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

Onondaga County Department of WATER ENVIRONMENT PROTECTION

Final October 2011

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

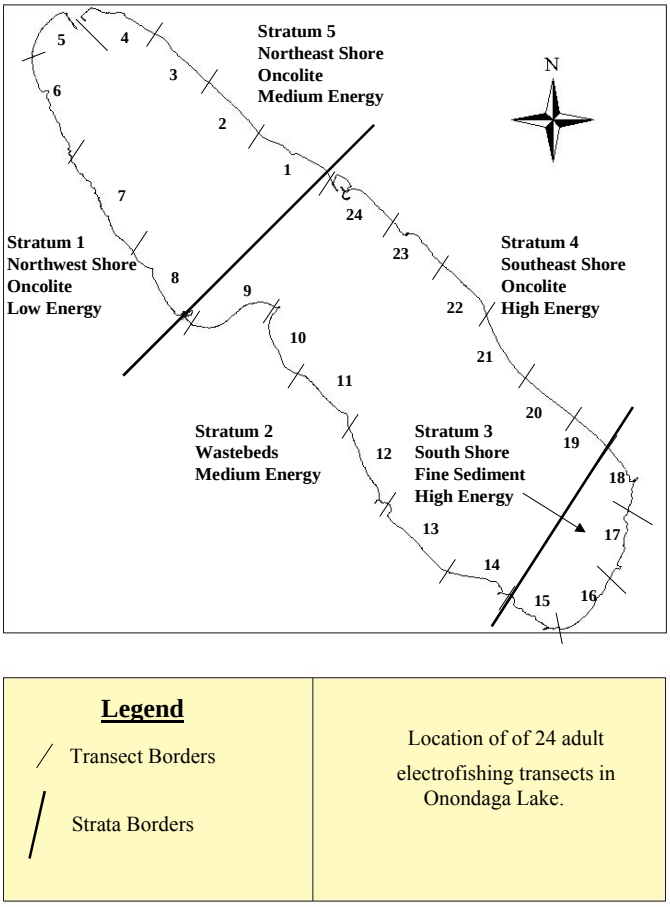
Largemouth bass were collected from Onondaga Lake in 2000 through 2010 to evaluate age, growth, and survivorship patterns. Age and growth estimations were made from scales collected from 810 largemouth bass sampled annually from 2000 through 2010. Growth rates for largemouth bass from 2000 through 2010, were compared to growth rate studies conducted on Onondaga Lake in the early 1990s. The comparison suggests that growth rates have not changed significantly in the past decade. Growth rates of largemouth bass from 2000-2004 were compared to those from 2006-2010 (pre- and post-phosphorus removal). This comparison also indicated no significant difference between the years. Overall growth rates of largemouth bass in Onondaga Lake are comparable to those found in many other New York lakes.

The population of largemouth bass sampled between 2000 and 2010 was composed mainly of young fish. Fifty-eight percent of the largemouth bass sampled were age I – V. The estimated annual survivorship rate of largemouth bass collected between 2000 and 2010 was 0.60. Proportional stock density (PSD) and relative stock density $(RSD)_{381}$, RSD_{508}, and RSD_{635} averaged 57%, 25%, 0.2%, and 0% respectively. A well conditioned external appearance was characteristic of largemouth bass examined in the spring and fall in Onondaga Lake between 2000 and 2010. Instantaneous rate of mortality (Z) of largemouth bass estimated from smoothed catch curves (Ricker 1975), was 0.51 for 2000 through 2010. Estimated annual survival was 0.60.

Methods

Adult fish were collected in one meter (m) of water using electrofishing gear along the entire shoreline of Onondaga Lake. The shoreline was divided into 24 transects, that were sampled annually from 2000 through 2010 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 along a line parallel to the shoreline for approximately fifteen minutes (900 seconds) within each transect.

Figure 1 – Electrofishing Transects



In order to describe age distribution, growth patterns, and mortality rates, scale samples were removed from all 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 scale envelopes 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.

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 2010 were pooled to reduce the effect of variable recruitment from year to year. Because of the variable recruitment, cohort analysis was also used to describe mortality rates of largemouth bass. 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 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 [mm]),
- quality length (12 inches [305),
- preferred length (15 inches [381 mm];
- memorable length (20 inches [508 mm], and
- trophy length (25 inches [635 mm]).

Results for Growth and Survival

A well conditioned external appearance was characteristic of largemouth bass examined in the fall in Onondaga Lake from 2000 through 2010. Largemouth bass exhibited condition factors ranging from 1.29 for age 1 in 2003 to 1.79 for age 7 in 2000 (Table 1). Proportional stock density estimates ranged from 33 in 2003 to 73 in 2005 (Table 2).

Table 1. Fulton Condition Factor (K) of largemouth bass, Onondaga Lake, 2000 – 2010.

					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
Average	**1.42**	**1.47**	**1.42**	**1.50**	**1.48**	**1.53**	**1.59**	**1.59**

Table 2. Proportional stock density and relative stock density of largemouth bass captured in Onondaga Lake 2000 - 2010.

		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
Average	**57**	**57**	**25**	**0.2**	**0**

Overall growth of largemouth bass in Onondaga Lake is satisfactory, considering an active growing season of approximately five (5) months. Largemouth bass growth rates from 2000 through 2010 compared to 1992 through 1993 using a two tailed t-test assuming unequal variance were 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 2010) 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).

Figure 2. *Average length (mm) at age of largemouth bass captured in Onondaga Lake 1992- 1993, 2000 - 2010 (P = 0.99).*

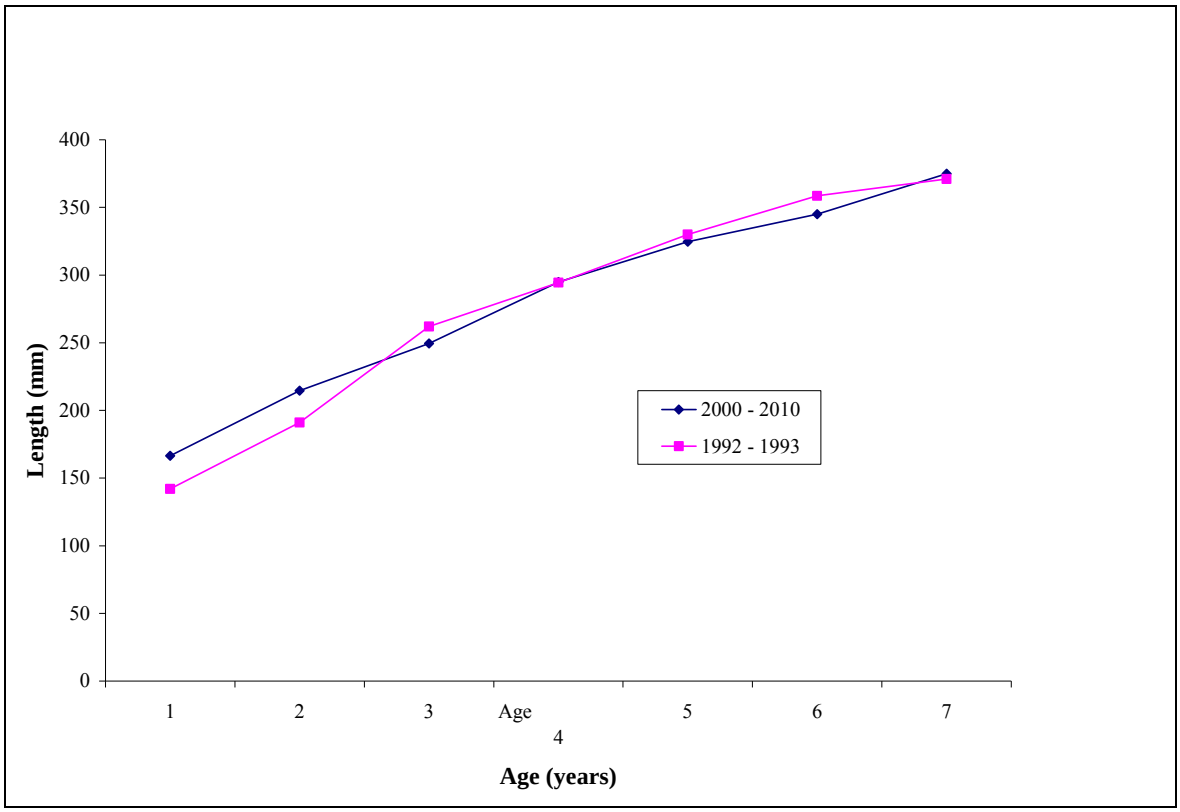


Figure 3. *Average length (mm) at age of largemouth bass captured in Onondaga Lake 2000 - 2004, 2006 - 2010 (P = 0.98).*

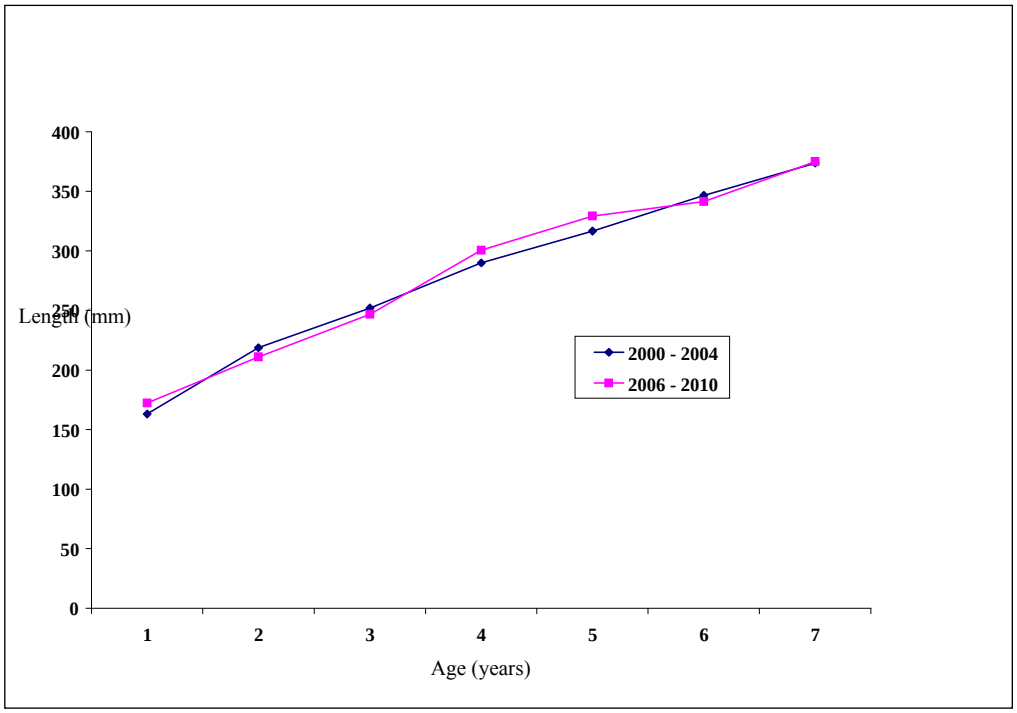
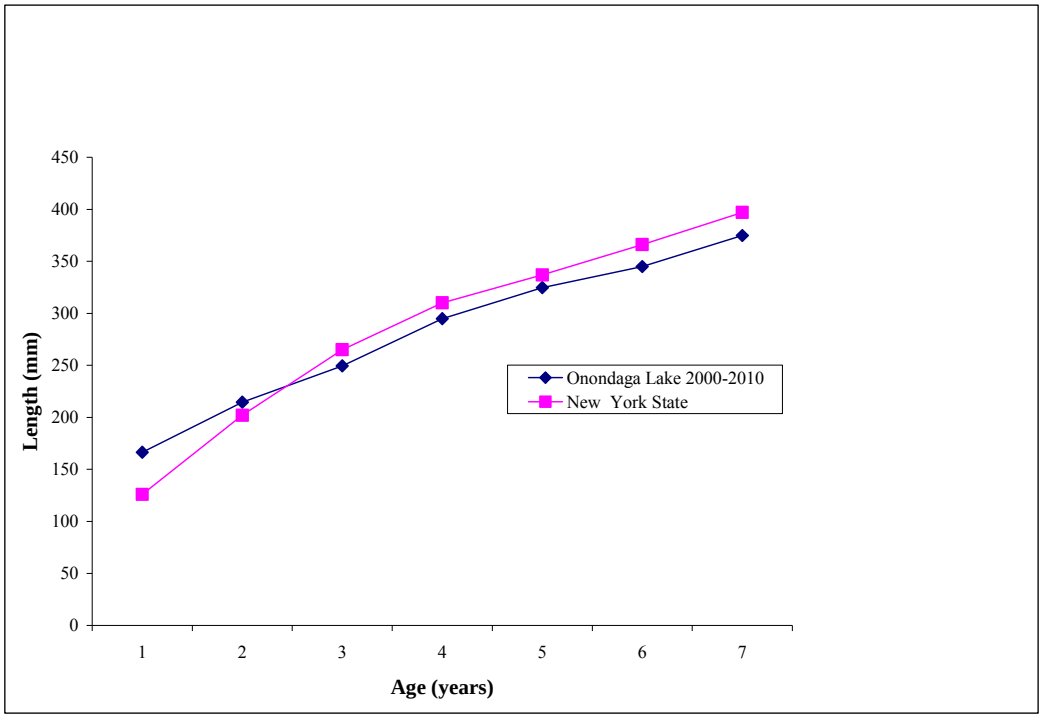


Figure 4. *Average Length of Largemouth Bass in Onondaga Lake compared to the New York State Average. (P = 0.75)*



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, most recruitment, on average, in New York occurred during the third or fourth growing season (Table 3).

Table 3. Average length (mm) of largemouth bass captured in Onondaga Lake 2000 - 2010.

				Age Years				
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1992		142	211	266	314	344	359	374
1993			171	258	275	316	358	368
2000	118	174	218	255	301	337	370	388
2001	100	201	222	278	297	319	343	385
2002	106	165	217	244	285	315	346	372
2003	93	138	218	246	280	309	330	368
2004	123	137	218	237	287	304	344	356
2005		153	212	250	291	342	355	380
2006	117	196	216	251	303	311	321	357
2007		172	220	270	288	344	346	369
2008		138	196	227	302	325	338	353
2009	111	172	215	247	297	340	345	397
2010		184	208	239	313	326	357	399
ONONDAGA LAKE 2000-2010	**110**	**166**	**215**	**249**	**295**	**325**	**345**	**375**
Average 2000-2004	**108**	**163**	**219**	**252**	**290**	**317**	**347**	**374**
Average 2006-2010	**114**	**172**	**211**	**247**	**301**	**329**	**341**	**375**
NEW YORK STATE		**126**	**202**	**265**	**310**	**337**	**366**	**397**

Annual survivorship rates varied from 2000 – 2010; from 0.34 in 2010 to 0.69 in 2008 and 2009 (Table 4). Instantaneous rate of mortality (Z) of largemouth bass estimated from smoothed catch curves (Ricker 1975) was 0.51 in 2000 through 2010 (Table 4). Estimated annual survival (S) was 0.60. This estimate of survival, when compared to annual survival from 1991 through 1993 (0.51), suggest that more fish are surviving per year now than previously (Table 4). The survivorship estimate derived from cohort analysis (Ricker 1975) from 2000 – 2006 was 0.87 (Table 4).

Table 4. Mortality and survivorship rates of adult largemouth bass captured in Onondaga Lake, 1993, 2000 – 2010.

YEAR	Z	S	A	N	Age Range	Method
1990	0.55	0.58	0.42	20	4 - 6	**Catch Curve**
1991	0.61	0.55	0.45	94	4 - 9	**Catch Curve**
1992	0.49	0.61	0.39	61	4 - 9	**Catch Curve**
1993	0.43	0.65	0.35	89	4 - 10	**Catch Curve**
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**
2000 - 2010	0.51	0.60	0.40	214	6 - 14	**Smoothed Catch Curve**
2000 - 2006	0.87	0.42	0.58	92	2 - 6	**Cohort Analysis**
2000 - 2006	0.87	0.42	0.58	92	2 - 6	**Cohort Analysis (CPUE)**

Where: Z = Instantaneous rate of mortality

S = Annual rate of survivorship = e^{-Z}

A = Annual rate of mortality = 1 – S

N = Sample size

Discussion

Estimated survival of largemouth bass in Onondaga Lake from 2000 - 2010 was 0.60. This is similar to rates reported for other lake populations in New York State. Reported annual survival rates ranged from 0.60 for Dryden Lake, NY to 0.65 in bass study waters (AFS warmwater workshop 1993). No exploitation rates are available for the Onondaga Lake population of largemouth bass, but exploitation rates are assumed to be very low due to elevated levels of mercury in the fish flesh and subsequent consumption advisories (Gandino 1996). However, over the past 10 years fishing primarily on a catch and release basis has increased markedly. Tournament angling has become increasingly popular. Local bass organizations compete weekly 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 fishermen usually release their fish, studies from other waters have shown post-release mortality has ranged from 0 to 52% for 20 different evaluations (Schramm et

al. 2006). Hartley (1995) reported that post-release 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 409 acres in 2010. One would expect bass growth to increase with this increase in vegetation providing additional habitat for prey species such as golden shiners and various juvenile fish species. However, catch per unit effort also has increased during this time from 10.3 fish per hour in 2000 to 30 fish per hour in 2010 (all largemouth bass caught boat electrofishing). The stable growth rates over the past 17 years may be related to food web dynamics. As conditions have improved in the lake, the largemouth bass population has increased in size. Other predatory species such as bowfin and northern pike also have 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 effects on growth.

Conversely, high densities of aquatic macrophytes have been shown to adversely affect largemouth bass growth and body condition (Brown 2002). 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. Largemouth bass conditions fell in Florida lakes when hydrilla coverage was greater than 40% (Colle 1980). How the increase in aquatic vegetation in Onondaga Lake has affected largemouth bass is not known.

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 increased to the highest levels in 2008 and 2009. Proportional stock density index values for largemouth bass in Onondaga Lake from 2000-2010 averaged 57 and ranged from 33-73. Gabelhouse (1984) suggested PSD values between 40 – 70 indicate a balanced largemouth bass population. PSD values for Onondaga Lake have fallen in this range in eight of the 11 years studied and in each of the past six years. The Memorable RSD value has averaged 25 in the past 11 years, indicating that there are a good number of 15” 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, good news for anglers.

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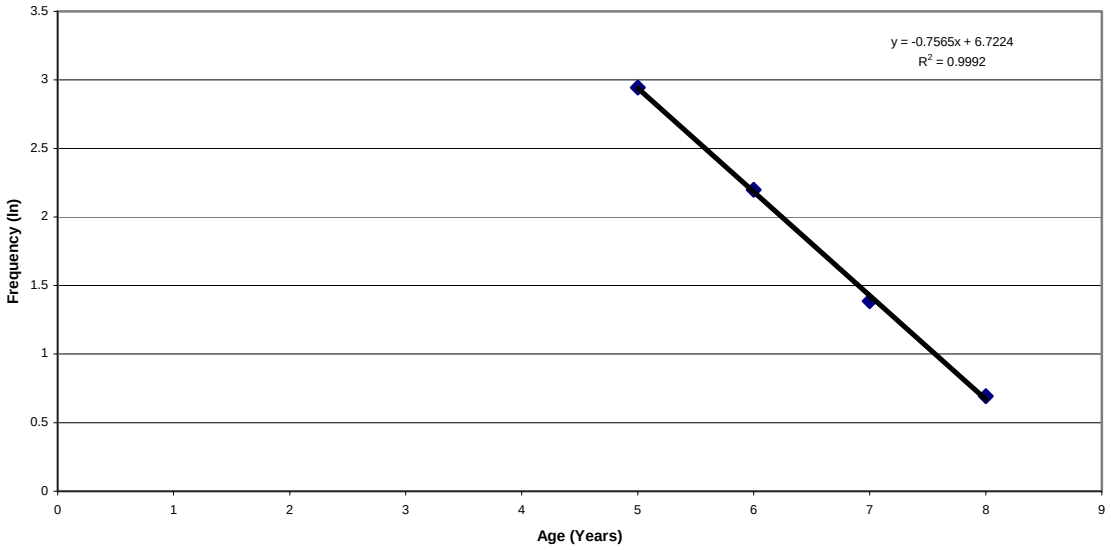
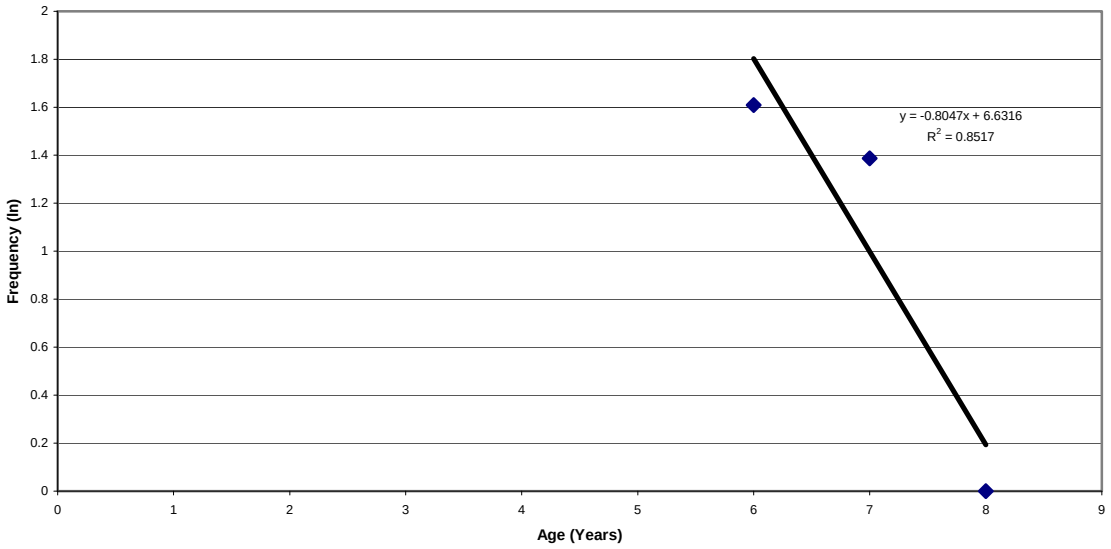
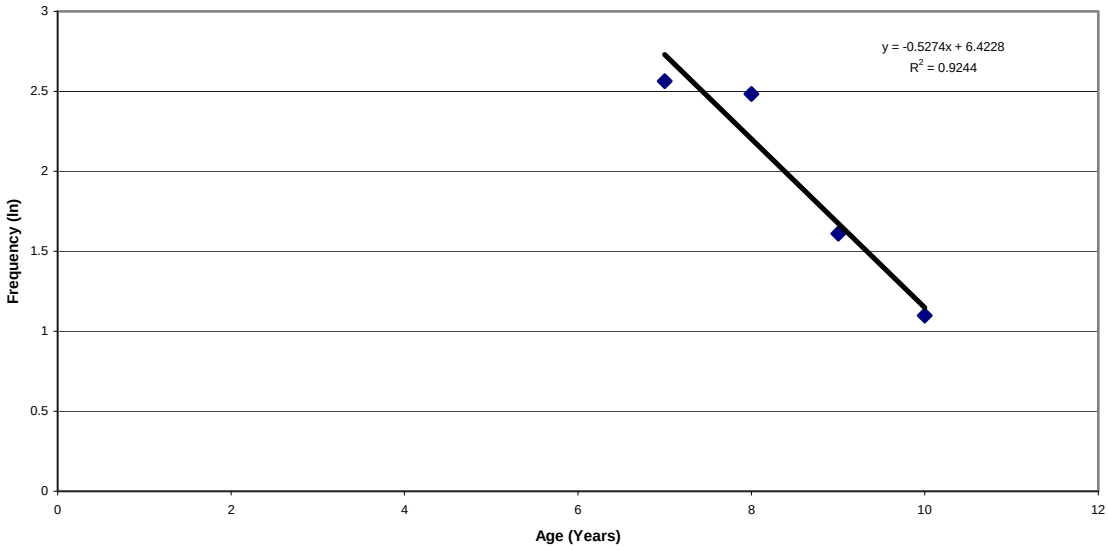
Appendix A. Catch curve of largemouth bass, Onondaga Lake, 2000.



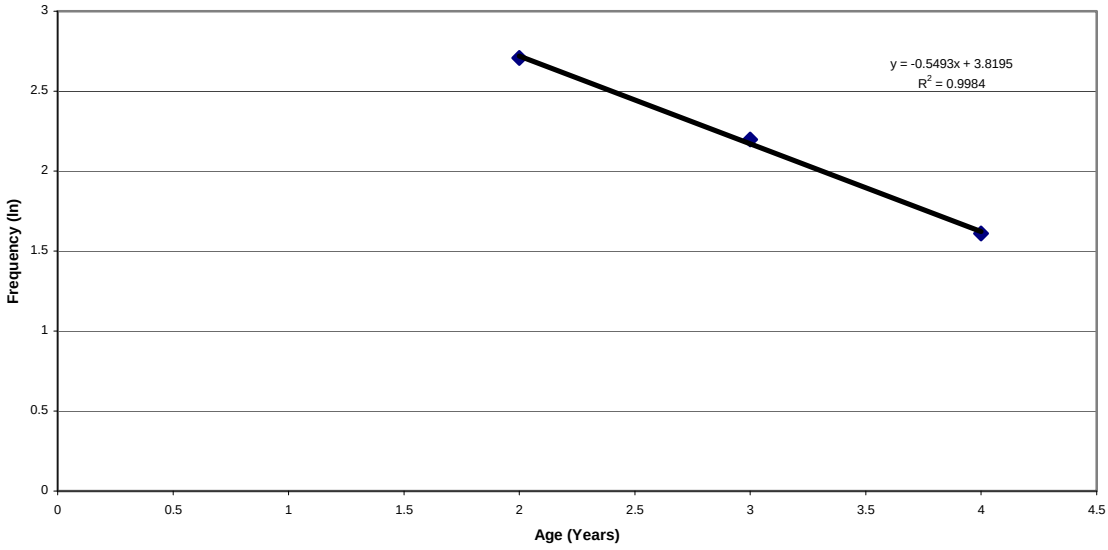
Appendix B. Catch curve oft largemouth bass, Onondaga Lake, 2002



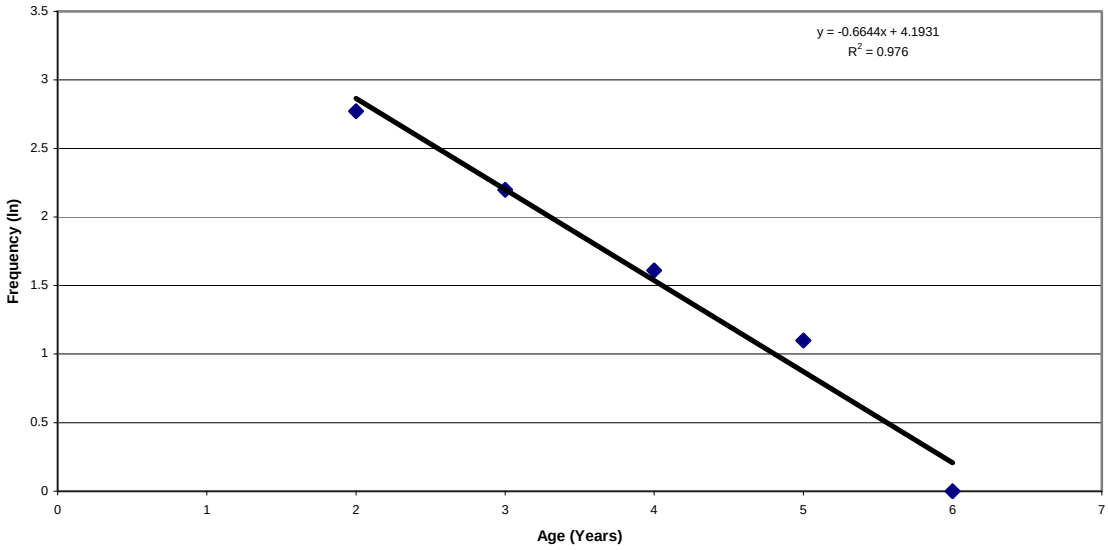
Appendix C. Catch curve of largemouth bass, Onondaga Lake, 2004.



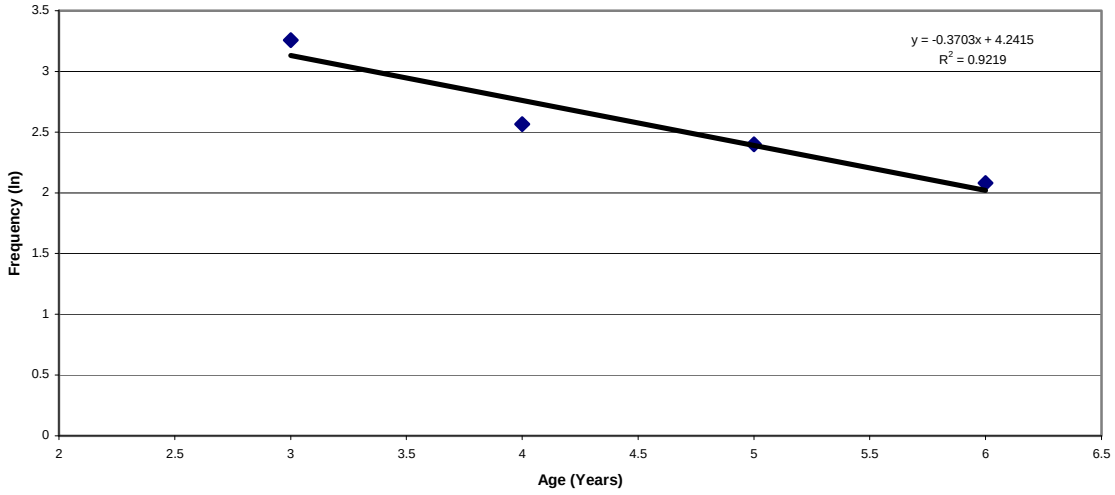
Appendix D. Catch curve of largemouth bass, Onondaga Lake, 2005.



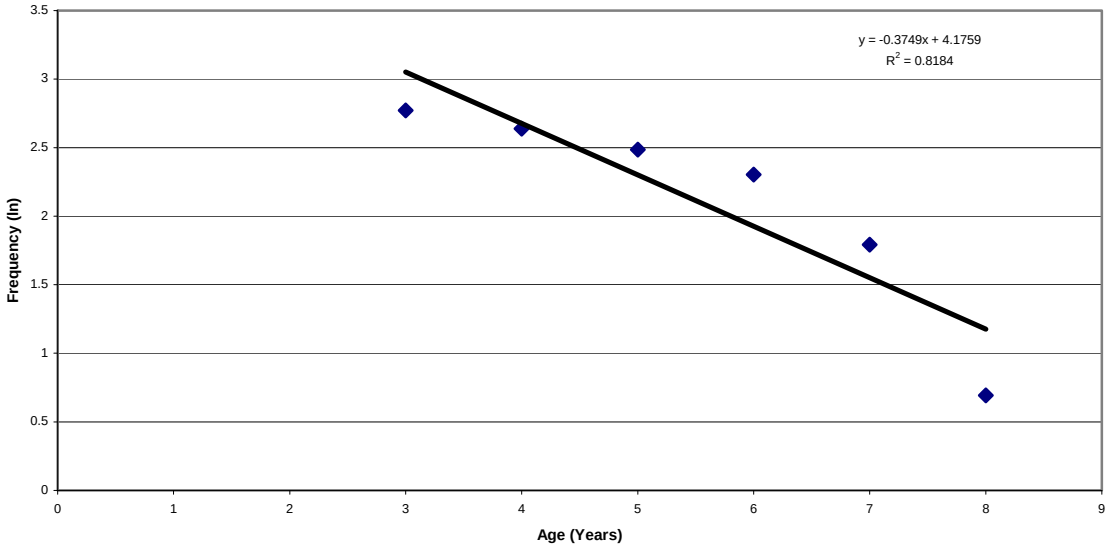
Appendix E. Catch curve of largemouth bass, Onondaga Lake, 2006.



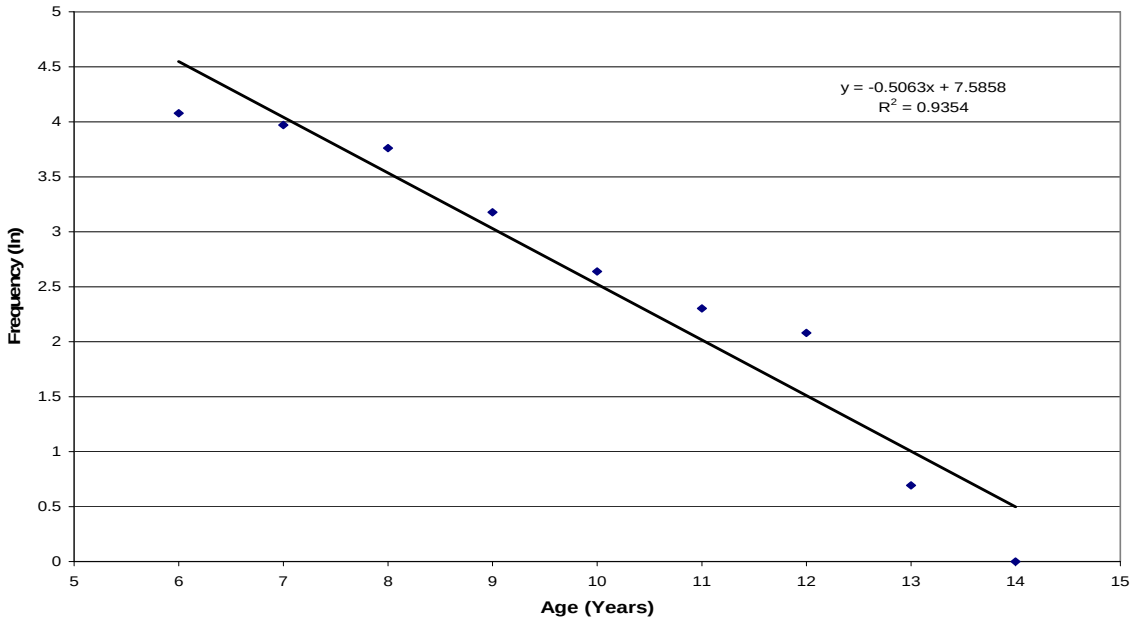
Appendix F. Catch curve of largemouth bass, Onondaga Lake, 2008.



Appendix G. Catch curve of largemouth bass, Onondaga Lake, 2009.



Appendix H. Smoothed catch curve of largemouth bass captured boat electrofishing, Onondaga Lake, 2000-2010.



Appendix I. *CPUE Catch Curve of Largemouth Bass captured boat electrofishing, Onondaga Lake, 2002-2006 Cohort.*