Appendix F-4

Growth and Survival of Largemouth Bass (*Micropterus salmoides*) in Onondaga Lake, New York

2013 Annual Report

In 2000, a biological monitoring program that included an examination of the population characteristics of Largemouth Bass (*Micropterus salmoides*) was initiated as part of the Ambient Monitoring Program (AMP). These data will be used in conjunction with other ongoing monitoring programs to evaluate the impact of collection and treatment system improvement projects associated with Onondaga County's Metropolitan Syracuse Wastewater Treatment Plant (METRO) and the requirements of the Amended Consent Judgment (ACJ).

Summary

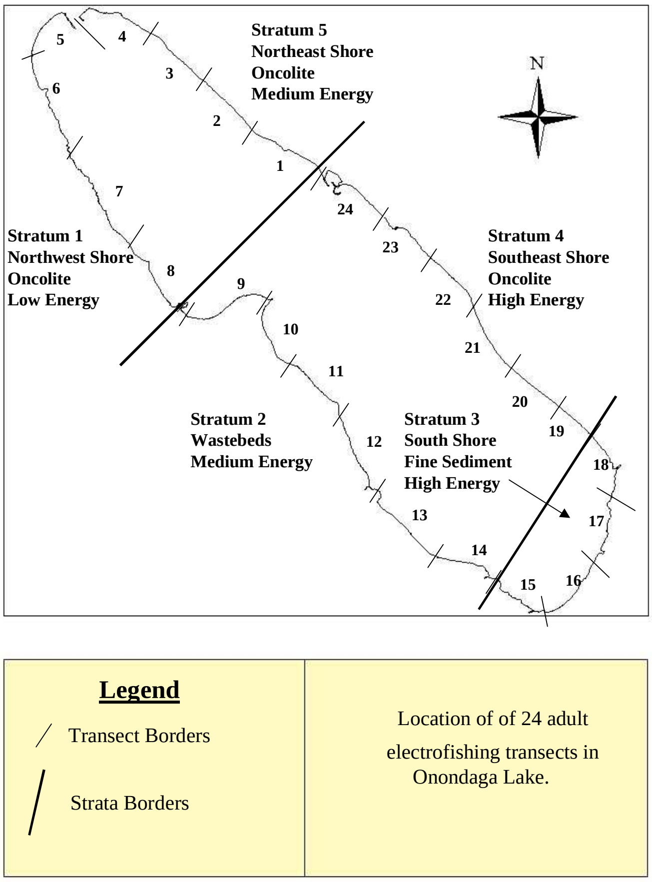
Largemouth Bass were collected from Onondaga Lake in 2000 through 2013 to evaluate age, growth, and survivorship patterns. Age and growth were estimated based on scales collected from 1,493 Largemouth Bass sampled from 2000 through 2013. Growth rate estimates for Largemouth Bass from 2000 through 2013 were compared to growth rates estimated during studies conducted on Onondaga Lake in 1992 and 1993 (Gandino 1996). Based on that comparison, growth rates have not changed significantly in the past two decades. In addition, growth rates of Largemouth Bass from 2000-2004 were compared to those from 2006-2013 to evaluate potential changes based on METRO upgrades (i.e., pre- and post- phosphorus removal) and no significant difference was observed between the years. The average growth rate estimated for Largemouth Bass in 2013 was not significantly different to annual averages since 2000. Overall growth rates of Largemouth Bass in Onondaga Lake are comparable to those found in many other New York lakes (AFS warmwater workshop 1993).

The Largemouth Bass population sampled annually between 2000 and 2013 was composed primarily of young fish. Seventy-one percent of the Largemouth Bass sampled were estimated between one and five years old. The estimated annual survivorship rate of Largemouth Bass collected between 2000 and 2013 was 0.56 (age 5-14). For 2013, proportional stock density (PSD) and relative stock density $(RSD)_{381}$, RSD_{508}, and RSD_{635} were 49, 16, 0, and 0, respectively. Largemouth Bass examined in the fall in Onondaga Lake between 2000 and 2013 were characterized as having good condition based on length and weight ratios. Instantaneous rate of mortality (Z) of Largemouth Bass estimated from smoothed catch curves (Ricker 1975), was 0.58 for 2000 through 2013.

Methods

The shoreline of Onondaga Lake was divided into 24 transects, that were sampled annually from 2000 through 2013 during the spring (May – June) and fall (September – October) (Figure 1). Sampling was conducted with a boat-mounted electrofishing unit using pulsed direct current. Sampling occurred at night from 0.5 hour after sunset to 0.5 hour before sunrise. Electrofishing was conducted parallel to the shoreline for approximately fifteen minutes (900 seconds) per transect in one meter of water. Largemouth Bass captured during the survey were measured (total length in mm) and weighed (nearest gram, fall only) prior to being released for assessment of size structure each year.

Figure 1 – Electrofishing Transects



To evaluate age distribution and growth patterns, scale samples were removed from Largemouth Bass greater than 100 mm collected during fall electrofishing surveys. Scales were removed from the left side of the body below the lateral line, near the tip of the depressed pectoral fin. At least 15 scales were removed from each fish and placed in a scale envelope with total length (mm), weight (g), date, and site of capture recorded. Scales were pressed on clear cellulose acetate plastic slides and projected with a 40X Ken-A-Vision micro projector. Ages were estimated by counting annuli, which were verified through blind comparisons by experienced personnel. Growth rates were determined by calculating the mean length at age of capture for all of the fish collected within each age-group.

Mortality rates for largemouth bass fully recruited to the sampling gear were developed from the frequency distribution of the catch by age (catch curve; Ricker 1975). Instantaneous mortality rate (Z) was determined by calculating the slope of the descending (right) limb of the catch curve generated by plotting the natural log of frequency versus age. Annual rate of total survivorship (S) was determined by the following formula: $S = (1 – A) = e^{-z}$. Annual rate of total mortality (A) was also calculated from this formula. Data from 2000 through 2013 were pooled to reduce the effect of variable recruitment from year to year. Because of the variable recruitment, catch per unit effort of individual yearclasses, in successive years (cohort analysis) was also used to describe mortality rates of largemouth bass (Ricker 1975).

To assess general condition of fish (“plump” or “skinny” fish), Fulton’s “coefficient of condition”, K, was determined from the following formula: K = Weight (g)/ Length^3 (mm) x 100,000 (Everhart and Youngs 1981). K values greater than 1.0 are generally considered to represent a fish in good condition.

Proportional stock density (PSD) and relative stock density (RSD) are calculated to describe length frequency data and the general structure of a fish population. These are calculated by the following equations:

PSD= (number of fish ≥ minimum quality length/number of fish ≥ minimum stock length) x 100
RSD = (number of fish in length class/number of fish ≥ minimum stock length) x 100

The PSD and RSD ratios are calculated based on values for largemouth bass as follows (Anderson and Neumann 1996):

- stock length (8 inches [203 mm]),
- quality length (12 inches [305 mm),
- preferred length (15 inches [381 mm];
- memorable length (20 inches [508 mm], and
- trophy length (25 inches [635 mm]).

Results for Growth and Survival

Largemouth bass examined in the fall in Onondaga Lake from 2000 through 2013 were characterized as being in good condition. Condition factors for Largemouth bass ranged from 1.29 for age 1 in 2003 to 1.95 for age 7 in 2011 (Table 1). Proportional stock density estimates ranged from 33 in 2003 to 73 in 2005 (Table 2). Relative stock density of quality (RSD $_{305}$) and preferred (RSD $_{381}$) Largemouth Bass averaged 55 and 25 respectfully from 2000-2013. Very few memorable (RSD $_{508}$) and trophy (RSD $_{635}$) Largemouth Bass have been collected since 2000 (Table 2). Overall growth of Largemouth Bass in Onondaga Lake is satisfactory, considering an active growing season of approximately five (5) months. Average length at age of Largemouth Bass from 2000 through 2013 was compared to 1992 through 1993 using a two tailed t-test assuming unequal variance was not significantly different ($p > 0.05$) (Figure 2). In 2005, a high-rate flocculated settling physical-chemical treatment system came online at METRO to reduce effluent total phosphorus concentrations. Largemouth Bass growth rates prior to this upgrade (2000 through 2004) compared to post upgrade (2006 through 2013) using a two tailed t-test assuming unequal variance were not significantly different ($p > 0.05$) (Figure 3). Finally, Largemouth Bass growth rates in Onondaga Lake were not significantly different from New York State averages ($p > 0.05$) (Figure 4).

Table 1. Fulton Condition Factor (K) of Largemouth Bass, Onondaga Lake, 2000 – 2013.

					Age			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
YEAR								
2000	1.49	1.62	1.44	1.63	1.54	1.51	1.79	1.70
2001			1.35	1.45	1.36	1.45	1.44	1.50
2002	1.34	1.38	1.41	1.43	1.35	1.38	1.51	1.51
2003	1.29	1.41	1.42	1.51	1.59	1.45	1.47	1.74
2004	1.44	1.45	1.39	1.57	1.48	1.69	1.67	1.74
2005	1.42	1.51	1.52	1.54	1.57	1.61	1.72	1.64
2006	1.37	1.56	1.34	1.45	1.54	1.53		
2007	1.41	1.46	1.41	1.50	1.36	1.58	1.68	1.53
2008	1.51	1.46	1.48	1.40	1.44	1.45	1.40	1.40
2009	1.53	1.49	1.46	1.51	1.50	1.51	1.51	1.63
2010	1.36	1.41	1.37	1.54	1.55	1.72	1.66	1.57
2011	1.46	1.55	1.57	1.74	1.72	1.81	1.95	1.82
2012	1.40	1.41	1.48	1.50	1.49	1.52	1.51	1.51
2013	1.43	1.47	1.52	1.53	1.53	1.52	1.67	1.63
Average	1.42	1.47	1.44	1.52	1.50	1.55	1.61	1.61

Table 2. Proportional stock density and relative stock density of Largemouth Bass captured in Onondaga Lake, 2000 - 2013.

		Quality	Preferred	Memorable	Trophy
YEAR	**PSD**	**RSD 305 (12")**	**RSD 381(15")**	**RSD 508(20")**	**RSD 635(25")**
2000	50	50	22	0	0
2001	57	57	17	0	0
2002	37	37	17	1	0
2003	33	33	16	0	0
2004	66	66	20	0	0
2005	73	73	33	0	0
2006	69	69	40	0	0
2007	55	55	29	0	0
2008	59	59	28	0	0
2009	64	64	19	0	0
2010	68	68	29	1	0
2011	69	69	36	0	0
2012	50	50	24	0	0
2013	49	49	16	0	0
Average	57	57	25	0	0

Figure 2. *Average length (mm) at age of Largemouth Bass, Onondaga Lake, 1992-1993, 2000-2013 (P=0.93)*

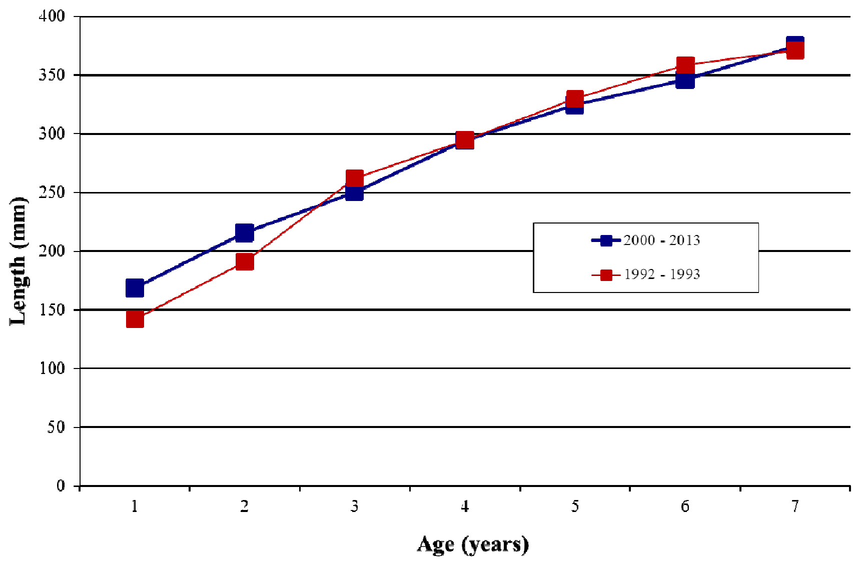


Figure 3. *Average length (mm) at age of Largemouth Bass captured boat electroshocking, Onondaga Lake; (2000 - 2004) vs. (2006 - 2013); p = 0.94*

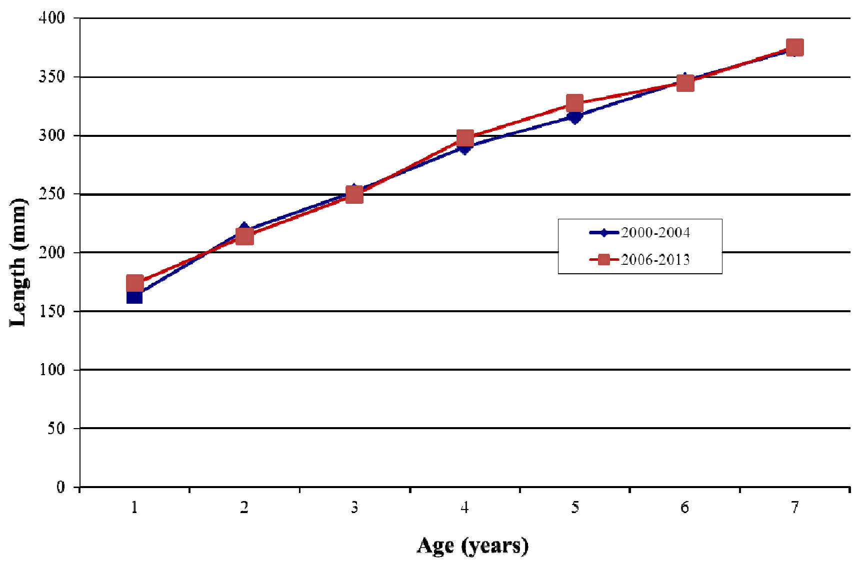
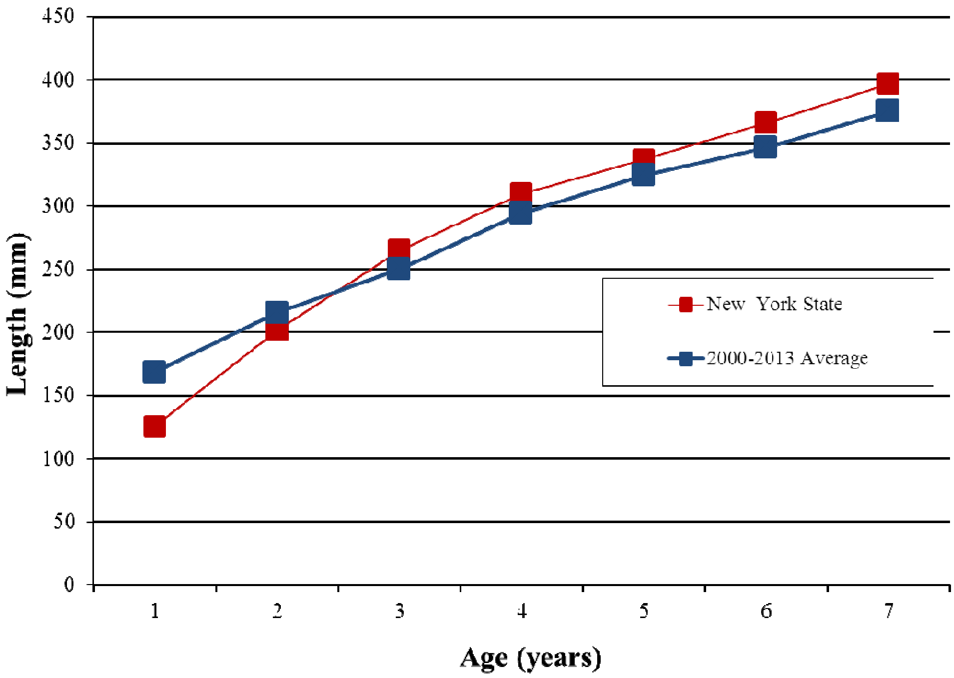


Figure 4. *Average length (mm) at age of Largemouth Bass from Onondaga Lake compared to New York State Average (1993); P=0.93*



Under the current 305 mm (12 inch) minimum statewide size limit, most Largemouth Bass in Onondaga Lake were recruited into the fishery during their fourth or fifth growing season. In comparison, on average, Largemouth Bass in New York State are recruited to harvestable population during their third or fourth growing season (AFS warmwater workshop 1993) (Table 3).

Table 3. Average length (mm) at age of Largemouth Bass, Onondaga Lake, 1992-1993, 2000-2013.

				Age Years				
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1992 (Gandino 1996)		142	211	266	314	344	359	374
1993 (Gandino 1996)			171	258	275	316	358	368
2000 (Onondaga County)	118	174	218	255	301	337	370	388
2001 (Onondaga County)	100	201	222	278	297	319	343	385
2002 (Onondaga County)	106	165	217	244	285	315	346	372
2003 (Onondaga County)	93	138	218	246	280	309	330	368
2004 (Onondaga County)	123	137	218	237	287	304	344	356
2005 (Onondaga County)		153	212	250	291	342	355	380
2006 (Onondaga County)	117	196	216	251	303	311	321	357
2007 (Onondaga County)		172	220	270	288	344	346	369
2008 (Onondaga County)		138	196	227	302	325	338	353
2009 (Onondaga County)	111	172	215	247	297	340	345	397
2010 (Onondaga County)		184	208	239	313	326	357	399
2011 (Onondaga County)	118	155	218	241	297	326	358	379
2012 (Onondaga County)	112	180	218	251	285	319	351	389
2013 (Onondaga County)	117	193	220	269	295	328	343	360
Onondaga Lake 2000-2013	**111**	**168**	**215**	**250**	**294**	**325**	**346**	**375**
Average 2000-2004	**108**	**163**	**219**	**252**	**290**	**317**	**347**	**374**
Average 2006-2013	**115**	**174**	**214**	**249**	**298**	**327**	**345**	**375**
NYS (AFS warmwater workshop 1993)		**126**	**202**	**265**	**310**	**337**	**366**	**397**

Instantaneous rate of mortality (Z) of Largemouth Bass estimated from smoothed catch curves (Ricker 1975) was 0.58 in 2000 through 2013 (Table 4). Estimated annual survival (S) was 0.56. Estimated annual survival from 1991 through 1993 calculated from smoothed catch curves was 0.51(Table 4). The survivorship estimate derived from cohort analysis (Ricker 1975) from 2000 – 2006 was 0.42 (Table 4).

Table 4. Mortality and survivorship rates of adult Largemouth Bass captured in Onondaga Lake, 1990 - 1993, 2000 – 2013.

Where: *Z = Instantaneous rate of mortality*
S = Annual rate of survivorship = e^{-Z}
A = Annual rate of mortality = 1 – S
N = Sample size

YEAR	Z	S	A	N	Age Range	Method
1991-1993	0.67	0.51	0.49	144	4 - 9	Smoothed Catch Curve
1991-1993	0.57	0.57	0.43	44	4 - 6	Cohort Analysis (CPUE)
2000	0.76	0.47	0.53	15	5 - 8	Catch Curve
2002	0.75	0.47	0.53	17	6 - 8	Catch Curve
2004	0.53	0.59	0.41	33	7 - 10	Catch Curve
2005	0.84	0.43	0.57	38	2 - 4	Catch Curve
2006	0.66	0.51	0.49	34	2 - 6	Catch Curve
2008	0.37	0.69	0.31	58	3 - 8	Catch Curve
2009	0.37	0.69	0.31	60	4 - 6	Catch Curve
2010	1.08	0.34	0.66	38	2 - 4	Catch Curve
2011	0.23	0.79	0.21	103	1-11	Catch Curve
2011	0.62	0.54	0.46	26	7-11	Catch Curve
2012	0.59	0.58	0.42	109	3-9	Catch Curve
2013	0.40	0.67	0.37	276	3-10	Catch Curve
2000 - 2013	0.58	0.56	0.44	610	5 - 14	Smoothed Catch Curve
2000 - 2006	0.87	0.42	0.58	92	2 - 6	Cohort Analysis (CPUE)

Discussion

Estimated survival of Largemouth Bass in Onondaga Lake from 2000 - 2013 was 0.56, comparable to the New York State average of 0.65 in bass study waters (AFS warmwater workshop 1993). No exploitation rates are available for the Onondaga Lake population of Largemouth Bass; however, exploitation rates are assumed to be very low due to elevated levels of mercury in the fish flesh and subsequent consumption advisories (Gandino 1996). In addition, over the past 10 years angling primarily on a catch and release basis has increased markedly. Tournament angling has become increasingly popular. Local bass organizations compete several weekends throughout the summer, and several large-scale fishing tournaments have been held on Onondaga Lake including the Bassmasters Memorial in 2007 and the BASS Junior World Championship in 2008. Although tournament bass anglers usually release their fish, studies from other waters have shown initial mortality (fish dead at weigh-in) ranged from 0 to 15.2% and post-release mortality (5 days after tournament) ranged from 0 to 43% (Schramm et al. 2006). Hartley and Moring (1995) reported that initial mortality for Largemouth Bass from three Maine lakes averaged 3.2% and the larger fishing tournaments had a significantly higher mortality than smaller tournaments.

Although growth of largemouth bass in Onondaga Lake has not changed significantly, at least since 1992, the lake itself has. The most notable physical change has been the increase in the amount of aquatic vegetation in the lake, increasing from 85 acres in 2000 to 505 acres in 2012 and 387 acres in 2013. Remedial activities occurring in the southern end of the lake may account for the reduced vegetation observed in 2013 compared to 2012. Macrophytes have been described as one of the most influential factors structuring freshwater ecosystems (Benson and Magnuson 1992). Aquatic plants perform many ecosystem functions including primary production; stabilizing sediments; maintaining water clarity; and providing habitat for zooplankton, macro-invertebrates, and many fish species. Numerous species of fish depend on aquatic vegetation for their survival (Valley et al. 2004). Game fish such as sunfish, Largemouth Bass, and Northern Pike, depend on submersed aquatic vegetation for food and shelter. Other non-game species such as darters, minnows, and killifishes depend primarily on nearshore emergent and submersed vegetation for much of their life history (Smith 1985; Werner 2004).

However, extensive macrophyte growth in lakes and reservoirs can alter trophic interactions (Boyd 1971). Increases in habitat complexity have been shown to decrease foraging efficiency of piscivores (Savino and Stein 1989) and several studies have suggested that a delay in piscivory in young-of–year Largemouth Bass may increase mortality going into their first winter (Miranda and Hubbard 1994, Sammons et al. 2005). Additionally, high densities of aquatic macrophytes have been shown to adversely affect Largemouth Bass growth and body condition (Brown 2002, Sammons et al. 2005, and Valley et al. 2004). Savino and Stein (1989) reported that high densities of macrophytes caused largemouth bass to switch their feeding behavior from searching to ambushing which decreased foraging success. Valley et al. (2004), reported that condition of game fish declined when submerged aquatic vegetation fell below 10% or exceeded 60% lake wide coverage. A review of the literature estimates optimum macrophyte coverage for Largemouth Bass between 36 percent and 60 percent of the littoral zone (Stuber et al. 1982, Wiley et al. 1987) to maximize Largemouth Bass production by providing adequate prey fish recruitment while still allowing for successful predation (Sammons et al. 2005). Based upon these relationships it appears that macrophyte coverage in Onondaga Lake in 2013 (50%) is currently in the ideal range for Largemouth Bass. Catch rates of largemouth bass in 2013 were the highest observed since the start of the AMP, possibly reflecting this relationship. Basin morphometry (shallow versus deep) ultimately controls how much vegetation naturally grows within a lake and may play a role in Onondaga Lake. Field observations in 2010 identified the maximum depth of plant growth generally between 4 and 6 meters, leaving the majority of the lakes basin devoid of macrophytes possibly diminishing the effects of dense beds found shallower.

Catch per unit effort from electrofishing survey s also has increased during this time from 11.15 Largemouth Bass per hour in 2000 to 24.2 Largemouth Bass per hour in 2012 and 43.6 in 2013 (all Largemouth Bass caught boat electrofishing). The stable growth rates over the past 13 years may be related to food web dynamics. As conditions have improved in the lake, the Largemouth Bass population has increased. Other predatory species such as Bowfin and Northern Pike populations have also increased since 2000. This increase in predatory species most likely has increased the amount of interspecific and intraspecific competition for prey species (i.e., food availability) in the lake which may have negative effects on growth in the future.

Large numbers of Alewife (*Alosa pseudoharengus*), an invasive species, became established in Onondaga Lake 2003. The impacts exerted on the trophic dynamics of a system when large populations of alewife are present are well published in the literature (Brown 1972, Wells 1970, Keller and Rudstam 2012) and have been observed in Onondaga Lake. Alewife populations generally undergo annual die-offs and periodic mass mortalities. When these large scale die-offs occur, any predator that uses Alewife as a main food source will have difficulty finding food, potentially resulting in poor growth rates and increased mortality**.** Largemouth bass are known to feed on alewife in Onondaga Lake, having been frequently observed regurgitating partially digested Alewife when captured. However, in years of low Alewife abundance in Onondaga Lake (2006-2009) no such effects on growth have been observed.

Additionally, Round Gobies were first collected in Onondaga Lake in 2010 and have continued to increase in abundance to date. Like Alewife they are preyed on by larger, fish-eating species. Hurley (2013) reported that round gobies were the most common food source of Largemouth Bass in Onondaga Lake based on the analysis of 137 stomach samples. The long-term effect of Round Gobies on the Largemouth Bass populations in Onondaga Lake is still open to question.

Overall, the population of largemouth bass in Onondaga Lake appears typical of other regional populations. Growth and condition are comparable to those found in other New York lakes. Catch per unit effort has steadily increased since 2000, and annual survivorship has shown little variation over the past 14 sampling seasons. Proportional stock density index values for largemouth bass in Onondaga Lake from 2000-2013 averaged 57 and ranged from 33-73. Gabelhouse (1984) suggested PSD values in the range of 40 – 70 indicate a balanced largemouth bass population. PSD values for Onondaga Lake have fallen in this range 12 out of the 14 years studied and in each of the past ten years. The Preferred RSD value has averaged 25 in the past 14 years, indicating that there are a good number of 15 inch or larger bass in the system. These values show that a fairly large portion of the largemouth bass population in Onondaga Lake is well over the New York State minimum length of 12 inches.

References

American Fisheries Society Northeast Division Warmwater Workshop. 1993. *Biological Characteristics of Black Bass Populations in Northeastern United States and Southeastern Canada.* October 5–6, 1993 Alexandria Bay, NY.21pp.

Anderson, R.O., and R.M Neumann. 1996. *Length, weight, and associated structural indices*. Pages 447-482 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Benson, B. J. and J. J. Magnuson. 1992. *Spatial heterogeneity of littoral fish assemblages in lakes: Relation to species diversity and habitat structure*. Can. J. Aquat. Sci. 49: 1493-1500.

Boyd, C.E. 1971. The role of aquatic macrophytes and their relationship to reservoir management. American Fisheries Society Special Publication 8:153-166.

Brown, E.H., Jr. 1972. *Population biology of alewives, Alosa pseudoharengus, in Lake Michigan*, 1949-70. Journal of the Fisheries Research Board of Canada 29:477-500.

Brown, S.J. and M.J. Maceina. 2002. *The Influence of Disparate Levels of Submersed Aquatic Vegetation on Largemouth Bass Population Characteristics in a Georgia Reservoir*. Journal of Aquatic Plant Management 40:28-35..

Everhart, W.H., and W.D Youngs. 1981. *Principles of Fishery Science*. Cornell University Press, Ithaca New York. 349 pp.

Gabelhouse, D.W., Jr. 1984. *A Length-Categorization System to Assess Fish Stocks*. North American Journal of Fisheries Management 4:273-285

Gandino, C.J. 1996. *Community Structure and Population Characteristics of Fishes in a Recovering New York Lake*. 108 pp. M.S SUNY College of Environmental Science and Forestry.

Hartley. R.A., and J. Moring. 1995. *Differences in Mortality Between Largemouth Bass and Smallmouth Bass Caught in Tournaments.* North American Journal of Fisheries Management 15:666-670.

Hurley. D. 2013. *Comparison of Micopterus salmoides population characteristics between two basins Onondaga Lake, New York.* Final Report Edna Bailey Sussman Foundation. 5 pp.

Keller. E.M. and L. Rudstam. 2012. *Factors Affecting Growth and Condition of Alewife.* Intern Report 2012 Cornell Biological Field Station Department of Natural Resources 900 Shackelton Point Road Bridgeport, NY 13030. 15 pp.

Miranda, L. E, and W. D. Hubbard. 1994. *Length-dependent winter survival and lipid composition of age-0 largemouth bass in Bay Springs Reservoir, Mississippi.* Transactions of the American Fisheries Society 123: 80-87.

Ricker, W.E. 1975. *Computation and Interpretation of Biological Statistics of Fish Populations*. Bulletin 191. Fisheries Research Board of Canada, Ottawa. 382 pp.

Sammons, S.M, M. J.Maceina, and D.A. Partridge. 2005. *Population Characteristics of Largemouth Bass Associated with Changes in Abundance of Submersed Aquatic Vegetation in Lake Seminole, Georgia.* J. Aquat. Plant Manage. 43: 9–16.

Savino, J.F. and R.A. Stein. 1989. *Behavioral Interactions Between Fish Predators and their Prey: Effect of Plant Density.* Anim. Behavior. 37: 311-321

Schramm, H.L., A.R. Walters., J.M.Grizzle., B.H.Beck., L.A., Hanson, and S.B., Rees. 2006. *Effects of Live -Well Conditions on Mortality and Largemouth Bass Virus Prevalence in Largemouth Bass Caught During Summer Tournaments*. North American Journal of Fisheries Management 26:812-825.

Smith, C. L. 1985. The Inland Fishes of New York State. New York State Dept. of Environmental Conservation. 281 pp.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: Largemouth bass. U.S. Dept. of Interior, Fish and Wildl. Service. FWS/OBS-82/10.16.

Valley, R.D., T.K. Cross and P. Radomski.2004. *The Role of Submersed Aquatic Vegetation as Habitat for Fish in Minnesota Lakes, Including the Implications of Non-Native Plant Invasions and Their Management*. Minesota Department of Natural Resources Special Publication 160. 25 pp.

Wells, L.R. 1970. *Effects of Alewife Predation on Zooplankton Populations in Lake Michigan*. Limnology and Oceanography 15:556-565

Werner, R. G. 2004. Freshwater fishes of the northeastern United States : a field guide. Syracuse University Press. 335 pp.

Wiley, M.J., P.P. Tazik, and S.T. Sobaski. 1987. *Controlling aquatic vegetation with triploid grass carp*. Circular 57. Ill. Nat. History Surv., Champaign, IL