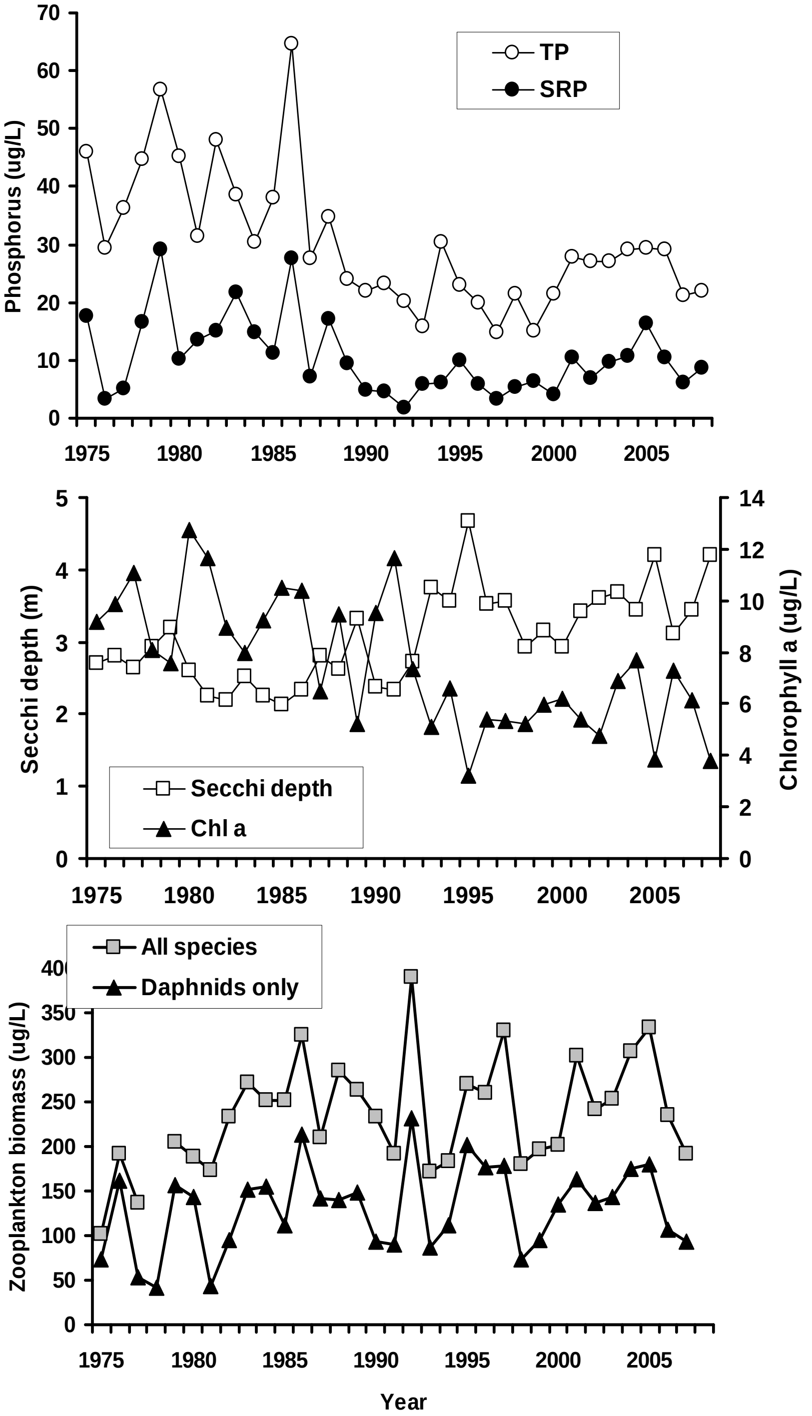


Figure 2. Time trends in lower trophic indicators in Oneida Lake, New York, 1975 to 2008.

Fish Community Changes

Oneida Lake continues to be dominated by yellow perch, white perch (*Morone americana*) and walleye. As is typical for Oneida Lake, yellow perch was the most abundant species in our standard gill net catches, representing over 46% of the catch (Fig. 3). White perch was the most abundant species caught in 2007 and the second most abundant species in 2008 (23%). Walleye remained the third most abundant species in our gill net samples at 14 % of the catch. Total number of fish caught in the standard gill nets in 2008 (1605 fish) was similar to the numbers caught in the 2000's (average 1616, range 1214-2204).

The standard gill net sets are important for tracking changes in the fish community in Oneida Lake (Irwin et al. submitted 2008). We caught 18 different species in these nets in 2008. Time trends in species catch varies among species, with significant negative trends in walleye, yellow perch, burbot (*Lota lota*), golden shiner (*Noemigonus crysoleucas*), rock bass (*Ambloplites rupestris*), white bass (*Morone chrysops*), and cisco (*Coregonus artedi*) (Fig. 4), and significant positive trends in brown bullhead (*Ameiurus nubulosus*), freshwater drum (*Aplodinotus grunniens*), gizzard shad (*Dorosoma cepdianum*), redhorse sucker (*Moxostoma sp.*), smallmouth bass, lake sturgeon (*Acipenser fulvescens*) and white perch (Fig. 5). Species with no significant time trends that have been caught with some regularity through time include pumpkinseed (*Lepomis gibbosus*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), carp (*Cyprinus carpio*), and white sucker (*Catostomus commersonii*) (Fig. 5). Two processes likely contribute to these fish community trends: 1) increased water clarity with associated increase in littoral and benthic area and production and 2) climate change that results in increased water temperatures and decreased ice cover. Cisco and burbot are cold-water fish that are declining at the southern range of their distribution, which includes Oneida Lake (Jackson et al. 2008). Conversely, the recent increase in gizzard shad catches are due to comparatively high over-winter survival of the 2005 shad year class in a year with exceptionally large fish in the fall and a mild winter, although the increase in the 1980s and decline in 1992 of this species is less clearly associated with winter severity (Fitzgerald et al. 2006). Several other species that increased may be responding to warmer summer temperature (smallmouth bass, white perch). Some species may benefit from increased benthic production (freshwater drum, brown bullhead, smallmouth bass) although not all species that are expected to increase did so (pumpkinseed, white sucker), and at least one declined (rock bass). But most of the increasing species are littoral or benthic supporting the conclusion of Irwin et al. (submitted) and Jaeger Miehls et al. (submitted) that the fish community in the lake is becoming more dependent on benthic production. However, it should be remembered that fish community composition not only respond to environmental change, but also to inter-specific interactions.

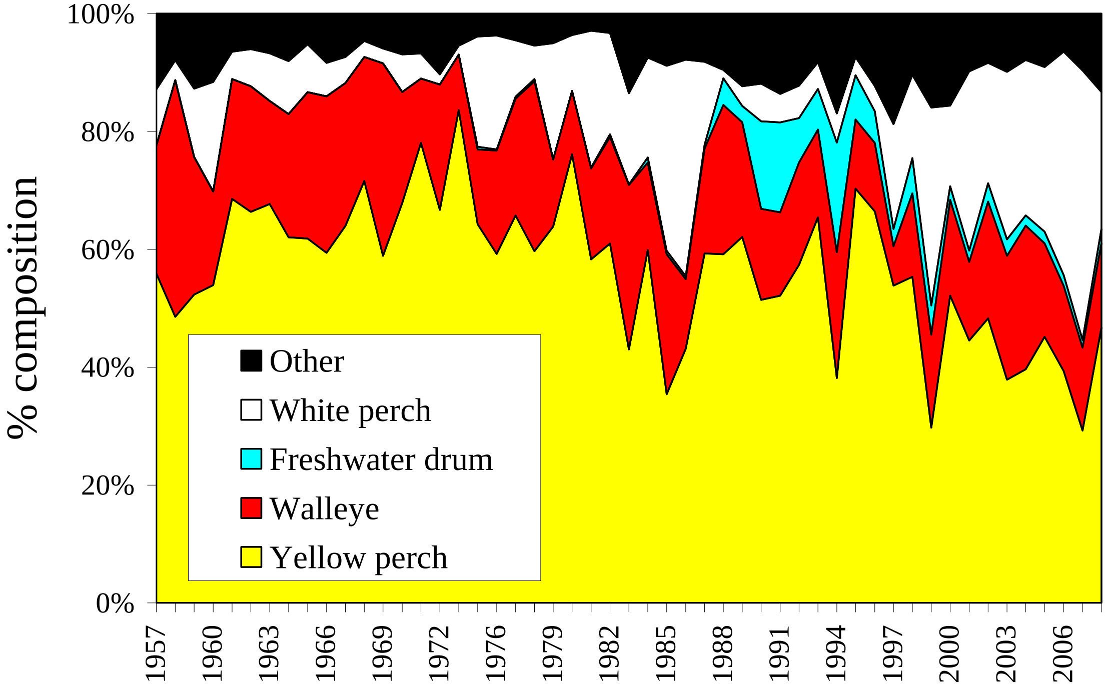


Figure 3. Proportion of four major fish species in standard gill net sets in Oneida Lake since 1957.

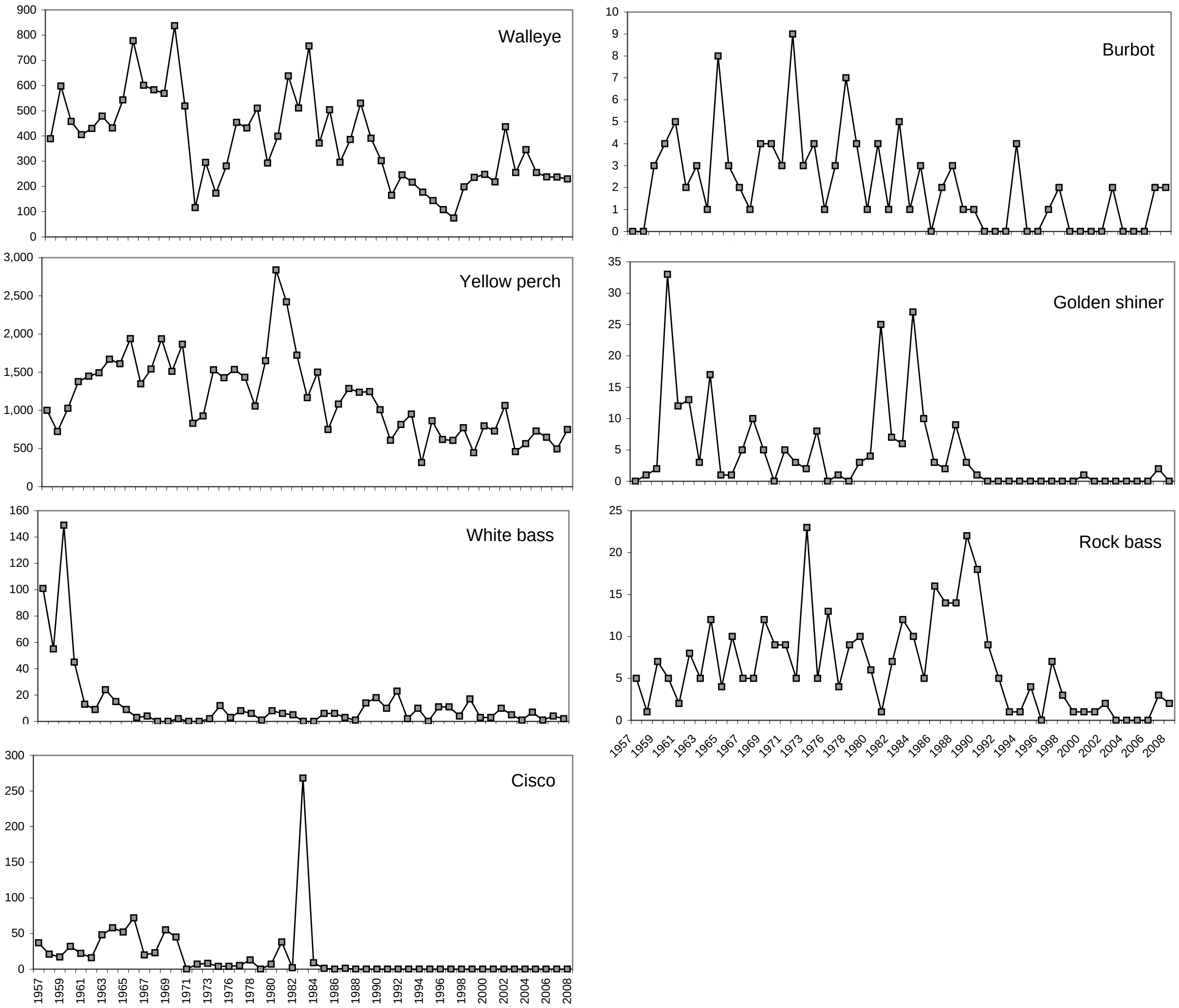


Figure 4. Time series of gill net catches for fish species with a decreasing population time trends (Pearson's correlation coefficient < -0.28, P<0.05, N=51).

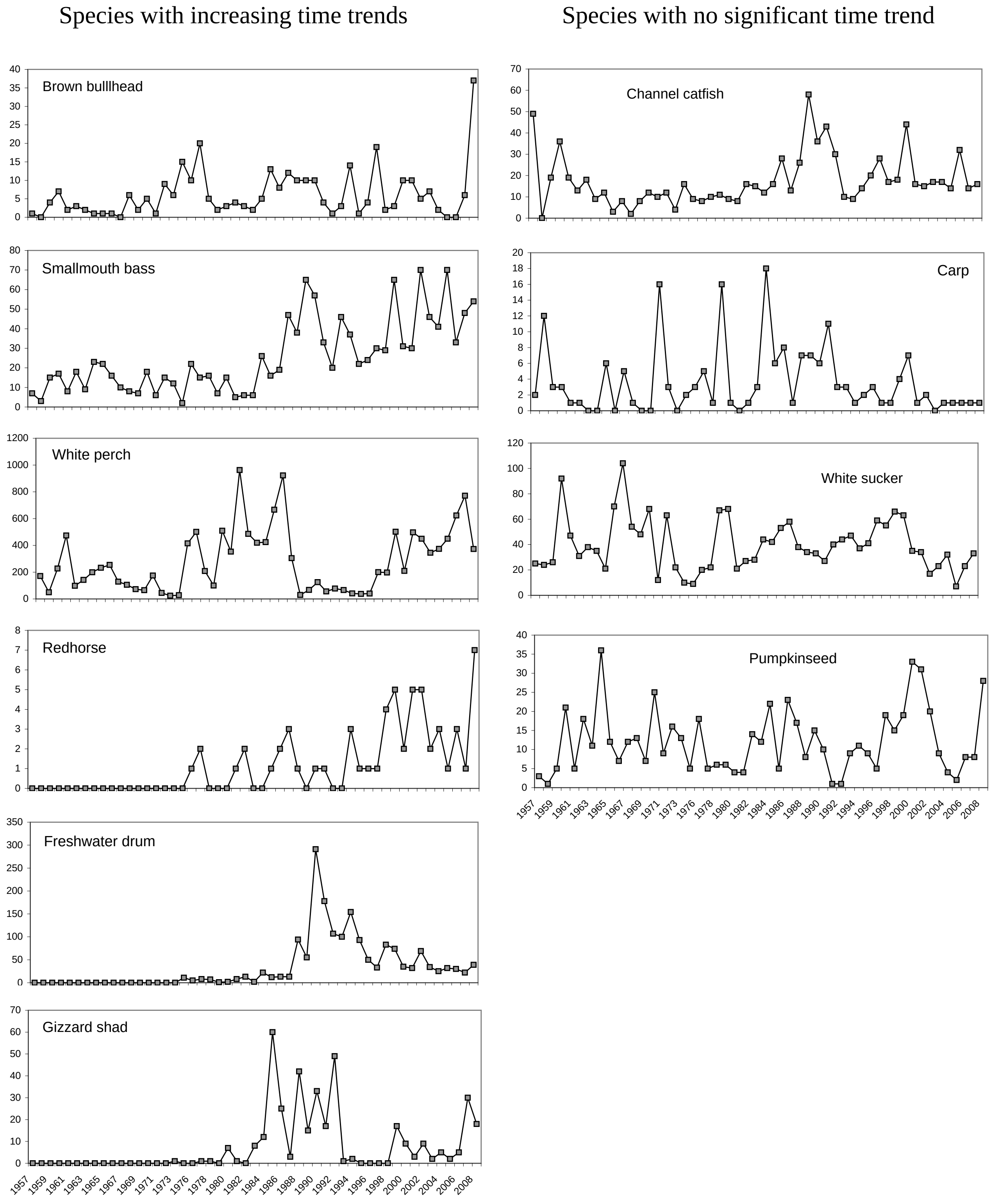


Figure 5. Time series of gill net catches for fish species with an increasing population time trend (Pearson's correlation coefficient r > 0.30, P<0.03, N=51), as well as species with no significant time trend (r < 0.25, P>0.12, N=51).

Walleye

The walleye population in Oneida Lake is assessed at several stages; with Miller high speed samplers as larvae (length of 9 to 13 mm), with bottom trawls in the spring, summer and fall, with gill nets in the summer, and with mark-recapture for adult fish (age 4 and older) at regular intervals (currently every 3 years).

Abundance of adult walleye (age 4 and older) was estimated by mark-recapture in 2007 to be 18.7 fish/ha or 386,500 fish in the lake. The estimate for 2008 (406,000 fish) is based on the 2007 mark-recapture estimate and assuming 15% annual mortality (Appendix Table A2). Estimates using gill net catches and the Irwin et al. (2008) catchability coefficients (the proportion of the walleye population caught by our standard gill nets, see explanations in Irwin et al. 2008) are higher at 25.7 fish/ha or 531,800 fish in the lake. The difference between 406,000 and 531,800 may seem large, but gill net catches are affected by other factors than population size as well as random error. Also the confidence limits for the 2007 mark-recapture estimate was 267,400-505,700 (VanDeValk et al. 2008b), and there are additional uncertainties associated with estimates of mortality and recruitment that enters the calculations of the population in 2008 when based on the 2007 mark-recapture study. As a comparison, our estimates of the walleye population in 2007 using Irwin et al.'s (2008) catchability coefficients was 386,600, which was very close to the mark-recapture estimate for that year.

We predict the future walleye population using the average of catches in trawls and gill nets of age-1 and age-2 walleye (Appendix Table A2). We have discontinued the use of the predictive equation based on trawl catches of age-1 walleye from Rudstam et al. (2004) because we believe that catchability in either the trawl or the gill net or both has changed over time, likely associated with the changes in water clarity and extent of littoral zone. We now estimate density of age 1 to 3 walleye from the average of the estimate from the trawl and the gill net using the age and gear specific catchabilities derived by Irwin et al. (2008) (see Appendix Table A2). Irwin et al. (2008) also showed that including a variable for the cormorant period improves predictions. The "best" model (lowest AIC) given the data for year classes 1957- 2004 includes the natural logarithm of age 1 and age 2 walleye abundance and an index of cormorant feeding days:

$$\mathrm{Ln}(\mathrm{Age}\ 4) = -0.059 + 0.239\ \mathrm{Ln}(\mathrm{Age}\ 1) + 0.593\ \mathrm{Ln}(\mathrm{Age}\ 2) - 1.177\ \mathrm{DCCO} \qquad (1)$$

Where Age 1, Age 2 and Age 4 are densities of walleye age classes in fish/ha, and DCCO is the index of cormorant feeding days from Coleman (2009, updated by DeBruyne in prep.) ($R^2 = 0.84$, $N = 48$, $P<0.0001$ for the full model).

Predictions for age 4 walleye produced by the 2005 year class in 2009 is 76,500 fish and produced by the 2006 year class in 2010 is 57,600 fish using Equation (1). Whether these recruitment levels are sufficient to maintain the walleye population at current levels depends on adult mortality rates. Our harvest estimate for 2007-08 was 58,000 fish (Krueger et al. 2009), which was similar to our estimated recruitment to age 4 from the 2004 year class (69,000 fish). Clearly, the population is not likely to increase if harvest rates are similar to annual recruitment, especially as there is always some natural mortality from diseases and other predators each year. Assuming a 15% total mortality in the future (average of observed mortality between mark-recapture estimates since 1995 (range 9 – 26%), we predict that the walleye population will remain over 400,000 through 2010 (Fig. 6). We do not expect higher recruitment in 2011 and 2012 based on available data for the 2007 and 2008 year classes. For both year classes, the densities at age 1 and age 0 are below values for the 2005 and 2006 year-classes (see below). Therefore we expect the population will decrease some in 2011-2012.

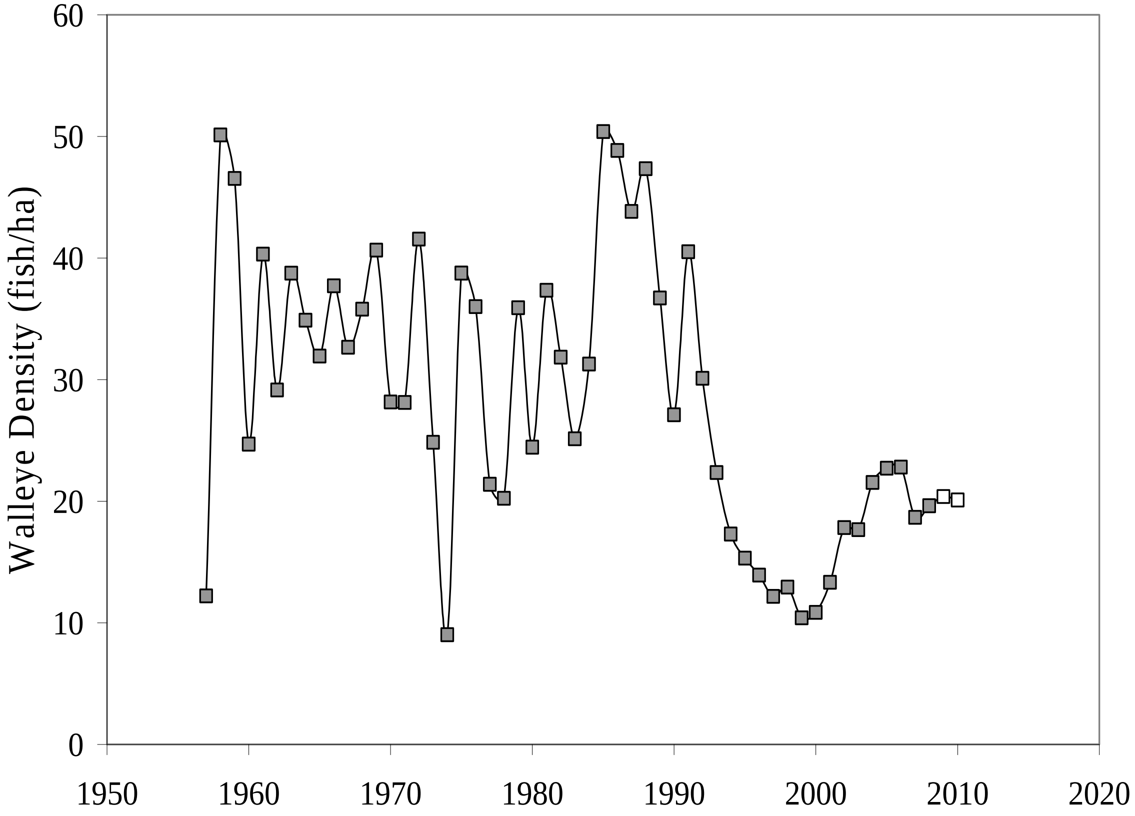


Figure 6. Abundance of walleye in Oneida Lake. Grey squares are observed values, open squares are predictions for 2009 and 2010.

Abundance of adult walleye is high in Oneida Lake compared to other lakes where we have information on their absolute abundance (Fig. 7). Most such lakes are from northern Wisconsin and are smaller (Nate et al. 2000), but there is information from other lakes, including Lake Winnebago, a shallow, productive lake that is three times larger than Oneida Lake and also polymictic (data provided by Kendall Kamke and Steve Hewett, Wisconsin Department of Natural Resources). There are also a few lakes with adult walleye abundance in Colby et al.'s (1979) compilation of walleye biology.

Adult walleye growth rate is calculated from back-calculated length-at-age of fish caught in the standard gill net sets. We use the geometric mean of growth in length from age 4 to 5, 5 to 6, and 6 to 7 as an index of growth rate. This index requires length at last annulus and therefore the data collected in 2008 represent growth in 2007 (we calculate growth for 2007 based on spring length in 2008). This index shows poor growth of adult walleye in 2007, especially for males which exhibited the slowest growth since 1986 (Fig. 8). Growth rates of sub-adults (age 1 and age 2) were also poor, less than 68% of average growth in length in the previous ten years (1997-2006, age-1 males - 48% age-1 females - 68%, age-2 males - 40%, age-2 females - 54%). Poor growth indicates that walleye in Oneida Lake are abundant relative to the abundance of forage fish (Rudstam et al. 1996).

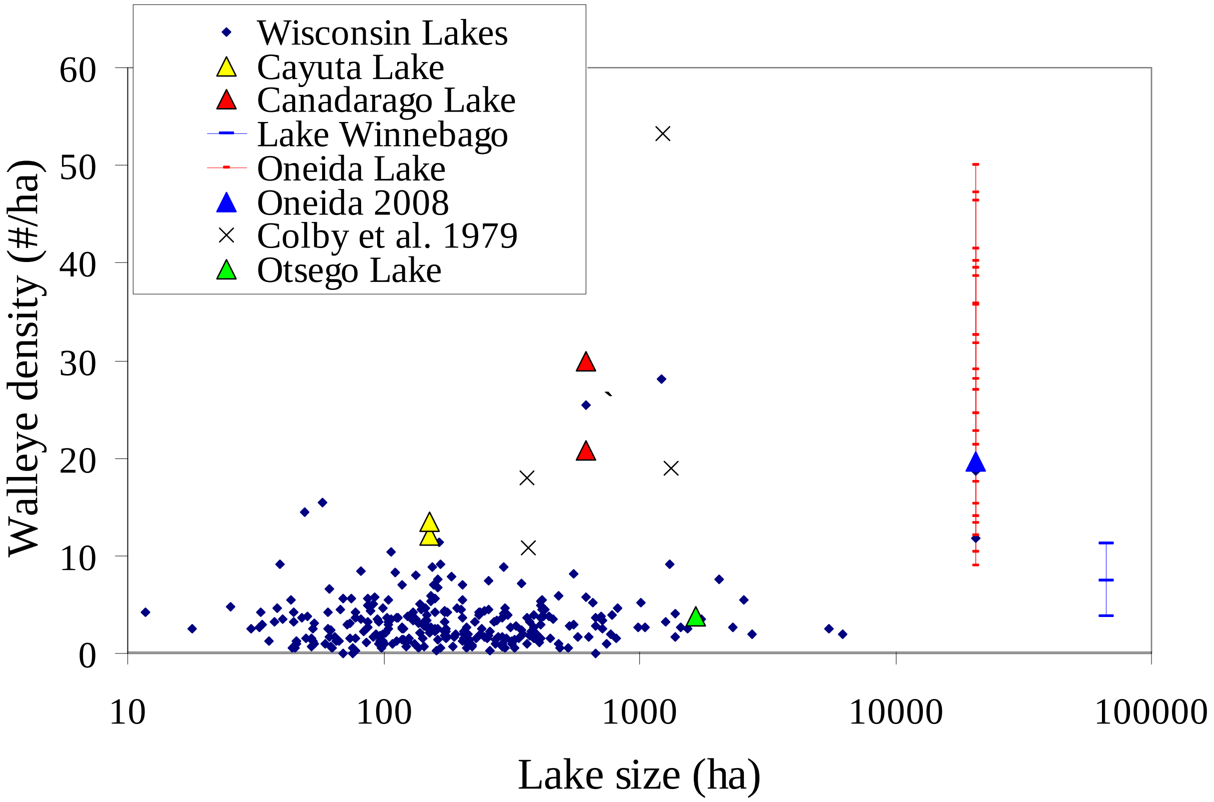


Figure 7. Density estimates for walleye larger than 15 inches in a number of Wisconsin lakes and selected lakes in New York State. The Wisconsin data is for the northern ceded territory and Lake Winnebago and was provided by the Wisconsin Department of Natural Resources (Kendall Kamke and Steve Hewett).

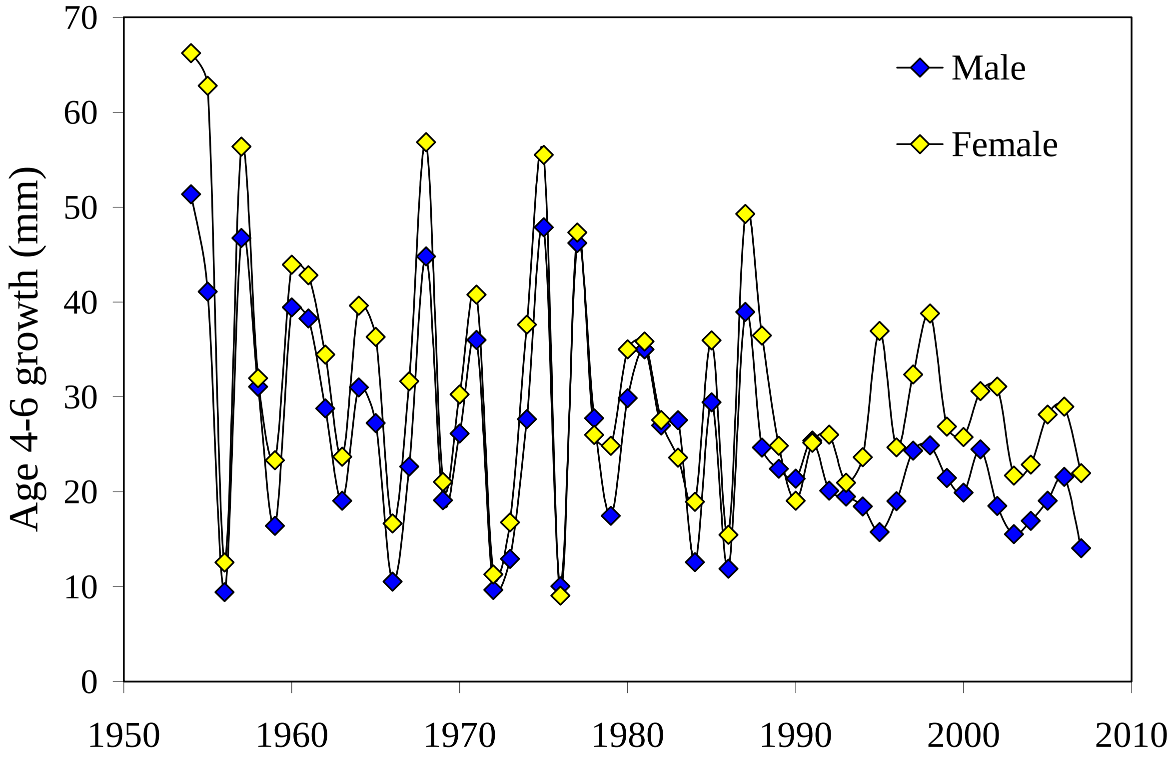


Figure 8. Growth index for walleye in Oneida Lake (geometric mean growth in length (mm) of age 4-5, 5-6 and 6-7 fish).

Growth is a useful index for evaluating the balance between the forage base and walleye abundance. Feeding rate is predictable from growth rates in Oneida Lake (Lantry et al. 2008). The geometric average growth rate used to date is one option and it is highly correlated with the abundance of age-0 yellow perch (correlation with age-0 yellow perch in October is highly significant for the 1961-1983 time period but not for the 1984-2007 time period, Fig. 9). The lack of correlation in more recent years is likely due both to the relatively small range of yellow perch densities and to other prey fish, in particular gizzard shad, being abundant in some years (see below). Walleye feed on gizzard shad in the fall (Fitzgerald et al. 2006, Appendix Table A3). We need to evaluate different growth indices using available data, including the geometric mean growth (Fig. 8), relative weight (VanDeValk et al. 2008a), a relative growth index derived by Quist et al. (2003), and a growth index based on the vonBertalanffy growth equation (He et al. 2005, 2008). We also need to understand the seasonal growth pattern of walleye. Some prey species, such as gizzard shad, are more available in late summer and walleye may use increased fall consumption for gonads rather than somatic growth. Thus, walleye growth rate may be a function not only of average prey biomass, but also of the seasonal availability of appropriately sized prey species. We are in the process of evaluating seasonal growth and consumption patterns with walleye feeding on prey species other than age-0 yellow perch by comparing analyses of growth and consumption during the 1970s (Forney 1980) with data from the 1990s and 2000s (Lantry et al. 2008, Fetzer in prep).

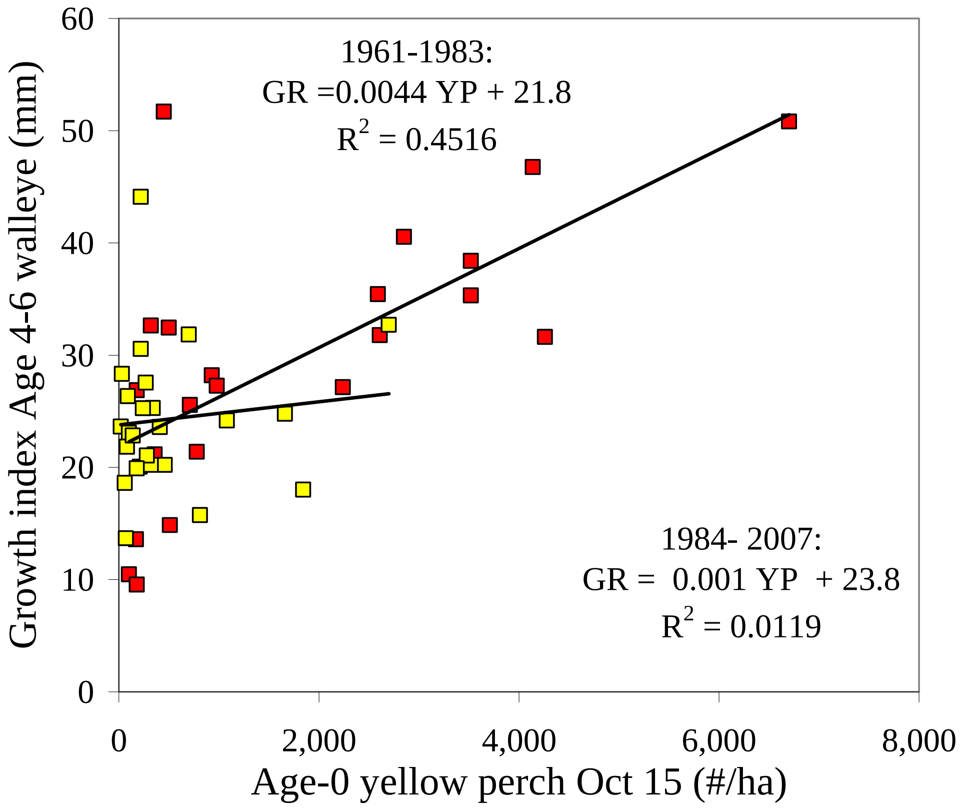


Figure 9. Walleye growth index (average of annual growth in lengths for 3 age groups, in mm) as a function of abundance of age-0 yellow perch in October. The time period 1961-1983 is filled squares, the time period 1984-2007 is open squares.

Oneida Fish Cultural Station (OFCS) personnel stocked 173 million walleye fry from 4/23/08 to 4/27/08. The CBFS Miller sampler estimate of larval walleye density is conducted together with our first estimate of yellow perch larvae (at 8 mm length). In 2008, this occurred between 5/12 and 5/13, 19 days after walleye stocking. Larval walleye were 10.3 mm at that time. In several past years, walleye were assessed earlier when average lengths were approximately 9 mm (9.4 mm, range 9.0-10.2 mm, N=18). In years when both the 9 mm survey and the values from the yellow perch 8 mm survey were available, the two surveys are correlated ($R^2 = 0.58$, P=0.010, N=10). With one outlier removed (2002, when few stocked walleye larvae survived a cold period after an early stocking date) the correlation improves ($R^2 = 0.88$, P=0.0002, N=9). The equation is

$$WD_{YP} = 203.6 + 0.722\ WD_{9mm} \qquad (2)$$

where, WD_{YP} is walleye density at the 8 mm yellow perch survey, WD_{9mm} is walleye density at the 9 mm survey, both in fish/ha. Our walleye larvae index (Appendix Table A4) is the number of walleye larvae at the time of the 8 mm yellow perch survey, either measured directly (N=15) or calculated from the 9 mm survey with this equation (years 1966, 67, 69, 99, 2000, 03, 04).

The walleye larval abundance in 2008 was 5102 fish/ha which is the second highest estimate on record (after 2005) and substantially higher than the long term estimate of 1545 larvae/ha (23 years, 1966 – 2007). There is a time trend of increasing larval walleye abundance, but it is not significant ($R^2 = 0.12$, P=0.09, N=24).

Age 0 walleyes are monitored with bottom trawls at 10 standard stations. Catch per unit effort is translated to density in fish/ha assuming that each trawl samples an area of 0.1 ha. Trawling in 2008 started on July 7 and continued through October 20. We calculate density of age-0 walleye from 5 surveys (50 trawls) around August 1, 4 surveys (40 trawls) around September 1, and 5 surveys (50 trawls) around October 1. The 2008 walleye density estimates were 8 fish/ha on August 1, 2.5 fish/ha on September 1, and 5.4 fish/ha on October 1. Average length on October 1 was 130 mm. Abundance was low compared to the long term data and about average for the last 10 years (Fig. 10, Appendix Table A4). Length was also lower than expected, as walleye first year growth rates have been increasing from the 1960s to 2002 (Fig. 10, He et al. 2005). Small size and low numbers suggest that the 2008 year class is not going to produce a large number of age-4 recruits to the fishery in 2012.

The 2007 year class was not large compared to the historic record but still the third largest since 2000 (Fig. 10). Individual fish were relatively small (average 132 mm, Fig. 10) and this year class did not survive the winter well. Abundance of age 1 in the spring of 2008 (2007 year class) was 3.3 fish/ha, substantially below the long-term average of 30 fish/ha in the spring, and the lowest number obtained since 1999 (2000-2007: 9.3-33.0 fish/ha).

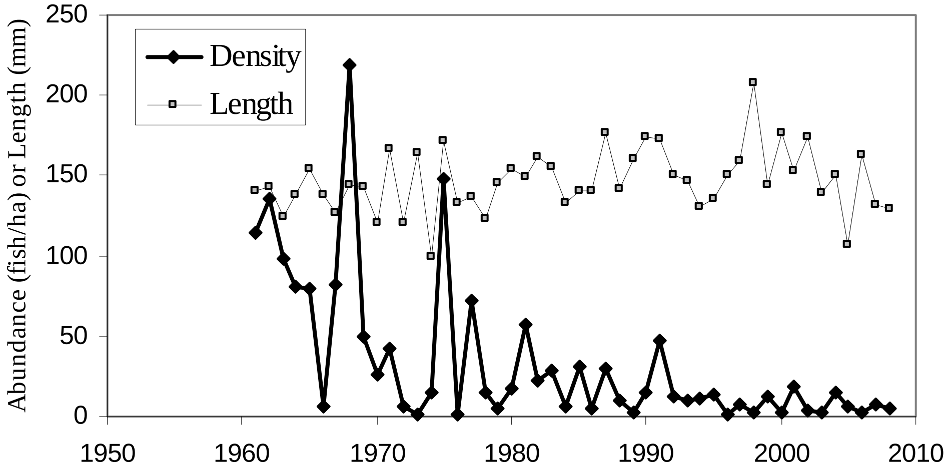


Figure 10. Estimated density and length of age-0 walleye on October 1 based on bottom trawls.

We have measured larval walleye abundance during two separate time periods, for 12 years between 1966 and 1977, again in 1992, and then for 11 years between 1998 and 2008. These data can be used to investigate the following three questions: 1) is larval density different in recent years compared to the 1966-77 period?, 2) is larval density correlated with the number stocked by OFCS?, 3) is larval density correlated with the abundance of age-0 walleye on August

1 or October 1? Larval walleye abundance average 2165 fish/ha in 1992-2008 (SD = 2346, N = 12, range 213 – 8106 fish/ha) compared to 1222 fish/ha in 1966-77 (SD = 697, N = 12, range 309 – 2327 fish/ha), but this difference is not significant (one-way ANOVA, $F_{1,22} = 1.78$, P = 0.20) even though the 4 highest abundance estimates are in recent years. This is consistent with not detecting a significant time trend in larval abundance (see above). This analysis does suggest that the decrease in age-0 fish in October in recent years is not due to fewer walleye larvae in the spring. Second, walleye larval abundance is correlated with the number of stocked larvae, although the correlation is not strong (one-way test, $R^2=0.14$, P=0.04, N=24). A one-way test is appropriate in this case because we test the hypothesis that walleye larval abundance will increase with higher stocking levels. This indicates that the more larvae are stocked, the more larvae are present in the lake in the spring, which is consistent with previous analyses on the 1966-1977 data (Forney 1980). The OFCS hatchery is believed to contribute about 75 % of the walleye larvae in the lake (data from the 1966-1977 where nine years with stocking had a density of 1414 larvae/ha and 3 years without stocking had a density of 363 larvae/ha). Third, age-0 walleye abundance on August 1 or October 1 was not correlated with abundance of larval walleye ($R^2 < 0.015$). This is also true if each time period is considered separately although the trend is then at least positive (highest correlation has an R^2 of 0.22). Thus, although stocking larvae from OFCS increases the number of walleye larvae in the lake, it is less clear that the number of larvae present in the spring is important for the future strength of that year class.

Although the last results may be somewhat disconcerting for management through larval stocking, they are not unexpected. Correlations from larval fish numbers to older age groups tend to be weak due to the large variation in first year mortality among years (see such analysis by Irwin et al. 2009 for yellow perch in Oneida Lake). In model analyses, larval stocking made little difference to future walleye abundance (Rose et al. 1999), although stocking larvae did decrease variance in recruitment among years. This data set warrants further analysis as we now have a respectable number of years (a total of 24) with larval densities varying from a low of 213 fish/ha (2002) to a high of 8106 fish/ha (2005). In the past, walleye numbers in October were correlated with the number of larval fish present in years with high numbers of yellow perch larvae. We have not had a comparable year in the 1992-2007 data. In future analyses, we will include environmental factors such as temperature, as well as density of zooplankton in the spring, density of larval perch, growth rates of age-0 walleye, and density of predators. Irwin et al. (2009) presented such an analysis for yellow perch.

To summarize, the adult walleye population in Oneida Lake is high compared to other lakes and compared to the current productivity of Oneida Lake. Growth rates are declining and were unusually low in 2007. Preliminary observations suggest that growth rates are low in 2008 as well. Survival of age-0 walleyes is low even though the number of larvae present in the spring is high. In the past, first year mortality has been attributed to cannibalism, and this is particularly high when the abundance of age-0 yellow perch is low (Chevalier 1973, Forney 1980). Low growth rates and poor first year survival are likely responses to high population abundance relative to the current forage base. Oneida Lake may no longer be able to support the number of walleyes that were present during 1960 to 1990. The reason is less clear, and may include effects of lower productivity, increased water clarity, changes in distribution patterns, and changes in the timing of the hatch of the current complement of forage species which include gizzard shad and white perch in addition to yellow perch. In addition, walleye may compete for food with increasing number of littoral predators such as smallmouth and largemouth bass. Exploring these alternative explanations is ongoing and the topic of two PhD theses in progress (Fetzer and DeBruyne).

Yellow perch

Adult yellow perch numbers were estimated in 2008 from the catches in standard gill nets and estimates of catchability (Forney et al. 1994). The yellow perch population was estimated to be 1.6 million age 3 and older fish, which is larger than our estimates from 2003 to 2007 (Fig. 11 Appendix Table A5). The yellow perch population has been increasing slowly since 1997. A decline from 1990 to 1997 has been reversed. We attributed that decline to cormorant predation (Rudstam et al. 2004) and the reversal of the decline is consistent with expected responses to current cormorant control. Rudstam et al. (2004) predicted the yellow perch adult population to rebound to around 1.6 million fish by 2006 if cormorants were removed in 1998, a population size that we may now have reached. Because our estimates are based on gill net catches, variability is relatively high between years. Mark-recapture estimates with the method we used in the past are no longer practical for yellow perch because too few fish can be marked in the spring to get a reasonable estimate.

Our predictions of future recruitment to the adult population from catches of age-1 perch in bottom trawls are now more similar to the pre-cormorant years than the cormorant years (Rudstam et al. 2004, Fig. 12). Using the pre-cormorant regression, we predict that the year class of 2006 will yield 443,000 fish to the adult yellow perch population in 2009 and the year class of 2007 will yield 234,000 adult perch in 2010. With the average annual mortality of adults observed since 2003 (24%), the perch population is expected to stay above 1.5 million fish through 2010 (Fig. 11).

We also measure abundance of yellow perch at the larval stage (8 and 18 mm), in bottom trawls through the summer, and again in the trawls centered on May 1 (Appendix Table A6). We use the decline in catches in the bottom trawl to estimate age-0 yellow perch abundance on Aug 1 and Oct 15. Data from the 18 mm survey and Oct 15 are presented in Fig 13. The two data series are correlated, although only 16% of the variation in Oct 15 numbers can be predicted from the abundance of 18 mm larvae ($R^2 = 0.162$, $N = 43$, $P = 0.007$). Recent high abundance on October 15 occurred in 1999, 2002 and 2007, with the 2007 number being the highest since 1985. Abundance of age-0 yellow perch in 2008 was very low.

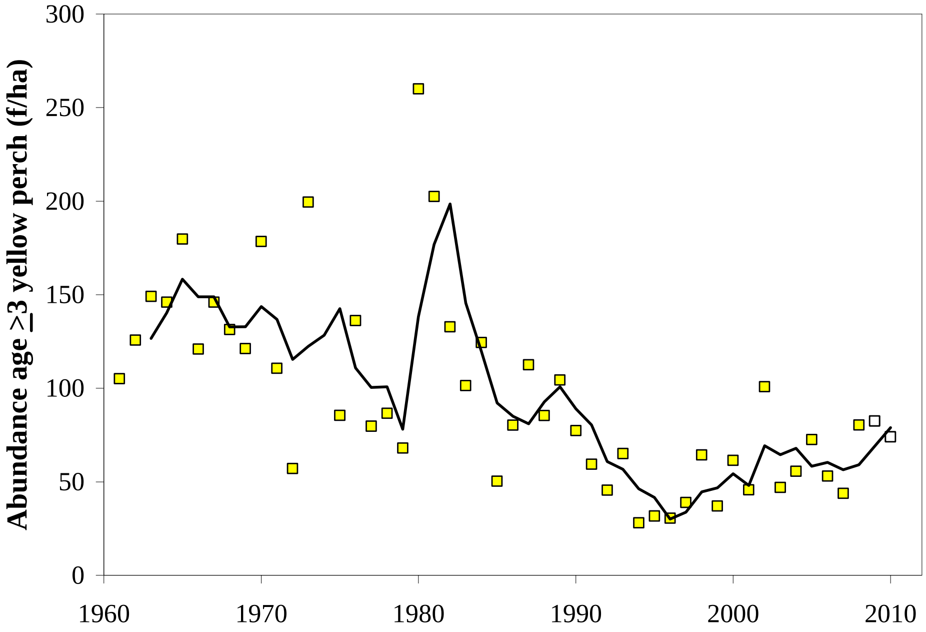


Figure 11. Age≥3 yellow perch densities (#/ha) since 1961. Open squares are predictions for 2009 and 2010.

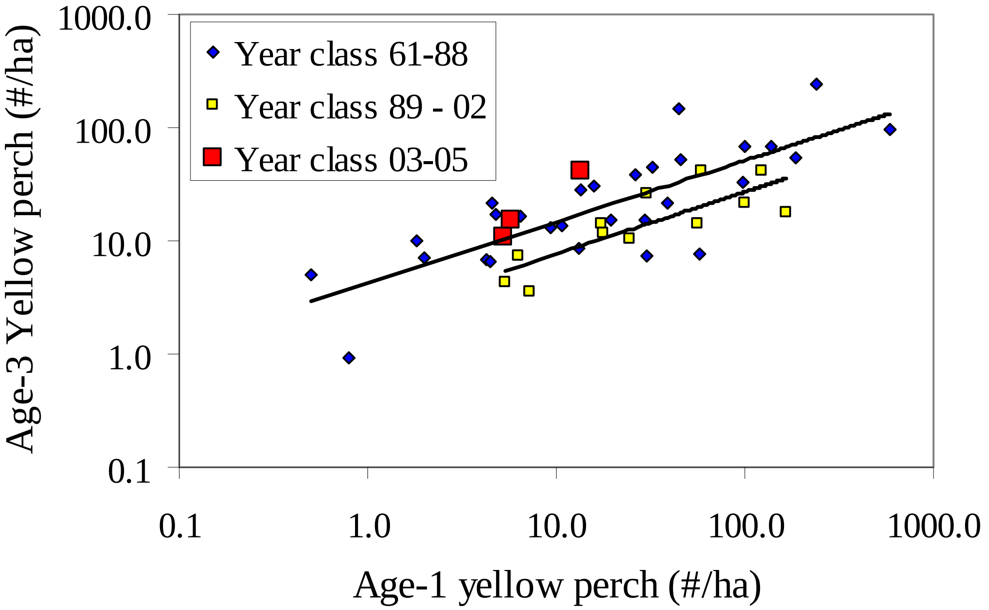


Figure 12. Relationship between age 1 yellow perch caught in bottom trawls and subsequent recruitment to age 3 yellow perch (updated from Rudstam et al. 2004). The upper regression is for the pre-cormorant years and the lower regression is for the post-cormorant years. The most recent years with more intense cormorant management are for year class 03-05 and are not included in the regressions.

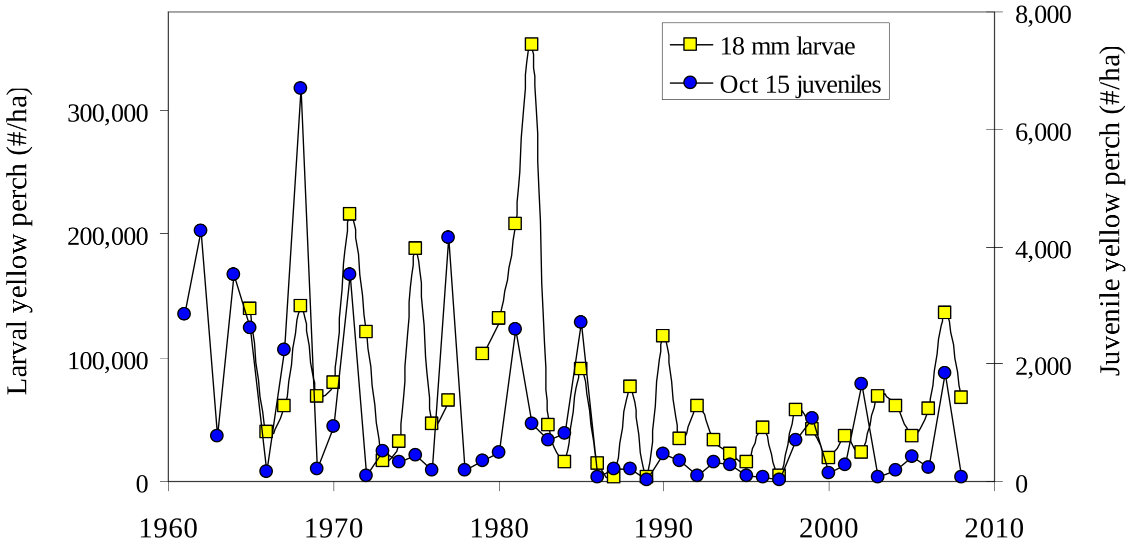


Figure 13. Abundance of yellow perch larvae (at 18 mm length, left axes) and on October 15 (right axes).

Interestingly, the 2007 year class did not show up in the expected large numbers in the spring of 2008, although densities (245 fish/ha) were above the average for the 1990 – 2006 year classes (average 200 fish/ha, Fig. 14). The relatively low over-winter survival of the 2007 age-0 yellow perch year class is surprising because the average length of these fish was relatively high (81 mm, average since 1992 - 82.3 mm). Age-0 yellow perch growth rate is density dependent and size in the fall has increased over time, which is consistent with lower abundance (Irwin et al. 2009). Large size in the fall results in better over-winter survival (Fitzgerald et al. 2006, Irwin et al. 2009), but the gizzard shad population which buffer yellow perch from walleye predation in the winter (Fitzgerald et al. 2006, Fetzer in prep), was low in 2007. Nor were there many age-1 yellow perch caught in summer-fall bottom trawls. The summer trawl catches of age-1 yellow perch have been low since 1999 (Fig. 14). This is a cause of concern, as age-1 yellow perch numbers in trawls are a reasonable predictor of future recruitment to the fishery (see Fig. 12). However, we do note that recruitment of age 3 from the 2005 year class was above expectations from the trawl catches. This may be the result of changes in distributions associated with increased water clarity and macrophyte coverage. This is being investigated by Fetzer (PhD thesis).

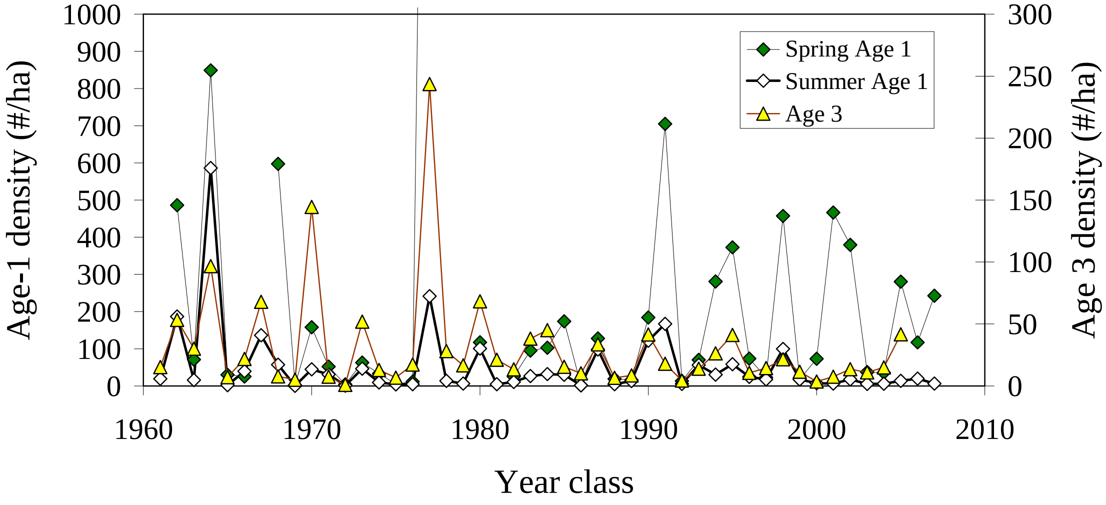


Figure 14. Abundance of age 1 yellow perch in the spring and summer-fall bottom trawls as well as abundance of the same year class as age-3 based on gillnet catches.

White perch

White perch is the second most abundant species caught in standard gill nets. This species has increased in recent years and catches have been over 200 fish per year since 1999 (Appendix Table A7). Recruitment is variable and poorly correlated with abundance of age-0 fish caught in bottom trawls in September – October (Fig. 15). Young white perch are known to be sensitive to cold winters (Johnson and Evans 1991), but we were not able to correlate over-winter survival with ice duration in Oneida Lake (Fitzgerald et al. 2006). The low recruitment years from 1988 to 1994 may be related to a disease that caused large kills of adult white perch in 1987 and 1988. White perch diets are similar to yellow perch, although they appear to feed more on larval fish early in the season. Increases in white perch could therefore be part of the explanation for increased early mortality of larval percids.

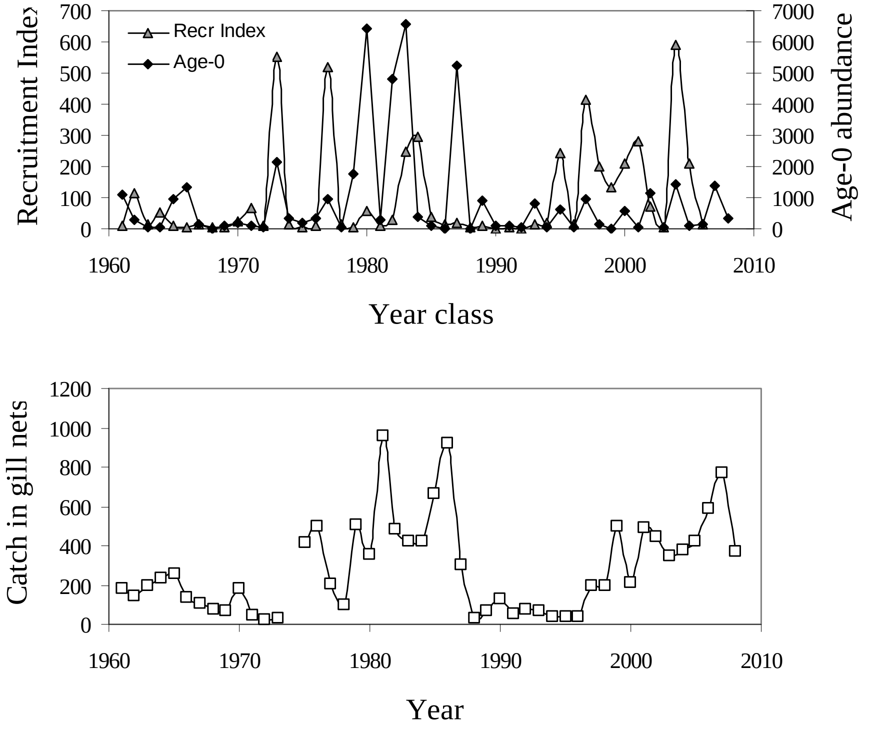
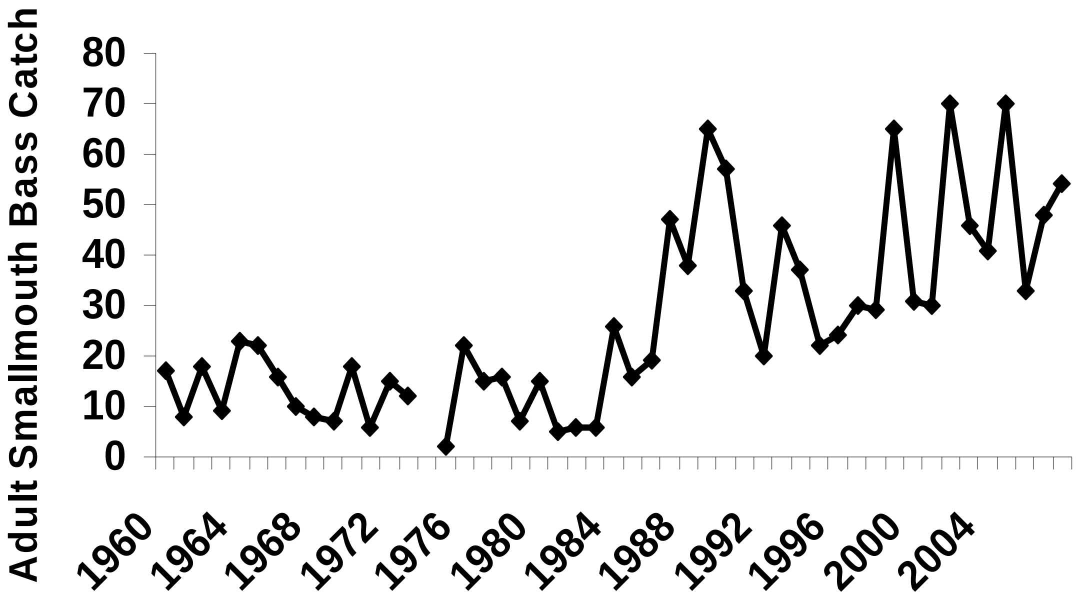


Figure 15. Upper panel: abundance of age-0 white perch in bottom trawls in September-October (fish/ha) and the recruitment index calculated as the sum of catches of age 2 and 3 in the standard gill nets from that age class. Lower panel is the time trend in gill net catches.

Smallmouth bass

Smallmouth bass are important both because they are a major sport fish in Oneida Lake, and because the species is increasing and can have large effects on littoral fish communities when abundant (VanderZanden et al. 1999, Lepak et al. 2006). Catches of age-0 smallmouth bass were among the highest on record in our bottom trawl in both 2007 and 2008 and catches in standard gill nets are also high (Fig. 16). We expect that the year classes of 2007 and 2008 are strong and that catches in gill nets will increase. We are investigating diets of smallmouth bass monthly from June through October (Fetzer PhD thesis). Although fish (age-0 and age-1 yellow perch, age-0 gizzard shad) are common, the diet of smallmouth bass also consists of invertebrates like crayfish. Walleye are more piscivorous than either black bass species in Oneida Lake. We did find an age-0 walleye in a smallmouth bass stomach in June 2008, but the number of young walleye in the black bass diets (both species) is substantially less than the number found in adult walleye. More detailed analysis of this data set is part of Fetzer's PhD thesis.



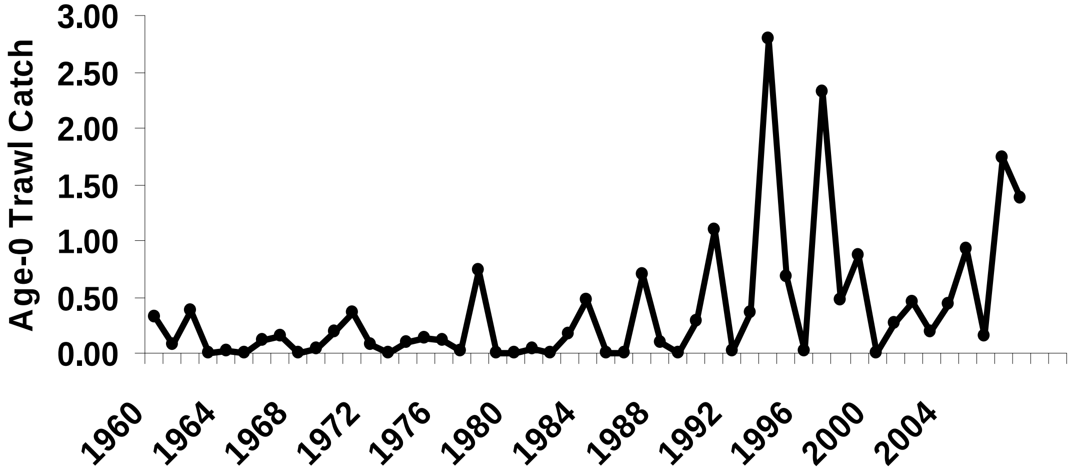


Figure 16. Time trends of smallmouth bass catches in standard gill nets and bottom trawls.

Open water forage fish (gizzard shad and emerald shiner)

Pelagic fish biomass was estimated in 2008 on September 2 and 3. Total pelagic fish density was estimated to be 10,400 fish/ha of which 7900 fish/ha were age-0 emerald shiner *Notropis atherinoides*, 381 were age 1 emerald shiner, and 2070 were gizzard shad (Appendix Table A8). Biomass was estimated at 22.5 kg/ha, of which 14.6 kg/ha was gizzard shad. Although the abundance of gizzard shad was up slightly from 2006 and 2007, the fish were relatively small (7 g) and the biomass similar to previous years. The combined abundance of gizzard shad and emerald shiners in 2007 (the year for which we have estimated walleye growth in this report) was the lowest since acoustic surveys were initiated in 1995, and combined biomass was about half of the long-term average. Gizzard shad typically constitute the majority of the pelagic biomass (65% in 2008) even though emerald shiners are sometimes more abundant numerically. Few shad appear to have survived the winter, and most adult gizzard shad in Oneida Lake are still from the 2005 year class, when the weight of age-0 shad in September averaged 21.6 g, three times larger than the weight of the age-0 shad in 2008. It is noteworthy that gizzard shad were the most common diet items of walleye in October 2008 even though abundance of shad was not high (Appendix Table A3). This may be partly due to the relatively low abundance of other forage fish in 2008 (such as age-0 yellow perch and age-0 white perch).

Sturgeon

May lake sturgeon *Acipenser fulvescens* catches from directed sampling with large mesh gill nets declined from those observed in 2007 (Appendix Table A9). The May gill net catch per hour in 2008 was 0.17/h, compared to 0.30/h in 2007. June catches (0.13/hr) were slightly higher than observed in the previous three years (0.11/hr). Sturgeon likely do not begin to fully recruit into our nets until age-5 or older, and out-migration does take place, so catches from the year classes stocked between 1995 and 2000 might be expected to exhibit declines. New year classes recruiting to the gear will be the small 2003 stocking (368 fish, average total length 233 mm) and a larger 2004 stocking (1200 fish, average total length 187 mm), which will reach age-5 in 2008 and 2009. As the 2004 stocking recruits, we would expect to see increases in spring gill net catches. Length and weight data from collected sturgeon still indicate a population with fish in excellent condition that are growing at high rates. Fish over 140 cm total length (TL) are routinely encountered and one fish over 32 kg was captured in 2008. We still have not seen evidence of ripe females or attempted spawning, but efforts to survey potential spawning areas in the spring have not been undertaken. There have been tag returns from fish running up spawning streams (Fish Creek). Males appear to reach maturity in Oneida Lake at age 8, so several year classes of mature males are now present in the lake.

Double-crested Cormorants

The double-crested cormorant population was managed on Oneida Lake in 2008, continuing a program initiated in 1998 and expanded in 2004. The population goals established by NYSDEC for 2004 to date included 100 adult cormorants and 20 active nests, with no successful hatching. In 2008, cormorant numbers averaged 60 birds in April and May, around 8 birds in June and July, and increased to around 200 in August through October. Diets of 169 cormorants collected by USDA APHIS NY Wildlife Service personnel from April through October were examined by CBFS staff. Of the 1953 identifiable items recovered from stomachs, gizzard shad accounted for 87% (1657 age-0 gizzard shad and 32 adult gizzard shad). Other species found in stomachs in decreasing order of abundance included emerald shiners (6%), yellow perch (5%), and white perch, walleye, pumpkinseed sunfish, smallmouth bass, rock bass, and burbot, combined accounted for the remaining 2%. Young-of-year gizzard shad did not appear in cormorant diets until late July and August. Given the importance of gizzard shad in cormorant diets in the fall and the low cormorant abundance throughout the summer, cormorants should not have had a measurable effect on percids in 2008, however sample sizes from the spring and early summer period were small (April = 10 birds; May = 0 birds; June = 5 birds; July = 16 birds).

2008 Nearshore Sampling

In 2007, 24 sites were selected around the lake representative of nearshore habitat types. Sites were selected to represent the common substrates in the nearshore in the proportions they occur and distributed around both shores of the lake as evenly as possible while still achieving representation of all habitats. Each site was sampled via 24 hour sets of a fyke net comprised of a 0.9 m x 1.5 m frame fitted with 12.7 mm (1/2”) delta knotless mesh. Additionally, several sites were also sampled with a fyke net comprised of a 0.9 m x 1.5 m frame fitted with 5 mm (1/4”) delta knotless mesh to assess level of recruitment by young-of-year bass into the larger mesh. Catches indicated that while recruitment into the larger mesh had occurred for larger bass in the cohorts of both species, some smaller bass were likely missed by the nets fit with the larger mesh.

Comparisons of bass catches in the two mesh sizes were repeated in 2008. Results suggested slower bass growth in 2008 than previous years, and as a result, catches were conspicuously higher in the smaller mesh nets than the larger mesh. Assessment of length-frequency distributions in the two net styles suggests that bass do not recruit into the 12.7 mm mesh until they reach total lengths of 85 mm or more (Fig. 17).

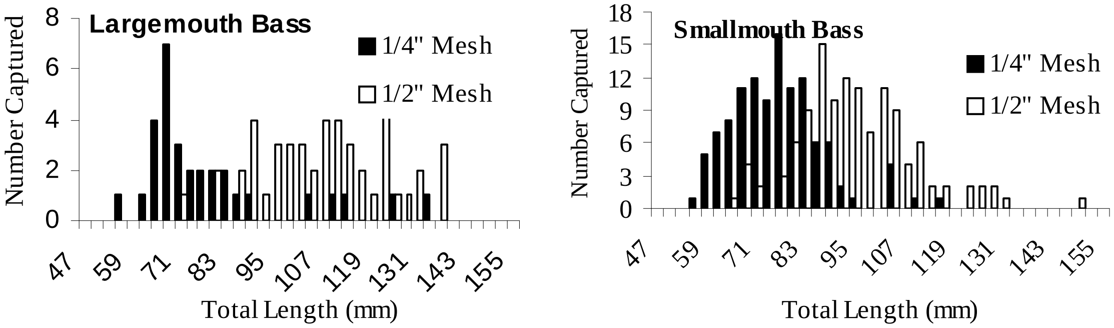


Figure 17. Length frequencies of bass captured in fyke nets with different mesh sizes.

Based on observed growth rates of young of year bass during initial nearshore gear assessments during 2005-2006, we had anticipated that bass would fully recruit into the ½” mesh by September. Reassessment now suggests that the summers of 2005 and 2006 were characterized by above average temperatures and faster than average bass growth rates. If first year bass growth is largely temperature dependent, then efficiency of the ½” mesh fyke nets will vary from year to year based on growth differences and therefore not provide a reliable index.

Because of observed inefficiencies in the ½” mesh fyke nets at sampling smaller young of year bass, we modified the nearshore fyke net protocol to add overnight sets of ¼” mesh fyke nets at 14 of the 24 original sites. The ½” fyke net samples should still provide reliable indices of most common nearshore species, but the ¼” mesh nets will need to be used to develop a reliable young of year bass index that is not sensitive to annual differences in bass growth.

The 2008 nearshore fyke net survey was conducted between 18 September and 7 October, and consisted of 24 hour sets of the ½” mesh fyke nets at the same sites used in 2007 as well as 24 hour sets of the ¼” fyke net at 14 sites concurrent with sets of the larger mesh nets. Total catch was 1477 fish in the ½” mesh nets and 1040 in the ¼” mesh nets. Twenty-two unique species were captured by the ½” mesh nets (compared to 26 in 2007) and 19 in the ¼” mesh nets (Table 4). With few exceptions, catch rates in the ½” mesh nets for most common species were similar to rates observed in 2007, with no observed increases or decreases in catch rates beyond what would be expected due to normal sampling variability. Catch rates of YOY smallmouth bass and YOY yellow perch appear to be lower in 2008 than in 2007 (Table 4), which at least for YOY yellow perch is consistent with results from trawl sampling. Sampling under the new protocol will continue in 2009.

Table 4. Fyke net catches, Oneida Lake 2007-2008 (1/2” Mesh n=24 sites; ¼” mesh n=14 sites).

		Mean Catch/Net (±1SE)		
		2007	2008	
Scientific Name	Common Name	½” Mesh	¼” Mesh	½” Mesh
Family Lepisosteidae				
Lepisosteus osseus	Longnose gar (Adult)	0.04 (±0.04)	0.00	0.00
Family Amiidae				
Amia calva	Bowfin (Adult)	0.13 (±0.07)	0.14 (±0.14)	0.25 (±0.17)
Family Clupeidae				
Dorosoma cepedianum	Gizzard shad (YOY)	0.08 (±0.06)	0.07 (±0.07)	0.21 (±0.10)
	Gizzard shad (Adult)	0.08 (±0.06)	0.00	0.17 (±0.10)
Family Cyprinidae				
Cyprinus carpio	Common carp (Adult)	0.00	0.00	0.04 (±0.04)
Notemigonus crysoleucas	Golden shiner (All)	0.17 (±0.13)	0.07 (±0.07)	0.46 (±0.42)
Notropis atherinoides	Emerald shiner (All)	0.00	0.07 (±0.07)	0.04 (±0.04)
Notropis hudsonius	Spottail shiner (All)	0.13 (±0.07)	0.00	0.00
Pimephales notatus	Bluntnose minnow (All)	0.00	0.21 (±0.21)	0.00
Family Catostomidae				
Catostomus catostomus	Longnose sucker (Adult)	0.04 (±0.04)	0.00	0.00
Catostomus commersoni	White sucker (YOY)	0.00	0.00	0.17 (±0.10)
	White sucker (Adult)	0.58 (±0.19)	0.00	0.67 (±0.17)
Erimyzon oblongus	Creek chubsucker (All)	0.04 (±0.04)	0.00	0.00
Moxostoma valenciennesi	Greater redhorse (Adult)	0.04 (±0.04)	0.00	0.04 (±0.04)

Family Ictaluridae				
Ameiurus natalis	Yellow bullhead (YOY)	0.00	0.07 (±0.07)	0.08 (±0.08)
	Yellow bullhead (Adult)	0.17(±0.10)	0.50 (±0.23)	0.46 (±0.18)
Ameiurus nubulosus	Brown bullhead (YOY)	0.04 (±0.04)	0.00	0.00
	Brown bullhead (Adult)	0.79 (±0.32)	0.50 (±0.37)	0.88 (±0.35)
Family Esocidae				
Esox niger	Chain pickerel (YOY)	0.29 (±0.15)	0.00	0.08 (±0.06)
	Chain pickerel (Adult)	0.08 (±0.06)	0.00	0.00
Family Gadidae				
Lota lota	Burbot (Adult)	0.04 (±0.04)	0.21 (±0.15)	0.04 (±0.04)
Family Cyprinodontidae				
Fundulus diaphanus	Banded killifish (All)	0.04 (±0.04)	0.36 (±0.17)	0.00
Family Percichthyidae				
Morone americana	White perch (YOY)	1.58 (±0.72)	0.00	0.04 (±0.04)
	White perch (Adult)	0.04 (±0.04)	0.00	0.08 (±0.06)
Family Centrarchidae				
Ambloplites rupestris	Rock bass (YOY)	0.50 (±0.19)	1.57 (±0.57)	1.00 (±0.30)
	Rock bass (Adult)	2.58 (±0.56)	2.00 (±0.48)	1.91 (±0.36)
Lepomis cyanellus	Green sunfish (Adult)	0.21 (±0.10)	0.29 (±0.19)	0.13 (±0.09)
Lepomis gibbosus	Pumpkinseed (Adult)	9.54 (±2.34)	2.0 (±1.12)	12.75 (±4.40)
Lepomis macrochirus	Bluegill (Adult)	2.58 (±1.02)	2.43 (±0.92)	3.58 (±1.23)
Lepomis spp.	(YOY - <75mm)	3.29 (±1.39)	43.29 (±17.33)	3.38 (±1.09)
Micropterus dolomieu	Smallmouth bass (YOY)	11.58 (±2.83)	12.00 (±5.34)	4.75 (±1.13)
	Smallmouth bass (Adult)	0.00	0.07 (±0.07)	0.08 (±0.06)
Micropterus salmoides	Largemouth bass (YOY)	1.25 (±0.42)	2.57 (±0.89)	1.96 (±0.53)
Micropterus salmoides	Largemouth bass (Adult)	0.08 (±0.08)	0.07 (±0.07)	0.38 (±0.38)
Pomoxis nigromaculatus	Black crappie (YOY)	0.08 (±0.06)	0.07 (±0.07)	1.95 (±0.53)
	Black crappie (Adult)	2.29 (±1.00)	0.21 (±0.15)	1.08 (±0.41)
Family Percidae				
Perca flavescens	Yellow perch (YOY)	18.21 (±4.68)	18.14 (±5.95)	1.50 (±0.56)
	Yellow perch (Adult)	16.04 (±3.33)	2.00 (±0.98)	26.08 (±6.57)
Percina caprodes	Logperch (All)	0.08 (±0.08)	0.07 (±0.07)	0.08 (±0.06)
Etheostoma olmstedi	Tessellated darter (All)	0.00	0.07 (±0.07)	0.00
Sander vitreus	Walleye (YOY)	0.17 (±0.08)	0.00	0.38 (±0.21)
	Walleye (Adult)	0.54 (±0.12)	0.00	0.50 (±0.17)

Family Sciaenidae				
Aplodinotus grunniens	Freshwater drum (Adult)	0.04 (±0.04)	0.00	0.00
Mean Total Catch/Net		**70.58 (±8.99)**	**86.64 (±23.49)**	**61.54 (±9.48)**
Mean # Species/Net		**8.08 (±0.53)**	**6.21 (±0.49)**	**7.54 (±0.55)**

Recommendations for management and future research directions.

Last year we identified several ongoing ecological changes that are likely to affect the fish community in Oneida Lake. These included climate warming, species invasions, and increased water clarity. The data collected in 2008 are consistent with these trends. The lake was 0.8 ^{o}C warmer and had 10 days shorter ice duration than the long-term average (1975-2008), water clarity was second highest on record, and a new invader was documented in the lake (the quagga mussel). In the future, we expect further increases in temperature, decreases in ice duration with intermittent ice break-up, increases in water clarity, and additional invasions. Four invasive species are possible, the round goby (*Neogobious melanostomus*), the spiny waterflea (*Bythotrephes longimanus),* the fish hook waterflea (*Cergopagis pengoi*) and the littoral mysids ("the bloody red shrimp" *Hemimysis anomala*). Continuing analysis and monitoring of the Oneida Lake data set should not only give us information on the response to these ongoing ecological changes of lakes and fisheries that is relevant to Oneida Lake, but also to the northeastern US and southeastern Canada. A baseline data series is essential for evaluating system responses to ecological change. In addition, we are evaluating cormorant-percid interactions by observing the response of the Oneida fish community, in particular walleye and yellow perch, to the removal of most cormorants from the lake. This represents a whole lake management experiment, and it is important that this effort is evaluated thoroughly. We have an opportunity to do adaptive management as it was intended (Walters 1986) by making monitoring and evaluation an integral part of management. It is also important because similar cormorant management activities are planned for other lakes in the US and Canada.

We made the following predictions specific to the fish community of Oneida Lake in VanDeValk et al. (2008b). Data from 2008 largely support these predictions.
Prediction 1: Cold water fish like burbot and cisco Coregonus artedi *will be extirpated from Oneida Lake.* We continue to see low burbot catches relative to historic data and cisco have been all but absent from samples since the 1980s.
Prediction 2. Littoral species such as black bass, other centrarchids, esocids, as well as bowfin and longnose gar will increase in importance and play a larger role in the fish community dynamics of the lake. Littoral and benthic species are increasing. Pumpkinseed and bullheads were more common in samples in recent years. Smallmouth bass are abundant and largemouth bass likely increasing.
Prediction 3. Gizzard shad will become the dominant fish species by weight in Oneida Lake. White perch will also increase. Although not as abundant as in 2007, both species maintain high abundance in 2008.

Prediction 4. Gobids will invade Oneida Lake and become abundant. The importance of benthic production will increase. We have not yet found gobids in the lake although they are present in Oswego harbor and to the west in the Erie Barge Canal.
Prediction 5. The walleye and yellow perch populations will maintain populations at current levels for the foreseeable future. Populations of both species are similar or higher than 2007 although low numbers of young fish are a cause for concern. Poor growth rates of walleye suggest that the population is close to the maximum sustainable by the current complement of forage fish species.

We suggest the development of new indices for walleye management based on walleye growth rates to complement our current management plan that is based on walleye biomass and predicted future recruitment (Forney 1980). Walleye growth is variable and correlated with prey abundance, at least in 1961 - 1983 (VanDeValk et al. 2008a, Fig. 9). Current slow growth rates indicate a high walleye population relative to their prey supply and abundance of walleye in Oneida Lake is high compared to other lakes. The TP levels indicate that the lake is no longer eutrophic; TP concentrations are at levels expected for mesotrophic lakes. It is well established that overall fish production increases with increased primary productivity of a system (Downing and Plant 1993, Jeppesen et al. 2000). However, it is unclear if the overall primary productivity of Oneida Lake has declined with decreased nutrient loading, both because of a compensatory increase in production per unit phytoplankton biomass (Idrisi et al. 2001) and because of increased benthic primary production (Cecala et al. 2008). It is also intriguing that growth in yellow perch has increased (Mayer et al. 2000, 2001), total zooplankton biomass has increased over time (Table 1), and benthic production has increased (Mayer et al. 2002). Two processes are likely operating; the decrease in production associated with decreased nutrient loading, and an increase in benthic production associated with benthification through zebra and quagga mussel activities. In any case, the management options for Oneida Lake were developed when water clarity was half and phytoplankton biomass twice the current values. Walleye growth rate is an attractive indicator in a changing ecosystem where the effect of ecosystem change on the potential for walleye production is uncertain. It is a way of letting the walleye tell us how much biomass can be supported by the production potential of the lake. The disadvantage with relying solely on a growth index is that we will not be able to have pro-active regulation changes that respond to anticipated future changes to the adult population. We therefore propose to revise the management plan to include both a growth index and a prediction of future recruitment.

In the short term, we do not believe that management should strive to increase walleye abundance in Oneida Lake much higher than the 400,000 fish currently supported in the lake. Higher abundance may lead to further declines in growth rates and likely limit recruitment of both walleye and yellow perch. Of course, if growth rates increase in the future, this recommendation should be revisited. If growth rates continue to decline, it may be wise to consider less restrictive regulations. However, our analyses to date suggest that catch rates should increase when walleye growth rate is low, leading to higher angling mortality and decreased population abundance without changes in regulations (VanDeValk et al. submitted).

Recommendation for current management: Fisheries management on Oneida Lake includes stocking of walleye larvae, size and creel limits for walleyes, black bass, and other species, and control of cormorants. We recommend maintaining these efforts and regulations at current levels in 2009-2011.

Stocking of walleye larvae. Continue stocking at current levels. This will maintain a consistent supply of walleye larvae to the lake and makes walleye less sensitive to potential increases in egg predation from a future abundant gobid population. Our best estimates suggest that the number of naturally produced walleye larvae in the lake is about 25% of the numbers stocked.

Size and creel limits for walleye. The adult walleye population is estimated to be 406,000 fish in the spring of 2008 which is similar to 2002-07. The poor growth rates of walleye in the lake do not indicate a need for protecting the current population. Therefore, maintain the current size limit for Oneida Lake walleyes at 15 inches. A 5 fish creel limit can be considered if there is a need to be consistent with statewide regulations.

Cormorant control. We have observed an increase in both the walleye and the yellow perch population concomitant with more intensive cormorant control. This suggests that removing cormorants does increase percid recruitment. Current more-intensive cormorant control by APHIS has been ongoing since 2004, and we intend to fully evaluate the response of the fish populations to this management action through DeBruyne's PhD thesis. Therefore, it is important to continue this management, although removing cormorants from the lake may be possible with less effort, and allowing a few cormorants to nest and produce young would simplify diet analysis.

Given the result and discussion in this report, we recommend the following research and monitoring activities in 2009:

1) Continue standard sampling program. This program includes two larval fish sampling surveys (8 and 18 mm yellow perch surveys), 15 standard gill nets, weekly trawl surveys from August 1 through October, pelagic prey fish survey with acoustics, midwater trawl and pelagic gill nets at the end of August, fyke net sampling for nearshore fish in September, and large mesh gill nets for sturgeon. We recommend that the next walleye mark-recapture estimate be conducted in 2010.

2) Evaluate walleye growth as an indicator for change in regulations. Compare walleye growth with prey abundance indices, and compare different growth indices available in the literature.

3) Examine the yellow perch data set for patterns in mortality using modern estimation models (ADmodel Builder). This is part of Robin DeBruyne's PhD thesis.

4) Continue the evaluation of cormorant management on percid populations including publication of chapters in Jeremy Coleman's PhD thesis and the analysis of PhD student Robin DeBruyne. This is a collaborative project with USDA-APHIS.

5) Finish analysis of over-winter mortality of gizzard shad (Fetzer M.Sc. thesis)

6) Finish analysis of creel survey techniques (Krueger M.Sc. thesis).

7) Increase attention to the effect of alternative prey fish species on the interaction between walleyes and yellow perch and the importance of changing spatial distributions for age-0 yellow perch survival (Fetzer PhD thesis).

8) Develop better methods for estimating open-water prey fish abundance in surface waters (e.g., horizontal beaming acoustics).

9) Develop a low cost creel survey for monitoring of catch rates and angler use of the lake

10) Develop a sampling strategy to monitor the largemouth bass population in Oneida Lake.

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Appendix 1: Data collection methods

Limnology. Zooplankton samples are collected weekly (May-October) from 2-5 sites with a 153 um mesh nylon net (0.5 m diameter) using a vertical tow from 0.5 m above the bottom to the water surface. Samples are preserved in 70% ethyl alcohol (8% sugar-formalin solution 1975-1996). Zooplankton are identified, counted, and measured (to the nearest µm) using a digitizing tablet and microscope (1998 – present). Previous methods include use of a dissecting microscope and calipers (1975-1982), and a touch screen setup with computer-assisted plankton analysis system WSAM (1983-1997) (Hambright and Fridman 1994). Seasonal mean biomass is calculated from weekly averages. Integrated water samples for total phosphorous (TP) and soluble reactive phosphorous (SRP) are collected using a 1.9 cm inside diameter Nalgene tube lowered to a depth of 1 meter above bottom, and frozen for later analysis. In the lab, a 50 mL aliquot of unfiltered water is analyzed for TP using the persulfate digestion method (Menzel and Corwin 1965). For SRP, lake water is filtered through a Whatman 934-AH glass fiber filter and a 50 mL aliquot is analyzed using the molybdate method of Strickland and Parsons (1972). For chlorophyll-*a* measurements, lake water (up to 2.0 L) is filtered through Whatman 934-AH glass fiber filters and the filters are assayed using the acetone extraction method (Strickland and Parsons 1972). Annual averages are calculated as the average of weekly values at 2 to 5 stations from May to October. All 5 stations are included when available, except for Secchi depth from the shallow station (Three Mile Bay) because the Secchi disk is sometimes observed on the bottom.

Larval fish surveys: Miller high-speed sampler surveys are designed to estimate abundance of larval walleye and yellow perch. Larval walleye and yellow perch are sampled when yellow perch reach approximately 8 mm and again at approximately 18 mm. For each survey, the lake is divided into two or more horizontal and vertical depth strata and samples taken at a total of 46 randomly selected sites within designated strata. At each site, four Miller samplers are towed simultaneously at different depths and catches are pooled by stratum. Distance towed is about 1.6 km at a speed of 3.6 m/s. Larval fish captured are identified, counted, and measured. Density estimates are calculated for each strata based on catch and volume of water strained. Catches of yellow perch in the 18 mm survey are adjusted for size-specific gear avoidance (Noble 1970).

Gill net surveys: Standard gill net catches provide an index of the adult walleye and yellow perch populations as well as relative abundance estimates of various other species. A variable mesh multifilament gill net is fished overnight at a different standard site each week for 15 consecutive weeks starting in the beginning of June and continuing through mid-September. The net consists of four gangs 45.75 m long by 1.83 m deep sewn together to form one 183 m long net. Each gang consists of six 7.6 m panels with 38, 51, 64, 76, 89 and 102 mm stretch mesh. The net is set around sunset, fished on the bottom, and retrieved in the morning at about 07:30. The time fished varies somewhat with season but has been identical for each location each year. All fish (or a subsample of at least 60 individuals of a species) are measured (total length in mm), weighed (g), sexed, stomach contents recorded, and scales taken. Large mesh gill nets were used to monitor sturgeon reproductive status and abundance and growth in 4 different substrate types. Variable (152, 203, 254, and 305 mm stretch mesh) mesh monofilament gill nets 61 m in length were set for approximately 4 hours at 12 sites monthly in May and June. All sturgeon caught were examined for tags, measured, weighed, a fin ray section removed for age determination, diet recorded using gastric lavage, tagged with both a Carlin dangler tag and PIT tag, and released.

Trawl surveys: The catch in trawls provides an estimate of year class abundance for young-of-year (age-0) and yearling walleye as well as prey species, primarily young yellow perch. Trawling begins around the middle of July when age-0 yellow perch become demersal (at about 1 g in weight) and weekly surveys continue until three October surveys are completed. A 5.5 m otter trawl is towed for 5 minutes, sampling approximately 0.10 ha per haul. Ten standard sites are sampled in each survey. Age-0 fish are identified, counted, total weight by species recorded to the nearest gram, and a subsample of fish measured for length. Lengths are recorded and scale samples taken on all older fish.

Hydroacoustic surveys: Pelagic fish biomass is estimated in the end of August–beginning of September using hydroacoustics. Surveys are conducted using a 123 kHz split beam unit (Biosonics DT-X, pulse length 0.4 ms, 7.8° beam width) along a set of transects from the east to the west ends of the lake. Surveys are typically conducted during two consecutive nights starting one hour after sunset. Acoustic data are analyzed with EchoView (v4.4 in 2008). Echograms are checked for problems associated with poor bottom detection, bubbles from waves, echoes from macrophytes, and other sources of noise. Questionable areas are removed from the analysis. Attempts are made to sample as close to the bottom as possible by re-defining the bottom at high magnification when needed. All densities are calculated from in situ backscattering cross section (average for targets larger than –60dB) and echo integration according to the standard operating procedure for Great Lakes acoustics (Parker-Stetter et al. 2009). Noise level at 16 m, the maximum depth in Oneida Lake is estimated to be –85 dB (uncompensated TS) thus satisfying a 15 dB signal to noise ratio throughout the water column for the smallest targets included in the analysis as recommended by Rudstam et al. (2009). Analyses are conducted using each transect as cluster of elementary sampling units 500 m in 2008 (1000 pings in some years – approximately 520 m). Cluster analysis was used to estimate mean density and standard error using standard formulas (Scheaffer et al. 2006) and a program available on the web site “Acoustics Unpacked” (www.acousticsunpacked.org, Sullivan and Rudstam 2008).

Fish are sampled in association with acoustic surveys using a midwater fry trawl and fine mesh gill nets. These gears are used to assess the species composition of young fish in the pelagic zone. The trawl measures 2 m x 2 m at the mouth and is mounted in a metal frame. The first 2 m of the net is comprised of 12.7 mm stretch mesh, the next 2 m of 6.4 mm stretch mesh, and the cod end of the net consists of a 0.5 m plankton net and bucket with 1 mm mesh. At each site, one haul divided into 2.5 minutes at 4.3 to 6.1 m depth and 2.5 minutes at 2 to 3.8 m depth (determined from rope angles) and a second 5 minute haul at the surface (sampling the top 2 m of the water column) are conducted. Two trawl hauls are completed at each of 10 sites, and fish are preserved in formalin and returned to the lab for species identification, enumeration, and measurement. Fine mesh gill nets, 21 m long, are set either on bottom or suspended from the surface. Each gill net consists of seven 3 m wide by 6 m deep panels of different mesh sizes (6.2, 8.0, 10.0, 12.5, 15.0, 18.7 and 25.0 mm bar mesh). Paired (1 surface and 1 bottom) gill nets are set at each of 4 deep stations, and 4 shallow stations are sampled with only 1 net that samples the entire water column.

Acoustic density estimates are apportioned to emerald shiners, gizzard shad, and other fish based on catches in vertical gill nets and midwater trawls after accounting for the relative length selectivity and effort of the two gears. Fish in the top 2 m of the water column are accounted for by calculating the average density of gizzard shad and emerald shiners caught in the top 2 m in vertical gillnets set in 2008 (1.67 for gizzard shad, 1.55 for emerald shiner).

Appendix 2: Standard data tables.

Table A1. Physical, chemical and biological characteristics of Oneida Lake since 1975. Secchi depth (m), chlorophyll-*a* (µg/L), total phosphorous (TP, µg/L) soluble reactive phosphorous (SRP, µg/L), total zooplankton biomass (µg/L), and *Daphnia* spp. biomass (µg/L) are averages from 2 to 5 stations from May to October. Ice freeze day (day since Dec 1), ice duration and ice out day (day of year) are noted at CBFS and refer year refer to the year of ice break-up. The lake was not completely frozen over in the winter of 2001. Summer temperature (^{o}C) is the average temperature from June to Aug measured every hour at 2 m depth at the Shackelton Point station.

Year	**Secchi**	**Chl-*a***	**SRP**	**TP**	**Zoopl. Biomass**	***Daphnia* Biomass**	**First Freeze Day**	**Ice Duration**	**Ice Out Day**	**Sum Temp**
1975	2.7	9.2	17.7	45.9	101.8	74	no data	no data	87	22.2
1976	2.8	9.9	3.3	29.4	192.2	162.4	19	99	87	20.6
1977	2.6	11.1	5.2	36.2	136.4	52.7	3	118	90	20.9
1978	2.9	8.1	16.5	44.7	no data	42.4	15	121	105	22.0
1979	3.2	7.6	29.0	56.7	204.9	157.3	29	96	94	19.8
1980	2.6	12.7	10.2	45.2	188.3	143.1	35	91	95	20.4
1981	2.2	11.6	13.6	31.4	173.8	43.8	15	95	76	21.6
1982	2.2	9.0	15.2	48.0	233.9	95.3	20	118	107	20.8
1983	2.5	8.0	21.7	38.6	271.7	152.4	13	74	87	22.3
1984	2.3	9.2	14.8	30.4	251.5	155.1	21	111	101	21.6
1985	2.1	10.5	11.3	38.1	251.3	111	40	79	88	20.4
1986	2.3	10.4	27.5	64.7	325.4	214.1	19	104	92	20.4
1987	2.8	6.5	7.3	27.6	210.4	141.8	35	86	90	21.7
1988	2.6	9.4	17.1	34.6	285.4	140.1	34	91	94	20.8
1989	3.3	5.2	9.4	24.1	262.8	149	16	102	84	21.9
1990	2.4	9.5	4.8	22.0	234	92.9	5	107	81	21.7
1991	2.3	11.7	4.6	23.2	191.1	89.8	31	78	78	23.0
1992	2.7	7.4	1.8	20.1	389.4	231	25	93	102	20.2
1993	3.7	5.1	5.9	15.8	170.9	87.2	24	99	105	21.4
1994	3.6	6.6	6.2	30.4	182.9	111.6	27	113	109	22.0
1995	4.7	3.2	10.0	22.9	269.2	201.3	39	75	97	23.2
1996	3.5	5.4	5.9	19.9	260	177	32	100	101	22.0
1997	3.6	5.3	3.3	14.7	330	178.7	39	88	96	21.6
1998	2.9	5.2	5.2	21.5	180.7	72.9	48	58	86	22.5
1999	3.2	6.0	6.3	15.1	197.1	94.3	33	94	96	23.3
2000	2.9	6.2	4.1	21.5	202.2	134.5	45	63	77	21.3
2001	3.4	5.4	10.4	28.0	302.3	163.1	12	117	103	22.4
2002	3.6	4.8	7.0	27.2	241.8	136.8	no freeze	no freeze	62	23.0
2003	3.7	6.9	9.8	27.0	253.9	144.1	10	104	105	22.2
2004	3.5	7.7	10.8	29.0	306.6	174.7	21	90	95	21.5
2005	4.2	3.8	16.4	29.4	334	180.3	26	97	98	24.2
2006	3.1	7.3	10.6	29.2	235.1	106	18	72	91	22.9
2007	3.5	6.2	6.1	21.1	183.1	90.4	54	71	94	22.6
2008	4.2	3.8	8.8	22.3	NA	NA	19	83	92	22.5
Average	3.1	7.5	10.5	30.4	236.1	130.3	25.7	93.3	92.5	21.8

Table A2. Walleye age-specific density estimates since 1957 (in fish/ha). Age 1, 2 and 3 are estimated from the average of trawl and gill nets estimates using catchabilities in Irwin et al. (2008). Bold values are from mark-recapture estimates. Densities of walleyes for intervening years were approximated from the distribution of mortality between successive biannual population estimates. Estimates from 1978-1987 and 1992-1994 from (Irwin et al. 2008). Estimates for age 4 and older in 2008 are based on the 2007 mark-recapture estimates assuming 15 % mortality of each age class.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age ≥7	Total (age-4<)
1957	no data	no data	no data	**0.4**	**6.22**	**0.97**	**4.62**	**12.21**
1958	9.18	1.55	4.72	**37.82**	**0.6**	**6.12**	**5.59**	**50.13**
1959	0.60	12.23	3.72	**2.69**	**34.12**	**0.27**	**9.47**	**46.54**
1960	4.94	3.62	22.70	**1.8**	**2.36**	**15.74**	**4.8**	**24.7**
1961	27.87	18.72	4.76	**20.82**	**2.45**	**2.14**	**14.9**	**40.31**
1962	15.84	14.49	12.62	**3.15**	**13.93**	**1.71**	**10.35**	**29.14**
1963	24.58	16.31	17.92	**13.26**	**2.56**	**15.32**	**7.61**	**38.75**
1964	34.61	19.28	10.36	9.03	8.85	1.71	15.29	34.88
1965	43.68	19.15	12.78	**8.69**	**5.53**	**7.18**	**10.53**	**31.93**
1966	22.09	31.64	15.05	11.61	7.1	4.52	14.48	37.71
1967	3.99	19.27	29.23	**10.29**	**8.17**	**3.77**	**10.42**	**32.66**
1968	22.35	2.89	20.67	**17.37**	**5.66**	**3.88**	**8.88**	**35.79**
1969	93.66	31.11	4.87	12.74	13.83	4.65	9.44	40.65
1970	3.10	37.77	10.75	**1.18**	**8.41**	**9.53**	**9.05**	**28.16**
1971	4.07	0.53	8.00	9.53	1.01	5.48	12.1	28.12
1972	80.32	9.21	1.54	**23.09**	**6.19**	**0.86**	**11.42**	**41.55**
1973	0.65	43.68	4.58	1.41	12.63	3.63	7.17	24.84
1974	6.08	2.18	47.64	**0.37**	**2.65**	**2.52**	**3.48**	**9.02**
1975	1.56	3.68	1.08	29.91	2.6	0.36	5.88	38.76
1976	92.71	3.61	3.23	**1.08**	**27.76**	**2.11**	**5.06**	**36**
1977	0.70	55.05	2.56	**1.92**	**0.49**	**15.08**	**3.9**	**21.39**
1978	36.75	0.96	31.26	1.56	1.64	0.36	16.67	20.24
1979	3.35	30.20	1.04	22.17	1.24	1.23	11.27	35.91
1980	2.48	4.41	22.30	0.98	14.45	0.81	8.2	24.44
1981	39.70	4.52	5.71	21.39	0.64	9.45	5.87	37.35
1982	26.88	22.72	3.87	3.53	17.5	0.45	10.37	31.85
1983	14.32	33.19	30.66	2.58	2.88	12.55	7.12	25.13
1984	9.79	9.43	20.79	13.77	2.13	2.06	13.33	31.28
1985	10.23	6.85	14.32	26.89	11.68	1.55	10.27	50.4
1986	15.01	9.07	7.03	9.96	22.41	8.7	7.77	48.84
1987	3.09	13.46	6.31	7.89	8.05	16.75	11.13	43.82
1988	105.80	2.14	12.59	**10.34**	**5.02**	**9.66**	**22.32**	**47.34**
1989	3.88	50.90	2.80	8.16	7.58	7.68	13.29	36.71
1990	7.98	8.29	49.85	**1.16**	**5.99**	**5.41**	**14.54**	**27.1**
1991	12.22	7.31	3.91	19.75	2.78	4.84	13.15	40.51
1992	45.62	9.25	6.74	1.79	16.71	1.15	10.45	30.1
1993	3.55	26.66	2.87	1.8	1.42	11.57	7.57	22.35
1994	8.64	2.40	23.14	2.29	1.19	0.98	12.83	17.3
1995	5.81	5.31	1.14	**6.96**	**1.45**	**1.06**	**5.85**	**15.31**
1996	9.66	2.65	2.78	1.49	6.14	0.92	5.37	13.91
1997	3.67	4.82	3.01	**1.57**	**1.2**	**5.39**	**4**	**12.17**
1998	22.17	1.43	4.16	0.7	1.53	1.19	9.51	12.94
1999	13.65	7.68	1.88	**1.54**	**0.57**	**1.44**	**6.86**	**10.42**
2000	9.58	11.81	6.41	0.47	1.95	0.67	7.77	10.85
2001	7.26	12.47	5.99	**3.9**	**0.38**	**2.15**	**6.9**	**13.32**
2002	32.13	9.23	8.39	4.75	3.25	1.41	8.41	17.83
2003	10.87	14.43	3.65	**2.78**	**3.85**	**2.71**	**8.32**	**17.66**
2004	6.39	12.94	12.19	6.14	4.54	2.64	8.23	21.54
2005	8.52	1.59	4.65	**6.15**	**4.97**	**5.53**	**6.05**	**22.71**
2006	5.53	9.68	1.17	1.27	6.87	3.16	11.51	22.81
2007	9.24	6.67	4.41	**1.27**	**1.03**	**7.09**	**9.28**	**18.67**
2008	3.84	3.32	1.29	3.75	1.08	0.87	13.92	19.62

Table A3. Fish observed in stomachs of yearling and older walleye taken by trawls and electrofishing during October and November since 1971, expressed as numbers per kg of walleye.

Year	# examined	% empty	YP	Morone	Gizz	ES	Other	Unident	Total
1971	240	37	3.92	0.01	0.00	0.00	0.06	1.59	5.58
1972	163	58	1.02	0.10	0.00	0.00	0.62	0.89	2.63
1973	295	32	0.69	1.36	0.00	0.00	0.43	1.35	3.83
1974	228	27	2.11	1.15	0.01	0.11	0.38	1.76	5.52
1975	204	68	0.20	0.13	0.00	0.02	0.17	0.24	0.76
1976	156	36	1.31	0.89	0.00	0.16	0.75	1.17	4.28
1977	70	19	3.14	1.25	0.00	0.00	0.14	0.89	5.42
1978	85	56	0.51	0.12	0.00	0.00	0.47	0.74	1.84
1981	88	66	1.52	0.16	0.00	0.00	0.00	0.56	2.24
1982	122	11	0.38	5.27	0.00	0.00	0.00	0.54	6.19
1983	117	62	0.19	0.79	0.00	0.00	0.00	0.30	1.28
1984	148	59	0.21	0.45	0.97	0.00	0.07	0.46	2.16
1985	151	50	1.60	0.04	0.36	0.00	0.13	0.44	2.57
1986	193	45	1.60	0.16	0.05	0.00	0.15	0.49	2.45
1987	194	23	0.05	0.64	1.96	0.00	0.02	0.54	3.21
1988	180	55	0.36	0.00	0.30	0.00	0.07	0.33	1.06
1989	193	26	0.00	0.18	5.42	0.00	0.03	0.83	6.46
1990	179	28	0.03	0.00	4.91	0.01	0.00	0.66	5.61
1991	137	20	0.02	0.01	3.81	0.00	0.10	0.77	4.71
1992	65	58	0.17	0.02	0.22	0.00	0.07	0.32	0.80
1993	134	25	2.13	0.51	0.01	0.42	0.81	1.28	5.16
1994	120	55	0.36	0.06	0.71	0.17	0.04	0.75	2.09
1995	86	45	0.44	0.35	0.06	0.02	0.13	0.67	1.67
1996	184	32	0.85	0.37	0.10	0.07	0.52	1.39	3.30
1997	75	45	0.28	0.36	0.00	0.02	0.26	1.15	2.07
1998	78	40	0.28	0.15	0.00	0.10	0.18	0.66	1.37
1999	64	42	0.25	0.03	0.25	0.75	0.03	0.61	1.92
2000	134	21	0.04	0.28	2.32	0.01	0.01	0.92	3.58
2001	123	28	0.40	0.18	0.88	0.17	0.24	0.36	2.23
2002	83	41	0.03	0.04	1.03	0.16	0.03	0.31	1.60
2003	183	39	0.84	0.09	0.36	0.04	0.21	0.52	2.06
2004	135	13	0.30	0.38	2.36	0.57	0.06	0.91	4.58
2005	134	30	1.08	0.11	0.70	0.31	0.13	0.52	2.85
2006	110	25	0.37	0.29	2.50	0.15	0.09	0.51	3.91
2007	264	50	0.87	0.00	0.67	0.02	0.08	0.45	2.09
2008	324	16	0.58	0.08	3.54	0.02	0.08	1.39	5.69

Table A4. Young-of-year and age-1 walleye density estimates and mean lengths. Larval walleye density (at the time of the 8 mm perch survey) are from Miller sampler surveys at that time or calculated from the 9 mm larval walleye survey. Age-0 walleye densities (#/ha) and mean lengths (TL, mm) on October 1 are from trawl surveys surrounding the Oct 1 date (50 trawls 9/16 to 10/13 in 2008), and age-1 walleye densities (#/ha) and mean lengths on May 1 are from trawl surveys around May 1 (30 trawls 5/1 to 5/6 in 2008). Densities calculated based on area swept (0.1 ha per trawl) assuming no avoidance.

Year Class	Larval Density	Oct 1 Age 0 Density	Oct 1 Age 0 Length	May 1 Age 1 Density	May 1 Age 1 Length
1961		114.5	140.6		
1962		135.9	142.9	44.2	158.8
1963		98.5	124.2	37.9	153.6
1964		80.6	137.5	73.4	161.3
1965		79.4	153.8	133.0	163.7
1966	1,348	6.3	138.5	9.0	148.1
1967	967	82.4	126.6		
1968	1,580	219.0	143.9	184.2	163.8
1969	559	50.0	142.7	17.0	161.0
1970	2,271	25.8	120.7	24.5	166.7
1971	309	42.0	167.0	124	180.6
1972	1,599	6.0	120.6	12.5	156.0
1973	222	1.6	164.2	4.5	174.0
1974	1,464	14.8	99.6	6	143.6
1975	1,362	148.4	171.2	59	184.6
1976	2,327	1.6	133.2	1.5	158.5
1977	660	71.6	136.5	108	167.8
1978		14.6	123.0		
1979		4.6	145.9		
1980		17.8	154.5	28.0	165.1
1981		57.8	149.4		
1982		22.4	162.0	27.7	175.6
1983		28.0	154.9	25.5	166.8
1984		6.0	132.8	26.3	151.3
1985		31.0	141.0	31.5	159.1
1986		5.4	140.4	3.8	165.3
1987		29.8	176.7	25.0	186.5
1988		10.4	142.3	2.2	146.0
1989		3.0	160.3	17.0	154.2
1990		14.4	173.8	15.0	177.6
1991		46.7	173.2	44.0	175.2
1992	333	12.4	150.4	5.0	157.1
1993		10.4	147.1	13.0	168.2
1994		11.4	130.8	11.5	163.3
1995		13.6	135.4	11.3	165.7
1996		1.8	150.3	5.0	168.3
1997		8.0	158.8	0.7	141.5
1998	275	2.4	207.4	3.0	189.0
1999	1,773	12.4	144.3	2.7	121.8
2000	1,208	3.0	176.5	14.3	180.7
2001	2,541	19.2	153.0	33.0	154.0
2002	213	3.7	173.6	12.3	179.3
2003	986	2.5	139.1	19.5	167.4
2004	3,196	15.3	150.7	21.0	161.8
2005	8,106	5.6	106.5	13.3	143.2
2006	1,304	2.2	163.0	9.3	173.3
2007	942	7.50	131.9	3.3	183.3
2008	5,102	5.40	129.7		

Table A5. Yellow perch density estimates since 1961. Data are from mark-recapture (**bold**) or based on the catch in gill nets using size specific net selectivity.

Year	Density (#/ha) at age						Total (age3+)
	2	3	4	5	6	>6	
1961	51.2	11.3	56.7	9.4	10.2	17.5	105.1
1962	18.9	38.4	27.8	40.2	12.8	6.5	125.7
1963	15.6	26.7	40.1	32.7	33.5	16.1	149.1
1964	10.5	11.3	45.0	44.4	32.8	12.4	146.0
1965	11.3	44.2	12.7	67.2	41.4	14.1	179.7
1966	34.3	19.6	28.6	20.9	39.2	12.7	120.9
1967	1.4	50.1	28.1	27.2	20.4	20.3	146.0
1968	37.0	3.5	70.2	16.0	17.1	24.6	131.4
1969	33.2	**21.7**	**7.3**	**54.3**	**18.9**	**18.9**	**121.2**
1970	6.7	48.0	23.1	7.5	61.9	37.9	178.4
1971	1.9	**7.7**	**52.6**	**17.1**	**3.0**	**30.2**	**110.7**
1972	41.5	1.8	7.6	26.9	9.0	11.9	57.1
1973	4.6	**144.4**	**3.9**	**7.2**	**17.7**	**26.2**	**199.5**
1974	No gill netting						
1975	39.0	**0.9**	**5.7**	**61.3**	**2.5**	**15.0**	**85.5**
1976	5.3	56.5	2.8	11.2	51.2	14.4	136.1
1977	2.7	**12.9**	**40.0**	**0.5**	**2.2**	**24.2**	**79.7**
1978	19.7	3.9	8.6	41.7	3.6	28.8	86.6
1979	99.1	12.5	5.4	6.1	33.9	10.3	68.1
1980	4.9	179.2	16.3	8.6	14.5	41.3	260.0
1981	16.0	16.3	134.4	23.2	3.7	24.9	202.5
1982	31.2	10.3	10.6	99.6	4.3	8.0	132.8
1983	2.8	27.7	8.2	5.2	54.4	5.8	101.4
1984	18.6	12.6	48.3	17.2	10.3	36.0	124.5
1985	29.8	7.6	5.0	22.2	3.3	12.2	50.3
1986	29.5	24.0	10.3	8.1	28.9	9.0	80.3
1987	15.4	31.7	29.0	11.1	5.0	35.7	112.5
1988	10.0	**15.5**	**24.7**	**18.9**	**4.3**	**21.9**	**85.4**
1989	27.8	7.1	18.6	31.0	23.5	24.2	104.4
1990	8.7	**33.5**	**2.9**	**5.8**	**17.2**	**18.0**	**77.4**
1991	3.4	3.7	18.5	5.9	9.0	22.3	59.4
1992	47.9	5.5	5.2	18.4	6.5	10.0	45.5
1993	29.5	28.2	7.5	4.8	13.7	10.8	65.1
1994	1.7	10.4	8.9	1.5	0.8	6.5	28.1
1995	13.9	**4.3**	**16.1**	**5.9**	**1.4**	**4.0**	**31.7**
1996	26.4	10.7	4.0	8.5	3.6	3.8	30.6
1997	21.3	**26.3**	**7.0**	**1.4**	**2.7**	**1.7**	**39.0**
1998	13.2	23.9	22.0	10.4	4.2	3.9	64.3
1999	4.3	**10.5**	**13.1**	**8.9**	**2.7**	**1.7**	**37.0**
2000	20.3	8.9	15.2	19.4	10.5	7.3	61.4
2001	3.7	**21.5**	**7.1**	**4.8**	**5.8**	**6.5**	**45.7**
2002	5.7	7.9	46.0	11.5	10.7	24.6	100.8
2003	1.7	2.3	7.1	21.7	6.1	9.8	47.0
2004	3.4	5.4	5.5	8.3	17.0	19.5	55.7
2005	2.9	13.4	12.4	4.9	9.2	32.6	72.5
2006	15.5	11.0	12.6	8.1	2.9	18.5	53.0
2007	38.2	15.0	7.1	6.5	3.5	11.7	43.8
2008	14.7	41.7	16.0	5.6	3.7	13.4	80.4

Table A6. Young-of-year and age-1 yellow perch density estimates and mean lengths. Larval yellow perch densities (at 18 mm, #/ha) are estimated from Miller sampler surveys. Age-0 yellow perch densities (#/ha), age-0 mean lengths (TL, mm) are estimates for October 15 obtained from regression analysis of weekly catches throughout the season. Age-1 yellow perch density are from trawl surveys around May 1 and from mid-July through October (#/ha). Age-1 yellow perch mean lengths are from spring trawl surveys centered on May 1 since 1961.

Year class	Larval density	October age-0		Age-1		
		density	mean length	density spring	mean length	density summer
1961		2,850	60			19.4
1962		4,260	73	486	76	186.8
1963		780	60	71		15.8
1964		3,520	71	849	73	585.9
1965	140,100	2,610	60	30		2.0
1966	40,200	170	73	25	74	39.3
1967	61,200	2,240	72			136.5
1968	141,800	6,700	67	598	75	57.2
1969	69,200	210	65	2		0.5
1970	80,000	930	77	158	85	44.5
1971	216,400	3,520	57	52	62	30.5
1972	120,700	100	67	4	77	0.8
1973	16,600	510	86	63	90	46.0
1974	32,000	320	72	33	74	9.3
1975	188,700	450	65	5	75	4.3
1976	46,600	180	72	12	77	4.8
1977	65,200	4,140	69	3385	70	241.5
1978		180	73			13.5
1979	103,200	360	75			6.4
1980	131,600	500	81	118	81	100.9
1981	208,200	2,590	57			4.6
1982	353,400	980	63	25	68	10.6
1983	45,600	710	79	95	79	26.3
1984	16,000	810	71	103	73	32.1
1985	91,100	2,700	68	174	74	29.8
1986	14,600	70	82	2	84	1.8
1987	3,700	220	68	128	70	97.9
1988	76,200	220	81	19	83	4.5
1989	3,700	20	81	17	82	13.1
1990	117,000	460	73	184	70	121.9
1991	34,000	340	82	705	84	166.5
1992	60,800	100	73	13	79	5.4
1993	32,800	320	85	70	84	56.4
1994	21,800	280	83	281	83	30.1
1995	15,100	90	90	373	89	58.5
1996	43,600	80	80	74	81	24.3
1997	4,600	30	80	23	80	17.5
1998	57,100	700	83	457	84	99.3
1999	42,100	1,080	81	18	84	17.8
2000	19,300	140	78	73	79	7.2
2001	36,200	270	84	466	86	6.3
2002	23,400	1,660	76	380	80	17.6
2003	68,500	60	85	38	84	5.3
2004	60,700	180	86	36	84	5.7
2005	36,300	410	93	280	93	13.5
2006	58,502	240	79	117	79	19.6
2007	135,990	1,842	81	243	85	6.2
2008	67,420	71	73			

Table A7. Relative abundance of white perch year classes at successive stages of development. Age-0 white perch abundance represented by the calculated density from area swept in trawls in August-September, Age-0 Length is from October trawls, Age-1 Spring is from the CPUE in spring trawls, and age-1 and older are catches in standard gill nets. These values are data for the year of collection. The recruitment index (RI) is the sum of the gill net catch at age 2 and 3 of fish born that year (Fitzgerald et al. 2006). For example the RI value for years 1961 is the sum of the gill net catch of age 2 in 1963 and age 3 in 1964. Bold RI numbers for 1971 and 1972 includes an extrapolation of gill net catches for 1974 when gill nets were not used (see Fitzgerald et al. 2006).

Year	Age-0	Age-0 Length	Age-1 Spring	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age7+	RI	sum GN
1961	1114	84		2	9	20	94	6	8	39	10	178
1962	287	94		0	15	2	34	66	10	13	114	140
1963	54	68		0	5	28	5	83	62	15	12	198
1964	56	79	0.4	0	55	5	36	20	62	54	54	232
1965	963	77	9.3	6	7	59	9	56	43	74	9	254
1966	1320	78	0.0	0	19	5	28	8	54	19	5	133
1967	131	85	0.0	0	3	35	9	15	26	19	16	107
1968	12	86		0	0	6	18	6	20	22	7	72
1969	81	80	0.0	0	0	5	10	21	6	23	3	65
1970	178	81	0.0	0	4	16	20	46	37	56	25	179
1971	91	78	0.0	1	0	3	7	2	9	23	**69**	45
1972	30	84	0.5	0	11	3	0	0	2	8	**9**	24
1973	2155	85	0.0	0	6	14	1	1	0	6	551	28
1974	355	72	3.0								15	
1975	207	87	0.0	0	240	5	143	14	2	11	3	415
1976	314	64	0.0	0	4	311	5	101	39	41	8	501
1977	957	77	0.0	0	1	11	128	4	52	11	517	207
1978	37	85	12.0	23	0	2	3	53	1	18	12	100
1979	1740	78		1	224	8	17	1	228	30	6	509
1980	6428	79		0	8	293	0	1	3	48	59	353
1981	278	75	2.0	0	1	4	775	28	22	132	10	962
1982	4820	75		0	21	5	10	411	8	31	29	486
1983	6588	80	0.0	0	0	38	5	6	343	28	249	420
1984	364	72	0.0	0	6	10	141	10	13	244	297	424
1985	102	70	0.5	1	31	23	12	212	15	372	38	666
1986	17	72	0.5	4	142	218	29	26	195	309	15	923
1987	5223	62	0.0	1	27	155	31	11	11	69	17	305
1988	4	81	0.0	0	1	11	7	0	3	8	3	30
1989	886	78	0.0	3	4	14	34	4	0	8	8	67
1990	74	72	0.0	2	0	13	19	56	18	17	2	125
1991	86	90	0.0	6	4	3	1	4	19	19	6	56
1992	48	70	0.0	0	0	4	1	10	4	59	0	78
1993	797	79	0.0	0	3	2	2	1	18	40	15	66
1994	66	80	0.0	1	0	3	3	0	2	31	19	40
1995	613	97	0.5	2	4	0	6	2	4	18	243	36
1996	54	87	14.7	2	2	11	3	8	0	14	13	40
1997	956	76	0.0	0	155	17	8	1	5	14	415	200
1998	126	85	0.0	87	0	88	4	10	2	6	202	197
1999	8	97	0.7	40	315	13	122	9	0	4	132	502
2000	590	78	0.7	2	50	100	4	47	2	3	211	208
2001	59	84	2.3	6	56	152	211	14	55	0	283	494
2002	1145	82	8.3	32	122	76	65	120	7	26	72	448
2003	59	84	5.3	0	106	89	46	52	36	17	5	346
2004	1413	79	2.0	0	33	177	61	38	27	40	590	376
2005	81	98	1.3	44	1	39	227	40	53	17	210	421
2006	138	76	1.7	16	261	4	32	214	50	10	*16*	587
2007	1392	81	0.0	12	111	329	20	34	198	67		771
2008	335	75	0.0	5	16	99	126	11	42	74		373

Table A8. Abundance and biomass of pelagic fish (emerald shiners (ES), gizzard shad, and *Alosa* spp. (blueback herring and alewife)) in Oneida Lake since 1994.

	Abundance (fish/ha)					Biomass (kg/ha)				
Year	ES age-0	ES Age1+	Gizzard shad	*Alosa* spp.	Sum	ES age-0	ES Age1+	Gizzard shad	*Alosa* spp.	Sum
1994	3,589	1,352	2,515	607	7,457	2.2	4.1	15.6	6.1	28.0
1995	350	792	538	575	2,255	0.6	3.2	17.2	9.3	30.3
1996	2,909	280	22	492	3,704	2.3	1.0	1.3	5.3	10.0
1997	16,936	1,760	101	14	18,811	15.0	6.4	0.6	0.2	22.3
1998	2,254	5,668	41	3	7,966	1.0	16.1	0.4	0	17.5
1999	7,539	4,093	726	0	12,358	6.1	10.0	8.7	0	24.8
2000	3,463	1,836	1,936	0	7,235	3.4	5.2	6.3	0	14.9
2001	16,112	2,441	2,458	0	21,010	15.2	9.0	23.5	0	47.8
2002	20,529	2,516	2,924	0	25,969	9.4	7.2	5.6	0	22.2
2003	2,645	8,149	2,474	0	13,268	1.7	23.3	13.8	0	38.7
2004	9,057	1,407	2,664	0	13,128	10.1	4.9	14.6	0	29.6
2005	2,597	1,307	2,215	0	6,119	2.6	4.9	47.8	0	55.3
2006	2,651	666	1,716	0	5,033	2.6	2.3	15.5	0	20.4
2007	417	215	1,431	0	2,065	0.6	0.3	14.3	0	15.2
2008	7,900	381	2,073	0	10,354	6.6	1.3	14.6	0	22.5
Mean	6,602	2,100	1,890	114	10,706	5.4	6.4	14.7	1.4	28

Table A9. Catch/hour of lake sturgeon in large mesh gill nets at 12 standard sites.

Year	Month						
	May	June	July	August	September	October	November
2002	-	0.39	0.35	0.10	0.10	0.16	-
2003	0.32	0.17	0.09	0.09	0.56	-	-
2004	0.35	0.39	0.08	0.37	0.15	-	-
2005	0.18	0.11	-	-	-	-	-
2006	0.31	0.11	-	-	-	-	0.06
2007	0.30	0.11	-	-	-	0.07	-
2008	0.17	0.13	-	-	-	-	-

Appendix 3. Publications from the Cornell Biological Field Station on Oneida Lake in 2008 and first part of 2009.

A star indicates full or partial support from NYSDEC through the Cornell Warmwater Fisheries Research Program and these papers should be available through the New York Fisheries Report Data Base. Copies of all publications are available through JoAnne Getchonis, (jgg4@cornell.edu) or Lars Rudstam (lgr1@cornell.edu).

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