Development of Statistical Catch-At-Age Data Files of Lake Trout in Western and Southern Lake Michigan

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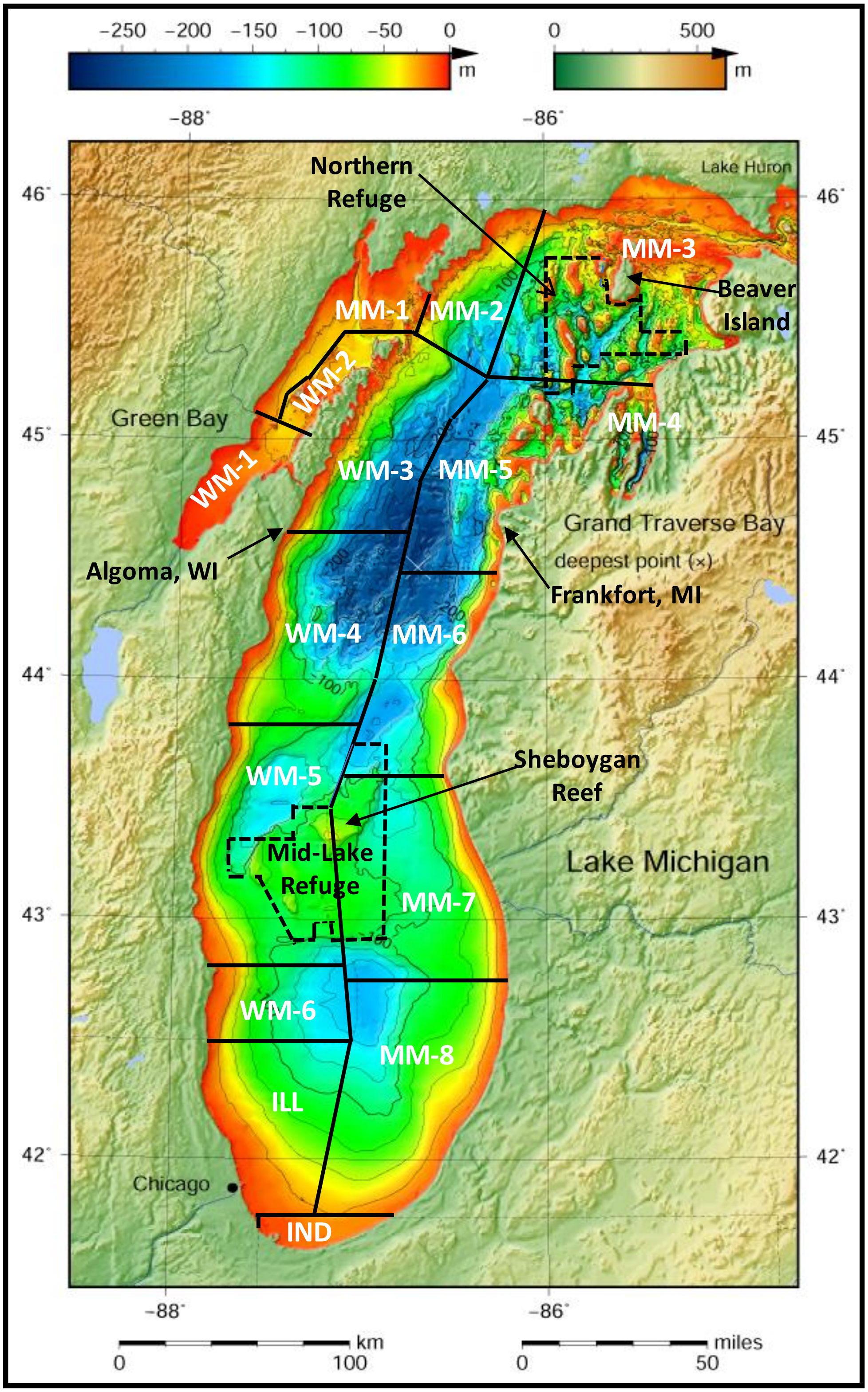
Frontispiece – Lake Michigan bathymetry, topography, statistical districts, refuges, and locations referenced in the text. Base map taken from Wikimedia at https://commons.wikimedia.org/wiki/File:Lake_Michigan_bathymetry_map.png



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Fishery managers have endorsed the use of statistical catch-at-age models (SCAAs) for Lake Trout *Salvelinus namaycush* populations in northeast waters of Lake Michigan (MM-1, MM-2, MM-3, MM-4, MM-5, MM-6, and MM-7 in Frontispiece) to satisfy the requirements of the 2000 Consent Decree in the 1836 Ceded Waters (Modeling Subcommittee, Technical Fisheries Committee 2018). These SCAAs provide a series of annual estimates of population-level parameters, such as abundance, mortality, and recruitment, and partition mortality into fishing and natural components and recruitment into hatchery-reared and natural components. Managers have used these estimates to monitor abundance, control fishing, and allocate the harvest between fisher groups (Caroffino and Lenart 2011; Truesdell and Bence 2016; Modeling Subcommittee, Technical Fisheries Committee 2018). While many of the same types of data that were used to develop SCAAs in northeast Lake Michigan were also collected in southwest waters (WM-3, WM-4, WM-5, WM-6, ILL, IND, and MM-8 in Frontispiece), stock assessment models have not been previously fit to the data collected in the southwest waters. This shortcoming has limited population-level analyses and management in southwest waters and lake-wide. For example, Tsehaye et al. (2014a, 2014b) estimated lake-wide abundance of Lake Trout and their consumption of prey fish by assuming that population density in southwest waters was equal to that in northeast waters. While there was little alternative to making this assumption at the time, evidence now suggests that these lake-wide estimates were likely inaccurate, because stocking, mortality, and reproductive rates differ between the southwest and northeast parts of Lake Michigan (Lake Michigan Lake Trout Working Group Report 2018).

Therefore, to help improve population-level analyses, we applied SCAAs to Lake Trout in western and southern waters of Lake Michigan. We wanted to compare estimates in these waters to the existing estimates in northeast waters and to combine estimates for both regions to obtain lake-wide estimates. This means that we used a spatial-partitioning approach to stock assessment. Our hypothesis was that spatial-partitioning would provide better estimates of lake-wide abundance, prey consumption, and other population statistics than extrapolating density from northeast to southwest waters, as well as allow assessment of regional differences. The basis for our approach was that substantial regional differences in abundance, fishing mortality, natural reproduction, and diets have been reported for Lake Trout in Lake Michigan. In addition, we know that Lake Trout are less mobile than other pelagic predators such as Chinook Salmon *Oncorhynchus tshawytscha*, which have been assessed using a lake-wide approach (Adlerstein et al. 2007, 2008; Tsehaye et al. 2014a; Clark et al. 2017). Accounting for spatial differences in life history parameters improved walleye assessments in Lake Erie (Berger et al. 2012) and will likely improve Lake Trout assessments in Lake Michigan.

The purpose of this report is to document data sources and analytical methods we used to develop the input for our SCAA models. Our hope is that biologists and managers will continue to update these models and assessments to help monitor Lake Trout populations, and that this report will be used as a resource for biologists working on future updates. Stock assessments like ours rely on inputs that are compiled to describe "observed" fishery catch and effort and biological statistics for the species under consideration. The essence of an SCAA is to derive estimates of population parameters like abundance, selectivity, catchability, mortality, and recruitment most consistent with these observed values. Developing the observed values for our SCAA stock assessments was complex and time-consuming. This report gives the details about how we organized and analyzed the data, and what assumptions we made in the process.

Many of the data in the Great Lakes for Lake Trout and other salmonines are organized by statistical districts (Smith et al. 1961; Frontispiece). This means that statistical districts are the smallest spatial unit for which an SCAA would be practical in Lake Michigan. We begin this report by presenting data and initial analyses of Lake Trout populations by individual statistical districts. This allowed us to evaluate the spatial differences in population parameters at the finest spatial scale practical. We also used this spatial analysis to help us combine statistical districts for our SCAAs. We analyzed spatial location of recovery, growth, and mortality of coded-wire-tagged (CWT) Lake Trout to help judge which statistical districts to combine.

DATABASE MANAGEMENT

We received, organized, and analyzed the following information to produce data files for our SCAAs of Lake Trout in Lake Michigan:

1. biological and catch information for Lake Trout contained in the Great Lakes Fishery Commission (GLFC) database that is maintained by the United States Fish and Wildlife Service (USFWS) Green Bay Fishery Conservation Office, Green Bay, WI;
2. CWT recovery information and biological data on Lake Trout harvested by recreational fisheries on lakes Michigan and Huron that was collected by the "BioTech" monitoring program of the USFWS Mass Marking Program (Bronte et al. 2012);
3. CWT information from the Great Lakes Fish Stocking Database (http://www.glfc.org/fishstocking/);
4. biological information (e.g., age, length, sex, maturity, etc.) on Lake Trout harvested by recreational fisheries provided by Wisconsin, Illinois, Michigan, and Indiana Departments of Natural Resources (DNRs);
5. biological information from spring/summer gill-net surveys conducted according to protocols in the Lakewide Assessment Program for Lake Michigan Fish Communities (LWAP; Schneeberger et al. 1998);

6. biological information from fall gill-net surveys under the Lake Trout Spawning Assessment Program (Lake Michigan Lake Trout Working Group 2018);
7. Lake Trout stocking information by year and statistical district from the GLFC stocking database;
8. creel survey estimates of recreational fishing effort and Lake Trout harvest and catch, including charter fisheries, from Wisconsin, Illinois, Michigan, and Indiana DNRs;
9. commercial fishery bycatch and fishing effort for Lake Trout from Wisconsin, Illinois, and Indiana DNRs; and,
10. SCAA inputs and results for the four assessment units (statistical districts or combinations of them, MM123, MM4, MM5, and MM67) in the 1836 Ceded Waters.

We synthesized all the information described above and collected during 1986-2017 into a Microsoft ACCESS® database to assist with organization of the data and to query subsets of data to be used for analysis. We based the original database structure on the GFLC database that is stored at the USFWS Green Bay Fish and Wildlife Conservation Office, 2661 Scott Tower Drive, New Franken, Wisconsin 54229, USA. We have provided the structure of our database in **Appendix 1** of this report. The ACCESS database that was being maintained for the GLFC to evaluate Sea Lamprey *Petromyzon marinus* marking of Lake Trout and other fish species contained the table "_LM Master Gear" that described date, agency, collection method, collection location, and gear characteristics for each fish in the database. A second table named "LM LAT Biodata – Ebener" contained information that linked biological data on length, weight, fin clips, aging structure, sex, maturity, and Sea Lamprey marks to the table "_LM Master Gear." Biological data on Lake Trout that were collected by the USFWS Mass Marking BioTech monitoring program and the creel survey programs of each DNR were also inserted into the ACCESS database. Last, we inserted information from the Great Lakes Fish Stocking Database for each CWT lot number into our ACCESS database.

We created four additional tables within the ACCESS database. The table "*All Harvest Monitoring*" contained biological information on Lake Trout collected during monitoring of commercial and recreational fisheries from 1982 through 2017. The table "*LAT Biodata non_monitoring*" contained biological data on Lake Trout captured in agency surveys during 1985-2017. The table "*CWT Bio data survey_fisheries*" contained biological data on CWT-marked Lake Trout collected from both agency surveys and monitoring of commercial and recreational fisheries during 1982-2017. Last, the table "*CWT stocking info*" contained data describing stocking history for each CWT lot number.

LAKE-WIDE SPATIAL EVALUATION OF POPULATION DEMOGRAPHICS

Many of the hatchery-reared Lake Trout that were stocked into Lake Michigan were tagged with CWTs for various research projects beginning in 1985. Most tagged fish were yearlings when stocked. Numbers of yearlings tagged during 1985-2011 varied annually, but after 2011, 100% of the yearlings stocked were tagged with CWTs (**Table 1**). No fingerling Lake Trout were CWT-marked prior to 2010, but afterward 100% of fingerlings were tagged (**Table 1**). Fishery agencies recovered 43,703 CWT-marked Lake Trout in all regions of Lake Michigan during 1985-2017. Numbers recovered by year varied due to both variable numbers of CWT-fish at large and annual variation in agency efforts directed at collecting CWTs (**Table 1**). The CWTs had unique numbers for locations and years stocked. When these CWT fish were recovered, their location, size, sex, and maturity were recorded. We relied heavily on these CWT recoveries to estimate growth, mortality, movement (recruitment), and maturity rates. We assumed that CWTs did not affect these biological processes. Most importantly, we assumed that CWTs provided ages of recaptured fish with extremely low rates of error. Lake Trout are long-lived and notoriously difficult to age accurately from scales and bony structures (see Burnham-Curtis and Bronte 1996; Schram and Fabrizio 1998; Campana et al. 2008), so we believe the CWT ages provided more accurate parameter estimates than has been achieved previously using other aging methods. The CWT-marked Lake Trout recoveries were essentially a large sample of known-age fish, and it is worth noting that during the 1980s and 1990s, over 1 million yearlings were CWT marked in many years (**Table 1**). These fish exhibited good survival in much of the lake, and so provided good sample sizes of known-age fish that were up to 20+ years old.

We estimated growth and mortality of CWT-marked Lake Trout in each statistical district of Lake Michigan to understand spatial variability in these population demographics. All length, weight, and age data for CWT-marked Lake Trout captured in each statistical district were aggregated to provide a single estimate of age composition for estimating total annual mortality, and mean length and weight-at-age for evaluating growth. We excluded CWT-marked Lake Trout collected from Grand Traverse Bay (MM-4) and Green Bay from our analysis and concentrated only on statistical districts of the main basin of Lake Michigan (see **Frontispiece**).

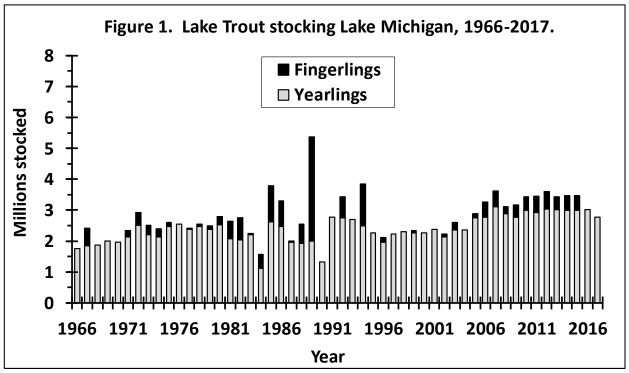
Table 1. Number of yearling and fingerling Lake Trout tagged with CWTs, total number stocked (tagged and untagged), percent tagged, and total number of CWTs recovered annually in Lake Michigan, 1985-2017.

	Yearlings			Fingerlings			
Year	Number tagged	Number stocked	Percent tagged	Number tagged	Number stocked	Percent tagged	Number of CWTs recovered
1985	774,968	2,623,419	30%	0	1,158,423	0%	0
1986	1,370,800	2,474,403	55%	0	822,600	0%	288
1987	0	1,973,350	0%	0	24,984	0%	56
1988	0	1,922,628	0%	0	623,600	0%	78
1989	149,000	2,005,600	7%	0	3,371,122	0%	590
1990	1,317,115	1,317,115	100%	0	0	0%	255
1991	1,534,697	2,779,482	55%	0	0	0%	155
1992	1,531,393	2,761,244	55%	0	673,621	0%	248
1993	1,288,235	2,696,835	48%	0	0	0%	180
1994	1,085,912	2,496,012	44%	0	1,357,821	0%	470
1995	1,241,028	2,264,528	55%	0	0	0%	1,043
1996	939,400	1,971,448	48%	0	143,630	0%	2,117
1997	937,800	2,235,200	42%	0	0	0%	1,268
1998	924,800	2,302,140	40%	0	0	0%	1,441
1999	815,100	2,273,626	36%	0	74,700	0%	1,764
2000	913,714	2,260,341	40%	0	0	0%	1,327
2001	808,066	2,381,612	34%	0	0	0%	1,303
2002	965,946	2,136,658	45%	0	87,519	0%	1,171
2003	810,557	2,354,029	34%	0	254,735	0%	1,108
2004	711,081	2,354,134	30%	0	0	0%	978
2005	62,832	2,749,581	2%	0	137,750	0%	1,261
2006	0	2,769,557	0%	0	485,879	0%	1,281
2007	0	3,103,340	0%	0	520,675	0%	988
2008	0	2,881,868	0%	0	240,216	0%	877
2009	0	2,770,659	0%	0	406,000	0%	911
2010	210,397	3,001,855	7%	427,767	427,767	100%	783
2011	2,848,094	2,928,094	97%	526,076	526,076	100%	328
2012	3,045,793	3,045,793	100%	552,847	552,847	100%	738
2013	3,017,899	3,017,899	100%	415,198	415,198	100%	976
2014	3,000,830	3,000,830	100%	477,861	477,861	100%	2,198
2015	3,007,663	3,007,663	100%	455,004	455,004	100%	4,764
2016	3,016,614	3,016,614	100%	0	0	100%	7,311
2017	2,769,470	2,769,470	100%	0	0	100%	5,447
Totals	39,099,204	125,840,167		2,426,986	17,451,427		43,703

Recruitment

Stocking of hatchery-reared fish

We summarized and organized the stocking history for Lake Trout in Lake Michigan to assist in estimating recruitment of stocked fish to each statistical district and spatial units that are combinations of statistical districts. Stocking of Lake Trout into Lake Michigan increased slowly through time and stabilized at roughly three million yearlings (13-15 month) and fingerlings (10-12 month) from 1966 through 2017 (**Figure 1**). Yearling Lake Trout have made up 86% of all fish stocked. Fertilized eggs, fry, and adults were also stocked, but we decided not to use these life stages because so few adults were stocked and because we assumed that the number of survivors of Lake Trout stocked as eggs and fry was negligible. Instead, we focused only on fingerlings and yearlings. Of the yearling fish stocked into Lake Michigan, 88% were placed into the main basin, 9% were placed into Grand Traverse Bay, and 3% were placed into Green Bay. Most of the Lake Trout were stocked into the northern portion (65%) of the main basin (**Appendix 2**).

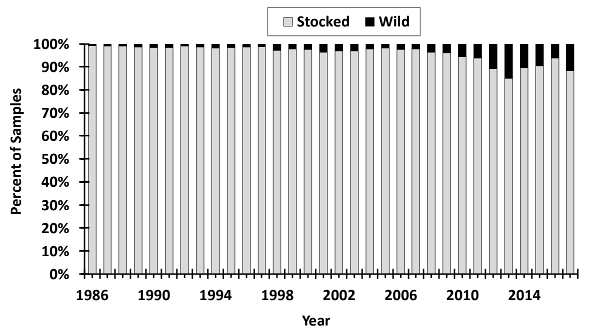


Stocking was more inconsistent for fingerlings than for yearlings. The annual number of fingerling Lake Trout stocked ranged from zero to 3.3 million and averaged 334,000 during 1966-2017. Large numbers of fingerlings were stocked during the mid to late 1980s and consistent annual plants of between 240,000 and 553,000 were made in nearshore areas of southern Lake Michigan during 2006-2015 (**Appendix 3**). No fingerling Lake Trout were stocked in 2016 or 2017.

Natural reproduction

Natural reproduction by Lake Trout in Lake Michigan has been low in comparison to the adjacent lakes Superior and Huron (Eshenroder et al. 1995; Hansen et al. 1995; Holey et al. 1995; Reid et al. 2001; Wilberg et al. 2003; Riley et al. 2007; Claramunt et al. 2012; He et al. 2012). Unclipped, presumably wild, Lake Trout have been observed every year in biological samples collected from agency surveys and monitoring of recreational and commercial fishery harvests in Lake Michigan. There were 231,105 Lake Trout in our biological database with 2.9% being wild during 1986-2017. The annual proportion of wild fish in our database for Lake Michigan ranged from 1% to 15% (**Figure 2**). The proportion of wild Lake Trout was less than 2% from 1986 to 1997,

Figure 2. Percent stocked and wild, 1986-2017.



ranged between 2% and 6% during 1998-2011, and increased to between 6% and 15% after 2011. The proportion of wild fish increased to its highest level at the end of the time series in 10 of the 12 statistical districts, the exceptions being MM-2 and MM-3 (**Table 2**).

Table 2. Proportion of unclipped Lake Trout represented in biological samples from survey, commercial, and recreational fisheries in statistical districts of Lake Michigan, 1986-2017.

	Statistical District											
Year	ILL	IND	WM-5	WM-6	MM-7	MM-8	MM-2	MM-3	MM-5	MM-6	WM-3	WM-4
1986			0.003		0.011			0.008	0.004	0.000	0.010	
1987			0.004	0.000	0.003			0.016	0.010	0.004	0.011	0.011
1988			0.004		0.017	0.833	0.250	0.024	0.009	0.038	0.009	0.009
1989			0.004	0.000	0.010		0.000	0.009	0.015	0.039	0.015	0.004
1990			0.010			0.050		0.012		0.037	0.016	0.015
1991			0.009				0.000	0.033		0.043	0.011	
1992			0.005				0.050	0.017		0.060	0.009	0.000
1993			0.016		0.000		0.000	0.012		0.000	0.013	0.021
1994			0.008		0.122	0.033	0.008	0.036	0.075	0.095	0.014	0.019
1995			0.008		0.051	0.086	0.033	0.021	0.000	0.032	0.018	
1996			0.004		0.046	0.050	0.031	0.017	0.013	0.174	0.012	0.000
1997			0.005		0.027	0.027	0.041	0.017	0.027	0.031	0.009	
1998	0.011		0.017		0.125	0.052	0.000	0.047	0.026	0.024	0.010	0.000
1999	0.011		0.008		0.000	0.013	0.029	0.038	0.051	0.018	0.017	0.018
2000	0.000	0.019	0.006		0.000	0.028	0.074	0.047	0.026	0.028	0.012	0.032
2001	0.006	0.164	0.020		0.000	0.057	0.017	0.046	0.021	0.025	0.014	0.018
2002	0.005	0.020	0.009		0.061	0.029	0.000	0.079	0.015	0.013	0.024	0.036
2003	0.036	0.030	0.018		0.000	0.007	0.018	0.066	0.003	0.034	0.041	0.038
2004	0.031	0.028	0.024		0.000	0.020	0.012	0.034	0.012	0.000	0.047	0.012
2005	0.029	0.000	0.007		0.015	0.023	0.000	0.012	0.019	0.000		0.059
2006	0.052	0.031	0.016		0.016	0.007	0.009	0.034	0.025	0.017	0.047	0.013
2007	0.038	0.010	0.009		0.025	0.014	0.000	0.039	0.020	0.013	0.066	0.017
2008	0.080	0.023	0.023		0.025	0.077	0.045	0.043	0.022	0.027	0.019	
2009	0.157	0.027	0.021		0.011	0.028	0.031	0.032	0.021	0.015	0.060	0.079
2010	0.175	0.006	0.040		0.020	0.026	0.037	0.060	0.023	0.046	0.111	0.050
2011	0.142	0.029	0.032	0.200	0.013	0.032	0.050	0.059	0.053	0.094	0.043	0.028
2012	0.448	0.000	0.056		0.085	0.035	0.009	0.045	0.037	0.137	0.125	0.750
2013	0.459	0.020	0.165		0.074	0.035	0.102	0.116	0.060	0.127	0.099	0.102
2014	0.519	0.070	0.194		0.087	0.046	0.000	0.026	0.030	0.076	0.070	0.079
2015	0.447	0.211	0.196		0.074	0.127	0.005	0.022	0.067	0.075	0.043	0.184
2016		0.056	0.161		0.107	0.153	0.021	0.022	0.028	0.070	0.099	0.131
2017	0.582	0.161	0.130		0.164	0.229	0.018	0.027	0.067	0.105	0.119	0.127
Total	0.172	0.054	0.022	0.129	0.036	0.066	0.024	0.034	0.021	0.044	0.014	0.030

The percentage of unclipped Lake Trout caught in the recreational fishery, LWAP, and spawning surveys (SPAWN) was inconsistent between these collection methods (**Figure 3**). There were 56,158 Lake Trout represented in biological (BIO) samples from the recreational fishery and the percentage of unclipped fish averaged 13.7% during 1986-2017. In comparison, there were 83,074 and 32,481 fish in BIO samples from the SPAWN (1986-2017) and LWAP surveys (1998-2017), respectively, and the percentage of unclipped fish averaged 4.6% and 4.1% respectively. The percentage of unclipped fish in the recreational fishery was greater than the percentage in the LWAP and SPAWN surveys in all statistical districts except MM-2 and MM-3 (**Figure 4**). The greater percentage of unclipped fish in the recreational fishery than other fisheries is confusing since the recreational fishery data covered years prior to 1998 when unclipped fish abundance was low throughout the lake (**Figure 2**). We suspect that clip miss-identification by inexperienced creel clerks may explain why the observed percentage of unclipped fish was greater in the recreational fishery than in surveys conducted by experienced field staff.

Figure 3. Length frequency by fishery type, Lake Michigan 1986-2017.

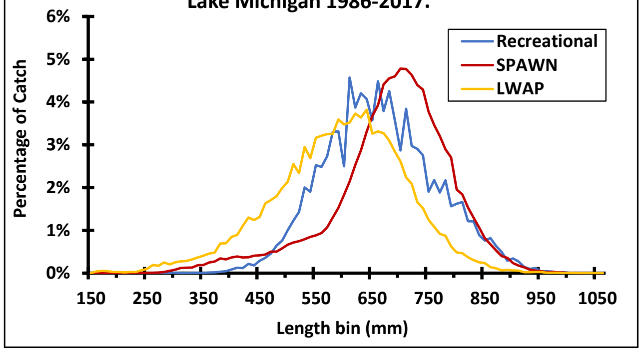
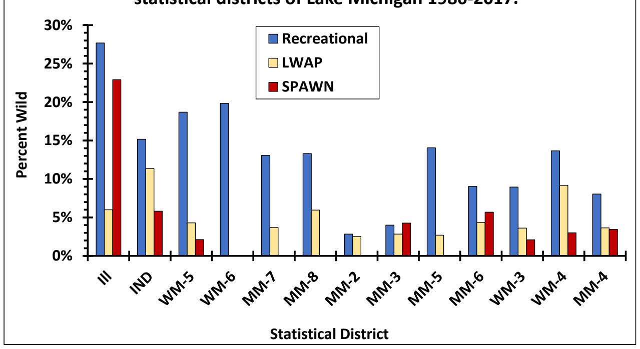


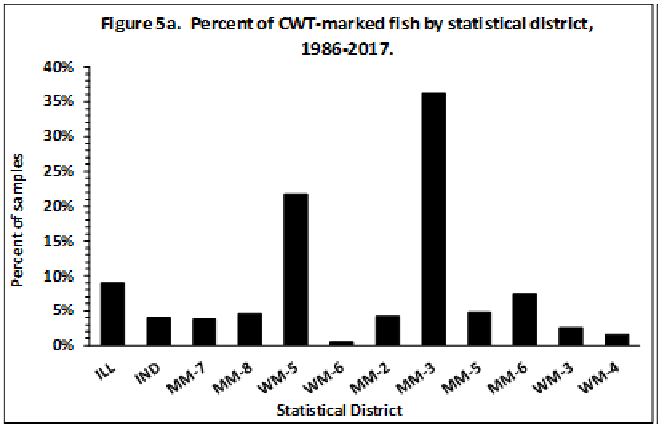
Figure 4. Percent wild by fishery type in statistical districts of Lake Michigan 1986-2017.

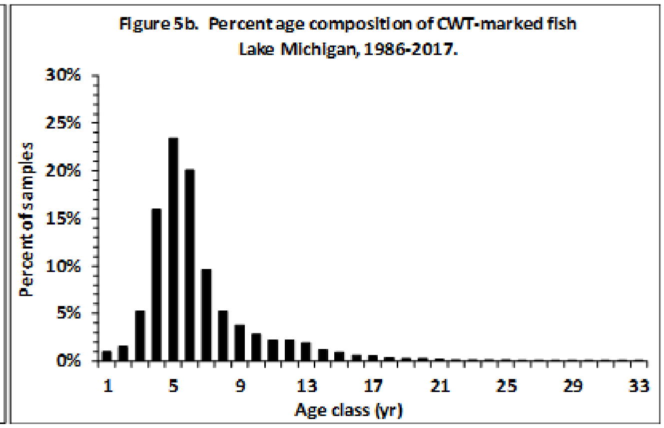


Growth

Growth in length

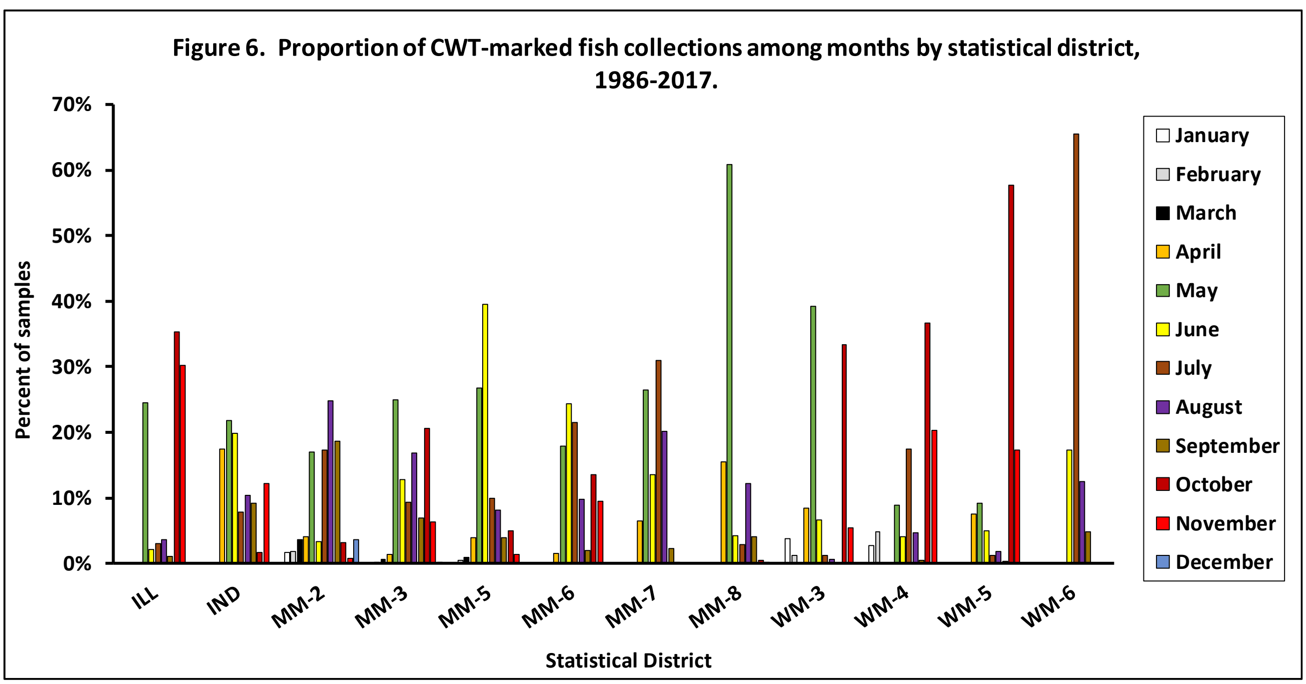
We estimated mean length-at-age of CWT-marked Lake Trout captured during agency surveys or monitoring of commercial and recreational fishery harvests in each statistical district during 1986-2017. There were 40,730 CWT-aged Lake Trout of ages 1-33 with length measurements in our database. Thirty-six percent of the CWT-aged fish came from MM-3 and 22% from WM-5 with other statistical districts making up 1% to 9% (**Figure 5a**). Lake Trout of ages 3-8 made up 79% of CWT-aged fish in our database, but 59% were ages 4-6 (**Figure5b**). Fish less than age-3 were represented in our database but 98% of age-1 and 83% of age-2 fish came from MM-3, where they were caught during Michigan DNR bottom trawl surveys.





Seasonal allocation of CWT-marked Lake Trout collections varied substantially among statistical districts. Only in MM-2 were fish collected in every month of the year, whereas in WM-6 fish were collected only during June through September. In ILL, WM-3, WI-4, and WI-5 CWT-marked fish were captured primarily during SPAWN surveys (43-75%) in October and November (**Figure 6**). In other units, CWT-marked Lake Trout were captured primarily during spring LWAP surveys and summer creel surveys.

Mean length-at-age of CWT-marked Lake Trout did differ somewhat among spatial areas at the youngest ages in Lake Michigan but not at older ages. Differences in mean total length-at-age among statistical districts ranged from 50 to 237 mm with the largest difference among fish being for ages 1-6, age-18, age-21, and age-31. The smallest difference in mean total length-at-age was for ages 7-16, ages 19-24, ages 26-28, age-30, and



age-32 and ranged from 50 to 98 mm among statistical districts. The large difference in mean length of ages 1-6 Lake Trout among statistical districts was primarily due to differences in the amounts of effort applied with different types of fishing gears among districts and the differences in the size and age selectivity of those gears. Mean total length-at-age was remarkably similar among statistical districts for age-4 and older Lake Trout (**Figure 7a**). Mean length of age-3 Lake Trout tended to be more variable among statistical districts than other ages with the largest fish coming from IND and the smallest from WI-3, WI-4, and WI-5 (**Figure 7b**).

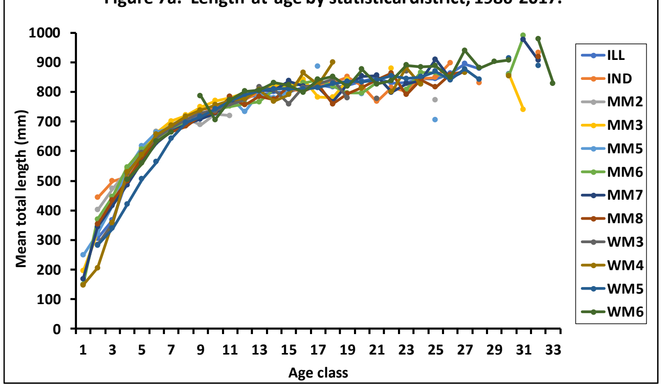


Figure 7a. Length-at-age by statistical district, 1986-2017.

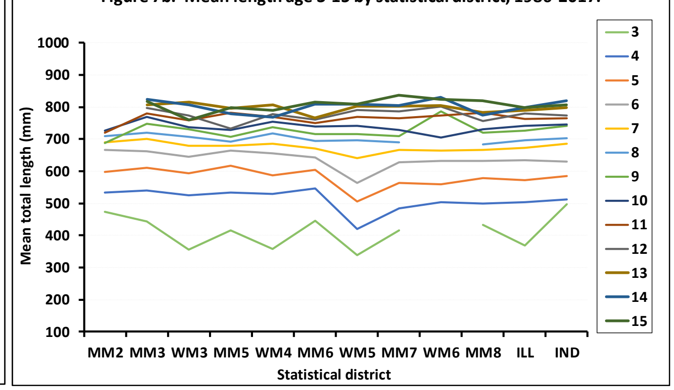


Figure 7b. Mean length age 3-15 by statistical district, 1986-2017.

Application of von Bertalanffy growth model

We fit von Bertalanffy (vonB) growth curves to data on length (dependent variable) at age (independent variable) for individual Lake Trout using a tailored AD Model Builder (ADMB) non-linear regression template (**Appendix 4**) to estimate the parameters $\boldsymbol{L_\infty}$, $\boldsymbol{t_0}$, and $\boldsymbol{k}$ in each statistical district during 1986-2017 as:

(1) $$\boldsymbol{L_t = L_\infty\left(1 - e^{(-k(t-t_0))}\right)}$$

where $\boldsymbol{L}$ is predicted total length in millimeters, $\boldsymbol{L_\infty}$ is the average asymptotic length, $\boldsymbol{k}$ is the rate in time at which a fish approaches $\boldsymbol{L_\infty}$, $\boldsymbol{t}$ is age, and $\boldsymbol{t_0}$ is the hypothetical age at which a fish is zero length. Along with estimating vonB parameters, the template estimated the intercept and slope for the relationship between the log of the coefficient of variation (CV) in length and mean length (as calculated from equation 1). The standard deviation ($\boldsymbol{\sigma}$ = sigma) for deviations about the age-length relationship (assumed to be normally distributed during model fitting) were then calculated as **σ = CV** $\boldsymbol{L_t}$ (see **Appendix 4**).

Our vonB growth coefficients showed limited spatial patterns. Estimates of $\boldsymbol{L_\infty}$ ranged from 783 mm total length in MM-5 to 899 mm total length in WM-6, $\boldsymbol{k}$ ranged from 0.15 in WM-6 to 0.34 in WM-3, and $\boldsymbol{t_o}$ ranged from -1.8 years in WM-6 to 1.1 years in WM-5 (**Table 3**). Sigma varied from 0.13 in MM-2 to 0.89 in WM-

4. Interestingly, vonB growth coefficients were similar among statistical districts that were at the same latitude. For example, $\boldsymbol{L_\infty}$ and $\boldsymbol{k}$ were similar between WM-3 and MM-5, WM-4 and MM-6, WM-5 and MM-7, and ILL and MM-8. Values of $\boldsymbol{k}$ were also similar for statistical districts WM-4, WM-5, Ill, MM-6, MM-7, and MM-8 but $\boldsymbol{L_\infty}$ was not similar among these same districts. We suspect that differences in $\boldsymbol{L_\infty}$ and $\boldsymbol{k}$ among statistical districts are in part due to relatively few old fish being observed near the asymptotic size because the actual mean length at age data do not provide strong evidence that length at older ages is different among statistical districts.

Table 3. Statistics for data used, parameter estimates, and ADMB convergence (maximum gradient) for fits of von Bertalanffy growth models for CWT-marked Lake Trout collected from statistical districts in the main basin of Lake Michigan by recreational, commercial, and survey fisheries during 1986-2017. ***CVexp_a*** is the intercept and ***CV_b*** is the slope of the relationship between the natural logarithm of the coefficient of variation in length and mean length (L) and was estimated as CV=exp(ln(CVexp_a)+CV_b*L).

Stat. district	Years	Number years	Age range	Length range	Number fish	Maximum gradient	von Bertalanffy parameters L-infinity	k	to	CVexp_a	CV_b
Ill	1998-2017	20	2-30	305-1010	3,648	1.35E-05	832	0.2305	-0.0623	0.272534	-0.00184
IND	2000-2017	16	2-32	393-976	1,630	1.67E-06	850	0.1920	-1.0624	0.323792	-0.00202
MM2	1991-2017	24	2-25	298-850	1,698	3.09E-04	892	0.1838	-1.0535	0.128917	-0.00057
MM3	1986-2017	32	1-31	137-930	14,737	1.98E-02	835	0.2639	0.0559	0.307494	-0.00208
MM5	1988-2017	27	1-25	218-886	1,913	7.46E-06	783	0.3269	0.4362	0.521899	-0.00263
MM6	1988-2017	30	1-31	194-990	3,012	4.41E-05	808	0.2379	-0.6612	0.496692	-0.00248
MM7	1989-2017	26	1-32	168-975	1,537	1.40E-05	850	0.2152	-0.0527	0.385328	-0.00215
MM8	1993-2017	25	2-32	196-955	1,847	1.48E-04	820	0.2332	-0.1938	0.374983	-0.00213
WM3	1995-2017	21	2-23	205-935	1,035	3.57E-04	785	0.3411	0.9348	0.446858	-0.00259
WM4	1998-2017	17	1-30	95-1020	619	2.25E-05	815	0.2907	0.6066	0.887765	-0.00349
WM5	1995-2017	23	2-32	198-978	8,846	4.29E-03	851	0.2332	1.1113	0.648872	-0.00287
WM6	2013-2017	5	2-33	451-980	208	5.17E-05	899	0.1496	-1.8218	0.201736	-0.00136

The ADMB fits to length-at-age for each statistical district were generally reasonable. Residuals showed no real trends and age-specific CVs declined quickly after age-1. Most of the residuals ranged from -200 to 200 mm although some were as large as -400 mm (**Figure 8**). The CVs for age-1 Lake Trout ranged from 11% to 69%, while the CVs for age-5 and older were 10% or less (**Figure 9**). Despite the differences in vonB parameters, mean length at age was quite similar among areas of Lake Michigan for ages 7-11 among assessment units (**Figure 10**). The largest differences among statistical districts occurred at age-1 and age-2 primarily because these ages were not sampled effectively in all statistical districts. Many of the CWT-marked Lake Trout captured in WM-3, WM-4, and WM-5 were taken during SPAWN surveys, which capture few fish less than 400 mm total length.

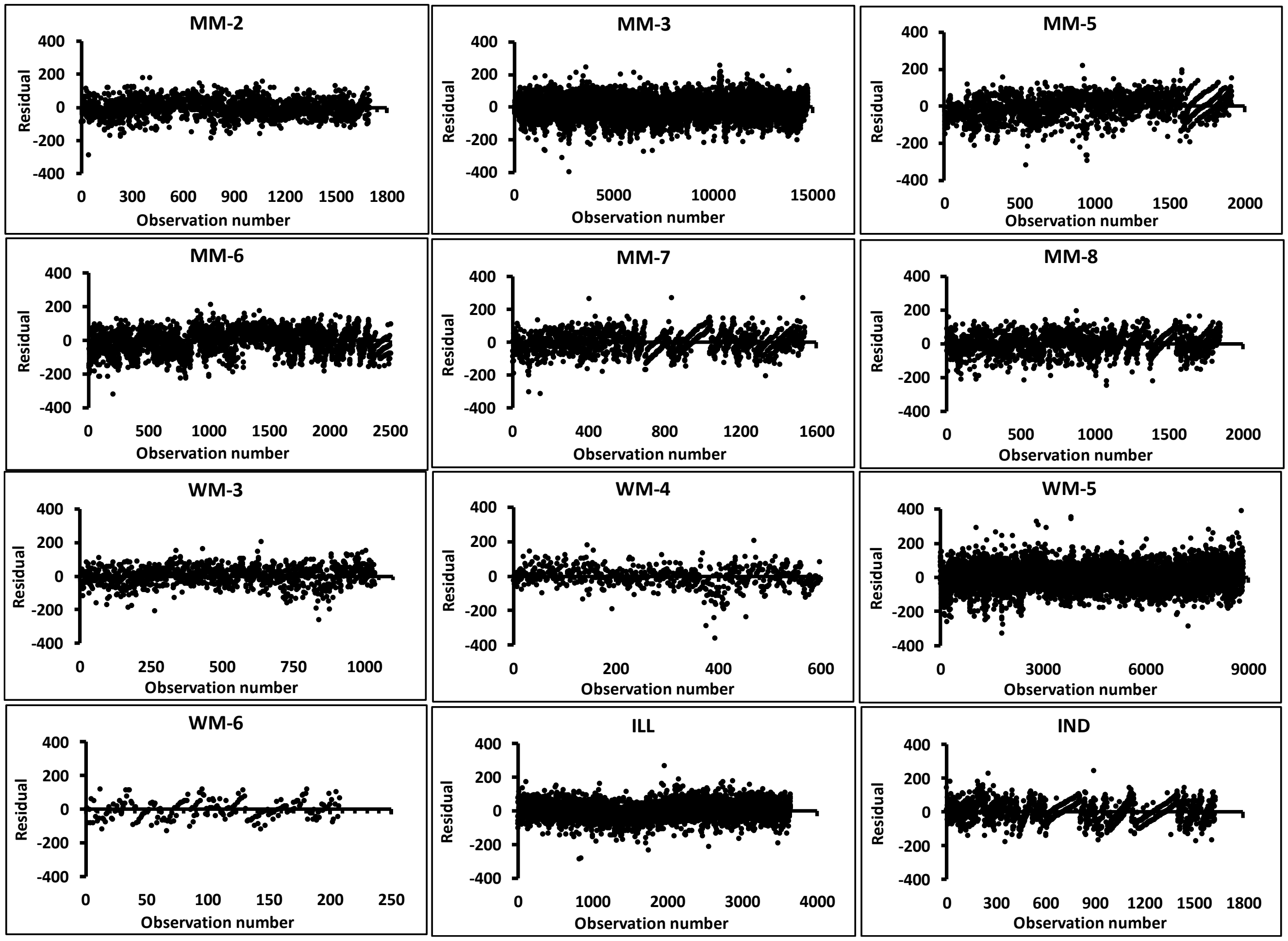


Figure 8. Residuals for von Bertalanffy predicted length at age of individual Lake Trout in statistical districts of the main basin of Lake Michigan, 1986-2017.

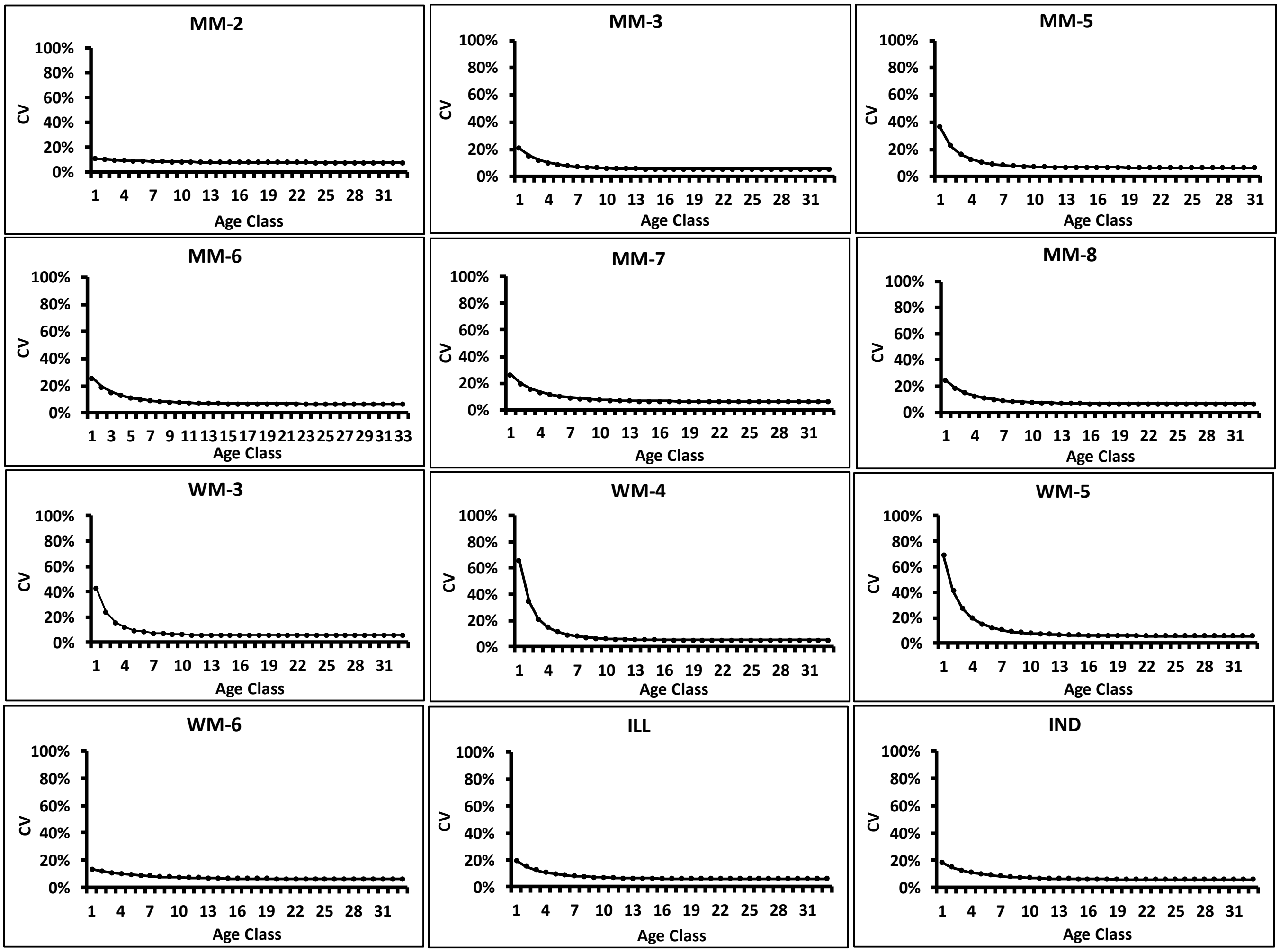
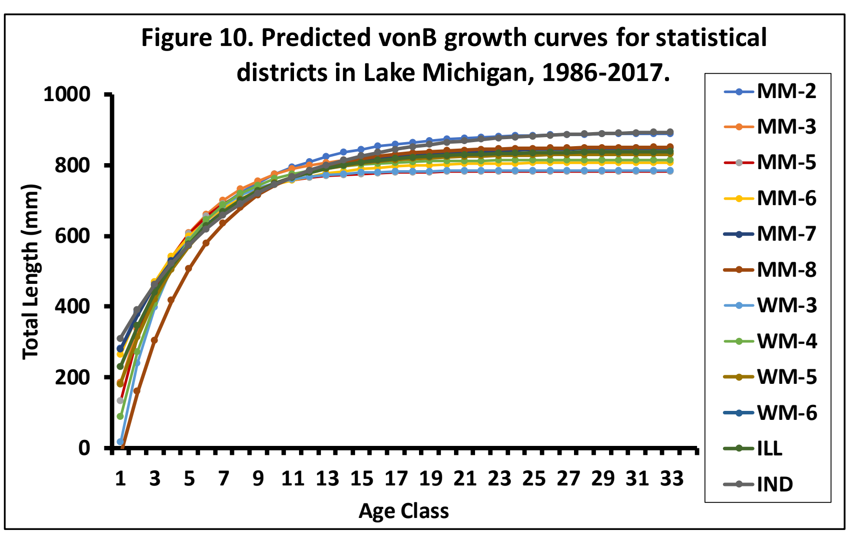
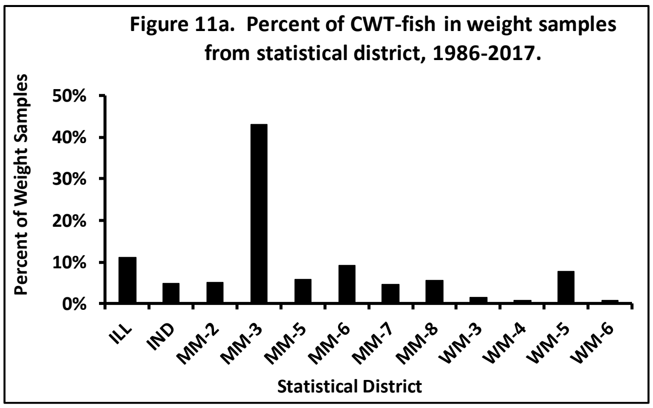


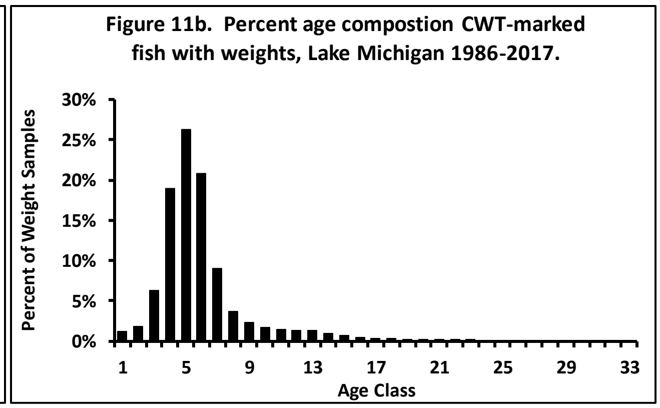
Figure 9. Age-specific coefficients of variation in total length of Lake Trout as predicted for von Bertalanffy growth in statistical districts of the man basin of Lake Michigan, 1986-2017.



Growth in weight

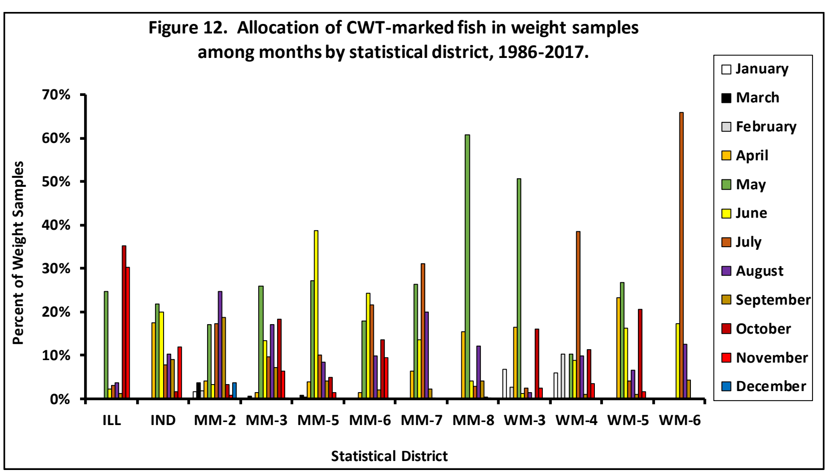
We estimated mean weight-at-age of CWT-marked Lake Trout captured during agency gill-net surveys or monitoring of commercial and recreational fishery harvests in each statistical district during 1986-2017. There were 32,999 CWT-aged Lake Trout of ages 1-33 with weight measurements in our database. Forty-three percent of the CWT-aged Lake Trout with weight measurements came from MM-3 and 1% to 11% came from other statistical districts (**Figure 11a**). Lake Trout of ages 3-7 made up 81% of the weight samples from CWT-aged Lake Trout in our database, but 66% were ages 4-6 (**Figure 11b**).





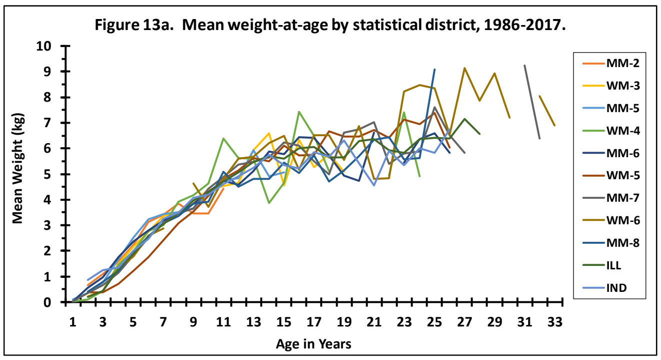
Weights of CWT-marked Lake Trout were collected during all months of the year, but like length samples, the weight samples were concentrated during April through early November. Most weight samples were collected from CWT-marked Lake Trout in May (27%) during the LWAP survey, followed by October SPAWN surveys (16%) and monitoring of commercial and recreational fishery harvests during June-August (38%). Only 1% of weight samples came from January-March and December.

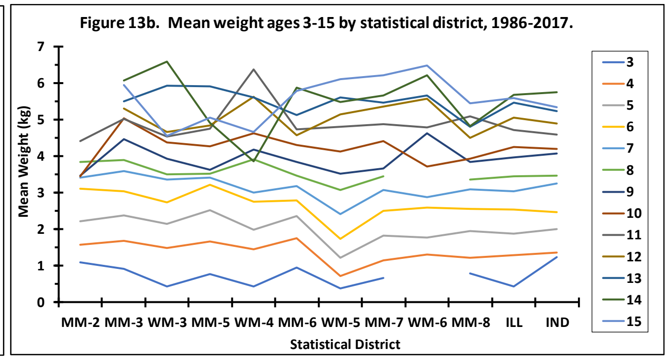
Like length samples, CWT-marked Lake Trout weight samples were not collected evenly across months within each statistical district (**Figure 12**). In ILL most weight samples were collected during SPAWN surveys in October and November followed by LWAP surveys during May, and in WM-6 most samples were collected during July. In IND, MM-2, MM-3, MM-5, and MM-6 weight samples were well distributed



among the months of May through November. In MM-8 and WM-3 most weight samples were collected during the LWAP survey.

Mean weight-at-age of CWT-marked Lake Trout was similar among statistical districts during 1986-2017 (**Figure 13a and 13b**). Lake Trout of ages 3-7 were of similar size among statistical districts, but as with mean length-at-age, fish from WM-3, WM-4, and WM-5 were generally smaller than in adjacent districts at younger ages. Lake Trout were similar in weight after age-7 even in WM-3, WM-4, and WM-5. Observed mean weight-at-age became much more variable among statistical districts after age-10, likely due to small samples sizes.





Length-weight relationship

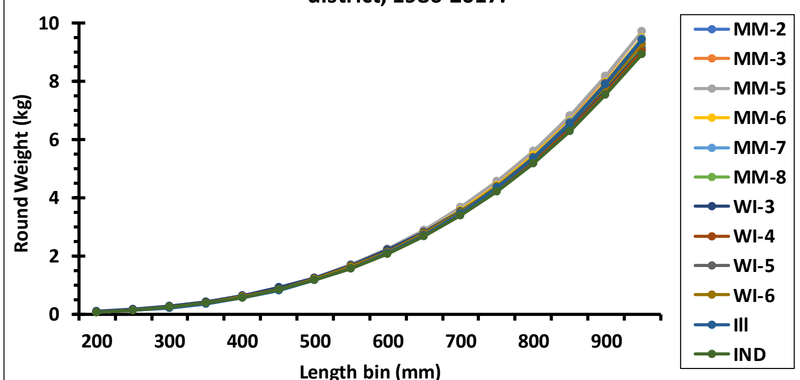
We estimated an average length-weight relationship for CWT-marked Lake Trout captured in each statistical district of the main basin of Lake Michigan during 1986-2017. Total length (L) in millimeters and whole weight (W) in kilograms were converted to natural logarithms (ln) and the ln(W) was regressed on the ln(L) to estimate the intercept and slope for each statistical district using an ADMB template (**Appendix 5**).

Predicted length-weight regression statistics were also remarkably similar among statistical districts in the main basin of Lake Michigan during 1986-2017. The slope and intercept of the regressions in each statistical district ranged from 3.09 to 3.28 and -20.25 to -18.98, respectively (**Table 4**). The convergence criteria of 1E-04 was met in nine districts, but was not met in MM-5, MM-7, and WM-5. Predicted mean weight-at-length was nearly identical among statistical districts, but differences among districts increased with increasing length (**Figure 14**).

Table 4. Statistics for length and weight data, regressions of natural logarithm length-weight, and ADMB convergence for CWT-marked Lake Trout in statistical districts of the main basin of Lake Michigan, 1986-2017.

Statistical district	Year range	Number years	Length range (mm)	Weight range (kg)	Number fish	Maximum gradient	Length-weight slope	Length-weight intercept
Ill	1998-2017	20	305-1010	0.21-10.4	3,638	3.85E-05	3.2812	-20.2542
IND	2000-2017	16	393-975	0.52-9.96	1,630	1.95E-07	3.1776	-19.5962
MM2	1991-2017	24	330-850	0.30-7.19	1,694	2.24E-05	3.1280	-19.2275
MM3	1986-2017	32	137-930	0.02-9.35	14,237	1.41E-05	3.2287	-19.8634
MM5	1988-2017	27	218-886	0.07-7.08	1,883	5.79E-03	3.2019	-19.6777
MM6	1988-2017	30	149-963	0.02-10.16	3,001	7.51E-06	3.2177	-19.8103
MM7	1989-2017	26	168-975	0.03-9.25	1,531	1.62E-03	3.2741	-20.1983
MM8	1993-2017	25	196-955	0.05-9.57	1,847	1.02E-05	3.2451	-20.0247
WM3	1995-2017	21	205-935	0.02-8.73	502	7.11E-05	3.0902	-18.9834
WM4	1998-2017	17	95-920	0.01-9.04	281	1.15E-05	3.1555	-19.4347
WM5	1995-2017	23	198-960	0.05-9.82	2,547	2.26E-03	3.2627	-20.1244
WM6	2013-2017	5	451-980	0.89-10.12	208	2.92E-05	3.1933	-19.6648

Figure 14. Predicted weight at a given length by statistical district, 1986-2017.



Mortality

We aggregated CWT-aged Lake Trout across years in each statistical district to evaluate spatial differences in total mortality and survival. We assumed that all fish in a district were collected at the same time from a single fishing gear. Then, we calculated catch-curve regressions (Ricker 1975) for fish in each district. We converted the number of fish (n) in each age class to its natural logarithm and regressed ln(n) on age to estimate instantaneous total annual mortality rate (***Z***). Annual survival (***S***) was estimated as the exponential value of -***Z*** and annual mortality rate (***A***) was estimated as 1-***S***. Age-5 or age-6 Lake Trout were typically the first ages that were fully recruited to the various fishing gears in each statistical district and were used as the starting age for each catch curve (**Figure 15**). The last age used in estimating catch-curve mortality was set as the oldest age class where there were at least two fish represented in our database.

Instantaneous total annual mortality ranged from 0.11 to 0.99 per year among statistical districts during 1986-2017. Our estimates of ***Z*** also appeared to decline from north to south and tended to be lower in western statistical districts than eastern districts (**Figure 15**). The highest mortality rates were in northern statistical districts MM-2 (63%), MM-3 (47%), and MM-5 (45%), whereas the lowest mortality rates of 11 to 20% were in southern districts WM-6, IND, MM-7, MM-8, and ILL. Total annual mortality rates in Wisconsin statistical districts WI-3 to WM-6 (11-37%) were slightly lower than in adjacent Michigan districts MM-5 to MM-8 (19-45%). Average ***Z*** was 0.25 per year outside the 1836 Ceded Waters (***S***=78%) and 0.55 per year in the Ceded Waters (***S***=58%).

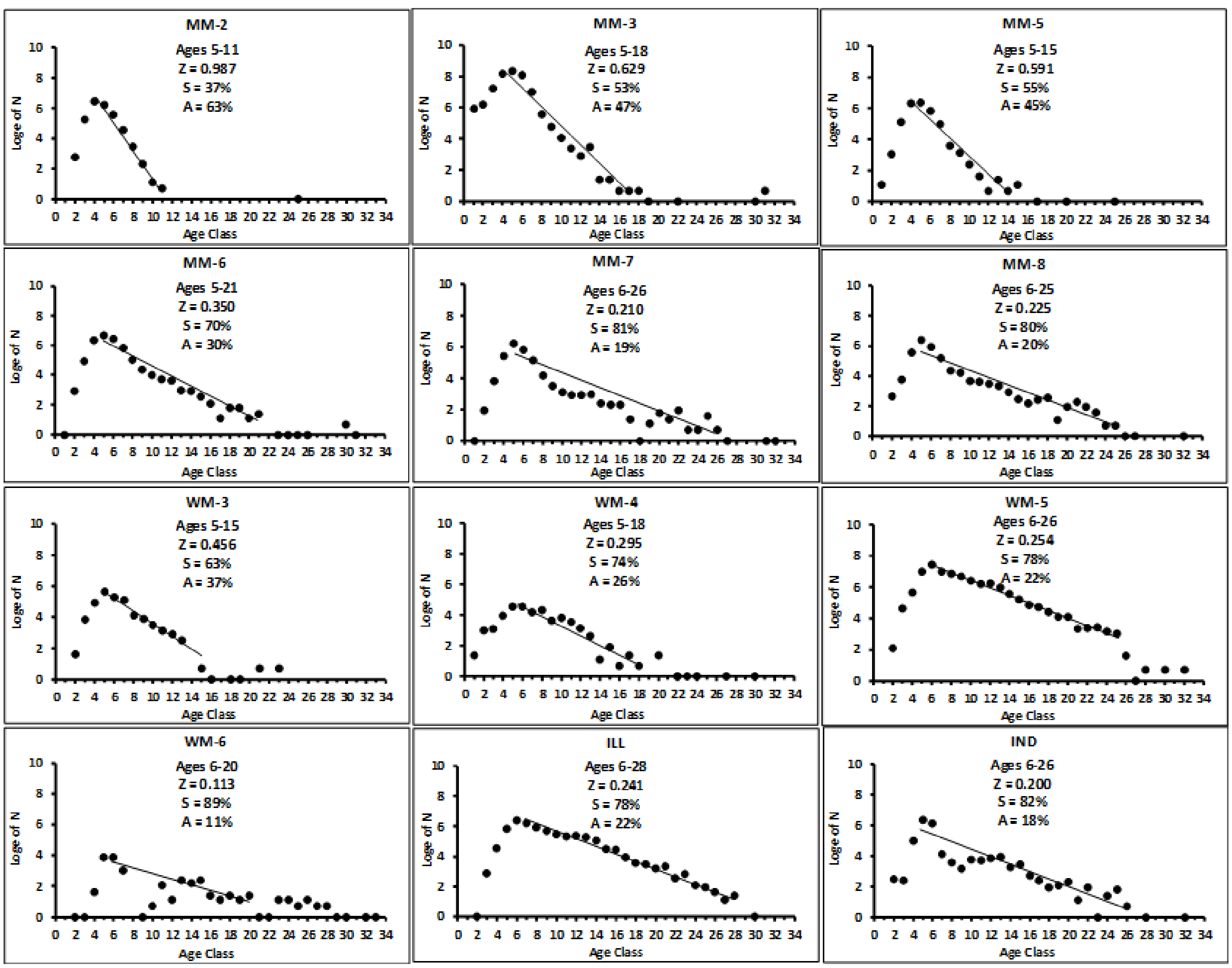


Figure 15. Catch curves and associated annual mortality and survival rates for CWT-aged Lake Trout in statistical districts of the main basin of Lake Michigan captured in recreational, commercial, and survey fisheries during 1986-2017.

DEVELOPMENT OF INPUT VALUES FOR STOCK ASSESSMENTS

Preliminary Analysis of Spatial Units

Eschmeyer (1957) subdivided Lake Michigan into three distinct geographic regions based on bycatch of Lake Trout in commercial small-mesh gill net fisheries targeting deepwater ciscoes (*Coregonus* spp., see Eshenroder et al. 2016). The northern region consisted of all waters north of an east-wide line between Frankfort, MI and Algoma, WI (see **Frontispiece**), while the eastern and western regions were all waters south of the Frankfort-Algoma line in Michigan (MM, east region) and Wisconsin (WM, west region) waters. Lake Trout caught at Sheboygan Reef (**Frontispiece**), the northern portion of the mid-lake reef complex, were unique from other areas in the southern region because monthly catch rates ranged from 0 to 20.7 fish per 1,000 ft. during 1948-1955 compared to 0 to 2.3 fish per 1,000 ft in southern regions other than the Sheboygan Reef during the same years (Eschmeyer 1957). The three regions were created because abundance of Lake Trout estimated from commercial fishery catch and effort data was sufficiently different to warrant separate analyses (Eschmeyer 1957). Statistical districts were created shortly after the Eschmeyer publication to further refine geographic regions of the Great Lakes with unique populations of Lake Trout and commercial fisheries (Smith et al. 1961).

We used CWT-recoveries from the USFWS Mass Marking Program (Bronte et al. 2012) to estimate the contribution of fish stocked in a statistical district (Stocking Site) to fisheries in other units (Recruitment Site). Preliminary analysis of the CWT-recovery information in May 2019 showed that most Lake Trout stocked into a statistical district were caught in the district of stocking and adjacent districts (**Table 5**). For example, 94.2% of fish stocked into ILL were recovered in ILL, IND, WM-5, WM-6, and MM-8 in southern Lake Michigan, while 83% of fish stocked into MM-3 in northern Lake Michigan were recovered in MM-3, MM-2, MM-4, MM-5, and MH-1 (northern Lake Huron). In addition, 88.7% of CWT-marked Lake Trout stocked into the Mid-Lake Refuge (WM-5 and MM-7) were recovered in WM-5, MM-7, ILL, IND, and WM-6, all statistical districts that are adjacent to the refuge.

We used the CWT-recovery data from **Table 5** to identify aggregations of Recruitment Sites where at least 90% of fish were captured to determine if we could justify combining statistical districts into larger Life History Units (LHUs). We define a Life History Unit as a spatial region that encompasses an intermixing, interbreeding population. In the case of Lake Trout in Lake Michigan, interbreeding must be considered broadly to include the production of both wild and hatchery recruitment. This seems reasonable considering that research has shown that hatchery fish in Lake Michigan have a homing tendency to return to reefs to spawn where they were stocked (Bronte et al. 2007). A population in a LHU should also have reasonably uniform

Table 5. Preliminary estimates of the proportion of CWT-marked Lake Trout stocked in statistical districts of Lake Michigan and subsequently recovered in statistical districts of lakes Michigan and Huron (MH) by commercial, recreational, and survey fisheries during 2014-2017.

Stocking District(s)	Statistical District of Recovery																	
in Lake Michigan	ILL	IND	MH1	MH2	MH3	MH5	MH6	MM2	MM3	MM4	MM5	MM6	MM7	MM8	WM3	WM4	WM5	WM6
ILL (n=760)	0.197	0.581	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.001	0.008	0.040	0.079	0.000	0.006	0.037	0.048
IND (n=121)	0.043	0.688	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.041	0.220	0.000	0.000	0.006	0.000
MM3 (n=1,093)	0.004	0.005	0.031	0.009	0.013	0.003	0.002	0.292	0.355	0.040	0.112	0.031	0.003	0.003	0.043	0.041	0.009	0.003
MM4 (n=154)	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.068	0.909	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.000
MM5 (n=745)	0.000	0.037	0.004	0.004	0.000	0.000	0.000	0.004	0.007	0.018	0.516	0.279	0.056	0.064	0.000	0.002	0.003	0.005
MM6 (n=96)	0.000	0.120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.126	0.290	0.247	0.212	0.000	0.005	0.000	0.000
MM7 & MM8 (n=82)	0.000	0.259	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.000	0.000	0.024	0.273	0.405	0.000	0.000	0.000	0.000
WM3, WM4 & WM6 (n=10)	0.000	0.949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.022	0.009
WM5 (n=1,808)	0.118	0.331	0.000	0.001	0.000	0.000	0.000	0.004	0.001	0.000	0.015	0.053	0.145	0.178	0.012	0.024	0.054	0.061

mortality and growth rates throughout the region, which would allow us to pool data from the entire unit for stock assessment purposes. In addition, creating unique LHUs would help us estimate the number of wild fish using the data on percent wild fish in survey catches. To estimate the 90% inclusion zones, we first multiplied the number of CWT-recoveries from each Stocking Site times the percentage of those recoveries made in each Recruitment Site to estimate the number of CWT-recoveries in each Recruitment Site. We then estimated the proportion of CWT-recoveries in each Recruitment Site for each Stocking Site. The 90% Inclusion Zones were usually made up of 7-8 statistical districts during 2014-2017 with a clear distinction between north and south (see below).

North Life History Unit – MM-2, MM-3, MM-5, North ½ MM-6, WM-3, and WM-4
South Life History Unit – South ½ MM-6, MM-7, MM-8, WM-5, WM-6, Illinois, Indiana
Other Life History Unit – WM-1, WM-2, MM-1, MM-4, MH-1, MH-2, MH-3, MH-5

Ecological and limnological features of the lake can also help identify LHUs, and from that perspective the main basin of Lake Michigan has two distinct regions, a deep and bathymetrically varied northern portion, and a shallower bowl-like southern basin. Most Lake Trout spawning habitat in Lake Michigan is located around the Beaver Island (**Frontispiece**) archipelago in the north and on the offshore underwater Mid Lake Plateau in the south. Both these spawning areas were designated as refuges (see **Frontispiece**) where retention of Lake Trout by all fisheries was, and still is, prohibited (Holey et al. 1995; Bronte et al. 2008). Deep water separates the two spawning reef complexes and should result in spatial differences in life history parameters, particularly recruitment and food preferences.

Dispersal of CWT-marked fish from nearshore locations appeared to be less than dispersal from the offshore refuges. For Lake Trout stocked at nearshore locations 75% to 98%, mean 88%, of the CWT-recoveries were made in the statistical district of tagging and one or two adjacent districts (see table below).

Stocking District	Recovery Districts	Percentage of Recoveries
Illinois	Ill, IND, MM-8	85.7%
Indiana	IND, MM-8, Ill	95.1%
MM-4	MM-4, MM-3	97.7%
MM-5	MM-5, MM-6	79.5%
MM-6	MM-6, MM-7, MM-8	74.9%
MM-7/MM-8	MM-7, MM-8, IND	97.8%

The CWT-marked Lake Trout stocked in the Northern Refuge were subsequently recovered in all 13 statistical districts of Lake Michigan and four districts of Lake Huron, but 69% were recovered in MM-3, MM-2, and MM-4. The CWT-marked fish stocked in the Southern Refuge were recovered in 12 statistical districts of Lake Michigan and one district of Lake Huron, and 44% were recovered in the unit of stocking (WM-5) and adjacent units WM-6, MM-7, and MM-8. One-third of CWT-marked Lake Trout stocked in the Mid-Lake Refuge were recovered in Indiana, indicating substantial southward movement of these fish.

We excluded Green Bay and Grand Traverse Bay (MM-4) from the analysis because they are, in reality, different types of habitat than the main basin. Grand Traverse Bay appears to be a LHU onto itself as 91% of CWT-recoveries were stocked there. About 7% of Lake Trout stocked into MM-4 moved into MM-3 and 2% moved into MM-5 and MM-6. There was little to no current information on movement of Lake Trout initially stocked into Green Bay, further, no Lake Trout have been stocked there since 1982 and the last sizable plantings occurred in 1979.

Therefore, based on stocking locations, movements of fish, uniformity in growth rates (**Table 4**; **Figure 7**), and ecological and limnological features, it appeared that the main basin of Lake Michigan contained two major LHUs for Lake Trout, north and south. However, one important condition for defining a LHUnit for stock assessment purposes was not met: uniformity of mortality rates throughout the region. Total mortality rates were higher on the east side than on the west side of the proposed north unit (**Figure 15**). For example, ***Z*** in districts MM-3 and MM-5 on the east side of the north unit were 0.629 and 0.591 per year, respectively, while in WM-3 and WM-4 on the west side was 0.456 and 0.295 per year, respectively. The difference in these mortality rates was due primarily to bycatch of Lake Trout in a large-mesh-gill net fishery for Lake Whitefish *Coregonus clupeaformis* in the 1836 Ceded Waters, which occurred on the east side (Modeling Subcommittee, Technical Fisheries Committee 2018). Consequently, we decided to develop stock assessment units for southern Lake Michigan that included WM-6, ILL, IND, and MM-8 that we termed WIIM, and Wisconsin statistical districts WM-

3, WM-4, and WM-5 that we termed WI345 (**Figure 16**). These stock assessment units were outside the 1836 Ceded Waters and, except for WM-3, have not had large-mesh-gill-net fisheries since the 1970s (**Figure 16**).

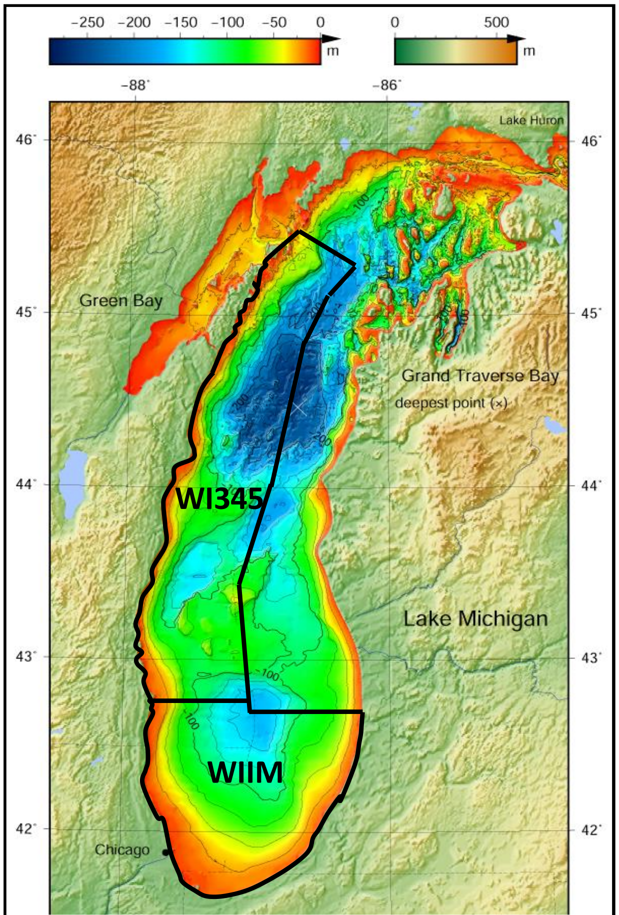


Figure 16. *SCAA stock assessment units*.

Recruitment

Development of hatchery fish movement matrix

We estimated annual recruitment of hatchery-reared Lake Trout by adjusting the numbers of fish stocked (Dexter et al. 2011) into each statistical district by their observed movement to (-) and from (+) other statistical districts. We based movements on a matrix of stocking and recovery locations for CWT-marked fish developed by the USFWS Mass Marking program to estimate recruitment of Lake Trout to WI345 and WIIM. Recoveries of the 2010- to 2017-year classes of CWT-marked Lake Trout were used to develop the movement matrix because they all received a CWT, and therefore, the exact stocking site was known.

We developed separate movement matrices for CWT-marked Lake Trout captured in agency surveys and the recreational fishery. The agency surveys and recreational fishery use gears that select different portions of the Lake Trout population (see **Figure 3**), they operate at different times of the year, and their spatial distributions are distinct. For example, the agency surveys use bottom-set gill nets primarily during spring and fall both inside and outside the Northern and Mid-Lake refuges, but the surveys have limited coverage in some statistical districts. The recreational fishery consists of a charter and non-charter troll fishery primarily during the summer and early fall and it is prohibited from fishing in both refuges. Thus, we felt it was prudent to separate survey- and recreational-caught CWT Lake Trout and then combine the results to produce a "blended matrix." The blended matrix is an average between the survey and recreational fishery as a default but relies on data from only one of the two capture methods when appropriate due to respective gaps in geographical coverage of both fisheries.

Survey movement matrix

We created the survey movement matrix for CWT-marked Lake Trout recovered during LWAP surveys, or LWAP-like surveys during 2012-2018. All LWAP surveys used multi-mesh, bottom-set gill nets fished during April-June, according to an established protocol (Schneeberger et al. 1998). Gill net effort with non-standard LWAP mesh sizes (1.5 and 2.0 inch) was excluded from the analysis, as were fish captured by those mesh sizes. Recoveries from other data sources such as commercial trap nets and gill nets were also not used due to incompatible or unreliable estimates of effort.

There were 8,543 CWT-marked Lake Trout recovered during agencies surveys that met the constraints above, including 8,127 from Lake Michigan and 416 from Lake Huron. All fish were age 1-8, although most were age 4-7 (**Table 6**). We used only CWT-recoveries made during 2014-2018 to develop the agency survey-based movement matrix because 98.5% of them occurred in these years (**Table 7**). We felt that the number of CWT-recoveries made during 2012-2013 was inadequate to produce reasonable estimates of CWT catch rates as there were many zeros. Only fish stocked as yearlings were considered because fall fingerlings, based on studies elsewhere, were expected to have lower survival than yearlings, and because most fall fingerlings were tagged with the same lot number and stocked across many statistical districts, precluding their use. Finally, CWT-recoveries in MH-4 (Saginaw Bay) were not included in the analysis because sampling effort and recoveries there were low in most years.

Table 6. Age composition of CWT-marked Lake Trout recovered during agency surveys in lakes Michigan and Huron during 2012-2018 and used to develop the movement matrix.

Age	Lake Huron recoveries	Lake Michigan Recoveries	Total recoveries
1		2	2
2	1	115	116
3	19	643	662
4	64	1,515	1,579
5	96	2,275	2,371
6	93	2,069	2,162
7	108	1,154	1,262
8	35	354	389
Total	**416**	**8,127**	**8,543**

Table 7. Annual number of CWT-marked Lake Trout recovered during agency surveys in lakes Michigan and Huron during 2012-2018 and used to develop the movement matrix.

Recovery Year	Lake Huron recoveries	Lake Michigan Recoveries	Total recoveries
2012		19	19
2013	6	104	110
2014	42	492	534
2015	76	1,439	1,515
2016	72	1,848	1,920
2017	119	1,803	1,922
2018	101	2,422	2,523
Total	**416**	**8,127**	**8,543**

We calculated the catch-per-unit effort (CPUE) of CWTs during agency surveys for each statistical district by combining recovery data for all years during 2014-2018 as:

(2) $$CPUE_R = \frac{N_R}{\sum Efflw_R * nights_R}$$

where ***N*** is the total number of CWT-marked Lake Trout caught during 2014-2018, ***Efflw*** is the kilometers of gill net fished during the LWAP survey, ***nights*** is the number of nights gill nets were fished during the surveys, and ***R*** is the Recruitment Site (i.e., statistical district). We combined all years during 2014-2018, rather than computing averages of year-specific CPUE values, due to a low number of CWT-recoveries in the surveys for many Stocking Sites. In all years combined, 6 of 11 Lake Michigan Stocking Sites had less than 127 CWT-recoveries while 5 of 6 Lake Huron stocking districts had less than 58 recoveries. Essentially, we felt that estimating an annual CWT-catch rate in the agency surveys would not provide adequate sample sizes in each year from which CPUE could be estimated for a Recruitment Site. The proportion of CWT-marked fish recovered in a Recruitment Site for fish from each Stocking Site was estimated by dividing the CPUE in the Recruitment Site by the sum of the CPUEs from all Recruitment Sites for each Stocking Site. We combined CWT-recoveries from all years to give greater weight to later years in which more fish were caught. Although there are arguments against this approach, its advantages include giving greater weight to data with greater sample sizes and higher confidence, limiting the effect of zeros in earlier years potentially being due to limited vulnerability of fish to the gear, and it is the least complex solution in the short term.

Lake Trout with CWT codes that were stocked in both lakes Michigan and Huron were assumed to have been stocked in the lake in which they were recovered. The number of fish stocked was not incorporated into the CPUE calculation because the movement matrix is based on the proportion of CWT-recoveries stocked in a statistical district, and the number of fish stocked within that district does not affect the proportion of recoveries. Tag Codes 640329, 640204, 640185, and 640502 were stocked on both sides of Lake Michigan (e.g., WM-4, WM-6 and MM-8 or WM-4, WM-6, MM-7, MM-8 and IND) and were excluded from the analysis because stocking location could not be determined. The Northern and Southern Refuges were designated as their own Stocking Sites. Fish stocked in both refuges were excluded from other statistical districts because stocking in the non-refuge areas occurred mainly near shore. Last, CWT codes applied to fish stocked in WM-3 (2 recoveries) were combined with tag codes for fish stocked in WM-3, WM-4, and WM-6 (8 recoveries) because the number of recoveries were so low. The subsequent Survey Movement Matrix illustrates the percent of fish from each Stocking Site that were recovered in each Recruitment Site of lakes Michigan and Huron (**Table 7**).

Recreational fishery movement matrix

We created a movement matrix based only on CWT-recoveries made by the recreational fishery during USFWS BioTech surveys. We estimated the CPUE for each CWT lot of stocked fish in each month in each Recruitment Site for each Stocking Site as:

(3) $$CPUE_{l,m,R} = \frac{N_{l,m,R}}{\sum Effs_R}$$

where ***N*** is the number of CWT recoveries, ***Effs*** is the number of number of days spent sampling the recreational fishery harvest, ***l*** is CWT lot number, ***m*** is month, and ***R*** is Recruitment Site. For example, if two fish from lot 642030 that were stocked in the Southern Refuge and subsequently recovered during June in MM-7 over four sampling days the CPUE would be 0.5 CWTs per day. Month-specific CPUEs were then averaged within each Recruitment Site for each CWT-tag lot and each Stocking Site. Recruitment Site catch rates were then averaged across tag lots for each Stocking Site and converted to percentages.

We considered using the monthly number of targeted angler hours in each Recruitment Site, but the initial analysis suggested that approach biased the analysis in favor of Recruitment Sites with low angler effort. Targeted angler hours are also summed to “salmon and trout” effort, which may be problematic if targeting for specific species varies spatially, as might be expected given that Chinook Salmon are commonly targeted in Lake Michigan but are much less prevalent in Lake Huron, where Lake Trout target fishing is more common. For the few CWT lots of fish stocked in both Lake Huron (MH-1 and MH-5) and Lake Michigan (MM-7 and MM-8), we assumed that fish were recovered in the same lake in which they were stocked. This methodology was used to develop the MM-7/MM-8 stocking group; fish stocked in Lake Huron from these tag lots were not used since MH-1 and MH-5 are far apart and thus data were not easily interpreted. The subsequent Recreational

Movement Matrix illustrates the percentage of fish from each Stocking Site that were recovered in each Recruitment Site of lakes Michigan and Huron (**Table 8**).

Blended movement matrix

We created a "Blended Movement Matrix" (**Table 9**) with information from agency surveys (**Table 7**) and with data from the recreational fishery (**Table 8**) to develop our movement matrix for estimating recruitment to the fisheries in WIIM and WI345. We used this matrix for all Lake Trout recovered after 2001, while the original movement matrix developed by Elliott (2002) was to be used for fish recovered prior to 2001. The Blended Movement Matrix represents an average percentage for each Recruitment Site for each Stocking Site with each method-specific value having equal weight with the following exceptions:

1) The percentage of fish stocked that were recovered in the refuges were estimated using only the agency gill net surveys. Only the gill net surveys can provide an accurate estimate of the proportion of fish that remained on or moved to the refuges because the recreational fishery is prohibited from fishing in the refuges. This calculation was done prior to all other calculations, such that the proportion of CWT-recoveries in areas other than the two refuges were re-calculated relative to the proportion in each refuge reported in the survey matrix.
2) Only the recreational fishery data was used for CWT-recoveries in IND, WM-6 and MH-6, because gill net surveys had limited or no coverage in these Recruitment Sites. The percentage of recoveries from each Stocking Sites in these three Recruitment sites were held constant in the Blended Movement Matrix, while the percentage of recoveries in other Recruitment Sites were re-calculated to reflect that they needed to sum to 100%.
3) The percentage of Stocking Site IND CWT-recoveries in each Recruitment Site were based on the recreational fishery recoveries (n = 114) because there were very few CWT-marked fish captured during agency surveys (n=14) in IND.
4) The percentage of Stocking Site MM-4 CWT-recoveries in each Recruitment Site were based on the gill net survey catches (n=944) because the recreational fishery had far fewer recoveries (n=28) in MM-4.
5) The percentages of fish stocked in ILL and recovered in ILL, IND, and WM-6 were based on the recreational fishery only because there were few surveys in IND and none in WM-6, the two adjacent regions to ILL where movement would be expected to be high. This would likely impact the percent of recoveries for fish stocked in ILL, which were observed at a much greater rate in IND (42%) and WM-6 (9%) in the recreational data than the surveys. We used recoveries made by both

the survey and recreational fisheries for Lake Trout stocked in ILL and recovered outside of ILL, IND, and WM-6 in development of the Blended Movement Matrix.

6) We have low confidence in our estimates of recruitment of fish stocked in WM-3, 4, and 6, MH-2/3, and MH-5 due to low numbers of recoveries in both the survey and recreational fisheries.
7) Values not covered in steps (1) and (2) above were averaged between the two tables, with each method-specific value having equal weight.

Some of the differences between the survey and Biotech movement matrices for Wisconsin waters may due to temporal or spatial differences in the surveys and recreational fisheries. Gill net surveys are conducted in spring whereas recreational fisheries are conducted mainly in the summer, and gill net surveys are conducted mainly in the northernmost sections of WM-3 and WM-5 while the recreational fishery operates mainly in southern WM-3, WM-4, and throughout WM-5.

Several interesting questions arose from our analysis of the CWT recovery data and development of the movement matrix.

(1) Do Lake Trout that move into Lake Huron stay in Lake Huron, or do they come back? If they do not come back, then they are essentially dead to Lake Michigan and the inter-lake movement rate would be equivalent to a mortality rate.
(2) At what age do Lake Trout move away from a Stocking Site? We are assuming that the movement from a Stocking Site to a Recruitment Site is instantaneous and permanent, and that these fish never contribute to reproduction or fisheries in the Stocking Site. If movement varies with age or Stocking Site, then this complicates our modeling effort.
(3) Does the distance a fish moves affect its ability to return to a spawning site? We assume that all fish that survive have the same ability to contribute to reproduction, but that may not be true, and would affect our estimates of spawning stock biomass and stock-recruitment.

These questions are not really a problem for our project but rather are a problem for the 1836 Ceded Waters Modeling Subcommittee and should be addressed in the future.

Table 7. Movement matrix for CWT-marked Lake Trout captured during agency surveys in lakes Michigan and Huron, 2014-2018. Numbers in parenthesis indicate total CWT-recoveries from that stocking site.

	Recruitment Site																	
Stocking Site	ILL	IND	MH1	MH2	MH3	MH5	MM2	MM-3	MM4	MM5	MM6	MM7	MM8	WM3	WM4	WM5	North Refuge	South Refuge
Stocked in Lake Michigan																		
ILL (127)	57.5	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	1.6	1.3	10.2	1.5	6.8	3.5	0.0	9.8
IND (14)	0.0	59.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.2	0.0	8.8	23.5	0.0	0.0	0.0	0.0	0.0
MM3 (2680)	0.2	0.0	1.8	0.5	0.1	0.0	3.7	69.3	7.1	7.2	0.5	0.3	0.1	1.5	0.6	0.2	6.8	0.1
MM4 (944)	0.0	0.0	0.0	0.0	0.1	0.0	0.0	7.6	87.4	4.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
MM5 (1479)	0.0	0.0	0.2	0.0	0.0	0.0	0.2	3.6	4.9	61.1	20.5	5.4	2.8	0.4	0.6	0.0	0.3	0.0
MM6 (86)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	15.9	48.9	17.9	14.1	0.0	0.0	0.0	1.5	0.0
MM7/8 (29)	0.0	34.7	0.0	0.0	0.0	0.0	0.0	0.0	1.3	4.9	1.6	12.1	45.4	0.0	0.0	0.0	0.0	0.0
WM3/4/6 (10)	6.5	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	20.4	68.9	0.0	0.0	0.0
North Refuge (2,003)	0.0	0.0	0.9	0.5	0.2	0.0	18.0	19.9	3.2	8.7	1.3	0.1	0.2	6.7	2.1	2.2	35.5	0.4
South Refuge (687)	4.6	0.0	0.0	0.0	0.1	0.0	0.0	0.7	0.9	1.5	4.9	4.6	8.7	1.9	8.7	7.0	0.0	56.4
Stocked in Lake Huron																		
MH1 (55)	0.0	0.0	50.7	37.8	4.6	0.0	0.0	0.8	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1
MH2 (197)	0.0	0.0	10.4	50.6	36.5	0.0	0.0	0.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
MH2/3 (13)	0.0	0.0	0.0	13.3	68.6	0.0	0.0	8.4	0.0	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MH3 (58)	0.0	0.0	2.7	7.4	72.2	17.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MH5 (4)	0.0	0.0	0.0	0.0	61.2	0.0	0.0	0.0	0.0	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8. Movement matrix for CWT-marked Lake Trout captured by the recreational fishery during the U.S. Fish and Wildlife Service BioTech monitoring program in lakes Michigan and Huron, 2014-2018. Numbers in parenthesis indicate total CWT-recoveries from that stocking site.

	Recruitment Site																	
Stocking Site	ILL	IND	MH1	MH2	MH3	MH5	MH6	MM2	MM3	MM4	MM5	MM6	MM7	MM8	WM3	WM4	WM5	WM6
Stocked in Lake Michigan																		
ILL (859)	14.2	42.4	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	1.8	9.3	15.1	0.0	0.5	6.8	9.1
IND (114)	3.4	55.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	11.8	27.8	0.0	0.0	0.9	0.0
MM3 (535)	0.1	0.2	0.8	0.4	0.4	0.5	0.3	11.9	80.0	0.5	1.8	1.2	0.3	0.0	0.5	0.5	0.4	0.0
MM4 (28)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	23.7	74.7	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0
MM5 (459)	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.8	7.8	3.6	36.8	29.3	9.3	7.2	0.0	0.1	0.5	2.2
MM6 (75)	0.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.8	38.0	32.3	0.0	0.5	0.0	0.0
MM7/8 (104)	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	41.8	43.6	0.0	0.0	0.0	0.0
WM3,4,6 (16)	0.0	84.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	7.9
North Refuge (281)	0.2	0.1	2.3	0.1	0.1	0.0	0.0	38.4	39.0	2.3	3.9	2.9	0.2	0.3	2.8	5.6	1.4	0.3
South Refuge (2118)	7.2	20.6	0.0	0.4	0.0	0.0	0.0	0.4	1.4	0.0	1.0	6.6	21.9	17.6	0.7	2.4	8.9	11.0
Stocked in Lake Huron																		
MH1 (58)	0.0	0.0	48.4	49.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.6	0.0	0.0	0.0	0.0
MH2 (120)	0.0	0.0	3.0	39.4	33.4	19.8	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MH2/3 (5)	0.0	0.0	43.4	21.1	35.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MH3 (78)	0.0	0.0	0.0	5.1	43.6	29.4	18.6	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MH5 (2)	0.0	0.0	0.0	82.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0	0.0	0.0	0.0	0.0

Table 9. Blended movement matrix for CWT-marked Lake Trout captured in recreational and survey fisheries in lakes Michigan and Huron, 2014-2018. Numbers in parenthesis indicate total CWT-recoveries from that stocking site. Recruitment sites NR and SR refer to the North and South refuges.

	Recruitment Site																		
Stocking Site	ILL	IND	MH1	MH2	MH3	MH5	MH6	MM2	MM3	MM4	MM5	MM6	MM7	MM8	WM3	WM4	WM5	WM6	NR	SR
---Stocked in Lake Michigan---																				
ILL (986)	13.4	39.9	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.1	0.4	1.6	5.0	11.9	0.7	3.4	4.9	8.6	0.0	9.8
IND (114)	3.4	55.4	0	0	0	0	0	0	0	0	0	0.7	11.8	27.8	0	0	0.9	0	0	0
MM3 (3,730)	0.1	0.2	1.3	0.4	0.2	0.2	0.3	7.5	72	3.7	4.3	0.8	0.3	0	1	0.5	0.3	0	6.8	0.1
MM4 (944)	0	0.1	0	0	0.1	0	0	0	7.6	87.4	4.8	0	0.1	0	0	0	0	0	0	0
MM5 (1,938)	0	2.3	0.1	0	0	0	0	0.5	5.6	4.2	47.8	24.3	7.2	4.9	0.2	0.3	0.2	2.1	0.3	0
MM6 (161)	0	7.2	0	0	0	0	0	0	0	0.8	7.6	33.8	26.7	22.2	0	0.2	0	0	1.5	0
MM7/8 (133)	0	14.9	0	0	0	0	0	0	0	0.7	2.7	1.7	30.2	49.8	0	0	0	0	0	0
WM3,4,6 (26)	3.1	40.4	0	0	0.8	0	0	0	0	0	0	0	0	1.2	9.8	33.1	3.8	7.8	0	0
North Refuge (1769)	0.1	0.1	1.2	0.2	0.1	0	0	22	23	2.2	5	1.6	0.1	0.2	3.7	3	1.4	0.2	35.5	0.4
South Refuge (2805)	2.9	10.2	0	0.1	0	0	0	0.1	0.5	0.2	0.6	2.9	6.6	6.5	0.7	2.8	4	5.5	0	56.4
---Stocked in Lake Huron---																				
MH1 (113)	0	0	48.8	42.9	3	0	0	0	0.4	0	1.4	0.1	0	0.3	0	0	0	0	0	3.1
MH2 (317)	0	0	6.5	43.9	34.1	9.6	4.3	0	0.1	0	0.7	0	0	0	0	0	0	0	0	0.8
MH2/3 (18)	0	0	21.7	17.2	52.1	0	0	0	4.2	0	0	4.9	0	0	0	0	0	0	0	0
MH3 (136)	0	0	1.1	5.5	52.2	20.8	18.6	0	1.8	0	0	0	0	0	0	0	0	0	0	0
MH5 (6)	0	0	0	41.1	30.6	0	0	0	0	0	19.4	9.0	0	0	0	0	0	0	0	0

Growth

Our basic SCAA models estimate population numbers and mortality rates by age for Lake Trout given catches-by-age, fishing effort, and CPUE of LWAP surveys. We then add supplementary data to make estimates of other population parameters of interest to managers. Annual estimates of mean weight-at-age are one such important supplementary type of data. These weights-at-age allow us to assess changes in growth of individuals and when combined with the estimated total numbers at age, estimate population biomass, production, and prey consumption each year.

Mean weight of age-2 and older

We used an R-script to estimate annual natural logarithm length-weight regression coefficients of CWT-marked Lake Trout captured by all sampling methods in WI345 and WIIM during 1993-2017. Length-weight data spanned 1995-2017 in WI345 but there was no data for 1996 or 1998. In WIIM length-weight data spanned 1993-2017 and there were data for every year. Annual slopes and intercept coefficients ranged from 3.051 to 3.394 and -20.981 to -19.201, respectively, in WI345 and 2.878 to 3.531 and -21.837 to -17.63, respectively, in WIIM (**Table 10**). Slope coefficients in WI345 tended to increase from 1995 to 2005 then generally declined thereafter while intercept coefficients were the mirror opposite. In WIIM, slope coefficients increased from 1993 to 1995, declined from 1995 through 2003, increased in 2004 then declined through 2012 before stabilizing during 2013-2017. As in WI345, annual trends in the intercept coefficients in WIIM were a mirror opposite of the slope coefficients.

We estimated mean weight of Lake Trout a given length using the annual length-weight regression coefficients to illustrate temporal trends in growth in weight. First, we estimated mean weight of Lake Trout at every 50 mm length interval from 350 mm to 900 mm. Next, we regressed the annual estimates of weight at each 50-mm length on year of collection to measure the change in weight over time (slope) of fish. There was little temporal variation in weight-at-a-given length for fish of 350 to 900 mm total length, but what variation did exist tended to be greater in WIIM than in WI345 (**Figure 17**). Trends in weight-at-a-given length were flat and did not differ much from zero in WI345.

Table 10. Total length (mm) and round weight (kg) regression coefficients for CWT-marked Lake Trout captured in our assessment units WI345 and WIIM during 1993-2017.

	WIIM			WI345		
Year	n	intercept	slope	n	intercept	slope
1993	24	-17.630	2.878			
1994	13	-19.699	3.204			
1995	24	-21.837	3.531	228	-19.622	3.176
1996	69	-20.047	3.259			
1997	37	-20.990	3.397	336	-19.990	3.227
1998	125	-19.269	3.129			
1999	70	-20.445	3.316	187	-19.723	3.205
2000	89	-19.492	3.157	186	-20.539	3.331
2001	209	-20.270	3.280	129	-20.739	3.368
2002	269	-20.071	3.253	158	-20.650	3.348
2003	330	-20.011	3.245	52	-19.657	3.194
2004	309	-21.205	3.428	115	-20.840	3.378
2005	288	-20.750	3.366	144	-20.981	3.404
2006	277	-20.701	3.351	192	-20.852	3.381
2007	292	-20.021	3.245	154	-19.859	3.228
2008	322	-19.967	3.237	155	-19.771	3.214
2009	263	-19.418	3.153	131	-19.947	3.241
2010	276	-20.590	3.330	94	-20.922	3.394
2012	215	-18.867	3.067	100	-20.100	3.260
2013	184	-20.119	3.261	134	-19.201	3.121
2014	237	-19.680	3.190	123	-19.427	3.157
2015	749	-19.984	3.236	210	-19.986	3.241
2016	1661	-19.504	3.163	286	-18.761	3.051
2017	874	-20.157	3.267	216	-20.947	3.389
Total	7169	-20.067	3.252	3330	-19.869	3.224

Figure 17a. Predicted mean weight at length WI345, 1995-2017.

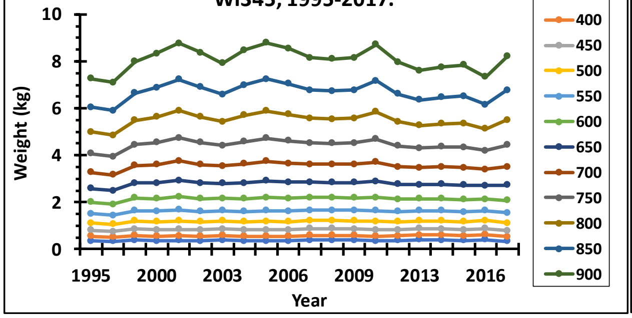
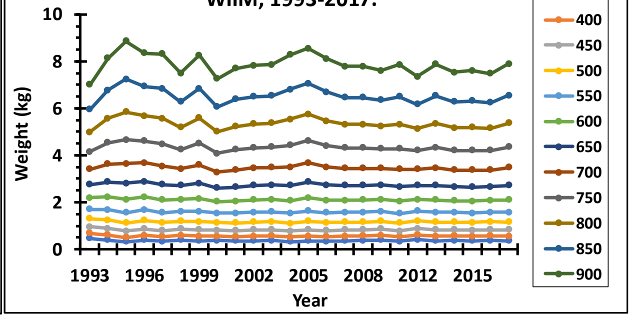


Figure 17b. Predicted mean weight at length WIIM, 1993-2017.



We used the annual length-weight regression coefficients and our vonB parameter estimates to estimate annual mean weight-at-age in both assessment units. The vonB growth coefficients shown in the table below were estimated by fitting a model without a year effect for all CWT-data from each

Assess. unit	Years	Number years	Age range	Length range	Number fish	Max. gradient	von Bertalanffy parameters				
							L-infinity	K	to	CVexp_a	CV_b
WI345	1995-2017	28	1-32	95-1020	10,500	1.25E-06	853	0.2195	0.6037	0.7710	-0.0031
WIIM	1993-2017	30	2-33	196-1010	7,333	8.20E-03	839	0.2120	-0.5042	0.3536	-0.0021

assessment unit to estimate mean length-at-age because growth in length did not appear to vary temporally to any sizable degree (see table in "Spatial Evaluation of Population Demographics/Growth in Length" section). We then used the annual length-weight regression coefficients (**Table 10**) to estimate mean weight-at-age as:

(4)
$$\boldsymbol{W_{k,i,j} = e^{\left[a_{i,j} + b_{i,j}\left(ln\left(L_{k,j}\right)\right)\right]}}$$

where ***W*** is mean weight in kilograms, ***a*** is the intercept coefficient for the length-weight relationship, ***b*** is the slope coefficient for the length-weight relationship, ***L*** is total length in millimeters estimated from the vonB growth relationship, ***ln*** is the natural logarithm, ***k*** is age, ***i*** is year, and ***j*** is assessment unit. We applied the assessment unit-specific length-weight coefficients (**Table 10** Total values) and not the annual values to years prior to 1995 in WI345 and 1993 in WIIM because there were no CWT-marked fish captured prior to those years. There was no information on weight of fish collected from WI345 in 1996 or 1998, so we used the length-weight regression coefficients for 1995 and 1997 to estimate mean weight-at-age in 1996 and 1998, respectively.

Mean weight of age-1

We decided to estimate mean weight of age-1 Lake Trout differently from older ages primary because these fish were raised in hatcheries and secondarily because there was evidence of substantial changes in their average size at stocking. We used data obtained from the Great Lakes Fish Stocking Database to estimate mean length and weight of yearling Lake Trout stocked into WI345 and WIIM during 1986-2017. Each record or observation in the database represents a single stocking event of a unique group or number of fish at a particular site on a particular day (http://www.glfc.org/fishstocking/dbstruct.htm). There were fields in the database for average total length (mm), total weight stocked (kg), and the number stocked for many, but not all, of the groups of

Lake Trout. There were slightly over 1,660 records in the Stocking Database that had mean length and total weight for each group of Lake Trout stocked in Lake Michigan. We divided the total weight of each group of fish, when available, by the number stocked to estimate mean weight of each group.

Mean length of yearling Lake Trout stocked into Lake Michigan generally increased through time, but the trends were substantially different between WI345 and WIIM. On a lakewide basis, mean length of stocked yearling Lake Trout increased linearly by 0.4 mm per year from the 1985-year class to the 2016-year class (r^2=19.6%) (**Figure 18a**). In WI345, mean length of stocked yearlings increased by 0.8 mm per year from an average of 143 mm total length for the 1985-year class to 175 mm total length for the 2016-year class (**Figure 186b**). In WIIM, mean length initially increased from 140 mm for the 1991-year class to 170 mm for the 2004-year class, but then declined to an average of 147 mm for the 2011- to 2016-year classes (**Figure 18c**). The average length of yearlings stocked into WIIM declined linearly by 0.7 mm per year from the 1985-year class to the 2016-year class. The divergence in length of yearling Lake Trout stocked between WI345 and WIIM was most evident for the 1994 to 2002 and 2008 to 2016-year classes.

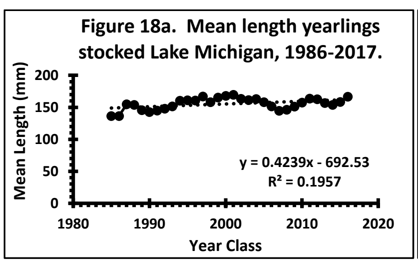


Figure 18a. Mean length yearlings stocked Lake Michigan, 1986-2017.

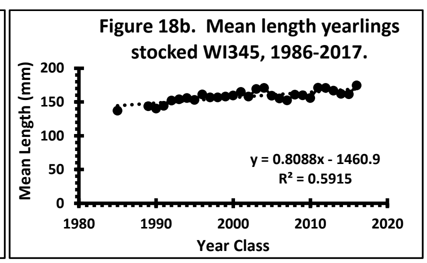


Figure 18b. Mean length yearlings stocked WI345, 1986-2017.

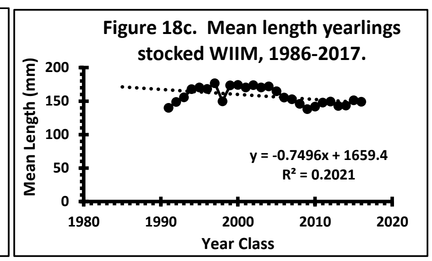


Figure 18c. Mean length yearlings stocked WIIM, 1986-2017.

Mean weight of stocked yearling Lake Trout followed similar trends to mean length in both assessment units. On a lakewide basis, mean weight of stocked yearlings increased by 0.3 g per year from the 1985- to the 2016-year class (**Figure 19a**). The largest changes in mean weight of stocked yearlings occurred in WI345 where it increased by 0.6 g per year. In WI345 mean weight of a stocked yearling ranged from 18 to 25 g for the 1985- to 1988-year classes and increased to between 33 and 40 g for the 2013-2016-year classes (**Figure 19b**). In WIIM mean weight of stocked yearlings declined by 0.1 g per year and mean weight of the 2013- to 2016-year classes were the same as for year classes stocked prior to 1994 (**Figure 19c**).

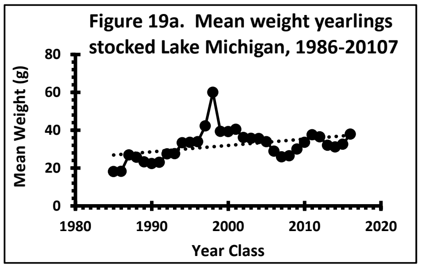


Figure 19a. Mean weight yearlings stocked Lake Michigan, 1986-20107

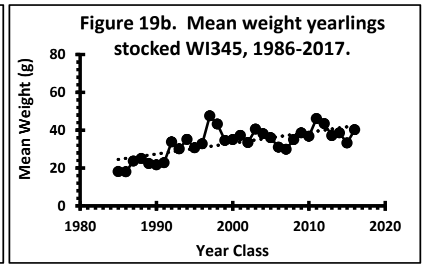


Figure 19b. Mean weight yearlings stocked WI345, 1986-2017.

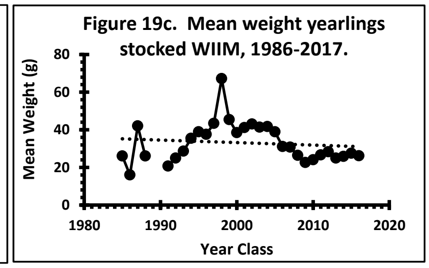


Figure 19c. Mean weight yearlings stocked WIIM, 1986-2017.

We used the mean weight data described above as the values for age-1 Lake Trout in the mean weight-at-age matrices. In WIIM there was no information on mean weight of the 1989- and 1990-year classes, so we used the value 0.023 kg for both year classes that was generated as mean of the weight of the 1988 (0.026 kg) and 1991-year classes (0.021 kg). The matrices of mean weight-at-age are shown in **Appendix 6**.

Natural Mortality

Our models required prior estimates and standard deviations of the instantaneous natural mortality rate for age-1 ($\boldsymbol{M_1}$), age-2 ($\boldsymbol{M_2}$), and age-3-and-older fish ($\boldsymbol{M_3}$). The table below gives values for prior estimates we used in our models. We based priors for $\boldsymbol{M_1}$ and $\boldsymbol{M_2}$ on field estimates made in netting surveys (Rybicki et al. 1990; Eck and Wells 1983). We made a subjective judgement on the value of the prior of $\boldsymbol{M_3}$ but reflected our uncertainty by providing a wide distribution (i.e., a large standard deviation = 0.500). This wide distribution allows the model flexibility in producing an estimate of the instantaneous natural mortality rate. As with most SCAA models, estimates of mortality rates in our model are heavily influenced by the age frequencies of the catches. We defined these age frequencies using ages derived from CWTs as described later.

Parameter	Input value	Standard deviation	Source
M_1	0.916	0.175	Rybicki et al. (1990)
M_2	0.528	0.100	Rybicki et al. (1990); Eck and Wells (1983)
M_3	0.150	0.500	

Female Maturity

We estimated age-specific maturity schedules for female CWT-marked Lake Trout captured in agency surveys and monitoring of commercial and recreational fisheries during 1995-2017. There were

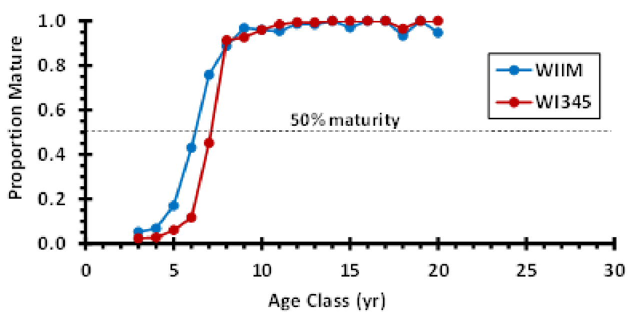
35,890 fish in our ACCESS database table “CWT Bio Data survey fisheries” with information on the state of sexual maturity. Female Lake Trout made up 38.4% of the fish with maturity information. In our two assessment units there was 15,221 fish with sex and maturity information and females made up 37%. Sexually mature females (3,039) made up 54% of the total number of females with maturity information.

Most female Lake Trout with maturity information in our database were captured during SPAWN and LWAP surveys. Lake Trout caught during these two surveys accounted for 89% of all our female maturity information, while the recreational fishery accounted for 7% and other sources 4%. The proportion of mature females was greater in SPAWN collections than other collection methods, particularly in WIIM. The lowest proportion of sexually mature females occurred in biological samples from the recreational fishery (see table below).

	WIIM			WI345		
Fishery	**female**	**mature**	**%mature**	**female**	**mature**	**%mature**
SPAWN	763	680	89%	2236	1264	57%
LWAP	654	346	53%	926	340	37%
Recreational	365	144	39%	122	33	27%
Other	199	75	38%	0		

We estimated the age-specific proportion of mature females in both assessment units during five-year time-blocks; 1995-1999, 2000-2004, 2005-2009, 2010-2014, and 2015-2017. The proportion mature in each time-block was estimated by dividing the number of mature females by the sum of the number of immature and mature fish. We created five-year time blocks of maturity because sample sizes of CWT-marked fish for individual years was highly variable and generated inconsistent estimates of maturity, particularly for ages 3-7 fish (see **Table 11**).

Figure 20. Female maturity ogive ages 3-20 in WI345 and WIIM, 1995-2017.



The mean female maturity schedule for 1995-2017 was similar among our two spatial areas. Sexual maturity of female Lake Trout increased rapidly from age-5 to age-9 and 100% maturity was achieved by age-12 in WIIM and WI345. Fifty-percent maturity of female fish was typically achieved between age-6 and age-7 (**Figure 20**).

Table 11. Annual proportion of sexually mature CWT-marked Lake Trout of ages 3-20 in WIIM, 1994-2017.

	Age Class																	
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1994			0.250				1	1										
1995				0.2500					1									
1996		0.000	0.000	0.3333	0.3636				1	1								
1997	0.000		0.500	0.1667	0.6667	0.500												
1998		0.000	0.000	0.5000	0.5294	0.500	0.714					1						
1999		0.000	0.000	0.0000	0.5000	0.857	1	1					1					
2000	0.000	0.000	0.000	0.1250	0.0000	0.333	0.667	1					1					
2001		0.000	0.250	0.2857	1	0.750	1	0.929	1	1				1				
2002	0.000	0.000	0.083	0.5556	0.643	0.800	0.800	1	1	1	1							
2003	0.000	0.000	0.375	0.7500	1	1	1	1	1	1	1	1						
2004	0.000	0.000	0.071	0.5625	0.900	1	1	1	1	1	1	1		1				1
2005	0.000	0.333	0.143	0.0625	0.750	0.889	1	1	1	1	1	1	1	1				
2006	0.000	0.000	0.000	0.3684	0.857	1	1	1	1	1	1	1	1	1	1			
2007		0.000	0.125	0.4615	0.875	1	1	1	1	1	1	1	1	1	1			
2008		0.000	0.100	0.1429	0.636	0.950	1	1	1	1	1	1		1	1		1	
2009				0.3810	0.789	0.938	1	1	1	1		1	1		1	1	1	1
2010				0.6154	0.840	0.941	1	1	1		1	1	1	1		1	1	
2011					0.833	0.929	1	1	1		1	1	1	1	1			
2012						1	1	1	1	1			1	1	1	1	1	1
2013	0.000	0.000					1	1	1	1	1		1	1	1			
2014	0.000	0.100	0.000					0.500	0.500	0.500	0.667	1	1		1	1	1	0.333
2015	1	0.034	0.250						1	1	1	1	1		1			
2016		0.059	0.189	0.500		1				1	1	1	0.500	1		0.667	1	1
2017	0.000	0.182	0.194	0.556	0.787	1					1	1	1	1	1	1	1	1
Total	0.053	0.068	0.171	0.431	0.758	0.888	0.969	0.961	0.953	0.986	0.984	1	0.971	1	1	0.933	1	0.857

There were different patterns in the rate of sexual maturity of female Lake Trout among the five-year time periods. In WI345, the maturity ogive was substantially shifted to younger ages during 2010-2014 than during other time periods (**Figure 21a**), whereas the maturity ogive in WIIM was more similar among time periods (**Figure 21b**) except during 1995-1999.

Figure 21a. Female maturity ogives by five-year time blocks WI345, 1995-2017.

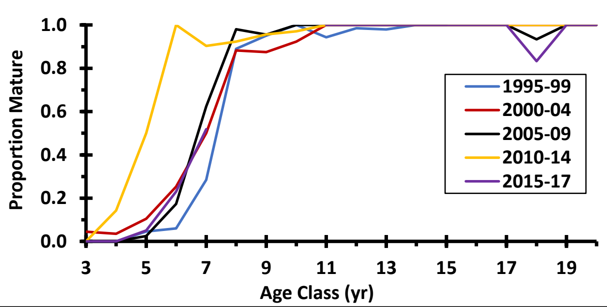
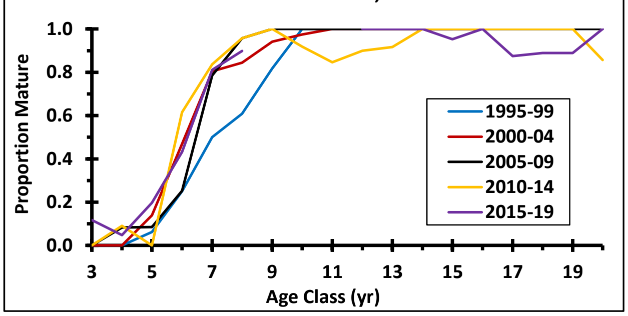


Figure 21b. Female maturity ogives by five-year time blocks WIIM, 1995-2017.



We fit non-linear logistic regressions to the age-specific maturity data to predict the proportion of mature fish ($\widehat{\boldsymbol{P}}$) at ages 3-20+ in each 5-year time-block as:

(5)
$$\hat{P}_{i,y} = \frac{1}{1 + e^{-(A_{i,y} - A_{50})/a}}$$

where $\boldsymbol{A}$ is age class, $\boldsymbol{A_{50}}$ is the age of 50% maturity, $\boldsymbol{a}$ is the slope of the relationship at $\boldsymbol{A_{50}}$, $\boldsymbol{i}$ is age, and $\boldsymbol{y}$ is the 5-year time block for which we aggregated the maturity data. We used Solver in Excel to estimate the parameters $\boldsymbol{A_{50}}$ and $\boldsymbol{a}$ by minimizing the difference in the sums of squares of the residuals as:

(6) $$\sum_{i=1}^{n}\left(P_{i,y} - \hat{P}_{i,y}\right)^2$$

where $\boldsymbol{P}$ is the proportion mature, $\boldsymbol{\hat{P}}$ is predicted proportion of mature fish, $\boldsymbol{i}$ is age, and $\boldsymbol{y}$ is the five-year time period.

Predicted $\boldsymbol{A_{50}}$ values for five-year time periods varied from 4.9 to 8.5 yr. for our two assessment units and maturity generally occurred at lower ages in WIIM than WI345 (**Table 12**). The average age at 50% maturity was 6.2 yr. in WIIM and 7.1 yr. in WI345. The $\mathbf{A_{50}}$ value was between age-5 and age-7 in WIIM and age-5 and age-8 in WI345. Slope values from the regressions were generally between 0.4 and 0.8 but were as high as 1.0.

Table 12. Logistic regresssion estimates of female sexual maturity during five-year time blocks in WIIM and WI345, 1995-2017.

Mgt unit	Time period	Number of females: immature	mature	Maturity parameters: A_{50}	a
WIIM	1995-1999	69	61	7.3	1.0210
	2000-2004	112	281	6.2	0.7026
	2005-2009	151	338	6.4	0.4633
	2010-2014	41	255	5.9	0.3839
	2015-2017	357	302	5.9	0.7729
	Total	730	1,237	6.2	0.8047
WI345	1995-1999	943	424	7.3	0.3559
	2000-2004	292	348	6.9	0.8211
	2005-2009	251	421	6.7	0.4528
	2010-2014	25	333	4.9	0.4233
	2015-2017	122	108	6.5	0.6460
	Total	1,633	1,634	7.1	0.4983

We used the fitted logistic regression parameters estimated with Solver in EXCEL to estimate age-specific maturity schedules for Lake Trout within each five-year time-block. We applied $\hat{P}$-values for the 1995-1999 time-period to all years prior to 1995 in WIIM and WI345 (**Appendix 7**).

Recreational Fishery

We used targeted salmonine fishing effort for the boat and charter fisheries in development of the stock assessments for Lake Trout in Lake Michigan. We excluded shore, pier, and stream fisheries from the analysis because they are extremely inefficient and inconsistent methods for catching salmonines, which are primarily offshore and inaccessible to shore, pier, and stream fishers for most of the year. On the other hand, open water boat fisheries are relatively efficient and consistent methods for catching salmonines and the data are available for 1986 to the present, and we think they provide the best representation of the force of fishing on Lake Trout populations. In nearly every data set we received from the states, there were missing values for either fishing effort, harvest, or catch in a specific year or series of years. We used various methods to fill-in these data gaps for our modeling efforts and to insure consistency of the data. The adjustments we made to fill-in data gaps is described in the sections that follow for each state.

Effort and harvest expansion in Michigan 1986–2017

The State of Michigan has not been able to maintain consistent sampling of all statistical districts every year. To compensate, they developed a method of estimating effort for unsampled sites using ratios between sites from previous years. The estimates by ratios are referred to as “expansion estimates,” and they are not included in monthly estimates of fishing effort or harvest that are generated by the general creel survey program. Thus, to achieve complete, lake-wide estimates of effort or harvest, expansion estimates must be obtained separately from the Michigan Creel Database. In some years and statistical districts, expansion estimates are a substantial part of the total, lake-wide estimate.

The Michigan DNR made two changes in creel survey methods over the years that are relevant to deriving a constant time series of effort and harvest estimates. First, estimates for charter fishing effort and harvest were not made separately from the other fisheries during 1986-1989. In 1990, charter fishing as split from the general creel survey and was estimated in a different way. A State law was passed that required all charter fishers to directly report their effort and harvest to the DNR. Charter effort and harvest is now considered a precise value rather than a survey estimate because compliance with the law is thought to be good. In addition, the Michigan DNR did not request charter fishers to report targeted salmonine effort and harvest until 2004. Thus, only total effort and harvest is available for the charter fishery from 1990 to 2003.

Consequently, we combined information from the charter fisheries and the expansion estimates to derive complete and consistent estimates of total fishing effort and harvest for statistical districts in Michigan. We obtained both general creel survey and charter-mode estimates from either the Lake Michigan Lake-Wide Creel Database or the Michigan Creel Database and expansion estimates from the Michigan Creel Database and then used them to calculate expanded recreational fishing effort in Michigan during 1986-1990 as:

(7) $$\boldsymbol{Xrf_{i,j} = Grf_{i,j} + Erf_{i,j}}$$

where ***Xrf*** is the complete effort or harvest estimate, ***Grf*** is the general creel survey estimate including the charter fishery, ***Erf*** is the expansion estimate, ***i*** is year and ***j*** is statistical district. For 1990 to the present we estimated the expanded fishing effort and harvest in Michigan as:

(8) $$\boldsymbol{Xrf_{i,j} = Grf_{i,j} + C_{i,j} + Erf_{i,j}}$$

where $\boldsymbol{C_{i,j}}$ is the charter-mode value for year ***i*** and district ***j***. To obtain region-wide totals for Michigan waters we summed over all statistical districts in the State (MM1 through MM8).

Additional complications with Michigan DNR data were that expansion estimates were available for total effort, but not targeted salmonine effort, and estimates of targeted salmonine effort are not available for the Michigan charter fishery for 1990-2003. We corrected for this by applying ratios. The first ratio was estimated by assuming that for each statistical district the ratio of targeted salmonine boat-only effort divided by total effort is the same for the expansion estimates as for the general creel survey estimates, the latter of which are available for every year. Thus, we estimated for 1990-2003 that targeted boat-only recreational fishery effort (***TARrf***) should be calculated as the expansion:

(9) $$\boldsymbol{TARrf_{i,j} = TOTrf_{i,j} * Rrf_{i,j}}$$

where, ***TOTrf*** is the total-effort expansion estimate, ***Rrf*** is the ratio of targeted salmonine to total effort, ***i*** is year, and ***j*** is statistical district.

We corrected for the second complication by assuming the ratio of targeted salmonine to total effort in the charter fishery in years they are both available (2004-2011) are the same as for the years they are not available (1990-2003). For Lake Michigan, we calculated an average ratio of 0.93 for 2004-2011. This ratio was quite consistent from year to year because most of the charter effort has always been from boats targeting salmonines. The standard deviation was only 0.01. Thus, we multiplied total effort estimates for the charter fishery by 0.93 during 1990-2003 to get targeted boat-only salmonine effort for the charter fishery in those years.

Recreational salmonine fishing effort in Illinois 1986–1995

Targeted open water boat recreational salmonine fishing effort was not estimated in the month of October prior to 1995 in Illinois Waters. We corrected this problem by calculating the average ratio of 0.09 for October to September effort during 1996-2011. This ratio was fairly consistent for the period with a standard deviation of 0.03. Thus, for 1986-1994, we multiplied targeted recreational salmonine fishing effort estimated in September in Illinois by 0.09 to get an estimate of targeted salmonine effort in October in Illinois.

Recreational fishing effort and harvest in Indiana

The creel survey for Indiana waters, which provides estimates of fishing effort and lake trout harvest does not cover all recreational fishing in Indiana's waters of Lake Michigan. Although the creel estimates are minimum values, we elected to include this component of the harvest as this was better than excluding it and we had no information on which to base an expansion. In Indiana waters targeted salmonine effort was not estimated prior to 1989. We corrected this by relating targeted salmonine effort in Indiana to targeted salmonine effort in Illinois via regression using the 1990-2011 data. Results of this regression are:

(10) $$\boldsymbol{INErf_i = 30,066 + ILErf_i * 0.52}$$ ($R^2 = 0.46$, $P < 0.01$)

where, ***INErf*** is the Indiana and ***ILErf*** is the Illinois targeted salmonine effort, respectively, in year ***i***. Thus, the estimate of targeted salmonine effort in Indiana for 1986-1989 was based on this regression using the Illinois estimate for those years.

In addition, there was no estimated recreational fishing effort estimated for Indiana waters of Lake Michigan in 2012. Recreational salmonine fishing effort in Indiana had been declining by 8,800 angler hours per year since 1987 (**Figure 22a**), but the methodology for estimating effort and harvest changed in 2006. Thus, we developed a simple linear regression of fishing effort on calendar year for 2009-2017 to predict what fishing effort would have been in 2012. The regression was highly significant and predicted that angler effort declined by 17,916 hours per year during 2009-2017 (**Figure 22b**), twice the rate of the decline during 1987-2017. Consequently, we used the regression equation to predict salmonine fishing effort in 2012 (year = 4) as:

Figure 22a. Recreational salmonine angler effort Indiana, 1987-2017.

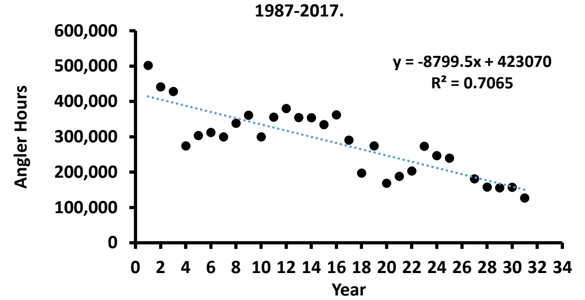
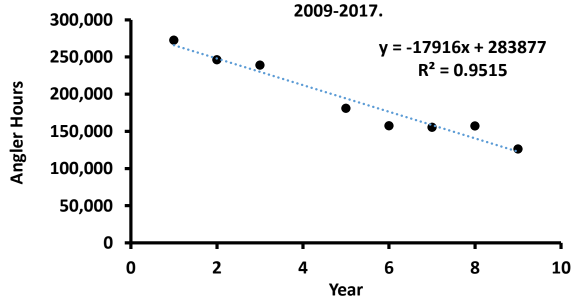


Figure 22b. Recreational salmonine angler effort Indiana, 2009-2017.



(11) $$\boldsymbol{INErf_4 = 283,277 + 4 * -17,916}$$ (R^2 = 0.95, P<0.01)

where ***INErf*** is total salmonine fishing effort in Indiana, 4 is the year 2012, -17,916 is the rate of change in fishing effort per year from the regression, and 283,277 is the intercept of the regression in angler hours.

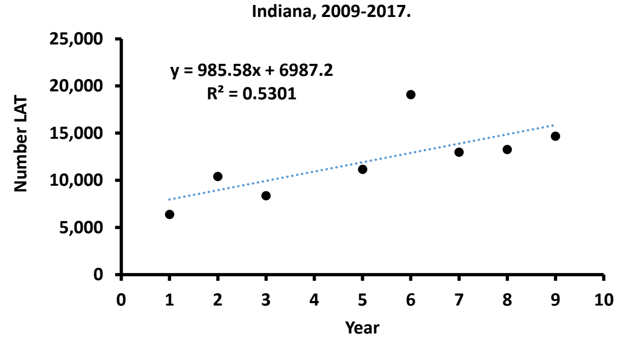
We used the same methodology to predict the harvest of Lake Trout from Indiana waters in 2012. The estimated harvest of Lake Trout by the recreational fishery in Indiana waters was regressed on year and the following equation was used to predict the harvest in 2012 (year = 4):

(12) $$\boldsymbol{INHrf_4 = 6,987 + 4 * 985.85}$$ (R^2 = 0.53, P <0.01)

where ***INHrf*** is the harvest, 4 is the year 2012, 985.85 is the rate of change in harvest (number of fish) per year, and 6,987 is the intercept of the regression in number of Lake Trout (**Figure 23**).

There also was no estimate of the total number of Lake Trout caught in Indiana waters during 2012. To estimate the 2012 catch we estimated the ratio of harvest to catch for the years 1999-2017 when both statistics were estimated for Indiana waters. On average the ratio of harvest to catch was 0.9273 during 1999-2017 with annual values ranging from 0.6 to 1.0. We divided the estimated number of Lake Trout harvested in 2012 by 0.9273 to estimate the total catch in 2012 from Indiana waters.

Figure 23. Recreational Lake Trout harvest Indiana, 2009-2017.



Recreational effort in Wisconsin 2012

The State of Wisconsin estimates recreational fishery statistics on a county basis. Unfortunately, there was no estimates of open water recreational boat fishing effort for Kenosha and Kewaunee Counties in 2012. We estimated effort for these counties based on the proportional change in fishing effort in the other counties. Angling effort in Wisconsin counties other than Kenosha and Kewaunee increased by 15.64% from 2011 (533,413 angler hours) to 2012 (632,279 angler hours). We then estimated recreational fishing effort in Kenosha and Kewaunee counties for 2012 by adding 15.64% to the 2011 fishing effort values.

Effects of adjustments on effort

Of all the corrections described above, adding the expansion estimates to Michigan general creel survey estimates was by far the most important. Expansion estimates increased lake-wide estimates of targeted salmonine effort for Lake Michigan during 1986-2011 by an average of 316,678 hours per year, or 8.1% per year. The range was from 2% of the lake-wide estimate in 2001 to 22.7% of the lake-wide estimate in 1992.

Other corrections for fishing effort were relatively unimportant numerically, but we argue that applying them is better than not because it maintains the consistency of the data. The corrections for boat-only salmonine targeted charter estimates in Michigan reduced lake-wide estimates during 1990-2003 by an average of only 21,572 hours per year, or 0.7% per year. The corrections for October boat-only salmonine targeted effort in Illinois increased lake-wide estimates in 1986-1995 by an average of only 4,053 hours per year, or 0.1% per year.

Catch and release in Michigan 1986-1996

There were no estimates of the number of Lake Trout discarded by the recreational fishery in Michigan waters during 1986-1996, but there were estimates for 1997-2017. Consequently, we estimated the number of Lake Trout discarded during 1986-1996 by estimating the ratio of the number of fish discarded to the estimated number of fish harvested (killed) by the fishery during 1997-2017 (**Figure 24**). Size limit regulations were imposed on Lake Trout caught by the recreational fishery in Michigan statistical districts MM-3, MM-4, and MM-5 beginning about 2005, consequently we felt that the ratio of discards to harvest that would be most representative of the fishery during 1986-1996 when catch and release information was not collected would be for years prior to 2005. Thus, we estimated the arithmetic mean ratio of discards to harvested Lake Trout for each statistical district for a specific number of years and used these district-specific ratios to project the number of Lake Trout caught and released by the fishery in years prior to 1997. The statistical district ratios and years included in estimating the mean ratio are shown in the table at the left.

District	Year	Ratio
MM3	1997-2004	0.7527
MM4	1997-2004	0.9846
MM5	1997-2003	0.6716
MM6	1997-2003	0.7484
MM7	1997-2004	0.8596
MM8	1997-2012	0.6409

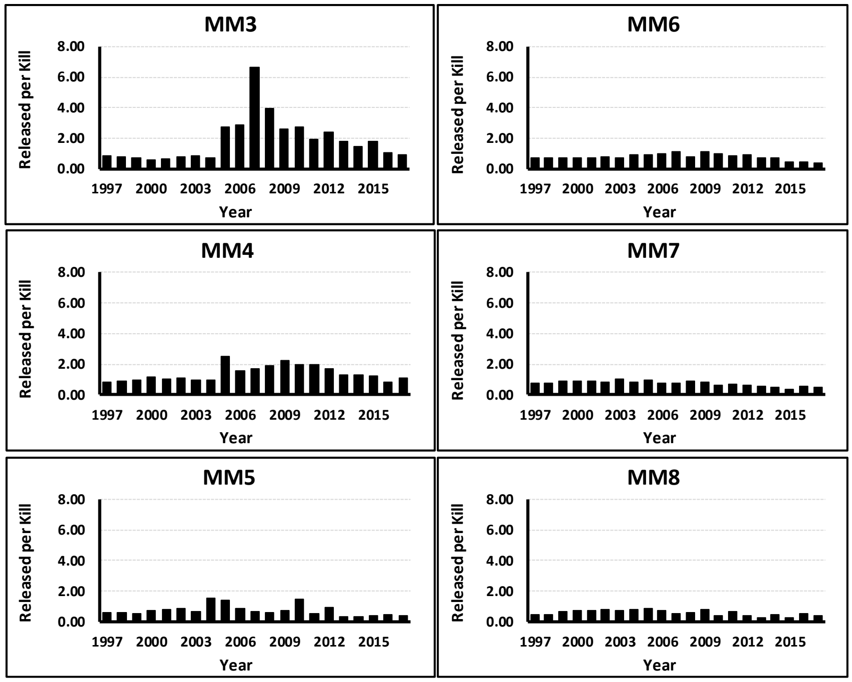


Figure 24. Annual ratio of the number of Lake Trout released to the number killed by the boat-only salmonine recreational fishery in statistical districts of Michigan waters of Lake Michigan, 1997-2017.

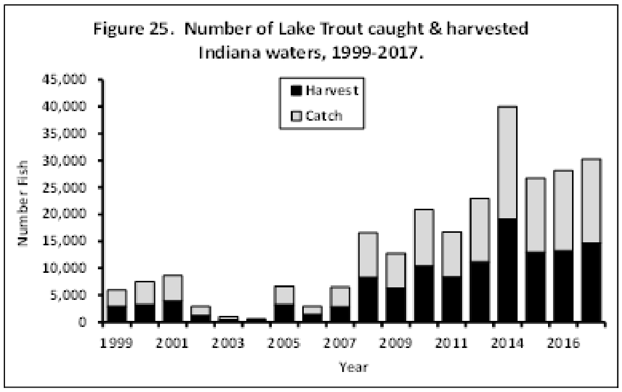
The number of Lake Trout discarded annually by the recreational fishery in each Michigan statistical districts during 1986-1996 was estimated as:

(13) $$\boldsymbol{DISCMIrf_{i,j} = MIHrf_{i,j} * \ DISCMIrf{:}MIHrf_{j}}$$

where ***DISCMIrf*** is the number of Lake Trout discarded by the recreational fishery, ***MIHrf*** is the harvest of Lake Trout by the recreational fishery, ***DISCMIrfI:MIHrf*** is the average ratio of the number of Lake Trout caught and released to the number harvested, ***i*** represents year, and ***j*** represents statistical district.

Lake trout catch in Indiana 1986-1998

The State of Indiana estimated the Lake Trout harvest but not the catch during 1986-1998, but during 1999-2011 and 2013-2017 they estimated both catch and harvest. We estimated the arithmetic mean ratio of the number of Lake Trout harvested to the number caught by the fishery during 1999-2011 and 2013-2017 to extrapolate the Lake Trout catch during 1986-1998. The annual harvest to catch ratio ranged from 0.6 to 1.0 during 1999-2011 and 2013-2017 and the arithmetic mean ratio was



estimated to be 0.93 (**Figure 25**). Annual estimates of the number of Lake Trout harvested from Indiana waters during 1986-1998 were then divided by 0.93 to estimate the annual catch.

Estimating total recreational kill

Projecting total kill of Lake Trout by the recreational fishery involved accounting for post-release mortality. We applied an average post-release mortality rate of 45% reported by Sitar et al. (2017). Sitar et al. (2017) conducted a mark and recapture study with Lake Trout at Marquette, Michigan in Lake Superior and Alpena, Michigan in Lake Huron. Their study involved tagging and releasing Lake Trout captured by recreational fishermen and comparing the recapture rate with that of Lake Trout captured, tagged and released from commercial trap net fisheries in the same general geographic area. The trap net-tagged and released Lake Trout acted as a control against the recreational fishery catch and release information.

Surface water temperature had a strong effect on post-release mortality of recreationally caught Lake Trout in the Sitar et al. (2017) study. Post release mortality at the Lake Superior site was estimated to be 15.0% at surface water temperatures <10°C, 42.6% at temperatures of 10–16°C, and 43.3% at temperatures >16°C. The estimates of post release mortality were 52.5% for the Lake Huron study site at surface water temperatures <10°C, 45.2% at temperatures of 10–16°C, and 76.4% at temperatures >16°C. We decided to use the 45% model average for water temperatures of 10-16°C in Lake Huron for our estimate of post-release mortality. The recreational fishery in Michigan waters of Lake Huron is more like that in Lake Michigan than in Lake Superior where vertical jigging and hand lining were common capture techniques during the study (Sitar et al. 2017). The fisheries on lakes Huron and Michigan are typically downrigger trolling fisheries. Total Lake Trout kill by the recreational fishery (***KILLrf***) was estimated as:

(14) $$\boldsymbol{KILLrf_{i,j} = Hrf_{i,j} + (DISCrf_{i,j} \times 0.45)}$$

where ***Hrf*** is the recreational harvest in number of fish, ***DISCrf*** is the number of fish discarded by the recreational fishery, ***i*** and ***j*** are as defined previously.

Age composition of recreational fishery

Age of Lake Trout was not included in the recreational harvest monitoring data obtained from the states of Wisconsin, Illinois, or Indiana. Biological data from these states typically only included length, sometimes weight, fin clip, and only the State of Wisconsin occasionally recorded sex and maturity. Age of Lake Trout along with length, weight, fin clip, sex, maturity, and designation of aging structure was included with the biological data obtained from the Michigan DNR.

In total, 53% of 58,033 Lake Trout sampled from the recreational fishery had ages assigned to them. A slightly higher proportion of wild Lake Trout were aged (55%) than stocked fish (53%). In Michigan waters 97% of the Lake Trout were aged, compared to 2 to 5% of Lake Trout from Illinois, Indiana, and Wisconsin waters (see table at left). The USFWS BioTech program aged 64% of their fish, but 62% of these were CWT-marked or wild.

	Unaged fish		Aged fish	
Data source	Stocked	Wild	Stocked	Wild
Illinois Creel	1,147	281	26	
Indiana Creel	5,025	719	283	
Lamprey database	71	9	482	
Michigan Creel	581	120	19,549	2,064
USFWS Bio Tech	10,985	1,321	6,075	2,226
Wisconsin Creel	5,871	1,070	128	
Total	23,680	3,520	26,543	4,290

Age composition assessment unit WIIM

We evaluated applying age-length keys to the lengths of unaged Lake Trout to estimate age composition of the recreational fishery in WIIM during 1986-2017. Applying an age-length distribution to length frequency distributions of unaged fish to estimate age composition of the unaged fish requires that the aged and unaged fish come from populations with the same age distribution conditioned on length. To evaluate these assumptions, we compared age and length distributions of Lake Trout caught during gill net surveys and recreational fisheries in WIIM. The surveys and recreational fishery monitoring data were:

LWAP - Multifilament nylon graded-mesh gill nets of 2.5 to 6-inch stretch measure in ½-inch increments fished during the spring coordinated Lake Trout survey (Schneeberger et al. 1998);

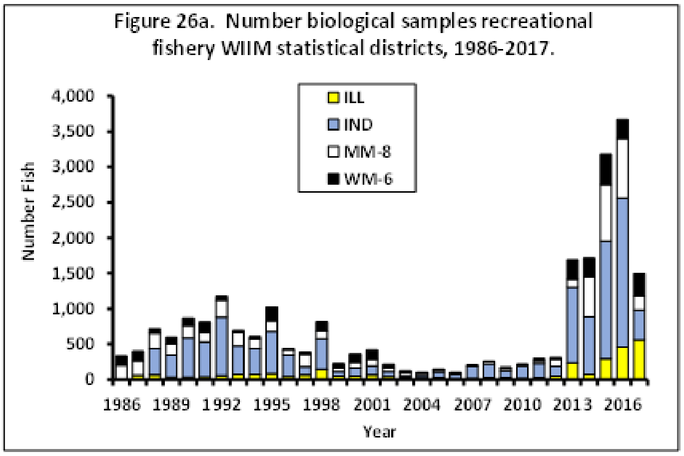
SPAWN - Multifilament nylon graded mesh gill nets of 4.5 to 6-inch stretch measure in ½-inch increments fished during the fall to target spawning aggregations of adult Lake Trout;

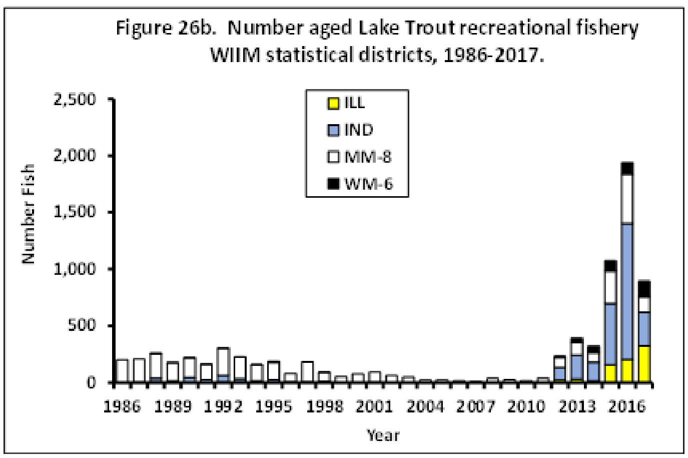
SURVEY – Trawl, impoundment gear, and multifilament and monofilament gill nets of 2.0 to 6-inch stretch measure in ½-inch increments fished during the spring and summer to survey Lake Whitefish and Lake Trout populations; and,

SPORT - Recreational hook and line fisheries monitored in each state.

The number of biological samples usable for extrapolating age composition of the recreational fishery in WIIM was not equally distributed among statistical districts. Total length was collected from

23,790 Lake Trout caught by the recreational fishery with 52% coming from Indiana, 22% from MM-8, 14% from WM-6, and 12% from Illinois (**Figure 26a**). The annual number of biological samples ranged from 103 to 3,668 and averaged 734 fish during 1986-2017. Annual biological samples were lowest during 1999-2012 and ranged from 103 to 419 fish. The large number of biological samples after 2012 were collected by the USFWS BioTech monitoring program.





On the other hand, most of the Lake Trout aged from the recreational fishery in WIIM were from MM-8 (**Figure 26b**). One-third of the Lake Trout sampled from the recreational fishery were aged by all the fishery agencies and 48% of these came from MM-8, whereas only 22% of all biological samples from WIIM recreational fisheries were from MM-8. Prior to 2012, 79-100% of the annual number of aged fish came from MM-8, whereas after 2011 only 16-38% of the aged fish came from MM-8. The percentage of Lake Trout aged among statistical districts in WIIM was consistent with the number of biological samples collected from the recreational fishery after 2011 but not before.

Length and age composition of biological samples should be similar among statistical districts for the unbalanced spatial sampling to produce unbiased estimates of the age composition of the recreational fishery. We compared length distributions and age compositions of Lake Trout in the recreational fishery harvest among statistical districts to evaluate the appropriateness of the biological sampling for extrapolating age compositions to unaged samples.

Length distribution of recreationally caught Lake Trout from WIIM was similar among statistical districts for aged and unaged samples. The length distribution of unaged Lake Trout was nearly identical for IND, MM-8, and WM-6 while length distribution in the ILL recreational fishery was skewed slightly to the left and did not contain as many fish of 750-850 mm total length as the other districts (**Figure 27a**). Ninety-five percent of unaged Lake Trout caught by the recreational fishery in WIIM were 520-890 mm

Figure 27a. Length frequency UNAGED fish recreational fishery in WIIM statistical districts, 1986-2017.

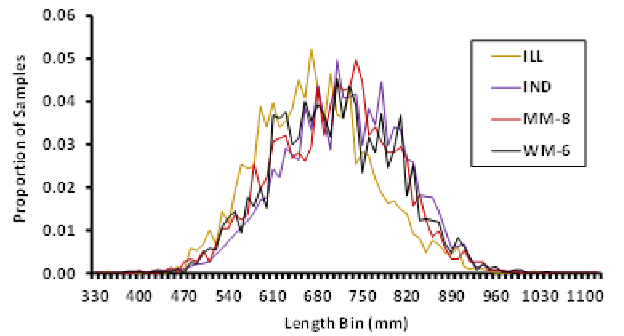
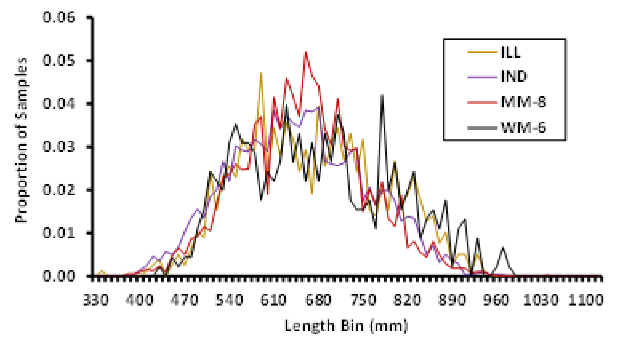


Figure 27b. Length frequency AGED fish recreational fishery in WIIM statistical districts, 1986-2017.

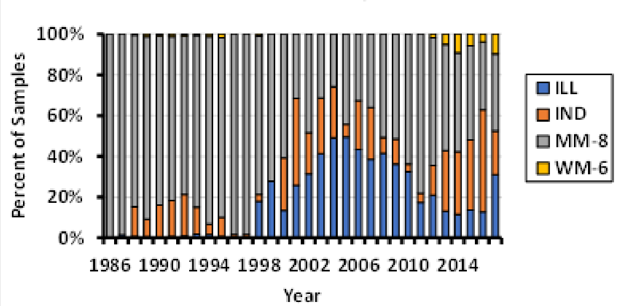


total length. The length distribution of aged Lake Trout was identical between all four statistical districts with 95% of fish being between 470- and 860-mm total length (**Figure 27b**).

While length distributions from statistical districts overlapped well for aged and unaged Lake Trout caught by the recreational fishery, distributions of unaged fish were more skewed toward larger fish than were the aged fish. The length distribution of aged and unaged Lake Trout was very similar with 99.9% being larger than 400 mm total length and less than 910 mm total length. The proportion of Lake Trout of 690 to 920 mm total length was much greater for the unaged samples than for the aged samples. Thus, while the total length distributions were similar for aged and unaged Lake Trout, they did not completely overlap. It seems possible that the absence of ages for larger Lake Trout could reflect challenges in aging older fish and suggests that the underlying distributional assumption for an age-length key is violated.

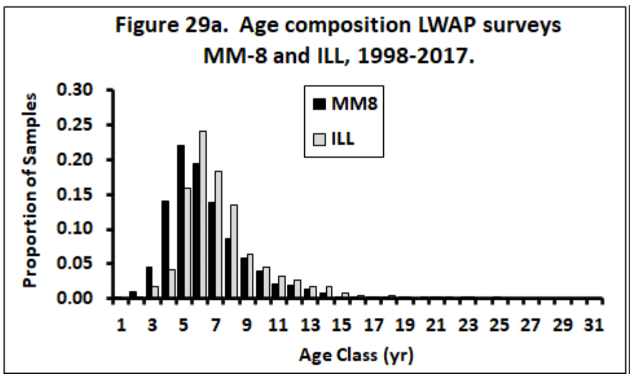
We decided not to use age-length distributions developed from Lake Trout caught by the recreational fishery in WIIM to extrapolate age composition of the unaged portion because age samples were spatially unbalanced for most years during 1986-2017. Eighty-nine percent of aged Lake Trout samples during 1986-2011 came from MM-8 (**Figure 28**) and there were no fish >age-16. In comparison, 52% of the aged Lake Trout in the recreational fishery harvest during 2012-2017 came from IND, 24% from MM-8, 16% from ILL, and 9% from WM-6, and 5% were >age-16.

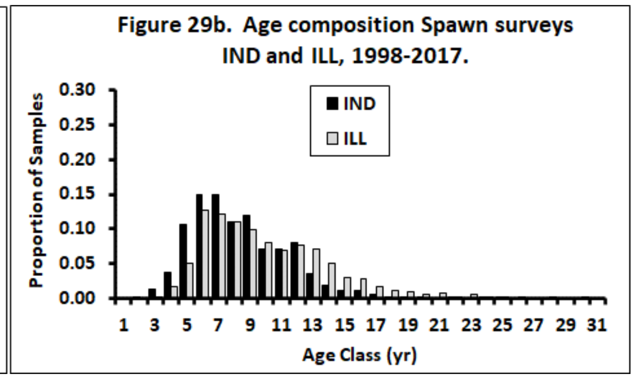
Figure 28. Allocation of AGED samples among statistical districts WIIM, 1986-2017.



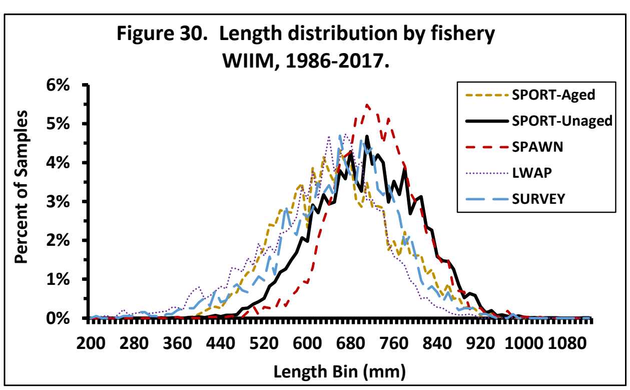
There did appear to be some differences in age composition of Lake Trout populations between eastern and western areas of WIIM. We choose to compare age composition of Lake Trout caught during LWAP surveys in MM-8 and ILL and SPAWN surveys in IND and ILL to evaluate potential spatial differences in age structure of the populations. Lake Trout from WM-6 were excluded from the comparisons because neither LWAP nor SPAWN surveys were there. We excluded biological samples from LWAP surveys conducted in IND because less than 50 fish were aged from there during 1998-2017. SPAWN surveys were not conducted in MM-8 so that district was excluded from the SPAWN age composition comparisons.

We found that more age 2-5-year-old Lake Trout were captured during LWAP surveys from MM-8 than from ILL, and more age 6 to 15-year-old fish were captured from ILL than from MM-8 (**Figure 29a**), but the age distributions were generally similar during 1998-2017. We also found that there was more age-3 to 7-year-old Lake Trout in SPAWN samples from IND than from ILL (**Figure 29b**), very similar distributions between IND and ILL for age 8 to 12-year-old fish, and many more age-13 and older fish from ILL than IND during 1998-2017.





We decided to use CWT ages collected from all data sources in all statistical districts of WIIM across all years available to develop the age-length keys for estimating age composition of Lake Trout caught in the recreational fishery. Ages collected from all sources provided better spatial coverage than using only SPORT collected fish and CWTs provided ages with minimal error. In addition, our earlier analysis showed that there were no major changes in growth rates in WIIM over the 1986-2017 period. Sample sizes of CWT ages in WIIM were good (7,369). We created annual age-length distributions for age-3 and older Lake Trout of 410 mm and larger by combining CWTs collected from LWAP, SPAWN, SURVEY, and SPORT biological samples in statistical districts WM-6, ILL, IND, and MM-8 during 1986-2017. Length distributions collected by all surveys overlapped length distributions of the unaged Lake Trout caught in the recreational fishery reasonably well (**Figure 30**). Certainly,



including SPAWN surveys in development of the age-length distribution helped ensure overlap between aged and unaged samples particularly for 1999 to 2011 when recreational fishery biological samples were scarce. Most important, we believe that most of the differences in length distributions are due to differences in the size selective nature of the gears and not due to differences in underlying age distributions at a given length.

We created a field in the ACCESS biological databases titled *Lengthbin_10mm* (**Appendix 1**) and computed the 10-mm length bin for individual fish through the formula:

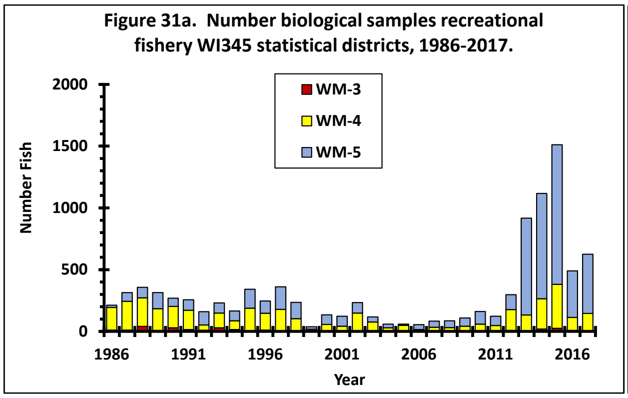
(15) ***Lengthbin_10mm = INT(Length_mm/10)*10***

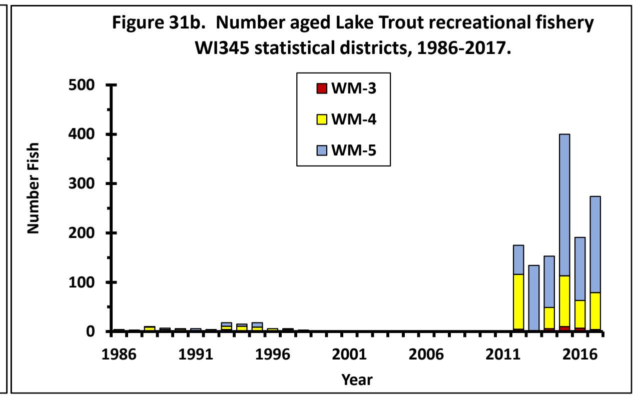
where ***INT*** is the integer of dividing total length of individual fish (*Length_mm*) by ten and multiplying that result by ten. Annual age-length distributions were then generated in ACCESS for CWT-marked fish of ages 3 to 20+, imported into EXCEL, converted to age-length frequencies, and multiplied by the annual number of unaged Lake Trout in biological samples from the recreational fishery in each 10-mm length bin. The estimated number of Lake Trout of each age in each length bin where then summed across all length bins for each age class to estimate the annual age composition of unaged fish in the recreational fishery. The estimated annual age structure of unaged Lake Trout was then added to the composition of aged fish in the recreational fishery to estimate the total age composition of the harvest (**Appendix 8**).

We had to estimate the number of age-20+ Lake Trout using our age-length template somewhat differently than younger age groups. Our template included all ages of fish collected in all years, however, fish of age-20+ were not present in the population until 1986 as the 1966-year class was the first stocked into WIIM, and WI345. Consequently, fish older than the maximum age possible in a year were excluded from our estimates of age composition. For example, the oldest fish possible was age-20 in 1986, age-21 in 1987, age-22 in 1988, etc., so fish older than age-20 in 1986, age-21 in 1987, and age-22 in 1988 were excluded from our estimates of the proportion of age-20+ fish in those years. The oldest fish in our database were age-33, age-34, and age-35 in 2017-2019 and the oldest CWT-marked fish observed in each assessment unit increased linearly through time.

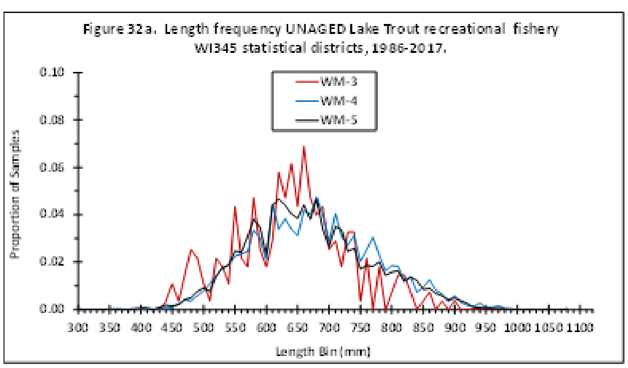
Age composition assessment unit WI345

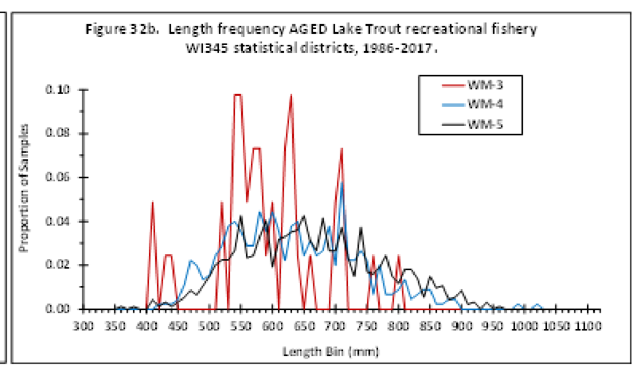
We used the same process to estimate age composition of Lake Trout caught in the recreational fishery in assessment unit WI345 as we did in WIIM. We did this by comparing length and age composition of fish caught in LWAP, SPAWN, SURVEY, and SPORT fisheries in statistical districts of WI345 during 1986-2017. The number of biological samples usable for extrapolating age composition of the recreational fishery in WI345 was not equally distributed among statistical districts. Total length was collected from 9,807 Lake Trout caught by the recreational fishery with 3% coming from WM-3, 38% from WM-4, and 59% from WM5 (**Figure 31**). The annual number of biological samples ranged from 38 to 1,511 and averaged 306 fish during 1986-2017. Annual biological samples were lowest during 1999-2011 and ranged from 38 to 234 fish. The large number of biological samples after 2012 were collected by the USFWS BioTech monitoring program.





Length distribution was generally similar among statistical districts for aged and unaged fish, but small sample sizes made comparisons difficult. The length distribution of unaged Lake Trout was similar among statistical districts except there were fewer fish larger than 750 mm total length in WM-3 than in WM-4 or WM-5 (**Figure 32a**). Ninety-five percent of unaged Lake Trout caught by the recreational fishery in WI345 were 490 to 880 mm total length. The distribution of aged Lake Trout was less similar among statistical districts than for unaged fish because few were aged; 1,433 fish were aged during 1986-2017 or only 4.5 fish per year (**Figure 32b**). Ninety-five percent of aged Lake Trout caught by the recreational fishery were 460-870 mm total length. Length distribution of unaged and aged Lake Trout in the recreational fishery were similar in WI345 unlike in WIIM, particularly for fish larger than 560 mm





total length. Unfortunately, so few Lake Trout were aged prior to 2012 that a reliable annual age-length key could not be developed to estimate age composition of the recreational fishery for unaged fish. Consequently, we choose to develop annual age-length keys in WI345 the same way we did for WIIM. That is, by using age and length data from CWT-marked Lake Trout from all surveys and all years. As in WIIM, ages collected from all sources in WI345 provided better spatial coverage than using only SPORT and CWTs provided ages with minimal error. Also, our earlier analysis showed that there were no major changes in growth rates in WI345 during the 1986-2017 period. There were 10,405 CWT-ages for fish from WI345 used to develop the age-length template. Estimated age composition of the recreational fishery in WI345 is shown in **Appendix 9**.

Weight at Age in Recreational Harvest

For age-3-and-older Lake Trout, we estimated the mean weight-at-age harvested by the recreational fishery by averaging the weight of fish sampled in the catch across all years of available data. The data was input to the stock assessment as a vector that was constant across all years for ages 3-20+ (**Table 13**).

Table 13. Mean weight (kg) of ages 1-20+ Lake Trout recreational fishery, 1986-2017.

	WIIM		WI345	
Age	N	mean	N	mean
1	197	0.087	197	0.087
2	16	0.827	16	0.827
3	83	1.428	23	1.209
4	545	1.516	123	1.719
5	1735	1.998	294	1.807
6	1667	2.519	258	2.310
7	1050	3.109	217	2.892
8	747	3.568	140	3.086
9	434	4.054	38	3.928
10	254	4.700	46	4.178
11	199	5.070	38	4.144
12	147	5.443	43	5.078
13	131	5.232	23	5.443
14	154	5.450	64	4.909
15	87	5.819	23	5.597
16	59	5.742	11	5.893
17	37	6.166	7	5.803
18	32	5.392	10	6.229
19	24	5.632	4	5.845
20+	164	6.239	56	6.090

Age-1 and 2 Lake Trout

We consolidated all weight data collected from age-1 Lake Trout in Lake Michigan to estimate mean weight caught in the recreational fishery. We summarized mean weight of all age-1 fish caught during surveys and harvest monitoring in Lake Michigan during 1986-2017 because only two age-1 fish were represented in our harvest monitoring database. There were 531 age-1 Lake Trout in all our databases that averaged 54.2 g with a standard deviation of 33.6 g. We estimated the $Z_{0.99}$ confidence interval about the mean to be 50-58 g. Consequently, we used only age-1 Lake Trout larger than 58 g to estimate the mean weight of an age-1 fish in the recreational harvest because we felt that only the largest 0.5% of them would be caught and killed by the fishery. The mean weight of 197 age-1 Lake Trout larger than 58 g was estimated to be 87 g. There were 40 age-1 Lake Trout in our database larger than 100 g and the largest was 250 g. We applied the 87 g (0.087 kg) mean weight value to age-1 fish in both WI345 and WIIM stock assessments.

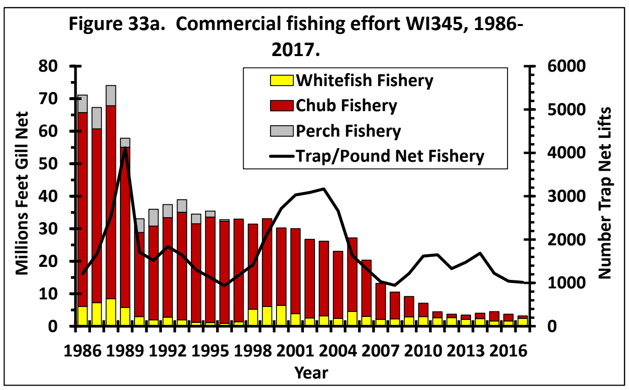
The estimated mean weight of an age-2 Lake Trout in the recreational fishery from WI345 was estimated to be 1.439 kg, which is larger than for age-3 fish. We felt this value was incorrect possibly because errors with length and weight in our database. Consequently, we applied the mean weight value of 0.827 kg in the recreational fishery of WIIM to age-2 fish in WI345.

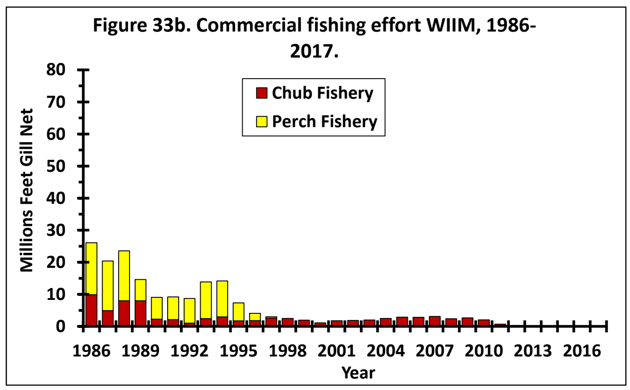
Commercial Fishery

We consolidated commercial fishery effort and its bycatch of Lake Trout from multiple sources because no single source contained the information needed for our purposes. Initially, we sought to use the "Great Lakes Commercial Fishing Database with Artificial Serial Numbers Comat_1971-2016-New.accb" that is maintained by the U.S. Geological Survey Great Lakes Science Center in Ann Arbor, MI, as our source of commercial fishing effort and harvest. While the Great Lakes Commercial Fishing Database (GLCFD) is the only single source repository of commercial fishing effort and harvest available for the Great Lakes, the database is not without issues. First, we discovered that fishing effort in the GLCFD does not match that obtained directly from an agency. For instance, gill net effort in the GLCFD is expressed as 100s of ft., while all agencies report effort in 1,000s of ft. Second, entrapment gear effort (trap net, pound net, fyke net, etc.) in the GLCFD is expressed as net-nights, not the number of individual lifts that all agencies report, and further, the number of nights fished is not readily identifiable in the database! Thus, it is impossible to directly estimate the standard number of trap net lifts in the GLCFD. Compounding the fishing effort issues with the GLCFD is that effort for gill nets is contained in a separate field labeled "Gearsize," while entrapment gear effort is found in the field "OP_units." Researchers should use great caution in using the GLCFD!

In nearly all instances, we used commercial fishing effort obtained directly from the state agencies. There is no commercial fishery operating in statistical district MM-8, so we used only information from the States of Wisconsin, Illinois, and Indiana. The Wisconsin DNR, Sturgeon Bay, WI, provided a simple database of the commercial effort from WI waters. Commercial fishery effort and harvest data from Illinois waters was not available in electronic format. Fortunately, the Illinois Department of Natural Resources (ILDNR) provided us photocopies of reports that contained monthly summaries of commercial Chub *Coregonus hoyi* and Yellow Perch *Perca fluvescens* fishing effort and harvest for Illinois waters from 1980-2000 that were submitted as annual agency reports to the Lake Michigan Committee of the Great Lakes Fishery Commission. The Illinois photocopy summaries were incomplete for 1991-1994, so we had to use the GLCFD as the source of gill net effort in Illinois waters for April 1991 through March 1994.

Commercial fishery gill net effort was high during the early part of our time series, but it declined to low levels at the end of the time series in both WI345 and WIIM. Small-mesh monofilament and multifilament gill nets (GNS) of 60 to 70 mm (2.375 to 2.75 in.) stretch measure and 15 to 32 meshes deep was the dominate gear fished by the commercial fishery to target Yellow Perch at depths of 11-23 m (37 to 75 ft.) and chubs in depths of 37 to 146 m (120-480 ft.) The GNS effort ranged from 15,800 to 19,800 km (52 to 65 million ft.) in WI345 during 1986-1989 but it declined almost annually thereafter (**Figure 33a**). In WIIM, between 6,100 and 7,900 km (20 to 26 million ft.) of GNS was fished during 1986-1988 and effort declined thereafter (**Figure 33b**). Commercial fisheries for Yellow Perch in the main basin of Lake Michigan were prohibited by the state agencies in 1996 and early 1997 and have remained that way through 2017 (see Marsden and Robillard 2004; Wilberg et al. 2005). Commercial GNS fisheries for chubs remained open through 2017, but because of large declines in chub abundance and reduced growth of individual fish, the fisheries dwindled and only 229 km (750,000 ft.) of GNS was fished for chubs in WI345 in 2017. Commercial fisheries for chubs in WIIM ceased in 2011.





Large-mesh gill net (GNL) effort targeting Lake Whitefish was confined to statistical district WM-3 within WI345 because GNL fishing has been prohibited in statistical districts WM-4 and WM-5 since the mid-1970s. Large-mesh gill nets were constructed of monofilament webbing of 4.5 to 5.25 stretch measure, 0.15 to 0.20 mm twine diameter, and 36 to 50 meshes deep (12 to 20 ft. tall). Annual GNL effort ranged from 279 to 2,590 km (916,000 to 8.5 million ft.) during 1986-2017 with peaks during 1986-1989 and again during 1998-2000 (**Figure 33a**). Annual GNL effort was reasonably consistent after 2000 ranging between 487 and 1,189 km (1.6 and 3.9 million ft.). In most instances GNL were fished on the lake bottom but in September and October commercial fishermen tend to suspend them in the water column because Lake Whitefish are more pelagic during this time of the year than other months in WM-3 (D. Hickey, Bailey Harbor Fish Company, Bailey Harbor, WI, personal communications).

Annual entrapment gear (TRAP) effort ranged from 936 to 4,116 lifts during 1986-2017 but was generally stable around 1,750 lifts with peaks in 1988-1989 and 1999-2002. TRAP effort occurred only in WI345, there was no TRAP fishery in WIIM. Trap nets made up 97.5% of the entrapment gear fished in WI345 during 1986-1987. Pound nets were last fished in 2009. The typical commercial trap net has plastic webbing, a 30 ft. tall lead with 305 to 356 mm (12 to 14 in.) stretch measure, hearts that are 152 mm (6 in) stretch measure on the sides and 356 mm (14 in.) stretch measure in the top, and a single lifting pot of 114 mm (4.5 in.) stretch measure. Lake Trout are typically captured and held live in commercial TRAP, but they are also typically gilled in the top and corner of the lifting pots, and in the tunnel as well as in the hearts and leads (Schorfhaar and Peck 1993; Smith 1998; Peeters 2001; Johnson et al. 2004).

There was a single bottom trawl (BT) fishery in statistical district WM-4 that was permitted to harvest Lake Whitefish on an experimental basis and Lake Trout bycatch does occur in this fishery (Seilheimer 2018). The experimental trawl fishery logged 410 hr. in 2016, 353 hr. in 2017, and 360 hr. in 2018.

Bycatch and mortality

The commercial harvest of Lake Trout has been prohibited in Wisconsin, Michigan, Illinois, and Indiana waters of WI345 and WIIM during and before the time frame (1986-2017) for our analysis. Commercial fisheries in these waters were required to return all Lake Trout to the water dead or alive, and as far as we know, only the State of Illinois required commercial fisheries to report their Lake Trout bycatch. Thus, there was no direct estimates of the Lake Trout harvest or kill by the commercial fisheries in WI345 or WIIM. Consequently, we had to access several internal agency reports (Toneys 2000; Peeters 2001) along with summaries of commercial fishery catch and effort and Lake Trout bycatch provided to us by the ILDC to estimate both the number of Lake Trout killed (i.e. harvested) and the number discarded annually by the fishery.

Large-mesh gill net fishery in WI345

The bycatch of Lake Trout in the WI345 GNL fishery was estimated by the Wisconsin Dept. of Natural Resources (WIDNR) from onboard monitoring of commercial fisheries conducted from the 1980s through 1999 (Toneys 2000). The Toneys (2000) report detailed onboard monitoring activities conducted by WIDNR staff including a description of how they classified fish as either dead or live at the time of capture. The Lake Trout kill in the commercial fishery targeting Lake Whitefish was estimated by multiplying average catch rate of fish classified as dead at the time of capture during onboard monitoring times the total fishing effort for the spatial area and time period under consideration. Toneys (2000, Table 7) classified 323 Lake Trout as dead of 916 caught during their onboard monitoring of the GNL fishery in WI345 during 1996-1999. Thus, on average, 35.3% of Lake Trout were considered dead at the time GNL were lifted, the other 64.7% were considered alive and discarded overboard.

We back-calculated the annual number of Lake Trout discarded by the GNL fishery in WI345 by using the average proportion of dead fish (0.353) observed in the catch and the estimated number of fish killed that was reported by Toneys (2000, Figure 13) as:

(16) $$\boldsymbol{DISCgnl_i = (1 - 0.353) * \frac{(KILLgnl_i)}{0.353}}$$

where ***DISCgnl*** is the number of Lake Trout discard by the GNL fishery, ***KILLgnl*** is the number of Lake Trout killed by the GNL fishery as reported by Toneys (2000), and ***i*** is year. The annual number of Lake Trout killed, average annual catch rate of dead fish, and our estimates of the annual number of discards from the GNL fishery in WI345 are shown in **Table 14**.

Table 14. Lake Trout kill, catch-per-unit-effort (CPUE), and the number of discards by the commercial large-mesh gill net fishery in WI345, 1986-1999.

Year (***i***)	Number dead (***KILLgnl***)	Mean kill/1000 ft (***CPUE***)	Number discards (***DISCgnl***)
1986	22,500	3.682	41,239
1987	38,100	5.243	69,832
1988	20,600	2.427	37,757
1989	11,300	1.960	20,711
1990	12,200	4.123	22,361
1991	2,700	1.368	4,949
1992	3,900	1.399	7,148
1993	5,700	2.900	10,447
1994	2,400	1.941	4,399
1995	2,100	1.879	3,849
1996	1,800	1.964	3,299
1997	2,700	1.956	4,949
1998	10,100	1.920	18,512
1999	11,700	1.915	21,444

Small-mesh gill net fishery WI345

The bycatch of Lake Trout in the GNS fishery for chubs in the Wisconsin waters of Lake Michigan was estimated from onboard monitoring of commercial fisheries conducted by WIDNR from the 1980s through 1999 (Toneys 2000). Toneys (2000) detailed the onboard monitoring activities by WIDNR staff including a description of how they classified Lake Trout as either dead or live at the time of capture. The Lake Trout kill in the chub fishery was estimated by multiplying average catch rate of fish classified as dead at the time of capture during onboard monitoring times the total fishing effort for the spatial area and time period under consideration. Toneys (2000) estimated the proportion of dead Lake Trout in each season of the year in four spatial units: north (WM-3), central (WM-4), south (WM-5 & WM-6) and at the Mid-Lake

Reef (WM-5). The estimates of the proportion dead Lake Trout within individual seasons and spatial areas ranged from 52% to 74% (Toneys 2000, Table 2).

We combined the observations of the number of dead Lake Trout across all seasons and spatial areas to make a single estimate for both WI345 and WIIM. In total, Toneys (2000) observed 3,076 Lake Trout during onboard monitoring of the chub fishery during 1996-1999 and classified 1,989 of them as dead for an average of 64.7% dead fish per lift. Toneys (2000) reported the number of dead Lake Trout for the north (WM-3) and south (WM-4, WM-5, & WM-6) zones only (**Table 15**).

Table 15. Estimated number of Lake Trout Killed in the commercial chub fishery in Wisconsin waters, 1986-1999. Data taken from Toneys (1999).

	Spatial area		
Year	North	South	Total
1986	4,715	44,157	48,872
1987	4,669	41,309	45,978
1988	5,616	74,568	80,184
1989	5,548	61,526	67,074
1990	5,512	52,823	58,335
1991	6,334	57,788	64,122
1992	7,674	51,657	59,331
1993	10,702	54,446	65,148
1994	5,772	37,156	42,928
1995	3,760	30,547	34,307
1996	3,240	29,246	32,486
1997	3,082	30,120	33,202
1998	2,138	25,332	27,470
1999	1,179	26,743	27,922

We had to allocate the annual kill from the south unit between WI345 and WIIM because Toneys (2000) did not separate the bycatch into statistical districts. We estimated that 3.3% of GNS effort in the south area occurred in WM-6 during 1996-1999 when Toneys (2000) made his estimates of the Lake Trout kill. Consequently, we allocated 3.3% of the annual Lake Trout kill in the south unit to WIIM and the remaining 96.7% to WI345. The total annual kill in WI345 by the chub GNS fishery (***KILLgns***) was estimated as:

(17) $$\boldsymbol{KILLgns_i = KILLnorth_i + (KILLsouth_i * 0.967)}$$

where ***KILLnorth*** is the Toneys (2000, Table 3) estimated number of dead Lake Trout in the north area, ***KILLsouth*** is the Toneys (2000, Table 3) estimated number of dead Lake Trout in the south area, 0.967 is the proportion of the chub GNS effort in the south unit that occurred in WI345 during 1996-1999, and ***i*** is year.

We had no information on the bycatch of Lake Trout in the yellow perch fishery of WI345. Consequently, we estimated the annual number of fish killed and discarded from the fishery based on what proportion the yellow perch GNS effort made up of the total annual GNS effort in WI345; 1% to 15% during 1986-1997. We also estimated the average proportional difference in the CPUE of dead and discarded Lake Trout observed during onboard monitoring of the Yellow Perch and chub fisheries in assessment unit WIIM during 1979-1998 to help us estimate the bycatch in the Yellow Perch fishery of

WI345. The average CPUE of dead Lake Trout in WIIM during 1979-1998 was 1.266 fish per 303 m (1,000 ft.) in the Yellow Perch fishery and 6.477 fish per 303 m in the chub fishery, while average CPUE of discarded Lake Trout was 2.956 fish per 303 m in the Yellow Perch fishery and 4.136 fish per 303 m in the chub fishery. Thus, the average CPUE of dead and discarded Lake Trout in the Yellow Perch fishery represented 19.5% and 71.5%, respectively, of that observed in the chub fishery in WIIM. The total number of Lake Trout killed (***KILLyep***) and discarded (***DISCyep***) by the Yellow Perch GNS fishery in WI345 was estimated as:

(18) $$\boldsymbol{KILLyep_i} = \left[\left(\frac{\boldsymbol{KILLchb_i}}{\boldsymbol{1-EFFPROPyep_i}}\right) - \boldsymbol{KILLchb_i}\right] * \left(\frac{\boldsymbol{CPUEDEADyep}}{\boldsymbol{CPUEDEADchb}}\right)$$

(19) $$\boldsymbol{DISCyep_i} = \left[\left(\frac{\boldsymbol{DISCchb_i}}{\boldsymbol{1-EFFPROPyep_i}}\right) - \boldsymbol{DISCchb_i}\right] * \left(\frac{\boldsymbol{CPUEDISCyep}}{\boldsymbol{CPUEDISCchb}}\right)$$

where ***KILLchb*** is the kill by the chub fishery in WI345 as reported by Toneys (2000), ***EFFPROPyep*** is the proportion that the Yellow Perch fishery made up of the total GNS effort in WI345, ***CPUEDEADyep*** and ***CPUEDEADchb*** are the average catch rates of dead Lake Trout observed in the Yellow Perch and chub fisheries, respectively, in WIIM, ***DISCchb*** is the number of fish discarded by the chub fishery in WI345, ***CPUEDISCyep*** and ***CPUEDISCchb*** are the average catch rates of discarded Lake Trout observed in the Yellow Perch and chub fisheries, respectively, in WIIM, and ***i*** is year. We input the total kill and discards of Lake Trout from both the chub and Yellow Perch fisheries to the WI345 stock assessment as a single GNS fishery (**Appendix 10**).

Trap net fishery WI345

The by-catch of Lake Trout can, at times, be substantial in trap net fisheries on the Great Lakes including Lake Michigan (**Table 16**). The average catch rate of Lake Trout in trap net fisheries reported by other researchers ranged from 7 to 84 fish per lift and the average of these studies was 44 fish per lift on lakes Superior, Huron, and Michigan from the late 1970s through 2010 (Schneeberger et al. 1982; Smith 1988; Schorfhaar and Peck 1993; Johnson et al. 2004; MacMillan and Roth 2012). The number of dead Lake Trout observed by these researchers ranged from 0.26 fish per lift in Michigan waters of Lake Superior (Schorfhaar and Peck 1993) to 13.8 fish per lift in the Saginaw Bay area of Lake Huron (MacMillan and Roth 2012) and averaged 3.92 fish per lift across all the studies. The proportion of dead Lake Trout in these trap net fisheries ranged from 1.52% to 6.70% for all but the MacMillan and Roth (2012) study, where it was estimated to be 35.4% (**Table 16**). We estimated the average dead Lake

Table 16. Bycatch and associated mortality of Lake Trout in trap net fisheries on the Great Lakes reported in published studies.				
Citation	Lake	Number per lift	Dead fish per lift	Percent dead
Schorfhaar & Peck (1993)	Superior	7	0.26	3.71%
Schneeberger et al. (1982)	Huron	75	1.14	1.52%
Smith (1988)	Michigan	84	3.38	4.02%
Johnson et al. (2004)	Huron	15	1.01	6.70%
McMillan & Roth (2012)	Huron	39	13.80	35.38%
Arithmatic mean		44	3.92	10.27%
w/o MacMillan & Roth (2012)		45	1.45	3.99%

Trout catch rate and proportion of dead fish using information from all the studies except MacMillan and Roth (2012) because the number of nights between lifts was much greater in their study than others, and likely contributed to their high proportion of dead fish.

Peeters (2001) reported the bycatch kill of Lake Trout in the TRAP fishery for the entire Wisconsin waters of Lake Michigan during 1986-2000 using estimates of the number of Lake Trout killed per TRAP lift and annual TRAP effort. He did not separate his estimates of kill by statistical district, consequently, we used his kill per lift statistics to estimate the kill only in WI345. Peeters (2001) reported the number of Lake Trout killed per lift to be 0.169 and 0.200 in trap net and pound net fisheries of WM-3, respectively, and 0.284 in trap net fisheries of WM-4/WM-5 during quota years 1998-2000 (see Peeters 2001, Table 8). These estimates of kill per lift from Peeters (2001) included Lake Trout that were gilled in the leads, whereas the other studies did not include gilling of fish in the lead when estimating the number of dead fish per lift, they only counted dead fish in the lifting pot. Unfortunately, Peeters (2001) did not report the average catch rate in the TRAP fishery, nor did he report the proportions of dead Lake Trout in each lift. These were statistics we had to estimate ourselves from his data and the other studies listed above.

We subsequently estimated the number of dead Lake Trout in the WI345 TRAP fishery (***KILLtrap***) as a function of the average CPUE of dead Lake Trout for each gear type in each statistical district and its annual effort during 1986-2000 as:

(20) $$\boldsymbol{KILLtrap_i} = \sum\left(\boldsymbol{EFF_{g,i,j}} * \boldsymbol{KILLCPUE_{g,i}}\right)$$

where ***Eff*** is fishing effort, ***KILLCPUE*** is the average number of dead Lake Trout killed per lift (0.169, 0.20, and 0.284 from above), ***g*** is fishing gear, ***i*** is year, and ***j*** is statistical district. Next, we estimated the annual number of fish discarded by the TRAP fishery in WI345 (***DISCtrap***) during 1986-2000. We used the annual kill estimated above (***KILLtrap***) and the average proportion of Lake Trout caught in a trap net that were killed (3.99%) based on four of the five published studies identified previously, to estimate discards each year (***i***) from the TRAP fishery as:

(21) $$DISCtrap_i = (1 - 0.0399) * \left(\frac{KILLtrap_i}{0.0399}\right)$$

Our estimates of the annual number of Lake Trout killed and discarded by the TRAP fishery are shown in **Table 17**.

Table 17. Number of Lake Trout observed killed kill per lift, and the number of live fish discarded from commercial trap nets in WI345, 1986-2000.

Year (*i*)	Number dead (*KILLtrap*)	Mean kill/lift (*CPUE*)	Number Discards (*DISCtrap*)
1986	263	0.196	6,330
1987	375	0.210	9,031
1988	608	0.230	14,626
1989	741	0.189	17,843
1990	342	0.198	8,235
1991	313	0.199	7,523
1992	323	0.188	7,765
1993	340	0.197	8,183
1994	230	0.197	5,540
1995	227	0.195	5,455
1996	186	0.207	4,465
1997	239	0.198	5,743
1998	293	0.201	7,058
1999	406	0.190	9,761
2000	497	0.185	11,958

Trawl fishery WI345

Onboard observers or cameras mounted onboard trawling vessels monitored 85% of the trawl effort in WI345 during 2016-2018 and observed 2,584 Lake Trout caught in the experimental fishery. The average catch rate of Lake Trout was 3.7 fish per hour in 2016, 2.4 fish per hour in 2017, and 2.5 fish per hour in 2018 based on data in Table 1 of Seilheimer (2018).

We used Table 6 from Seilheimer (2018) to estimate the kill of Lake Trout by the experimental trawl fishery. Onboard observers classified the condition of each Lake Trout captured in trawl tows from February 2015 through January 2016 (period 1) as either good/ok, marginal, poor, or moribund. The average catch rate of Lake Trout in period 1 was 1.15 fish per hour and the catch rate of Lake Trout in each state of physical condition was:

- Good/ok – 0.97 fish per hour
- Marginal – 0.16 fish per hour
- Poor – 0.03 fish per hour
- Moribund – 0.00 fish per hour

Thus, 83.8% (0.97 fish per hour/1.15 fish per hour) of the Lake Trout caught in the trawl tows were alive and in good/ok physical condition, 13.6% (0.16 fish per hour/1.15 fish per hour) were in marginal physical condition, and 2.55% ((0.03+0.00 fish per hour)/1.15 fish per hour) were in poor condition or dead. For purposes of our analysis, we assumed that 50% of the Lake Trout in marginal condition would die and that 100% of the fish in poor condition also died. Consequently, we estimated that 8.7% of the

Lake Trout caught in the trawl tows, (0.97+(0.16*0.5))/1.15, would have died as consequence of the fishing process.

We believe our estimates of 50% mortality for fish in marginal condition and 100% mortality of Lake Trout in poor condition are reasonable given levels of bycatch mortality observed in other studies. Smith (1998) and Schorfhaar and Peck (1993) estimated that 3.8% and 3.7%, respectively, of Lake Trout caught in trap nets in lakes Michigan and Superior were considered dead, but they did not account for post-release mortality of live fish. Post-release mortality of Lake Trout was considered by Gallinat et al. (1997) and Johnson et al. (2004) and it substantially increased estimates of mortality of discarded Lake Trout in these studies. Johnson et al. (2004) estimated that 1.6% of Lake Trout caught in trap nets in Lake Huron were dead at the time nets were lifted, but when they accounted for post-release mortality, 12.2% of Lake Trout ultimately died. Gallinat et al. (1997) estimated that 75% of all Lake Trout caught in GNL fisheries died during the fishing process and that 28% of the live discarded fish later died. Taken together, the Gallinat et al. (1997) and Johnson et al. (2004) studies indicate that even Lake Trout considered in good physical condition at the time of release will die from the catch and release process regardless of how well the fish are treated at the time of release. Therefore, we believe that accounting for some level of mortality for Lake Trout considered in marginal or poor condition at the time of release is appropriate. Whether 50% mortality for Lake Trout in marginal condition is correct remains to be seen, but we believe it is not inappropriate.

We estimated the number of Lake Trout that were caught in the bottom trawls, the number killed by the capture process (poor condition or moribund = 2.55%), and the number of discarded fish during 2015-2017 as:

(22) $$\boldsymbol{Cbt_i = EFFbt_i * CPUEbt_i}$$

(23) $$\boldsymbol{KILLbt_i = Cbt_i * 0.0255}$$

(24) $$\boldsymbol{DISCbt_i = Cbt_i - KILLbt_i}$$

where ***Cbt*** is the number of Lake Trout caught by the bottom trawl fishery, ***EFFbt*** is the number of hours of bottom trawling, ***CPUEbt*** is the number of Lake Trout caught per hour of trawling, ***KILLbt*** is the number of Lake Trout killed by the trawling process, ***DISCbt*** is the number of discarded fish from the trawl fishery, and ***i*** is year. We did not model the trawl fishery in the WI345 stock assessment because it was such a minor fishery in terms of Lake Trout bycatch, so the estimates of kill and discards for the fishery was added to the TRAP fishery.

Small-mesh gill net fishery WIIM

We had access to ILDNR documents that summarized commercial fishery effort for the Yellow Perch and chub GNS fisheries each month and year, as well as information on the bycatch of Lake Trout in each fishery. We created simple databases of commercial fishery effort and onboard monitoring of Lake Trout bycatch from the ILDNR data to help us estimate the number of Lake Trout killed (i.e., harvested) by the fishery and the number of discards. Unlike in WI345, the data for WIIM allowed us to estimate the mean bycatch rate of Lake Trout and the proportion of dead fish from onboard monitoring of the fisheries in each month and year for both the chub and the Yellow Perch fisheries. We used the onboard monitoring data for Illinois waters to project the bycatch of Lake Trout in all jurisdictions of the WIIM assessment unit.

Onboard monitoring of the chub and Yellow Perch fisheries took place nearly year-round in Illinois waters. The ILDNR recorded the total fishing effort, depth fished, number of Lake Trout caught, and number of dead Lake Trout observed during 85 onboard monitoring trips made from 1979 to 1998; 27 in the chub fishery and 58 in the Yellow Perch fishery. The average bycatch of Lake Trout was 5.57 fish per 303 m in the chub fishery, 3.57 fish per 303 m in the Yellow Perch fishery, and 5.14 fish per 303 m when data was combined for both fisheries. The bycatch of Lake Trout in the chub fishery was highest during October through January and lowest during March through September as shown by the fourth-order polynomial fit to the monthly data (**Figure 34a**). Bycatch in the Yellow Perch fishery was more consistent across months, although the maximum bycatch rate tended to increase from April through October and was highest in October based on the third-order polynomial fit to the annual data (**Figure 34b**).

Figure 34a. Lake Trout CPUE each month in the chub fishery in Illinois, 1979-1998.

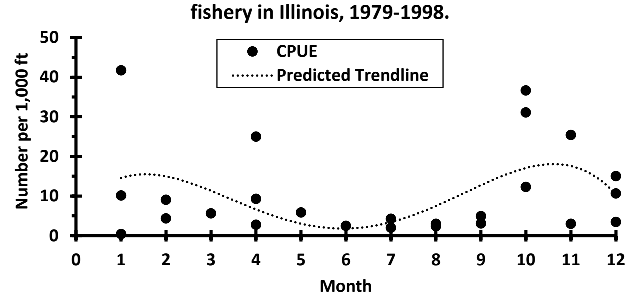
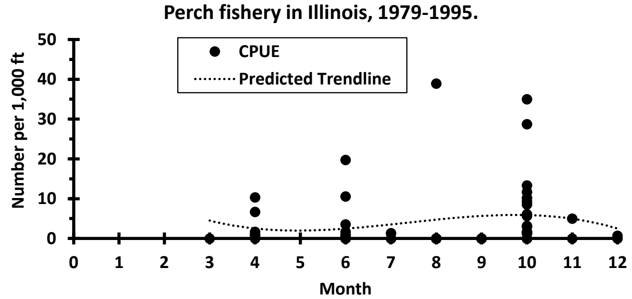


Figure 34b. Lake Trout CPUE each month in the Yellow Perch fishery in Illinois, 1979-1995.



There was no temporal trend over years in the bycatch rate of Lake Trout in the chub fishery, but there was a negative temporal trend over years in the bycatch rate in the Yellow Perch fishery in Illinois waters. The regression of Lake Trout CPUE on sampling year in the chub fishery was not significant (adjust. R^2 = -0.0396, F = 0.01, P = 0.9184) and the slope (0.0319 fish per 303 m per year, 95%CI = -0.6020, 0.6657) was not different from zero (**Figure 35a**). The regression of Lake Trout CPUE

Figure 35a. Lake Trout CPUE observed in the chub fishery in Illinois, 1979-1998.

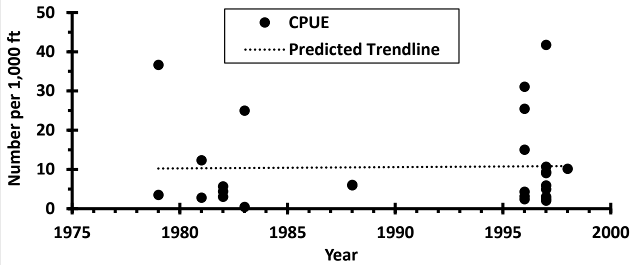
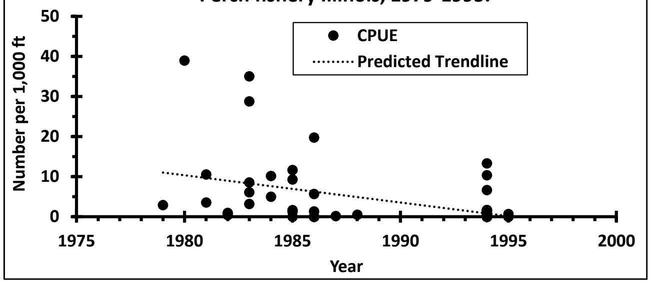


Figure 35b. Lake Trout CPUE observed in the Yellow Perch fishery Illinois, 1979-1995.



on sampling year in the Yellow Perch fishery was statistically significant (adjust. $R^2 = 0.168$, $F = 12.9057$, $P = 0.0008$) and the slope (-0.6795 fish per 303 m per year, 95%CI = -1.0644, -0.2946) was negative and statistically different from zero (**Figure 35b**).

We averaged the onboard monitoring data across years to estimate a weighted mean bycatch rate and proportion dead each month for each fishery. The weighted mean average monthly bycatch in the chub fishery ranged from 2.5 fish per 303 m in June to 27.0 fish per 303 m in October and during May through September it ranged from 2.5 to 5.9 fish per 303 m compared to 5.7 to 27.0 fish per 303 m during October through June. In the Yellow Perch fishery, the weighted mean monthly bycatch ranged from 0.0 fish per 303 m in March and September to 7.5 fish per 303 m in August, but bycatch rates were also near zero in July and December. The monthly proportion of dead Lake Trout at the time the nets were lifted averaged 73% (range 46 to 86%) in the chub fishery and 50% (range 0 to 66%) in the Yellow Perch fishery. In general, bycatch rate and mortality of Lake Trout was lower and more variable in the Yellow Perch fishery than the chub fishery (**Table 18**).

Table 18. Number of Lake Trout caught, number classified as dead, and the proportion dead in the chub and Yellow Perch fisheries each month in Illinois waters during 1986-2000.

	Chub Fishery			Yellow Perch Fishery		
Month	Catch	Dead	Prop. Dead	Catch	Dead	Prop. Dead
No month	108	51	0.4722	22	14	0.6364
Jan	229	197	0.8603			
Feb	424	279	0.6580			
Mar	68	31	0.4559	0		
Apr	256	132	0.5156	61	40	0.6557
May	950	732	0.7705			
Jun	523	361	0.6902	227	119	0.5242
Jul	440	335	0.7614	4	2	0.5000
Aug	880	582	0.6614	218	0	0.0000
Sep	792	514	0.6490			
Oct	561	302	0.5383	625	181	0.2896
Nov	956	761	0.7960	12	7	0.5833
Dec	551	397	0.7205	2	1	0.5000
Total	**6116**	**4476**	**0.7319**	**312**	**157**	**0.5032**

We estimated the number of Lake Trout killed and discarded each month of the year in the GNS fisheries for chub and Yellow Perch in WIIM using the onboard monitoring database and commercial GNS effort provided by ILDNR, WIDNR, and the GLCFD. These average monthly bycatch and proportion dead values were used to estimate the number of Lake Trout caught, killed, and discarded from each fishery as:

(25) $$\boldsymbol{C_{f,i,m} = CPUE_{f,m} * EFF_{f,i,m}}$$

(26) $$\boldsymbol{KILL_{f,i,m} = C_{f,i,m} * PRD_{f,m}}$$

(27) $$\boldsymbol{DISC_{f,i,m} = C_{f,i,m} - KILL_{f,i,m}}$$

where ***C*** is the number of fish caught, ***CPUE*** is the weighted mean number of fish caught per 303 m, ***EFF*** is fishing effort in 303 m, ***KILL*** is the number of fish killed during the fishing process, ***PRD*** is the proportion of fish dead at the time of capture, ***DISC*** is the number of fish discarded, ***f*** is fishery, ***i*** is year, and ***m*** is month. The fisheries (***f***) were; Yellow Perch in WM-6 and ILL and the chub fishery in ILL. Our estimates of the number of Lake Trout killed and discarded by the commercial fisheries in WIIM (**Appendix 11**) include 3% of the estimated discards reported in the south area by Toneys (2000).

Post-release mortality from commercial fisheries

We used estimates of post-release mortality of Lake Trout from the published literature to estimate the number of discards that died after being released alive from the fisheries in WI345 and WIIM. Gallinat et al. (1997) estimated that, on average, 28.4% of the Lake Trout released alive from the GNL fishery in the Apostle Islands area of Lake Superior did not survive. We applied the 28.4% post-release mortality value from Gallinat et al. (1997) to estimate of the number of discards in our stock assessments that would die after being released from the GNL and GNS fisheries. Mortality of Lake Trout captured alive in trap net pots in western Lake Huron was estimated to be 6.7% (Survival = 93.3%), but when the authors accounted for handling of fish released from the nets and gilling of fish in the trap net pots, mortality was estimated to be 12.2% (Johnson et al. 2004, Table 7). We applied the post-release mortality of 5.5% (12.2% minus 6.7%) from Johnson et al. (2004) to estimate the number of fish that died after being discarded from the TRAP fishery in WI345. Our estimates of the total kill (***KILLtot***) of Lake Trout in each commercial fishing gear was estimated within our stock assessment models as:

(28) $$\boldsymbol{KILLtot_{g,i} = KILL_{g,i} + \left(DISC_{g,i} * POSTmort_{g}\right)}$$

where ***KILL*** is the number of dead fish observed during the lifting process, ***DISC*** is the number of fish discarded from the fishery, ***POSTmort*** is the post-release mortality rate, ***g*** is gear or fishery***,*** and ***i*** is year. The ***POSTmort*** values were 0.284 for the GNL and GNS fisheries, 0.055 for the TRAP fishery, and 0.062 for the trawl fishery.

Gill net selectivity WI345

We developed a single generic age-specific selectivity curve for the commercial fishery in WI345 independently from the model fitting process using the average age composition of Lake Trout caught in the small-mesh chub fishery and selectivity of large-mesh gill nets reported for the MM-67 stock assessment. We estimated a single selectivity curve because the perch and chub fisheries essentially ended by 1997 and 2010, respectively, and there was no reported catch for either the small-mesh or large-mesh fishery after 1999. In addition, there was no age composition data for the large-mesh gill net fishery and little age data for Lake Trout caught as bycatch in the chub fishery.

First, we used length-frequency information reported by Toneys (2000) to estimate age composition of Lake Trout caught as bycatch in the chub fishery during 1996-1999. The proportion of fish in each 20-mm length bin was interpreted from Figure 3 of Toneys (2000) and then multiplied by the total sample size of 2592 to estimate the number of fish sampled in each length bin. We then divided the total number of fish in each length bin by four to estimate the number of fish sampled each year, i.e., we assumed that the same number of fish was sampled each year from each length bin. Year-specific age-length keys were then developed for fish caught in WI345 during 1996-1999 by all gears and fisheries and applied against the annual length distributions we generated from Toneys (2000). We also obtained age composition data for Lake Trout caught as bycatch during onboard monitoring of the chub fishery in WI345 by USFWS in 2011 and 2012 (Dale Hanson, USFWS, Green Bay Fish and Wildlife Conservation Office, New Franken, WI 54229, personal communication). We combined the data from USFWS with the estimated age composition data generated from Toneys (2000) to estimate age composition of Lake Trout in the small-mesh chub fishery in WI345 (**Table 19**).

Table 19. Proportional age composition of Lake Trout bycatch in commercial gill net fisheries targeting chubs in WI345 during 1996-1999 and 2011 and 2012. Data were collected during onboard monitoring by the State of Wisconsin during 1996-1999 and the USFWS in 2011 and 2012.

Age class	Year 1996	1997	1998	1999	2011	2012	Mean
2	0	0.0009	0	0.03933	0	0.0136	0.0090
3	0.1693	0.1605	0	0.23371	0.0610	0.6463	0.2118
4	0.3481	0.2857	0.2301	0.24158	0.4648	0.1837	0.2923
5	0.1837	0.2528	0.2302	0.1509	0.4319	0.1156	0.2275
6	0.1424	0.1492	0.2172	0.11141	0.0376	0.0204	0.1130
7	0.0803	0.0710	0.1616	0.05233	0.0047	0	0.0616
8	0	0.0003	0.0736	0.07231	0	0	0.0244
9	0.0025	0.0047	0.0379	0.03498	0	0.0068	0.0145
10	0.0007	0.0040	0.0003	0.02159	0	0	0.0044
11	0.0145	0.0165	0.0012	0.00994	0	0	0.0070
12	0.0585	0.0538	0	0.00894	0	0.0068	0.0213
13	0	0.0006	0.0133	0.00627	0	0.0068	0.0045
14	0	0	0.0346	0.00628	0	0	0.0068
15	0	0	0	0.01045	0	0	0.0017
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20+	0	0	0	0	0	0	0
Total	619	470	625	577	213	147	2651

We calculated age-specific selectivity of Lake Trout to the GNS fishery by adjusting the age composition data by cumulative survival at age. We divided the mean proportion of each age class (***$Prop_a$***) in the GNS fishery (**Table 19**) by the cumulative annual survival rate (***Sc_a***) for each age class to calculate adjusted selectivity. We estimated a mean instantaneous total mortality rate (***Z***=0.25 per year) as the average of catch curves in statistical districts of WIIM and WI345 (see **Figure 15**) and converted this to an average ***S*** of 0.78. We scaled the adjusted selectivity to the value for age-4 fish to estimate age-specific selectivity because age-4 fish were the most highly selected age class (**Appendix 12**). These selectivity values for the GNS fishery in WI345 were also applied to the GNS fishery in WIIM.

We created the hybrid selectivity curve for fish from WI345 by weighting the age-specific selectivity for the GNS and GNL fisheries by the proportion of the ***KILLtot*** made by each fishery in WI345 during 1986-1999. The estimated ***KILLtot*** was 780,700 fish by the small-mesh fishery and 233,000 fish by the large-mesh fishery. We then we multiplied the proportion of the ***KILLtot*** for each fishery by the age-specific selectivity for each fishery and scaled the resulting values to age-4 because it was the most highly selected age in our hybrid model (**Appendix 12**). The selectivity for the commercial fishery was input to the data file and was not fit inside the stock assessment.

Sea Lamprey Mortality

Sea lamprey-induced mortality was estimated from the number of wounds (King and Edsall 1979) observed per Lake Trout in spring (April-June) LWAP surveys during 1998-2017. The total number of A1, A2, and A3 wounds observed on individual fish during all years in an assessment unit was regressed on the fish's total length to fit a logistic function within a **R**-script template (**Appendix 13**) to estimate theta ($\boldsymbol{\theta}$), beta ($\boldsymbol{\beta}$), and alpha ($\boldsymbol{\alpha}$). The value of $\boldsymbol{\theta}$ represents the asymptotic wounding rate on the largest fish, $\boldsymbol{\beta}$ is the inflection point where wounding reaches 50% of the asymptote, and $\boldsymbol{\alpha}$ is the rate at which the wounding rate approaches the asymptote while passing through the inflection point

(Rutter and Bence 2003). The results from the logistic function fit were then used with information on the age and length distribution of fish and additional assumptions regarding how wounds relate to mortality to calculate age-specific Sea Lamprey induced mortality (**Appendix 13**). As a first step, the estimated average annual Sea Lamprey wounding rate (***W***) applicable to 20 mm length bins was calculated as:

(29)
$$\boldsymbol{W}_{y,m,l} = \frac{\theta_{y,m}}{\left(1+e^{\left(-1*\alpha_{y,m}*\left((l_n-10)-\beta_{y,m}\right)\right)}\right)}$$

where $\boldsymbol{\theta}$, $\boldsymbol{\beta}$, and $\boldsymbol{\alpha}$ are as defined previously, ***l*** is total length bin, ***y*** is year of capture, ***m*** is assessment unit, and ***n*** is the bin number that runs from 430 mm to 750 mm and larger in 20-mm increments (430, 450, 470, 490, 510…………..750 and older). Ten is subtracted from each bin value to calculate wounding on a fish in the middle of the bin. The value for $\boldsymbol{\alpha}$ is assumed to be constant among assessment units and years, while $\boldsymbol{\theta}$ and $\boldsymbol{\beta}$ varied among assessment units and years. Sea lamprey-induced mortality rate (***Ml***) in each length bin was estimated from the wounding data and the probability of surviving an attack (Bence et al. 2003, equation 4) as:

(30)
$$\boldsymbol{Ml}_{y,m,l} = \boldsymbol{W}_{y,m,l} * \frac{1-\boldsymbol{Ps}_l}{\boldsymbol{Ps}_l}$$

where ***W*** is the wounding rate, ***Ps*** is the probability of surviving a sea lamprey attack, and ***y***, ***m***, and ***l*** are as defined previously. The probability of survival was 0.35 for the 430 to 520 mm length bins, 0.45 for the 530 to 640 mm length bins, and 0.55 for all length bins greater than 650 mm. The ***Ps*** values of 0.35-0.55 align with those predicted by Swink's (2003) logistic regression model for 1 to 2.5 kg Lake Trout during the months of September to November (see Bence et al. 2003, Figure 3) when lamprey-induced mortality is greatest on Great Lakes fish.

To convert length-specific estimates of ***Ml*** to age-specific rates we estimated the proportion of each age class in each length bin using estimates of length-at-age and a coefficient of variation (***CV***). We estimated mean length-at-age using the predicted von Bertalanffy growth parameters for WIIM (L_∞ =839, K = 0.2120, t_o =- 0.5042) and WI345 (L_∞ =853, K = 0.2195, t_o = 0.6037) and assumed that mean length-at-age was constant through time in each assessment unit because our earlier analysis of growth showed both parameters to be relatively constant through time and among statistical districts. Predicted length-at-age in each assessment unit was multiplied by an average ***CV*** of 15% to estimate the standard deviation (***sd***) in length. The normal distribution function in the statistical software **R** was then applied to the mean length and ***sd*** for each age class to produce a normal distribution in length for each age class with the mean equal to the mean length and the standard deviation equal to ***sd***. The proportion of each age (***Pa***) in each length bin less than the maximum length bin of 760 mm was calculated as:

(31) $$\boldsymbol{Pa}_{n,a,y,m} = (\boldsymbol{pnorm}, (\, \boldsymbol{l}_{\mathrm{n}}, \boldsymbol{L}_{a,y,m}, \boldsymbol{sd}_a)\text{-}\boldsymbol{pnorm}(\boldsymbol{l}_n - 20, \boldsymbol{L}_{a,y,m}, \boldsymbol{sd}_a))$$

where ***pnorm*** is the normal distribution function in **R**, ***a*** is age class, ***l*** is length bin, ***L*** is the predicted mean length, and ***sd***, ***y***, ***m***, and ***n*** are as defined previously. We subtracted 20 mm to ensure that the entire left tail of the distribution was not included in the first calculation because these fish had a different ***Ps***. The ***Pa*** for the last length bin (>760 mm) was estimated as:

(32) $$\boldsymbol{Pa}_{n,a,y,m} = 1\text{-}\boldsymbol{pnorm}(\boldsymbol{l}_n - 20, L_{a,y,m}, \boldsymbol{sd}_a))$$

Finally, the proportion of each age class in a length bin was multiplied times the ***Ml*** for each length bin and these values were summed across all length bins for each age class to estimate the age-specific sea lamprey mortality rate as:

(33) $$\boldsymbol{Ml}_{a,y,m} = \sum(\boldsymbol{Ml}_{y,m} * \boldsymbol{Pa}_{a,y,m})$$

These age- and year-specific ***Ml*** values were then applied to the previous age in the previous year because spring wounding rates reflect sea lamprey attack rates and associated Lake Trout mortality suffered during the previous year (Swink 2003; Bence et al. 2003).

The magnitude and trend in sea lamprey wounding of Lake Trout was similar between WIIM and WI345 during 1998-2017. Marking rates were highest during roughly 2000 through 2008, then declined slowly and reached their lowest levels during 2015-2016 (**Figure 36a** and **36b**). The 2017 estimates were assumed to be the same as in 2016 because estimates for 2017 could not be made until marking rates in spring 2018 were estimated in 2019. Age-specific wounding rates ranged from 0.0 for age-1 Lake Trout to 0.23 for age 20+ fish. Sea lamprey wounding rates of age-6 and older Lake Trout averaged 0.100 per year in WIIM and 0.096 per year in WI345 during 1998-2017.

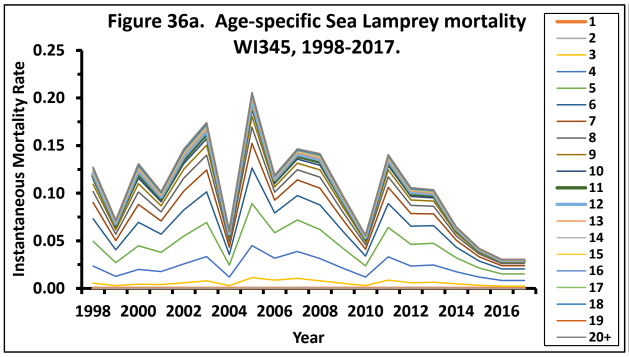


Figure 36a. Age-specific Sea Lamprey mortality WI345, 1998-2017.

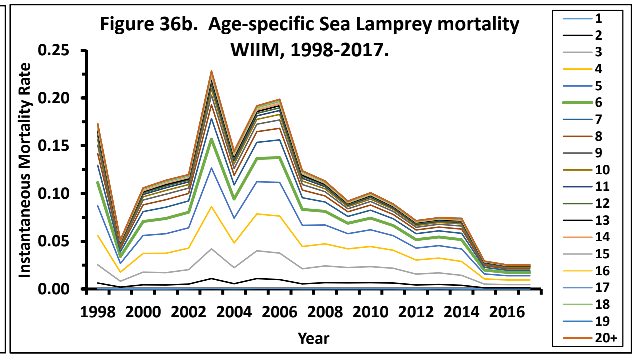


Figure 36b. Age-specific Sea Lamprey mortality WIIM, 1998-2017.

We applied sea lamprey mortality rates of Lake Trout estimated for MM-67 during 1986-1997 to WIIM and WI345 for the same years. Sea lamprey-induced mortality could not be estimated in WIIM or WI345 during 1986-1997 because the spring LWAP did not begin until 1998. There were, however, estimates of spring Sea Lamprey marking and the associated mortality rates for Lake Trout from MM-67 that is directly adjacent to both WI345 and WIIM.

The magnitude and temporal trends in both age-specific and age-6 and older Sea Lamprey-induced mortality of Lake Trout in MM-67 was similar to WIIM and WI345. Age-specific mortality rates ranged from 0.00 to 0.31 per year in MM-67 during 1986-2016 and the average rate of age-6 and older Lake Trout was 0.081 per year during 1998-2017 (**Figure 37**) compared to the rates of ~0.10 per year in WIIM and WI345. For the years 1998-2016 mortality rates in MM-67 overlapped and followed similar trends as mortality rates in WIIM and WI345 (**Figure 38**). Thus, we felt mortality rates from MM-67 were very applicable to our two units. We assumed Sea Lamprey mortality estimates for age-15+ fish in WIIM and WI345 were the same as age-15+ fish in MM-67 because the oldest age class in the MM-67 stock assessment was 15+, while in our stock assessments the oldest age class was 20+. Age- and year-specific matrices of sea lamprey-induced mortality are found in **Appendix 14**.

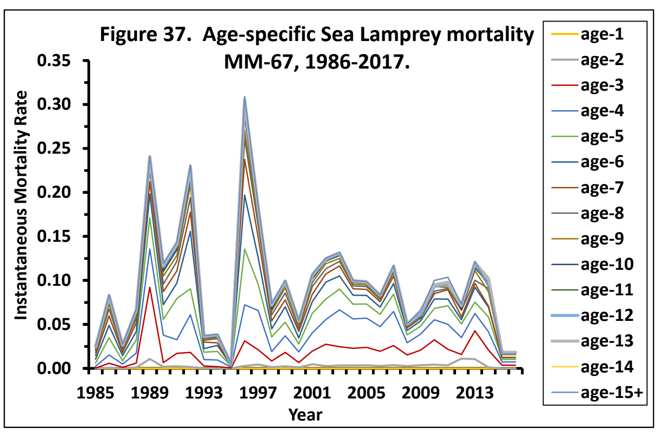


Figure 37. Age-specific Sea Lamprey mortality MM-67, 1986-2017.

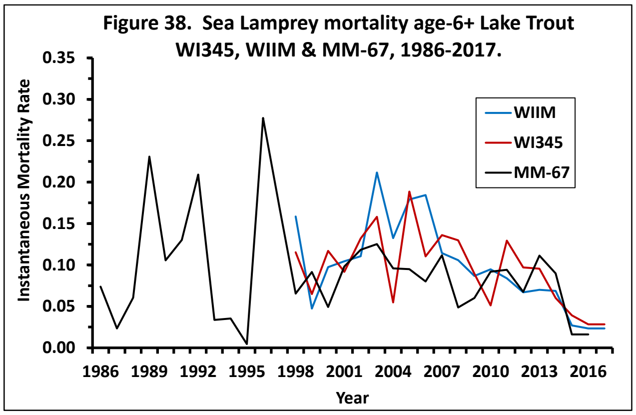


Figure 38. Sea Lamprey mortality age-6+ Lake Trout WI345, WIIM & MM-67, 1986-2017.

Survey Fisheries

We estimated the mean annual CPUE of Lake Trout caught in spring LWAP surveys in WI345 and WIIM during 1998-2017. The LWAP survey was intended to be a coordinated, collaborative, and standardized survey to determine relative abundance of Lake Trout and other species (Schneeberger et al. 1998). Six bottom-set graded-mesh gill nets lifts, fished for one night, at each of 11 sites throughout the lake has been the standard method used to capture Lake Trout since the study began. Specific locations at each of the nine nearshore landing port sites are to be chosen randomly along a 56 km transect that runs parallel to shore, and individual gill net gangs are to be set perpendicular to the 56 km transect. Netting locations in the offshore refuges are determined by superimposing a grid system that subdivides surrounding waters into 1 x 1-minute cells and random gill net sets are to be made in six of the cells each year (Schneeberger et al. 1998). The gill net surveys take place during early spring when the water column is not stratified and bottom temperatures at fishing depths are greater than 4°C (Schneeberger et al. 1998).

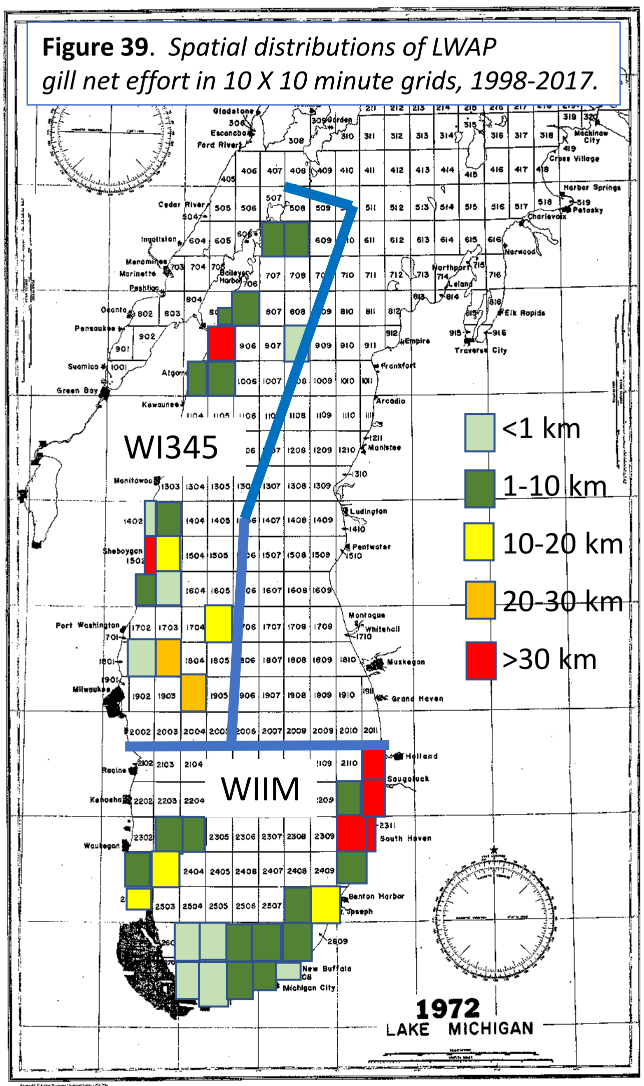


Figure 39. *Spatial distributions of LWAP gill net effort in 10 X 10 minute grids, 1998-2017.*

LWAP surveys in WI345 tended to be more consistent across time and space than in WIIM (**Figure 39**). Surveys in WI345 were focused primarily near Sturgeon Bay, Sheboygan, and offshore at the Mid-Lake Refuge. Surveys in WIIM were concentrated along the eastern shore from Saugatuck to St. Joseph, offshore at Waukegan, with lessor amounts in Indiana and very southern MI-8. In WI345, 81% of lifts were 0.49 km in length, 8% were 0.55 km, 7% were

0.24 km, and the remainder were between 0.27 and 1.83 km. In WIIM, 40% of LWAP lifts were 0.61 km in length, 34% were 0.48 km, 20% were 0.3 km, and 6% were 0.24 km.

The LWAP gill net effort did vary somewhat among years in each assessment unit. Annual effort averaged 9.3 km in WI345 during 1998-2017 with effort for individual years ranging from 4.4 to 16.1 km (**Figure 40a**). In WIIM annual effort averaged 12.2 km during 1998-2017 with effort for individual years ranging from 2.9 to 19.5 km (**Figure 40b**). Sixty-one percent of the effort in WI345 took place in WM-5, 34% in WM-3, and only 4% in WM-4. In comparison, 65% of effort in WIIM occurred in MM-8, 21% in Ill, 14% in IND, and there was no effort in WM-6.

Figure 40a. LWAP effort by statistical district WI345, 1998-2017.

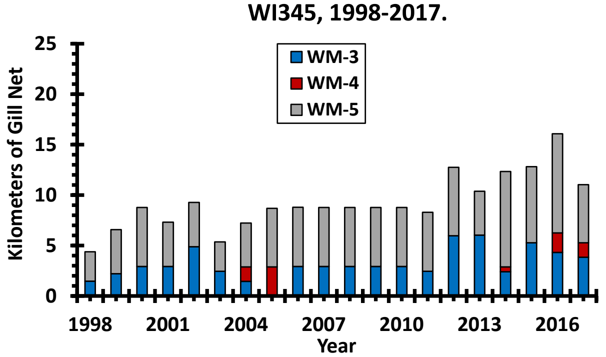
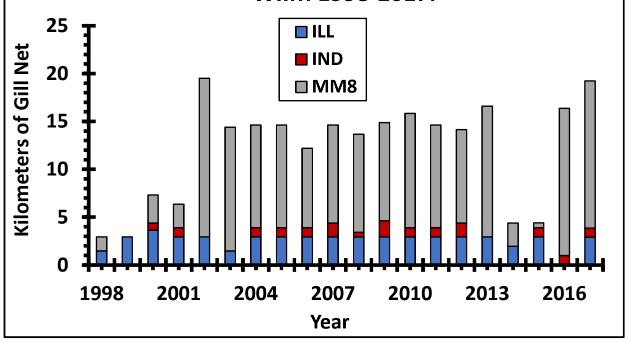


Figure 40b. LWAP effort by statistical district WIIM 1998-2017.



Allocation of LWAP effort within a year tended to be more consistent in WIIM than in WI345. In WIIM, 47% of the effort occurred in both April and May and 6% was in June (**Figure 41a**). In WI345, 67% of the effort took place in May, 17% in June, and 16% in April (**Figure 41b**). Allocation of effort within a month stayed more consistent in WIIM except in 2014 and 2015 when vessel problems and ice conditions reduced sampling effort. In comparison, April sampling was more common in WI345 during 1998-2005 than thereafter, and June sampling was more common during 2006-2013 than other years.

Figure 41b. LWAP effort by month WI345, 1998-2017.

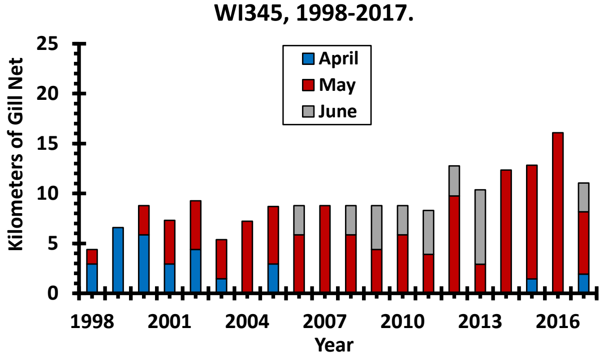
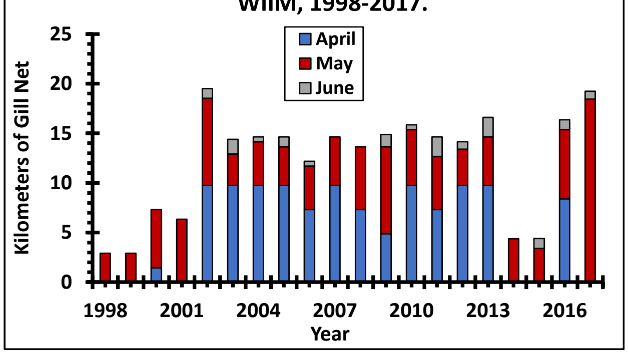


Figure 41a. LWAP effort by month WIIM, 1998-2017.



Catch-per-unit-effort survey fisheries

We used linear mixed effects models implemented using the **lme** function of the **R** package **nlme** to estimate the annual CPUE and its standard deviation for Lake Trout in WI345 and WIIM (**Appendix 15**). We calculated CPUE as the number of Lake Trout caught in each gill net lift divided by the kilometers of net lifted. All models were fit to the natural logarithms of CPUE+0.01. We added 0.01 to all CPUE values to account for taking the logarithm of zero catches. The variables year, and year and month were treated as fixed main effects in the models. Grid was treated as a random variable in the models, along with an interaction terms for grid and month, year and grid, and year and month. We fit six models using these fixed, random, and interaction terms, and used Akakie information criterion (AIC) to test for the model with the best fit, i.e. the lowest AIC value. The six models and their ANOVA output are shown in **Table 20** below. Log CPUE and the associated standard errors was extracted based on the estimated year effects in these models, given that the models had no intercept.

Table 20. Linear mixed effects model structure and Akakia Information Criterion (AIC) for Lake Trout catch-per-unit effort during LWAP surveys in assessment units WI345 and WIIM, 1998-2017.

Mgt Unit	Effects	Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
WI345	Fixed	year	X					X
		year & month		X	X	X	X	
	Random	grid		X	X	X	X	
		grid x month			X	X	X	X
		year x month	X			X	X	
		year X grid					X	
	AIC		**1623.74**	**1636.48**	**1627.63**	**1624.62**	**1626.62**	**1632.412**
WIIM	Fixed	year	X					X
		year/month		X	X	X	X	
	Random	grid		X	X	X	X	
		grid x month			X	X	X	X
		year x month	X			X	X	
		year X grid					X	
	AIC		**2005.62**	**2026.33**	**2028.33**	**2015.41**	**2017.41**	**1994.883**

There was little difference between models in WIIM, whereas there appeared to be two different plausible models in WI345. In WIIM, model 6 had the lowest AIC score but all six models produced similar estimates of annual Lake Trout CPUE. Model 1 had the lowest AIC score in WI345, but the AIC score for model 4 was similar to model 1. All models for WI345 illustrated similar trends but models 1 and 6 had substantially larger annual estimates of CPUE compared to models 2-5. The difference in scale results from the fact that models 1 and 6 only had a fixed effect of year, whereas models 3, 4, and 5 also included month. With month in the model the log CPUE estimate based on the year effect is an estimate of log CPUE averaged over months (weighting months) equally, whereas without month in the model the estimates weight times with more samples more highly. It is worth noting that differences in scale are not important when these estimates are treated as relative indices in the SCAA model, as the scale is adjusted for via an estimated catchability coefficient. Models 1 and 6 in WI345 had similar patterns but differed in estimates of CPUE during 1998-2002. Models 1 and 6 had the lowest estimated standard errors for means in WI345, while in WIIM the estimated standard errors, like the annual CPUE, was nearly identical across all models (**Figure 42**). We chose to use mean CPUE and its standard error from model 1 for use in the WI345 stock assessment and model 6 in the WIIM stock assessment because they had the lowest AIC scores in each unit. The mean annual CPUE and its standard error for these models were input to the data files in each of our assessment units and are shown in **Table 21**.

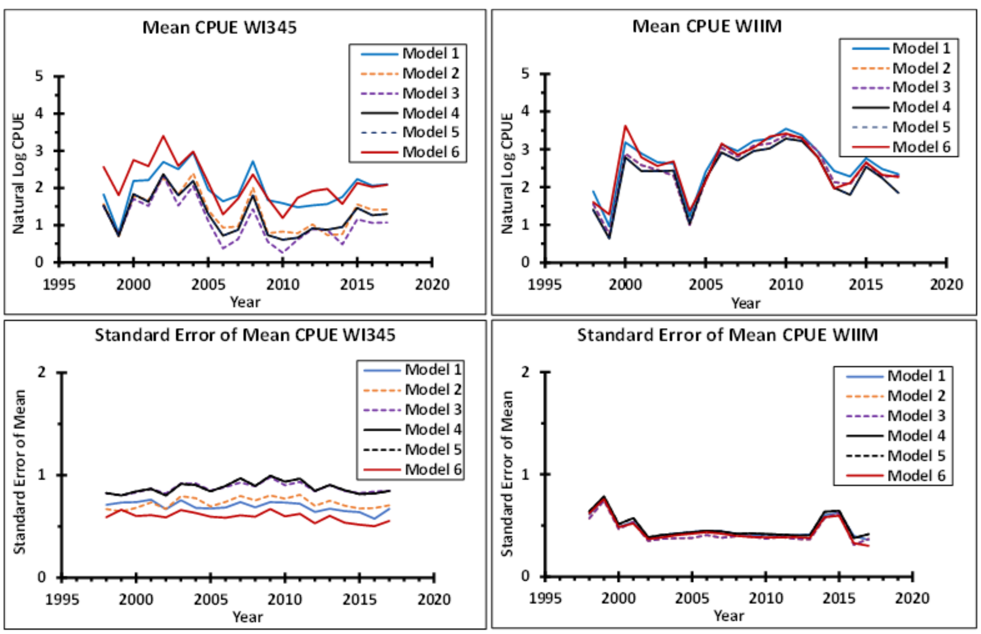


Figure 42. Linear mixed effects model estimates of the annual mean Lake Trout catch-per-unit effort (CPUE = fish per km) and the standard error for the mean during LWAP surveys in WI345 (left panels) and WIIM (right panels), 1998-2017. Both CPUE and its standard error are expressed as natural logarithms.

Table 21. Natural logarithm mean catch-per-unit effort (CPUE) and the standard error for the mean (se) from linear mixed effects models of Lake Trout captured in LWAP surveys in assessment units WI345 and WIIM, 1998-2017.

	WI345		WIIM	
Year	CPUE	se	CPUE	se
1998	1.8255	0.7122	1.8876	0.6106
1999	0.7795	0.7338	0.9652	0.7661
2000	2.1892	0.7379	3.1879	0.4860
2001	2.2137	0.7609	2.8930	0.5362
2002	2.7031	0.6679	2.6600	0.3736
2003	2.5043	0.7565	2.6278	0.4082
2004	2.9568	0.6817	1.2260	0.4236
2005	1.9564	0.6745	2.4063	0.4366
2006	1.6392	0.6847	3.1265	0.4507
2007	1.7970	0.7379	2.9546	0.4435
2008	2.7219	0.6868	3.2264	0.4205
2009	1.6729	0.7379	3.2803	0.4016
2010	1.5893	0.7338	3.5479	0.4105
2011	1.4799	0.7207	3.3741	0.4064
2012	1.5330	0.6416	2.9439	0.4053
2013	1.5678	0.6734	2.4298	0.4142
2014	1.7591	0.6504	2.2824	0.6022
2015	2.2382	0.6410	2.7681	0.6269
2016	2.0634	0.5762	2.4780	0.3987
2017	2.1004	0.6725	2.3455	0.3585

Age composition survey fisheries

We estimated the age composition of LWAP survey catches differently in WIIM and WI345. In WIIM, ages of fish in our database that were captured during the LWAP survey were determined using fin-clips (48%), CWTs (33%), scales (4%), otoliths (3%), maxillary (2%), and otoliths and scales together (<1%), while the aging structure was not recorded for 9% of the samples. In WI345, ages were determined from CWTs (71%), otoliths (6%), and scales (5%), aging structures were not recorded for 18% of samples, and no fin-clipped fish were aged. We felt that the age information in our database for the LWAP survey in WIIM was appropriate for estimating age composition because all structures were used to assign ages (**Appendix 16**).

On-the-other-hand, we felt that the age information from our database was not appropriate for estimating age composition of the LWAP survey in WI345. First, fin-clipped fish dominated LWAP catches in WI345 during most of the survey years but ages for these fish were not represented in our database. Additionally, 91 to 100% of the 2004- to 2009-year classes were fin clipped but these year classes were not represented in our LWAP age data as age-3, age-4, or age-5 but they were represented in our database as ages-6 and older. There were just too many inconsistencies in the LWAP age data for WI345 to use that information for determining age composition.

Consequently, we estimated age composition of the LWAP survey catch in WI345 in the same manner as for the recreational fishery, i.e., applying an age-length key developed from CWT-recoveries by all capture methods in WI345 across all years (**Appendix 17**) to the annual length distribution of fish captured during LWAP surveys. The age composition of LWAP catches in WI345 appeared more consistent using this method (**Appendix 16**) rather than relying on the biased age data in our database.

Proportion Wild Year Classes

Our SCAAs estimated abundance of all Lake Trout by age, and then apportioned abundance by age into stocked and wild components. Estimating abundance of wild fish was one of the objectives of our study because they are becoming more common in fishery and survey catches from Lake Michigan (see Hanson et al. 2013).

We used catches of wild and stocked Lake Trout in LWAP, SPAWN, and other SURVEYs to estimate the contribution of specific year classes of wild fish to the fishable populations, age-3+, in WI345 and WIIM. We used the table "LAT Bio data non-monitoring" in our ACCESS database to sum the number of wild and stocked Lake Trout of the 1973- to 2016-year classes caught during 1974-2019 to estimate the proportion of wild fish in WI345 and WIIM. We used data collected in 2018 and 2019 because of small samples sizes for the 2013- to 2016-year classes if we used data collected only through 2017. In addition, our analysis has indicated that the proportion wild developed from young fish was not consistently reliable as we will show below.

There were 170,339 stocked and 3,506 wild Lake Trout in our database that were caught in WI345 and 18,939 stocked and 3,515 wild fish from WIIM. The proportion of wild fish in catches from WI345 was extremely low for the 1973- through 2003-year classes but it increased substantially beginning with the 2004-year class (**Figure 43a**). Using catches from all LWAP and SPAWN surveys appeared to give a better estimate of the composition of wild fish in the population from WI345 than just using the LWAP data, and the proportion of wild fish was similar between LWAP and SPAWN surveys for the 2004- to 2010-year classes but not the 2011- to 2015-year classes (**Figure 43a**). In WIIM, trends in the proportion wild were similar between survey data and the USFWS BioTech monitoring program for nearly all year classes, but because fin-clipped fish collected by the BioTech program were not aged, the proportion wild from the BioTech program was unrealistic for year classes prior to 2010 (**Figure 43b**).

Figure 43a. Proportion wild year classes WI345, 1971-2016

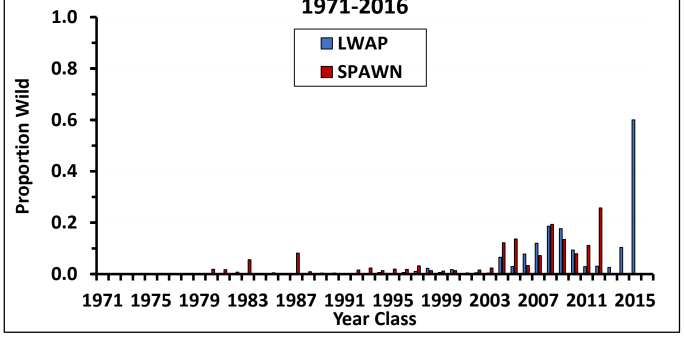
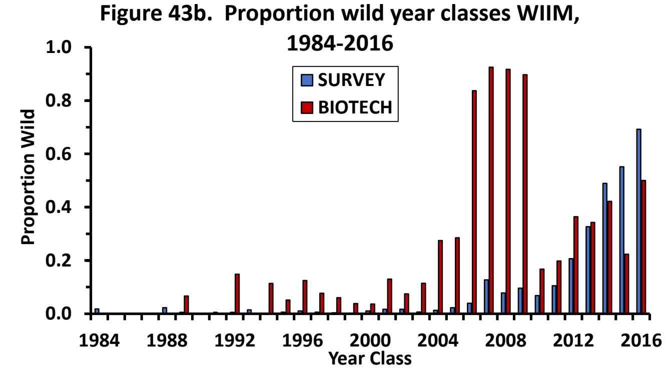
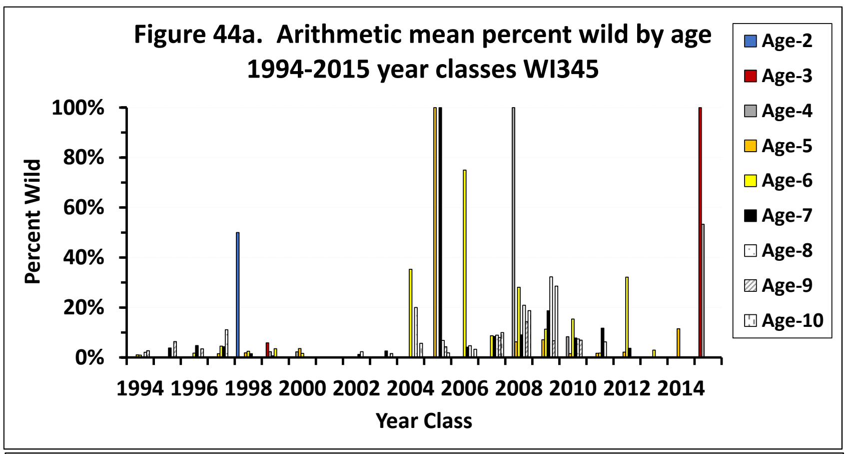


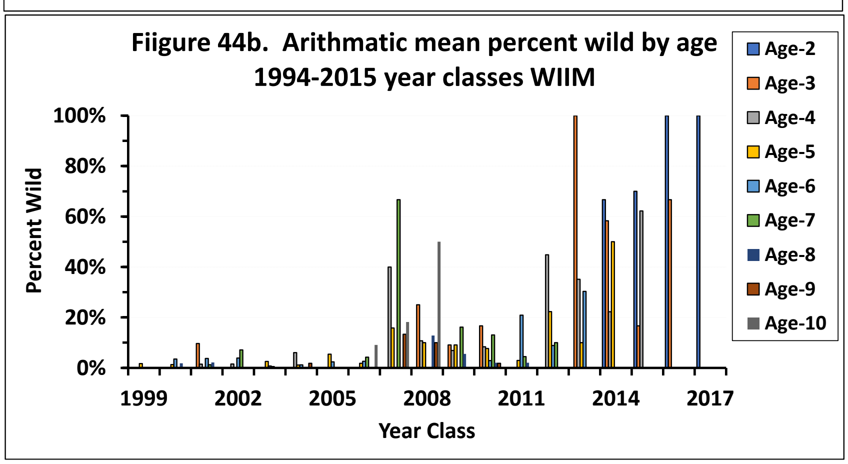
Figure 43b. Proportion wild year classes WIIM, 1984-2016



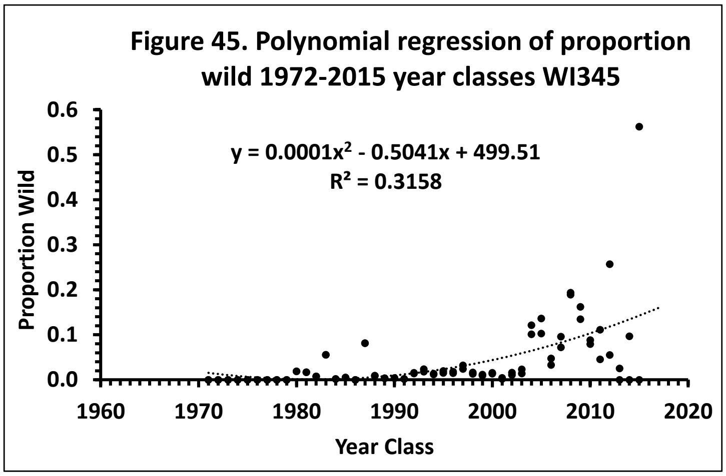
Consequently, we estimated the proportion of wild fish of age-3 and older using LWAP and SPAWN survey data in WI345 and all survey types in WIIM. Wild Lake Trout made up 5 to 56% of the 2004- to 2015-year classes caught in WI345. The proportion of wild Lake Trout in catches from WIIM was low for all year classes prior to the 2007, but for the 2007- to 2015-year classes wild fish made up 8 to 69% of the survey catches (**Appendix 18**).

We found that estimates of the proportion wild were not consistent among age classes for the same year class. In both WI345 and WIIM the proportion wild was nearly always greater when estimated for the first one or two ages within a year class than for subsequent ages. For example, estimates of the proportion wild in WI345 for the 2004-2008, and 2014- and 2015-year classes was always highest for the first age classes used in the calculations, while the proportion wild for the 2009-year class increased with increasing age (**Figure 44a**). The same pattern occurred in WIIM (**Figure 44b**).





In many instances the decline in proportion wild from the first age class considered in our analysis to the next was substantial, i.e. >two-fold. We were unsure of the exact causes of these discrepancies in proportion wild as fish aged, but certainly sample size, sample location, and vulnerability to the fishing gear must have exerted some influence. The number of samples for the 2014- and 2015-year classes in WI345 were 3 to 5-fold less than in WIIM, and no fish were sampled from the 2016-year class in WI345, leading us to have little confidence in the proportion wild for these year classes. In addition, the proportion wild for these year classes in WI345 was much less than in WIIM. Consequently, we decided to estimate the proportion wild differently for the 2014- to 2016-year classes in WI345 than in WIIM.



We fit a second-order polynomial regression to the proportion wild data for each year class in WI345 (**Figure 45**). We used this regression equation to predict the proportion wild for the 2014- to 2016-year classes in WI345, which was 13.4% for the 2014-year class, 14.2% for the 2015-year class, and 15.1% for the 2016-year class. We expanded our estimates of the proportion wild for each year classes across years and age classes to create matrices of the composition of wild Lake Trout of age-3+ in the populations of WI345 and WIIM (**Appendix 19**).

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APPENDIX 1 – STRUCTURE OF THE MICROSOFT ACCESS DATABASE

File Name: LAT BIO DATA FROM TRESKA.accdb

Table: _LM Master Gear

Columns:

Name	Type	Size
LiftID	Short Text	255
Lake	Short Text	255
Agency	Short Text	255
Location	Short Text	255
Latitude	Double	8
Longitude	Double	8
MU	Short Text	255
Model_unit	Short Text	255
Grid	Double	8
Year	Double	8
Month	Double	8
Day	Double	8
SurveyType	Short Text	255
SurveyType2	Short Text	255
SurveyDescription	Short Text	255
Gear	Short Text	255
Nights	Double	8
NetLength(km)	Double	8
Depth1(m)	Double	8
Depth2(m)	Double	8
AvgDepth(m)	Double	8
SurfaceTemp(C)	Double	8
BottomTemp(C)	Double	8
NetMaterial	Short Text	255
MinMesh(mm)	Double	8
MaxMesh(mm)	Short Text	255
Comments	Short Text	255

Relationships:

_LM Master GearLM LAT Biodata - Ebener

_LM Master Gear	LM LAT Biodata -
LiftID	LiftID

File Name: LAT BIO DATA FROM TRESKA.accdb

Table: All Harvest Monitoring

Columns:

Name	Type	Size
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SampleType	Short Text	255

APPENDIX 1 cont'd

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Month	Short Text	255
Year	Double	8
Lake	Short Text	255
STATD	Short Text	255
Model_unit	Short Text	255
Grid	Double	8
LIFTID	Short Text	255
FishID	Short Text	255
Species	Short Text	255
Length_mm	Integer	2
Lengthbin_10mm	Integer (Calculated)	2
Weight_kg	Double	8
FinClip	Short Text	255
Origin	Short Text	255
Sex	Short Text	255
Maturity	Short Text	255
CWT(Y/N)	Short Text	255
Snout	Short Text	255
Scale	Short Text	255
Otolith	Short Text	255
Maxillary	Short Text	255
Age	Double	8
Yearclass	Short Text	255
A1	Double	8
A2	Double	8
A3	Double	8
A4	Double	8
B1	Double	8
B2	Double	8
B3	Double	8
B4	Double	8

File Name: LAT BIO DATA FROM TRESKA.accdb
Table: CWT Bio data survey_fisheries
Columns:

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FisheryType	Short Text	255
Year	Double	8
Month	Short Text	255
STATD	Short Text	255
Model_unit	Short Text	255
Species	Short Text	10
Length_mm	Integer	2

APPENDIX 1 cont'd

Lengthbin_10mm	Long Integer	4
Weight_kg	Double	8
FinClip	Short Text	255
Yearclass	Long Integer	4
Age	Integer	2
AgeStructure	Short Text	30
Sex	Short Text	255
Maturity	Short Text	255

File Name: LAT BIO DATA FROM TRESKA.accdb

Table: CWT stocking info

Columns:

Name	**Type**	Size
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YEAR	Double	8
MONTH	Double	8
LAKE	Short Text	255
SPECIES	Short Text	255
YEAR_CLASS	Long Integer	4
STAGE	Short Text	255
AGEMONTH	Double	8
MARK	Short Text	255
CWTTAG_NO	Short Text	255

File Name: LAT BIO DATA FROM TRESKA.accdb

Table: LAT Biodata non_ monitoring

Columns:

Name	**Type**	**Size**
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STATD	Short Text	255
Model_unit	Short Text	255
Year	Double	8
Month	Double	8
SurveyType	Short Text	255
Species	Short Text	10
Length(mm)	Integer	2
Lengthbin_10mm	Long Integer	4
Weight_kg	Double	8
FinClip	Short Text	255
Yearclass	Long Integer	4
Age	Integer	2
AgeStructure	Short Text	30

APPENDIX 1 cont'd

Sex	Short Text	255
Maturity	Short Text	255

File Name: LAT BIO DATA FROM TRESKA.accdb

Table: LM LAT Biodata - Ebener

Columns:

Name	Type	Size
LiftID	Short Text	255
Lake	Short Text	12
Agency	Short Text	255
FishID	Short Text	255
MeshSize(mm)	Integer	2
SpeciesCommon	Short Text	255
SpeciesNumber	Short Text	255
SpeciesName	Short Text	255
SpeciesAbbrev	Short Text	10
Length(mm)	Integer	2
Weight(g)	Long Integer	4
R/D	Short Text	2
CWTAgency	Short Text	255
CWTTAG_NO	Short Text	255
StrainGLFSD	Short Text	255
StrainDescription	Short Text	255
Yearclass	Long Integer	4
SourceLake	Short Text	255
Age	Integer	2
AgeStructure	Short Text	30
SexAgency	Short Text	3
Sex	Short Text	255
MaturityAgency	Short Text	2
Maturity	Short Text	255
FinClipAgency	Short Text	255
FinClip	Short Text	255
A1-A3	Long Integer	4
A1	Long Integer	4
A2	Long Integer	4
A3	Long Integer	4
A4	Long Integer	4
B1	Long Integer	4
B2	Long Integer	4
B3	Long Integer	4
B4	Long Integer	4
A4/B4	Long Integer	4
B2/B3	Long Integer	4
Comments	Short Text	255

APPENDIX 1 cont'd

FRESH	Long Integer	4
OLD	Long Integer	4

Relationships:
LAT BIO DATA FROM TRESKA.accdb
Table: LM LAT Biodata - Ebener

_LM Master GearLM LAT Biodata - Ebener

_LM Master Gear	LM LAT Biodata -
LiftID	LiftID

APPENDIX 2 – YEARLING LAKE TROUT STOCKED INTO LAKE MICHIGAN, 1966-2017

	Statistical District																
Year	**ILL**	**IND**	**WM5**	**WM6**	**MM7**	**MM8**	**MM2**	**MM3**	**MM5**	**MM6**	**WM3**	**WM4**	**WM1**	**WM2**	**MM1**	**MM4**	**Total**
1966			201,500		99,900			427,700	100,000	164,990	248,700	120,400	190,300			212,700	1,766,190
1967	90,430	87,380			165,080	101,740		200,368	102,400	101,410	642,227	202,280				161,505	1,854,820
1968	103,650	100,000			141,240	100,300		257,710	116,830	61,990		439,200	193,310	184,250		177,420	1,875,900
1969	120,565	118,650	189,430		133,070	100,280	90,430	184,135		200,420	200,520	393,830	100,165		99,530	68,780	1,999,805
1970	100,000	85,000	300,000		135,000			250,000	50,000	200,000		400,000	200,000		90,000	150,000	1,960,000
1971	100,000	103,400	159,000		150,000	150,000	85,000	171,920	70,200	75,000		565,000	221,000		85,000	200,025	2,135,545
1972	110,000	110,000	200,000	100,000	184,810	99,360	104,350	225,500	125,000	150,000	330,000	450,000			104,700	226,400	2,520,120
1973	105,000	105,000	200,000	100,000	50,000	180,000		283,300	125,850	155,000	220,000	450,000			85,000	150,000	2,209,150
1974	176,000	180,000	253,000	96,000	99,000	99,000		281,700	106,800	96,000	98,000	281,000	93,000	25,000	102,600	150,000	2,137,100
1975	186,000	186,000	196,000	192,000	183,663	99,000		353,250	85,000	90,000	98,000	349,000	48,000	36,500	186,674	175,000	2,464,087
1976	160,000	164,000	104,000	75,000	477,300	150,000		340,500	111,000	150,000	102,000	315,000	102,000	70,000	125,000	102,000	2,547,800
1977	166,000	177,000	257,600	104,000	188,000	135,000		326,000	91,000	134,000	100,000	308,000	100,000	52,500	100,000	131,000	2,370,100
1978	116,000	175,000	223,000	80,500	255,000	192,000		308,000	104,000	145,000	140,000	280,100	140,800	65,000	100,000	150,000	2,474,400
1979	161,799	176,000	220,000	90,000	311,500	190,000		175,000	100,800	180,000	90,850	271,100	154,400	55,152	75,000	125,000	2,376,601
1980	87,000	174,000	340,100	80,000	220,000	190,000		319,000	116,950	202,150	400,200	193,200				200,000	2,522,600
1981	124,000	124,000	193,000	50,000	230,700	300,000		174,000	75,100	210,000	212,500	160,000				228,230	2,081,530
1982	151,800	152,550	228,500	66,340	423,300	182,000		75,300	74,700	226,300	218,200	149,800			90,000		2,038,790
1983	166,400	157,000			795,990	180,000		96,100	100,600	246,000	201,700	111,400				154,400	2,209,590
1984	100,000	107,800			332,300	200,000				80,000	237,440					61,600	1,119,140
1985	184,814		774,968					563,849	142,800	221,788	361,200					374,000	2,623,419
1986	100,000		683,929					923,674	150,000	69,800	367,000					180,000	2,474,403
1987	101,950		714,450					745,750			351,200					60,000	1,973,350
1988	137,548		273,900		270,000			766,500	130,000		192,300					152,380	1,922,628
1989	103,000		299,800		300,000			771,800	157,000		208,000					166,000	2,005,600
1990			445,393		254,136			617,586									1,317,115
1991	101,000		597,606		215,644			1,096,425	343,800		196,007					229,000	2,779,482
1992	100,000		578,452		257,092			987,200	308,500		200,000					330,000	2,761,244
1993	96,000	95,000	329,180		165,853	96,000		994,002	308,000		196,000	86,800				330,000	2,696,835
1994	96,700		209,778		107,165	102,000		943,969	308,000	198,500	196,900					333,000	2,496,012
1995	59,600	57,700	247,000		270,894	309,934		729,100	54,600	138,850	123,000	86,100				187,750	2,264,528
1996	60,900	60,000	255,000		160,500	169,000		578,200	185,160	118,845	121,500	64,343				198,000	1,971,448
1997	120,000	89,000	267,100	60,000	283,150	63,000		569,550	207,000	128,050	121,400	121,950				205,000	2,235,200
1998	60,000	65,800	330,200	65,000	166,000	193,900		621,300	205,100	125,600	114,900	135,740				218,600	2,302,140
1999	64,000	68,400	326,891	54,000	167,100	197,420		610,385	213,420	121,000	117,710	118,100				215,200	2,273,626
2000		61,480	295,500	114,000	161,000	180,600		609,911	200,374	120,000	116,066	115,980				285,430	2,260,341
2001	59,240	72,000	433,070	61,800	63,600	207,085		588,985	226,540	140,604	153,600	130,000				245,088	2,381,612
2002	61,024	60,000	435,110	65,000	62,880	120,174		725,852	168,408	60,000	120,000					258,210	2,136,658
2003	60,770	70,092	429,611	55,755	59,501	239,220		566,597	228,164	131,494	119,458	119,950				273,417	2,354,029
2004	60,300		430,150	62,500	60,000	255,789		676,675	196,742	120,081	193,020	57,480				241,397	2,354,134
2005	62,832	66,255	437,024	60,179	60,279	233,719		975,810	199,809	230,160	80,784	135,506				207,224	2,749,581
2006	67,849	59,547	412,179	60,785	57,237	182,786		1,177,445	192,026	119,641	95,135	161,980				182,947	2,769,557
2007	56,381	60,045	424,515	57,834	60,355	179,283		1,080,365	353,745	120,837	120,842	111,461				477,677	3,103,340
2008	126,631	37,981	612,524	49,500	38,213	56,674		1,178,157	191,758	133,394	56,052	57,221				343,763	2,881,868
2009	118,160	22,267	613,087	25,790	20,000	60,000		1,442,322	107,503	76,277	41,262	10,316				233,675	2,770,659
2010	120,166	38,385	614,287	46,500	25,000	67,000		1,483,478	141,500	71,674	59,262	18,500				316,103	3,001,855
2011	122,058	42,138	616,608	28,047	20,000	60,000		1,477,937	124,242	83,400	46,814	15,010				291,840	2,928,094
2012	125,692	42,420	610,373	27,216	20,000	60,993		1,493,854	209,862	82,419	50,760	15,000				307,204	3,045,793
2013	124,021	42,386	619,258	24,450	20,000	43,912		1,482,087	205,545	81,879	51,147	14,096				309,118	3,017,899
2014	123,784	41,707	619,880	27,810	12,500	36,800		1,480,939	203,907	81,391	50,000	15,000				307,112	3,000,830
2015	124,129	41,344	620,217	28,420	12,500	36,800		1,472,700	204,838	82,137	50,206	15,116				319,256	3,007,663
2016	123,120	41,329	620,300	25,657	12,500	37,000		1,485,516	204,696	81,676	50,760	15,660				318,400	3,016,614
2017	119,510		298,264		309,210	29,300		1,435,192	200,538	79,892						297,564	2,769,470
Total	5,365,823	3,718,056	18,740,734	2,034,083	8,268,162	5,867,069	279,780	36,802,595	7,929,807	5,887,649	7,862,622	7,060,619	1,542,975	488,402	1,243,504	11,218,415	124,310,295

APPENDIX 3 – FINGERLING LAKE TROUT STOCKED INTO LAKE MICHIGAN, 1966-2017

	Statistical District																
Year	**ILL**	**IND**	**WM5**	**WM6**	**MM7**	**MM8**	**MM2**	**MM3**	**MM5**	**MM6**	**WM3**	**WM4**	**WM1**	**WM2**	**MM1**	**MM4**	**Total**
1966																	0
1967			284,600							285,000							569,600
1968																	0
1969																	0
1970																	0
1971					208,000												208,000
1972			100,000		100,000							103,600				101,800	405,400
1973			100,000		100,000							100,000					300,000
1974						60,200		15,000				125,000				60,050	260,250
1975						49,000							100,000				149,000
1976																	0
1977												47,500					47,500
1978												65,000					65,000
1979			4,171									57,000				59,100	120,271
1980								44,000				141,800				82,900	268,700
1981	49,000	48,200	33,000					83,000	33,000		314,300						560,500
1982	52,000	63,000	125,777					111,500	28,000			132,870				194,200	707,347
1983											31,480						31,480
1984		36,000	216,020		90,000				43,900							60,000	445,920
1985	193,727		453,274		162,000	349,422											1,158,423
1986	202,000				54,600	164,000				58,600	76,000	267,400					822,600
1987	24,984																24,984
1988	29,000				283,650	199,450				111,500							623,600
1989	337,223	135,000	420,934		164,000	444,000		300,000	468,000	294,000	607,965					200,000	3,371,122
1990																	0
1991																	0
1992			287,160		186,000	200,461											673,621
1993																	0
1994			244,000						708,538	224,200						181,083	1,357,821
1995																	0
1996												143,630					143,630
1997																	0
1998																	0
1999						74,700											74,700
2000																	0
2001																	0
2002									87,519								87,519
2003			75,915	75,600				103,220									254,735
2004																	0
2005								137,750									137,750
2006			75,658					385,221				25,000					485,879
2007								189,749				188,212				142,714	520,675
2008				45,999								194,217					240,216
2009		52,160		28,140	57,446	109,606						158,648					406,000
2010		50,000		70,754	55,550	115,787						135,676					427,767
2011		63,557		48,327	31,773	191,005						191,414					526,076
2012		52,015		46,120	50,705	200,183						203,824					552,847
2013		52,500			48,968	203,321						110,409					415,198
2014		54,113		111,840	111,756	200,152											477,861
2015		132,774			110,689	101,281						110,260					455,004
2016																	0
2017																	0
Total	887,934	739,319	2,420,509	426,780	1,815,137	2,662,568	0	1,369,440	1,368,957	973,300	1,029,745	2,501,460	100,000	0	0	1,081,847	17,376,996

APPENDIX 4 – ADMB CODE FOR VON BERTALANFFY GROWTH MODEL

```
//von Bertalanffy Growth Model
DATA_SECTION
  init_int nobs
  init_matrix vonBdata(1,nobs,1,2)
  init_vector testvec(1,3)
  //!!cout<< "the test vector is " << testvec << endl;
  //!!exit(43);
  vector Ages(1,nobs)
  vector Lengths_obs(1,nobs)
  vector agelst(1,33)

LOCAL_CALCS
  Ages=column(vonBdata,1);
  Lengths_obs=column(vonBdata,2);
  agelst.fill_seqadd(1,1);
 END_CALCS

PARAMETER_SECTION
  init_number t0  //age at which length is 0
  init_number log_Linf // log of Linf
  init_number log_K // log of K (Brody growth coefficient)
//  init_number log_sigma //log of sigma for normal distribution
  init_number log_a //log of base CV
  init_bounded_number b(-0.004,0.004,2) //linear size effect
  init_bounded_number b2(-0.0005,0.0005,-3) // quad. size effect not used & bounds probably too
narrow
  number Linf
  number K
  //number sigma
  number a
  vector Lengths_pred(1,nobs)
  vector resids(1,nobs)
  vector sigma(1,nobs)
  vector CV(1,nobs)
  sdreport_vector predlst(1,33)
  objective_function_value nll  // The objective function (required)

INITIALIZATION_SECTION
//Starting values for parameters
  log_Linf 7.0
  log_K -1.6
  t0 0.
  log_a -3  //base log CV with no size effect ~0.05
  b 0 // linear size effect
  b2 0 //quadratic size effect
PROCEDURE_SECTION
```

APPENDIX 4 cont'd

```
// cout << "we are at top of procedure section" << endl;
 // exit(44);
  Linf=exp(log_Linf);
  K=exp(log_K);
 //sigma=exp(log_sigma);
  a=exp(log_a);
 // cout<<"print starting values for Linf, K, t0, and sigma, and quit"<<endl;
 //cout<<Linf<<" " <<K<<" "<<t0<<" "<<sigma<<endl;
 // exit(45);

  Lengths_pred=Linf*(1.-exp(-K*(Ages-t0)));
 //changed to make log CV a function of length to avoid negative CVs
 // not sure that was needed but if changed back init values and bounds need to be readjusted
  CV=exp(log_a+b*Lengths_pred+b2*square(Lengths_pred));
  sigma=elem_prod(CV,Lengths_pred);
  resids=Lengths_obs-Lengths_pred;

  predlst=Linf*(1.-exp(-K*(agelst-t0)));

 // cout<<"predicted lengths"<<endl;
 // cout<<Lengths_pred<<endl;
 // cout<<"residuals"<<endl;
 //cout<<resids<<endl;
 //exit(46);

 //  nll=nobs*log_sigma + (0.5/square(sigma))*norm2(resids);
 nll= sum(log(sigma))+0.5*norm2(elem_div(resids,sigma));
```

REPORT_SECTION

```
 report << "parameter estimates - backtransformed if needed: Linf, K, to, exp intercept for logCV, slope
 for logCV, second slope for logCV"      <<endl;
 report << Linf << " " << K << " " << t0 << " " << log_a << " " << b << " " << b2 << endl;
 report << "predicted lengths for ages 1-11" << endl;
 report << predlst << endl;
 report << "residuals for all observed values" << endl;
 report << resids << endl;
 report <<"CV for predlst"<< endl;
 report <<exp(log_a+b*predlst+b2*square(predlst))<< endl;
 report << "predictions for all observed values" << endl;
 report << Lengths_pred << endl;
 report << "CV by observation"<< endl;
 report << CV <<endl;
```

APPENDIX 5 – ADMB CODE FOR LENGTH-WEIGHT REGRESSION

```
DATA_SECTION
  init_int nobs
  init_matrix lgth_wght(1,nobs,1,2)
  init_vector testvec(1,3)
  //!!cout << "the test vector is " << testvec << endl;
  //!!exit(43);

  vector lgth(1,nobs)
  vector wght(1,nobs)

 LOCAL_CALCS
  lgth=column(lgth_wght,1);
  wght=column(lgth_wght,2);
 END_CALCS

PARAMETER_SECTION
  init_bounded_number a(-5,5);
  init_bounded_number b(-22,22);
  vector pred_wght(1,nobs)
  sdreport_number aa
  objective_function_value f

PROCEDURE_SECTION
 aa=a;
  pred_wght=a*lgth+b;
  f=(norm2(pred_wght-wght));
  f=nobs/2.*log(f);    // make it a likelihood function so that
                    // covariance matrix is correct

REPORT_SECTION
  report << "length-weight regression parameters" << endl;
  report << a << " " << b << endl;
```

APPENDIX 6 – POPULATION MEAN WEIGHT AT AGE, 1986-2017

Mean Population weight (kg) at age WI345, 1986-2017																				
	Age Class																			
Year	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9	Age-10	Age-11	Age-12	Age-13	Age-14	Age-15	Age-16	Age-17	Age-18	Age-19	Age-20+
1986	0.018	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1987	0.018	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1988	0.024	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1989	0.025	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1990	0.022	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1991	0.022	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1992	0.023	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1993	0.034	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1994	0.030	0.090	0.371	0.832	1.410	2.040	2.668	3.261	3.797	4.270	4.679	5.025	5.316	5.557	5.757	5.921	6.054	6.163	6.252	6.513
1995	0.035	0.089	0.358	0.794	1.336	1.922	2.504	3.051	3.545	3.980	4.354	4.672	4.938	5.159	5.342	5.491	5.613	5.713	5.794	6.032
1996	0.031	0.089	0.358	0.794	1.336	1.922	2.504	3.051	3.545	3.980	4.354	4.672	4.938	5.159	5.342	5.491	5.613	5.713	5.794	6.032
1997	0.033	0.081	0.334	0.750	1.273	1.842	2.410	2.946	3.432	3.860	4.229	4.542	4.805	5.024	5.204	5.353	5.474	5.572	5.652	5.889
1998	0.048	0.081	0.334	0.750	1.273	1.842	2.410	2.946	3.432	3.860	4.229	4.542	4.805	5.024	5.204	5.353	5.474	5.572	5.652	5.889
1999	0.043	0.094	0.384	0.857	1.449	2.091	2.730	3.333	3.878	4.358	4.772	5.123	5.418	5.663	5.865	6.031	6.166	6.276	6.366	6.631
2000	0.035	0.083	0.355	0.818	1.411	2.067	2.727	3.355	3.928	4.434	4.873	5.246	5.560	5.821	6.037	6.214	6.360	6.478	6.574	6.858
2001	0.035	0.083	0.361	0.839	1.457	2.143	2.837	3.498	4.102	4.637	5.101	5.496	5.828	6.106	6.335	6.523	6.677	6.802	6.904	7.207
2002	0.037	0.081	0.351	0.812	1.405	2.061	2.725	3.355	3.931	4.440	4.882	5.258	5.574	5.837	6.055	6.234	6.380	6.500	6.596	6.883
2003	0.033	0.095	0.384	0.856	1.444	2.082	2.716	3.313	3.854	4.329	4.739	5.086	5.378	5.620	5.820	5.983	6.117	6.226	6.315	6.577
2004	0.041	0.079	0.346	0.806	1.402	2.065	2.735	3.375	3.960	4.478	4.927	5.310	5.633	5.901	6.123	6.306	6.455	6.577	6.676	6.969
2005	0.038	0.079	0.350	0.821	1.434	2.117	2.811	3.474	4.080	4.619	5.086	5.484	5.820	6.100	6.331	6.521	6.677	6.804	6.907	7.212
2006	0.036	0.079	0.348	0.812	1.412	2.079	2.756	3.401	3.990	4.513	4.966	5.353	5.678	5.949	6.173	6.357	6.508	6.631	6.731	7.026
2007	0.031	0.093	0.383	0.861	1.460	2.113	2.766	3.380	3.938	4.429	4.853	5.213	5.515	5.766	5.973	6.143	6.282	6.395	6.487	6.759
2008	0.030	0.094	0.386	0.863	1.461	2.111	2.758	3.369	3.922	4.409	4.829	5.185	5.484	5.733	5.938	6.106	6.244	6.356	6.446	6.715
2009	0.035	0.092	0.379	0.853	1.451	2.103	2.755	3.370	3.928	4.420	4.845	5.205	5.508	5.760	5.968	6.139	6.278	6.391	6.484	6.756
2010	0.039	0.079	0.350	0.819	1.428	2.107	2.795	3.452	4.053	4.586	5.048	5.443	5.774	6.051	6.280	6.468	6.622	6.748	6.849	7.152
2011	0.037	0.079	0.350	0.819	1.428	2.107	2.795	3.452	4.053	4.586	5.048	5.443	5.774	6.051	6.280	6.468	6.622	6.748	6.849	7.152
2012	0.046	0.087	0.363	0.822	1.403	2.037	2.673	3.274	3.819	4.301	4.717	5.070	5.367	5.613	5.817	5.984	6.121	6.232	6.323	6.591
2013	0.043	0.101	0.396	0.865	1.442	2.061	2.673	3.246	3.762	4.215	4.604	4.934	5.210	5.439	5.628	5.783	5.909	6.012	6.095	6.342
2014	0.037	0.098	0.390	0.859	1.441	2.069	2.691	3.275	3.803	4.266	4.665	5.003	5.286	5.521	5.715	5.874	6.004	6.110	6.196	6.449
2015	0.039	0.088	0.364	0.821	1.396	2.023	2.649	3.241	3.778	4.251	4.659	5.006	5.298	5.540	5.740	5.904	6.038	6.147	6.236	6.498
2016	0.033	0.107	0.408	0.876	1.443	2.047	2.639	3.191	3.686	4.119	4.491	4.805	5.068	5.285	5.465	5.612	5.731	5.829	5.908	6.142
2017	0.040	0.075	0.332	0.775	1.350	1.990	2.639	3.258	3.825	4.327	4.763	5.134	5.447	5.708	5.923	6.100	6.245	6.363	6.459	6.744

APPENDIX 6 cont'd

Mean population weight (kg) at age WIIM, 1986-2017.

	Age class																			
Year	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9	Age-10	Age-11	Age-12	Age-13	Age-14	Age-15	Age-16	Age-17	Age-18	Age-19	Age-20+
1986	0.026	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1987	0.016	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1988	0.042	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1989	0.026	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1990	0.023	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1991	0.023	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1992	0.021	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090
1993	0.025	0.409	0.961	1.614	2.274	2.887	3.423	3.877	4.251	4.554	4.796	4.987	5.138	5.255	5.346	5.417	5.472	5.515	5.547	5.630
1994	0.029	0.344	0.890	1.585	2.323	3.029	3.662	4.207	4.661	5.032	5.330	5.567	5.754	5.901	6.015	6.104	6.173	6.226	6.268	6.372
1995	0.035	0.271	0.774	1.463	2.229	2.986	3.680	4.288	4.800	5.223	5.566	5.839	6.056	6.226	6.359	6.463	6.544	6.606	6.654	6.776
1996	0.039	0.334	0.880	1.582	2.334	3.057	3.708	4.269	4.739	5.122	5.432	5.678	5.872	6.024	6.143	6.235	6.307	6.362	6.405	6.513
1997	0.038	0.290	0.796	1.468	2.202	2.917	3.568	4.132	4.607	4.996	5.311	5.562	5.760	5.916	6.038	6.132	6.206	6.262	6.306	6.417
1998	0.043	0.342	0.865	1.520	2.208	2.861	3.444	3.943	4.358	4.696	4.968	5.184	5.354	5.487	5.591	5.672	5.735	5.783	5.820	5.914
1999	0.067	0.313	0.837	1.521	2.259	2.973	3.618	4.176	4.644	5.027	5.336	5.582	5.776	5.929	6.048	6.140	6.212	6.267	6.310	6.419
2000	0.045	0.322	0.821	1.451	2.114	2.746	3.310	3.795	4.198	4.527	4.792	5.002	5.167	5.297	5.398	5.477	5.538	5.585	5.621	5.713
2001	0.038	0.302	0.800	1.445	2.136	2.803	3.405	3.923	4.358	4.713	4.999	5.227	5.407	5.548	5.658	5.744	5.811	5.862	5.902	6.002
2002	0.041	0.315	0.828	1.488	2.192	2.870	3.481	4.006	4.446	4.805	5.095	5.325	5.507	5.649	5.761	5.847	5.914	5.966	6.006	6.107
2003	0.043	0.319	0.837	1.502	2.212	2.893	3.507	4.035	4.477	4.838	5.129	5.360	5.543	5.686	5.797	5.884	5.951	6.003	6.043	6.145
2004	0.041	0.280	0.776	1.439	2.166	2.877	3.526	4.089	4.563	4.953	5.268	5.519	5.718	5.874	5.995	6.090	6.164	6.221	6.265	6.376
2005	0.042	0.308	0.838	1.536	2.294	3.032	3.701	4.281	4.768	5.168	5.490	5.747	5.951	6.110	6.234	6.331	6.406	6.464	6.509	6.623
2006	0.039	0.297	0.803	1.468	2.189	2.889	3.523	4.073	4.534	4.912	5.217	5.460	5.652	5.803	5.921	6.012	6.083	6.138	6.181	6.288
2007	0.031	0.316	0.829	1.487	2.190	2.865	3.472	3.995	4.432	4.790	5.078	5.307	5.487	5.629	5.739	5.825	5.892	5.943	5.983	6.084
2008	0.031	0.318	0.833	1.492	2.195	2.871	3.478	4.000	4.437	4.794	5.081	5.309	5.490	5.631	5.741	5.827	5.894	5.945	5.985	6.085
2009	0.026	0.338	0.863	1.523	2.219	2.881	3.472	3.980	4.402	4.747	5.024	5.244	5.417	5.553	5.659	5.741	5.805	5.854	5.892	5.988
2010	0.023	0.293	0.789	1.437	2.138	2.816	3.431	3.962	4.408	4.773	5.068	5.302	5.488	5.633	5.746	5.835	5.903	5.956	5.997	6.100
2011	0.024	0.356	0.885	1.538	2.218	2.859	3.429	3.915	4.319	4.648	4.911	5.120	5.285	5.414	5.514	5.592	5.652	5.699	5.735	5.826
2012	0.027	0.315	0.829	1.491	2.200	2.882	3.496	4.025	4.468	4.830	5.122	5.354	5.538	5.681	5.793	5.880	5.948	6.000	6.041	6.143
2013	0.028	0.323	0.833	1.479	2.164	2.819	3.405	3.909	4.329	4.672	4.948	5.167	5.340	5.476	5.581	5.663	5.727	5.776	5.814	5.910
2014	0.025	0.311	0.814	1.458	2.145	2.804	3.397	3.907	4.333	4.682	4.962	5.185	5.361	5.499	5.607	5.691	5.756	5.805	5.844	5.942
2015	0.026	0.329	0.842	1.489	2.171	2.821	3.402	3.901	4.316	4.655	4.928	5.144	5.315	5.449	5.553	5.634	5.697	5.745	5.783	5.877
2016	0.027	0.314	0.827	1.491	2.201	2.884	3.501	4.032	4.476	4.840	5.133	5.366	5.550	5.694	5.806	5.894	5.962	6.014	6.055	6.157
2017	0.026	0.314	0.826	1.484	2.187	2.863	3.472	3.996	4.434	4.793	5.081	5.311	5.492	5.634	5.745	5.831	5.898	5.950	5.990	6.090

APPENDIX 7 – FEMALE MATURITY SCHEDULES, 1986-2017

Female maturity schedule WI345, 1986-2017.																				
	Age class																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1986	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1987	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1988	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1989	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1990	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1991	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1992	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1993	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1994	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1995	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1996	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1997	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1998	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1999	0.0000	0.0000	0.0000	0.0001	0.0015	0.0247	0.2959	0.8747	0.9914	0.9995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2000	0.0000	0.0000	0.0089	0.0294	0.0928	0.2569	0.5389	0.7980	0.9303	0.9783	0.9935	0.9981	0.9994	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000
2001	0.0000	0.0000	0.0089	0.0294	0.0928	0.2569	0.5389	0.7980	0.9303	0.9783	0.9935	0.9981	0.9994	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000
2002	0.0000	0.0000	0.0089	0.0294	0.0928	0.2569	0.5389	0.7980	0.9303	0.9783	0.9935	0.9981	0.9994	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000
2003	0.0000	0.0000	0.0089	0.0294	0.0928	0.2569	0.5389	0.7980	0.9303	0.9783	0.9935	0.9981	0.9994	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000
2004	0.0000	0.0000	0.0089	0.0294	0.0928	0.2569	0.5389	0.7980	0.9303	0.9783	0.9935	0.9981	0.9994	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000
2005	0.0000	0.0000	0.0003	0.0023	0.0209	0.1625	0.6385	0.9414	0.9932	0.9992	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2006	0.0000	0.0000	0.0003	0.0023	0.0209	0.1625	0.6385	0.9414	0.9932	0.9992	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2007	0.0000	0.0000	0.0003	0.0023	0.0209	0.1625	0.6385	0.9414	0.9932	0.9992	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2008	0.0000	0.0000	0.0003	0.0023	0.0209	0.1625	0.6385	0.9414	0.9932	0.9992	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2009	0.0000	0.0000	0.0003	0.0023	0.0209	0.1625	0.6385	0.9414	0.9932	0.9992	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2010	0.0000	0.0000	0.0101	0.0975	0.5341	0.9241	0.9923	0.9993	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2011	0.0000	0.0000	0.0101	0.0975	0.5341	0.9241	0.9923	0.9993	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2012	0.0000	0.0000	0.0101	0.0975	0.5341	0.9241	0.9923	0.9993	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2013	0.0000	0.0000	0.0101	0.0975	0.5341	0.9241	0.9923	0.9993	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2014	0.0000	0.0000	0.0101	0.0975	0.5341	0.9241	0.9923	0.9993	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2015	0.0000	0.0000	0.0403	0.0699	0.1184	0.1936	0.3003	0.4341	0.5783	0.7102	0.8142	0.8868	0.9333	0.9616	0.9781	0.9876	0.9931	0.9961	0.9978	0.9988
2016	0.0000	0.0000	0.0403	0.0699	0.1184	0.1936	0.3003	0.4341	0.5783	0.7102	0.8142	0.8868	0.9333	0.9616	0.9781	0.9876	0.9931	0.9961	0.9978	0.9988
2017	0.0000	0.0000	0.0403	0.0699	0.1184	0.1936	0.3003	0.4341	0.5783	0.7102	0.8142	0.8868	0.9333	0.9616	0.9781	0.9876	0.9931	0.9961	0.9978	0.9988

APPENDIX 7 cont'd

Female maturity schedule WIIM, 1986-2017.

	Age class																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1986	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1987	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1988	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1989	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1990	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1991	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1992	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1993	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1994	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1995	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1996	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1997	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1998	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
1999	0.0000	0.0000	0.0153	0.0398	0.0994	0.2271	0.4390	0.6757	0.8473	0.9366	0.9752	0.9905	0.9964	0.9987	0.9995	0.9998	0.9999	1.0000	1.0000	1.0000
2000	0.0000	0.0000	0.0112	0.0448	0.1629	0.4468	0.7703	0.9330	0.9830	0.9958	0.9990	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2001	0.0000	0.0000	0.0112	0.0448	0.1629	0.4468	0.7703	0.9330	0.9830	0.9958	0.9990	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2002	0.0000	0.0000	0.0112	0.0448	0.1629	0.4468	0.7703	0.9330	0.9830	0.9958	0.9990	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2003	0.0000	0.0000	0.0112	0.0448	0.1629	0.4468	0.7703	0.9330	0.9830	0.9958	0.9990	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2004	0.0000	0.0000	0.0112	0.0448	0.1629	0.4468	0.7703	0.9330	0.9830	0.9958	0.9990	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2005	0.0000	0.0000	0.0006	0.0051	0.0424	0.2771	0.7684	0.9664	0.9960	0.9995	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2006	0.0000	0.0000	0.0006	0.0051	0.0424	0.2771	0.7684	0.9664	0.9960	0.9995	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2007	0.0000	0.0000	0.0006	0.0051	0.0424	0.2771	0.7684	0.9664	0.9960	0.9995	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2008	0.0000	0.0000	0.0006	0.0051	0.0424	0.2771	0.7684	0.9664	0.9960	0.9995	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2009	0.0000	0.0000	0.0006	0.0051	0.0424	0.2771	0.7684	0.9664	0.9960	0.9995	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2010	0.0000	0.0000	0.0005	0.0071	0.0879	0.5659	0.9463	0.9958	0.9997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2011	0.0000	0.0000	0.0005	0.0071	0.0879	0.5659	0.9463	0.9958	0.9997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2012	0.0000	0.0000	0.0005	0.0071	0.0879	0.5659	0.9463	0.9958	0.9997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2013	0.0000	0.0000	0.0005	0.0071	0.0879	0.5659	0.9463	0.9958	0.9997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2014	0.0000	0.0000	0.0005	0.0071	0.0879	0.5659	0.9463	0.9958	0.9997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2015	0.0000	0.0000	0.0223	0.0769	0.2330	0.5255	0.8015	0.9364	0.9817	0.9949	0.9986	0.9996	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2016	0.0000	0.0000	0.0223	0.0769	0.2330	0.5255	0.8015	0.9364	0.9817	0.9949	0.9986	0.9996	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2017	0.0000	0.0000	0.0223	0.0769	0.2330	0.5255	0.8015	0.9364	0.9817	0.9949	0.9986	0.9996	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

APPENDIX 8 – PROPORTIONAL AGE COMPOSITION RECREATIONAL FISHERY WIIM, 1986-2017

	Age Class																	
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.002	0.031	0.191	0.258	0.161	0.113	0.072	0.042	0.030	0.028	0.022	0.015	0.012	0.008	0.004	0.004	0.003	0.005
1987	0.004	0.046	0.216	0.252	0.146	0.099	0.062	0.037	0.029	0.027	0.023	0.017	0.013	0.009	0.005	0.005	0.003	0.007
1988	0.002	0.024	0.133	0.198	0.145	0.118	0.085	0.054	0.047	0.046	0.042	0.029	0.020	0.018	0.008	0.007	0.007	0.017
1989	0.002	0.025	0.140	0.180	0.130	0.109	0.079	0.052	0.046	0.046	0.043	0.033	0.027	0.021	0.013	0.011	0.009	0.034
1990	0.001	0.014	0.087	0.155	0.133	0.117	0.089	0.058	0.053	0.059	0.055	0.041	0.031	0.027	0.016	0.012	0.011	0.041
1991	0.001	0.012	0.078	0.138	0.118	0.107	0.088	0.060	0.059	0.063	0.062	0.050	0.036	0.030	0.020	0.015	0.013	0.052
1992	0.002	0.021	0.094	0.120	0.101	0.094	0.082	0.060	0.062	0.066	0.065	0.053	0.038	0.034	0.020	0.015	0.013	0.060
1993	0.002	0.024	0.112	0.146	0.110	0.096	0.077	0.052	0.052	0.059	0.057	0.045	0.034	0.029	0.019	0.014	0.012	0.061
1994	0.003	0.030	0.124	0.147	0.103	0.086	0.071	0.050	0.052	0.057	0.056	0.050	0.035	0.029	0.019	0.014	0.013	0.061
1995	0.001	0.017	0.101	0.148	0.112	0.096	0.076	0.052	0.052	0.057	0.058	0.045	0.036	0.031	0.020	0.016	0.013	0.069
1996	0.002	0.030	0.131	0.159	0.107	0.086	0.068	0.046	0.046	0.050	0.052	0.042	0.034	0.028	0.020	0.014	0.013	0.072
1997	0.003	0.039	0.186	0.204	0.115	0.086	0.064	0.042	0.039	0.042	0.039	0.030	0.024	0.019	0.013	0.009	0.007	0.039
1998	0.001	0.024	0.134	0.175	0.111	0.086	0.066	0.045	0.046	0.049	0.052	0.040	0.032	0.028	0.017	0.013	0.012	0.069
1999	0.002	0.029	0.175	0.219	0.125	0.088	0.059	0.040	0.038	0.041	0.041	0.031	0.024	0.021	0.012	0.010	0.009	0.039
2000	0.002	0.030	0.161	0.222	0.143	0.106	0.072	0.044	0.036	0.038	0.034	0.025	0.019	0.015	0.009	0.007	0.006	0.031
2001	0.002	0.028	0.171	0.245	0.147	0.100	0.065	0.040	0.032	0.033	0.030	0.022	0.017	0.014	0.009	0.007	0.005	0.031
2002	0.001	0.022	0.149	0.234	0.159	0.111	0.071	0.044	0.034	0.035	0.030	0.022	0.017	0.014	0.007	0.006	0.006	0.036
2003	0.003	0.039	0.181	0.241	0.162	0.112	0.068	0.040	0.029	0.026	0.022	0.014	0.013	0.009	0.004	0.005	0.004	0.027
2004	0.006	0.058	0.224	0.207	0.124	0.093	0.065	0.038	0.033	0.033	0.029	0.020	0.017	0.013	0.007	0.006	0.004	0.021
2005	0.005	0.060	0.234	0.237	0.122	0.089	0.057	0.036	0.031	0.028	0.025	0.019	0.014	0.010	0.007	0.005	0.004	0.017
2006	0.003	0.058	0.283	0.315	0.142	0.077	0.037	0.022	0.015	0.014	0.010	0.006	0.004	0.003	0.001	0.002	0.001	0.004
2007	0.001	0.025	0.176	0.257	0.158	0.105	0.065	0.041	0.030	0.031	0.028	0.022	0.014	0.010	0.007	0.006	0.006	0.019
2008	0.002	0.038	0.180	0.220	0.141	0.102	0.072	0.045	0.038	0.037	0.032	0.024	0.017	0.013	0.007	0.007	0.005	0.019
2009	0.002	0.035	0.167	0.219	0.142	0.106	0.071	0.044	0.038	0.036	0.033	0.025	0.018	0.013	0.008	0.007	0.006	0.030
2010	0.002	0.031	0.138	0.206	0.152	0.115	0.078	0.049	0.041	0.041	0.035	0.027	0.021	0.014	0.009	0.008	0.006	0.025
2011	0.002	0.028	0.172	0.215	0.126	0.094	0.067	0.044	0.040	0.041	0.039	0.030	0.023	0.017	0.011	0.009	0.008	0.034
2012	0.004	0.036	0.131	0.154	0.104	0.085	0.063	0.045	0.049	0.055	0.055	0.043	0.034	0.032	0.018	0.014	0.013	0.064
2013	0.003	0.037	0.177	0.204	0.117	0.086	0.062	0.042	0.042	0.044	0.041	0.033	0.025	0.020	0.012	0.010	0.008	0.037
2014	0.003	0.040	0.184	0.201	0.114	0.084	0.060	0.041	0.039	0.042	0.040	0.033	0.025	0.020	0.013	0.010	0.008	0.043
2015	0.005	0.050	0.179	0.188	0.112	0.084	0.060	0.040	0.039	0.042	0.042	0.034	0.025	0.021	0.013	0.010	0.009	0.047
2016	0.004	0.048	0.188	0.209	0.123	0.087	0.059	0.038	0.035	0.038	0.036	0.029	0.022	0.018	0.012	0.009	0.008	0.037
2017	0.010	0.086	0.214	0.173	0.100	0.076	0.054	0.036	0.035	0.037	0.037	0.030	0.022	0.019	0.012	0.009	0.008	0.042

APPENDIX 9 – PROPORTIONAL AGE COMPOSITION RECREATIONAL FISHERY WI345, 1986-2017

								Age Class									
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.0006	0.0139	0.0909	0.1780	0.1937	0.1620	0.1057	0.0672	0.0450	0.0420	0.0319	0.0190	0.0156	0.0090	0.0097	0.0066	0.0041	0.0051
1987	0.0002	0.0106	0.0769	0.1647	0.1842	0.1650	0.1130	0.0739	0.0504	0.0474	0.0354	0.0223	0.0159	0.0106	0.0113	0.0069	0.0049	0.0063
1988	0.0003	0.0133	0.0914	0.1777	0.1835	0.1538	0.1021	0.0684	0.0492	0.0467	0.0350	0.0208	0.0160	0.0106	0.0091	0.0069	0.0052	0.0099
1989	0.0004	0.0132	0.0824	0.1596	0.1689	0.1516	0.1076	0.0754	0.0535	0.0529	0.0394	0.0246	0.0167	0.0118	0.0101	0.0115	0.0058	0.0148
1990	0.0004	0.0106	0.0713	0.1476	0.1701	0.1502	0.1029	0.0723	0.0552	0.0575	0.0454	0.0290	0.0223	0.0149	0.0128	0.0094	0.0071	0.0211
1991	0.0003	0.0102	0.0689	0.1411	0.1618	0.1441	0.1044	0.0758	0.0581	0.0586	0.0445	0.0290	0.0230	0.0162	0.0147	0.0158	0.0072	0.0264
1992	0.0003	0.0106	0.0652	0.1444	0.1598	0.1463	0.0999	0.0678	0.0540	0.0629	0.0491	0.0309	0.0228	0.0162	0.0145	0.0165	0.0078	0.0311
1993	0.0008	0.0209	0.1123	0.2064	0.1829	0.1319	0.0879	0.0576	0.0420	0.0417	0.0317	0.0185	0.0156	0.0109	0.0091	0.0055	0.0053	0.0190
1994	0.0011	0.0253	0.1348	0.2360	0.1853	0.1255	0.0787	0.0475	0.0321	0.0324	0.0253	0.0169	0.0140	0.0089	0.0084	0.0054	0.0039	0.0186
1995	0.0008	0.0181	0.1056	0.1861	0.1671	0.1268	0.0829	0.0568	0.0447	0.0494	0.0395	0.0264	0.0199	0.0131	0.0144	0.0095	0.0073	0.0317
1996	0.0021	0.0288	0.1357	0.2360	0.1584	0.1011	0.0637	0.0416	0.0368	0.0450	0.0353	0.0239	0.0184	0.0118	0.0128	0.0113	0.0080	0.0294
1997	0.0008	0.0216	0.1200	0.2171	0.1809	0.1240	0.0782	0.0485	0.0375	0.0418	0.0335	0.0218	0.0154	0.0109	0.0097	0.0095	0.0061	0.0228
1998	0.0006	0.0198	0.1199	0.2165	0.1826	0.1295	0.0833	0.0505	0.0386	0.0401	0.0308	0.0197	0.0157	0.0107	0.0091	0.0065	0.0055	0.0205
1999	0.0007	0.0140	0.0821	0.1825	0.1933	0.1692	0.1066	0.0648	0.0377	0.0340	0.0251	0.0178	0.0138	0.0080	0.0073	0.0069	0.0103	0.0258
2000	0.0005	0.0189	0.1132	0.2125	0.2093	0.1517	0.0892	0.0512	0.0341	0.0328	0.0241	0.0157	0.0113	0.0075	0.0074	0.0053	0.0031	0.0122
2001	0.0008	0.0139	0.0958	0.1853	0.1880	0.1477	0.0936	0.0572	0.0421	0.0422	0.0314	0.0181	0.0133	0.0123	0.0126	0.0126	0.0053	0.0279
2002	0.0008	0.0174	0.1026	0.2088	0.2067	0.1555	0.0964	0.0547	0.0360	0.0352	0.0246	0.0152	0.0106	0.0074	0.0066	0.0050	0.0033	0.0134
2003	0.0022	0.0354	0.1817	0.3062	0.1926	0.1092	0.0610	0.0346	0.0221	0.0187	0.0117	0.0064	0.0048	0.0029	0.0029	0.0022	0.0015	0.0038
2004	0.0028	0.0342	0.1836	0.2892	0.1996	0.1280	0.0709	0.0385	0.0195	0.0139	0.0070	0.0043	0.0024	0.0014	0.0018	0.0011	0.0004	0.0016
2005	0.0030	0.0436	0.2228	0.3494	0.1983	0.0937	0.0427	0.0190	0.0104	0.0069	0.0032	0.0021	0.0014	0.0006	0.0009	0.0007	0.0002	0.0011
2006	0.0015	0.0355	0.1738	0.2967	0.2128	0.1242	0.0654	0.0316	0.0163	0.0136	0.0082	0.0054	0.0039	0.0020	0.0030	0.0021	0.0006	0.0034
2007	0.0021	0.0323	0.1688	0.2780	0.2146	0.1321	0.0698	0.0350	0.0175	0.0151	0.0090	0.0068	0.0046	0.0032	0.0028	0.0016	0.0012	0.0056
2008	0.0019	0.0378	0.1902	0.3020	0.1977	0.0973	0.0531	0.0297	0.0209	0.0204	0.0142	0.0087	0.0070	0.0047	0.0038	0.0024	0.0018	0.0062
2009	0.0017	0.0269	0.1637	0.2611	0.2111	0.1324	0.0744	0.0382	0.0244	0.0220	0.0142	0.0077	0.0057	0.0039	0.0031	0.0026	0.0017	0.0049
2010	0.0022	0.0359	0.1808	0.2823	0.1971	0.1146	0.0628	0.0338	0.0209	0.0201	0.0143	0.0090	0.0060	0.0043	0.0034	0.0027	0.0025	0.0072
2011	0.0017	0.0253	0.1589	0.2734	0.2105	0.1289	0.0709	0.0359	0.0224	0.0206	0.0145	0.0090	0.0065	0.0040	0.0038	0.0033	0.0024	0.0079
2012	0.0017	0.0241	0.1241	0.2121	0.1753	0.1263	0.0829	0.0532	0.0401	0.0407	0.0311	0.0209	0.0158	0.0098	0.0099	0.0065	0.0053	0.0204
2013	0.0013	0.0280	0.1508	0.2579	0.1948	0.1204	0.0707	0.0409	0.0291	0.0290	0.0210	0.0133	0.0100	0.0068	0.0067	0.0041	0.0034	0.0117
2014	0.0017	0.0264	0.1315	0.2280	0.1747	0.1185	0.0748	0.0470	0.0366	0.0393	0.0309	0.0205	0.0148	0.0101	0.0097	0.0081	0.0059	0.0215
2015	0.0013	0.0222	0.1241	0.2141	0.1757	0.1235	0.0802	0.0517	0.0399	0.0422	0.0331	0.0212	0.0157	0.0108	0.0095	0.0070	0.0054	0.0224
2016	0.0010	0.0203	0.1121	0.1998	0.1712	0.1235	0.0791	0.0509	0.0406	0.0456	0.0377	0.0241	0.0197	0.0118	0.0140	0.0085	0.0077	0.0325
2017	0.0012	0.0210	0.1117	0.2007	0.1690	0.1233	0.0814	0.0529	0.0409	0.0476	0.0389	0.0255	0.0183	0.0121	0.0115	0.0093	0.0070	0.0276

APPENDIX 10 – LAKE TROUT KILL & DISCARDS SMALL MESH GILL NET FISHERY WI345, 1986-1999

	Catch	Calender Year													
Fishery	statistic	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Chub	Kill	47,415	44,615	77,723	65,044	56,592	62,215	57,626	63,351	41,702	33,299	31,521	32,208	26,506	26,628
	Discards	25,869	24,342	42,405	35,487	30,876	33,944	31,441	34,564	22,752	18,168	17,198	17,573	14,461	14,528
Yellow perch	Prop. Effort	0.0829	0.1094	0.0946	0.0524	0.1391	0.1518	0.1163	0.1047	0.0900	0.0528	0.0145	-------no fishery--------		
	Kill	838	1,071	1,587	704	1,788	2,176	1,482	1,449	806	363	91			
	Discards	1,670	2,136	3,165	1,403	3,566	4,340	2,957	2,889	1,607	723	181			
Total	Kill	48,252	45,686	79,310	65,747	58,380	64,391	59,109	64,800	42,508	33,662	31,612	32,208	26,506	26,628
	Discards	27,540	26,478	45,570	36,891	34,443	38,284	34,397	37,453	24,359	18,891	17,379	17,573	14,461	14,528

APPENDIX 11 – LAKE TROUT KILL & DISCARDS SMALL MESH GILL NET FISHERY WIIM, 1986-1999

	Catch	Calendar Year														
GNS fishery	statistic	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Chub	Catch	22,759	15,836	10,029	10,236	11,415	5,019	5,316	9,111	6,213	5,564	5,970	12,363	17,395	16,705	2,565
	Kill	16,365	11,699	6,867	7,602	8,779	3,533	3,857	6,237	4,297	3,529	4,205	7,808	11,002	10,794	1,747
	Discards	6,394	4,137	3,163	2,634	2,636	1,486	1,460	2,874	1,916	2,035	1,765	4,555	6,393	5,911	818
Yellow perch	Catch	37,475	44,253	48,811	19,338	16,078	12,941	14,896	20,444	28,099	6,876	5,139	170	---------No Fishery--------		
	Kill	9,573	8,193	7,904	5,820	5,275	4,690	5,234	6,986	8,696	2,563	1,905	112			
	Discards	27,902	36,060	40,907	13,519	10,803	8,251	9,662	13,457	19,403	4,313	3,233	58			
Total	Catch	60,234	60,089	58,840	29,575	27,493	17,960	20,212	29,555	34,312	12,440	11,108	12,533	17,395	16,705	2,565
	Kill	25,938	19,892	14,771	13,422	14,054	8,223	9,090	13,223	12,993	6,092	6,110	7,920	11,002	10,794	1,747
	Disdards	34,296	40,197	44,069	16,152	13,439	9,737	11,122	16,332	21,319	6,348	4,998	4,613	6,393	5,911	818

APPENDIX 12 – SELECTIVTY OF COMMERCIAL FISHERY WI345

Estimating hybrid selectivity of commercial fishing gears in WI345. ***Prop*** is the mean proportion at age in the small-mesh gill net (GNS) fishery, ***Sc*** is the mean cumulative survival rate, and GNL is the large-mesh gill net fishery. Adjusted selectivity = **Prop/Sc**.

Age			Adjusted	Selectivity			Scaled to
(a)	***Prop***	***Sc***	selectivity	GNS	GNL	mean	age-4
3	0.2118	0.7788	0.2720	0.5642	0.1271	0.2318	0.5163
4	0.2923	0.6065	0.4820	1.0000	0.5565	0.4490	1.0000
5	0.2275	0.4724	0.4817	0.9994	0.9160	0.4901	1.0916
6	0.1130	0.3679	0.3073	0.6375	0.9898	0.3593	0.8003
7	0.0616	0.2865	0.2152	0.4465	0.9990	0.2868	0.6388
8	0.0244	0.2231	0.1092	0.2266	1.0000	0.2023	0.4506
9	0.0145	0.1738	0.0834	0.1730	1.0000	0.1817	0.4046
10	0.0044	0.1353	0.0327	0.0678	0.9997	0.1411	0.3143
11	0.0070	0.1054	0.0667	0.1383	0.9992	0.1682	0.3747
12	0.0213	0.0821	0.2599	0.5392	0.9984	0.3224	0.7182
13	0.0045	0.0639	0.0702	0.1456	0.9972	0.1708	0.3804
14	0.0068	0.0498	0.1369	0.2841	0.9951	0.2239	0.4986
15	0.0017	0.0388	0.0449	0.0932	0.9917	0.1500	0.3340
16	0.0000	0.0302	0.0000	0.0000	0.9862	0.1135	0.2527
17	0.0000	0.0235	0.0000	0.0000	0.9772	0.1124	0.2504
18	0.0000	0.0183	0.0000	0.0000	0.9629	0.1108	0.2468
19	0.0000	0.0143	0.0000	0.0000	0.9402	0.1082	0.2410
20+	0.0000	0.0111	0.0000	0.0000	0.9052	0.1041	0.2320

APPENDIX 13 – R-SCRIPT FOR ESTIMATING SEA LAMPREY-INDUCED MORTALITY

#Program to calculate lamprey mortality figures for SCAA modeling, based on outputs of ADMB of year/MU specific alpha, beta and theta.
#Requires: table of length at age data (for LAT only), along with table of year specific alpha, beta and theta values from ADMB
#Data must have a unique number (NOT text) representing MU (area), if there is only one area, make them all 1's
#This code that all units being modeled have the same timer series for data, caution on Lake Superior!
#Output is written as a Year X Age matrix of mortalities for feeding into SCAA models
#Developed by Ted Treska USFWS July 2012
##REMINDER: Alpha, Beta and Theta headers in ADMBoutput in excel need to be CAPITLIZED!!!!!!!!!!
#Updated to allow for user input file using file explorer 11/18 TT
#Instructions:

```
library(xlsx)             #this allows the use of the function read.xlsx files (reads xls or xlsx file types)
library(rJava)            #this is used by xlsx library
options(scipen=999)       #this deactivates scientific notation, when writing out values

#Allow user to choose input file
Path<-choose.files(default="",caption="Select Data File")

#read in the appropriate data file, this works on an excel file with 3 sheets, one for Length at Age and one for ADMB outputs and one for Lake Name!!
#Use the previous years version and change input data.
#NOTE the specific tab names! See end of code for formatting of sheets if formatting is lost.
#Path<-"C:/TT/MSC/Lamprey MSC/LAT Lamprey Mort MSC/2018 Run thru 2017 data/Results sent to Modelers Spring 2018/LampMortInput_LM_2017.xlsx"
#Path<-"C:/TT/MSC/Lamprey MSC/LAT Lamprey Mort MSC/2018 Run thru 2017 data/Results sent to Modelers Spring 2018/LampMortInput_LS_2016_WI-2.xlsx"
#Path<-"C:/TT/MSC/Lamprey MSC/LAT Lamprey Mort MSC/2018 Run thru 2017 data/Results sent to Modelers Spring 2018/LampMortInput_LH_2017_MH12.xlsx"
#Path<-"C:/Users/ttreska/Desktop/LM Lakewide Morts/LampMortInput_LM_2017_WI345.xlsx"
#Path<-file
LengthAge <- read.xlsx(Path, sheetName="LengthAtAge")       #read in the LengthAtAge sheet info
ADMBout <- read.xlsx(Path, sheetName="ADMBoutputs")        #read in the ADMBoutputs sheet info
LakeName <- read.xlsx(Path, sheetName="LakeName")          #read in the LakeName sheet info, really only needed for Superior, but....

#Set first and last values for loops, and some other values
#assumes same time period/age range for all MUs that it is working on.  If they are not (i.e. Superior), should run them separately.
firstyear=min(LengthAge$Year, na.rm=TRUE)     #set first year
lastyear=max(LengthAge$Year, na.rm=TRUE)      #set last year
firstage=min(LengthAge$Age, na.rm=TRUE)       #set first age
lastage=max(LengthAge$Age, na.rm=TRUE)        #set last age
years=seq(firstyear,lastyear)                 #populate list of years covered
ages=seq(firstage,lastage)                    #populate list of ages covered
```

APPENDIX 13 cont'd

MUs=unique(na.omit(LengthAge$MU)) #list of unique mgmt units to be used
#coeff of variation for Length, from Weeks 1997 Dynamics of LAT in MI waters of LS
CV=0.15
#bins for assigning proportions at ages to length bins, min=440mm as this is where there are values for survival probability, values represent top of length bin
firstbin=440
lastbin=760 #780 #max 770mm, this is actually 750 and greater
binlist=seq(firstbin,lastbin,20) #list of bin values for determining proportion at age at length

#probabilities of survival for bins from 430-750mm by 20 mm increments, values are 0 for shorter lengths
#the length of this vector needs to be the same as binlist above
430,450,470,490,510,530,550,570,590,610,630,650,670,690,710,730,750,Plus
SurvProb = c(.35,.35,.35,.35,.35,.45,.45,.45,.45,.45,.45,.55,.55,.55,.55,.55,.55) #,.55)
#From Greig et al 1992 GLFC, page 3.30, which cites Swink 1990 and Swink & Hanson 1986, tho can't find these figures there

#wounding rates on size bins of fish, over years
#arrays used to hold intermediate values
Wounding=array(data=0, dim=c(length(binlist),length(years),length(MUs)),dimnames=list(binlist,years,MUs)) #array with Bin X Year X MU dimensions
PropAge=array(data=0, dim=c(length(binlist), length(ages), length(years), length(MUs)),dimnames=list(binlist,ages,years,MUs)) #Bin X Age X Year X MU
SLMort=array(data=0, dim=c(length(binlist),length(years),length(MUs)),dimnames=list(binlist,years,MUs)) #Bin X Year X MU
SLMort2=array(data=0, dim=c(length(ages), length(years), length(MUs)),dimnames=list(ages,years,MUs)) #Age X Year X MU
adjSLMort2=array(data=0, dim=c(length(years),length(ages),length(MUs)), dimnames=list(years,paste0("Age ",ages),MUs)) #Year X Age X MU

###
#Calculate average wounds, associated mortality and proportions at age
for(y in 1:length(years))
for(m in 1:length(MUs))

{ yrvals=subset(ADMBout, Year==years[y] & MU==MUs[m]) #subset ADMB output to appropriate year and MU
yrlength=subset(LengthAge, Year==years[y] & MU==MUs[m]) #subset Length/Age data to appropriate year and MU

Wounding[,y,m]=yrvals$Theta/(1+exp(-1*yrvals$Alpha*((binlist-10)-yrvals$Beta))) #calculate Wounding rate based on above values, binlist-10 is to calculate wounding on a fish in the middle of the 20 mm bin

the following code must step through by year, as in Superior calculations change mid time series
if(LakeName$LakeModel[1] == 1 && years[y] < 1985)

APPENDIX 13 cont’d

```
    {SLMort[,y,]=Wounding[,y,]*(1-SurvProb)/(SurvProb * 0.57)} else #adjustment for early wound
recording method in Lake superior used before 1985, based on data being recorded as fresh and scars
and conversion provided by Bence &Sitar
    {SLMort[,y,]=Wounding[,y,]*(1-SurvProb)/SurvProb}      #calculate sea lamprey mort for each
length bin (bin X year X MU)

#calculate SD of lengths (could be modified for SD for each age), this is standard that was being used
everywhere.
   sd=yrlength$Length * CV

   for(a in 1:length(ages))
   {
    for(b in 1:length(binlist))  #Calculate matrix of proportion of each age in length bin (bins X age X
year), with a plus group
    {
      if(binlist[b]<lastbin) {PropAge[b,a,y,m]=(pnorm(binlist[b],yrlength$Length[a],sd[a])-
pnorm(binlist[b]-20,yrlength$Length[a],sd[a]))} else #don't want to include entire left tail in first calc,
because those fish do not have same Surv Prob.
      {PropAge[b,a,y,m]= 1 - pnorm(binlist[b]-20,yrlength$Length[a],sd[a])} #this calculates proportion
under curve for area in right tail > than 760mm, assume constant survival of larger fish
    }
    SLMort2[a,y,m]=sum(SLMort[,y,m]*PropAge[,a,y,m])   #these are the mortalities, now need to be
adjusted for yr and age (see next loops)
   }  #end a for loop
  }  #end for y/m loop

#next loops increment values back a year and an age, so that wounding on age 8 in 2010 really reflects
wounding on age 7 in 2009
#!!!!!ASSUMING that wounding parameters were based on spring wounding data collections  !!!!!!!!!!!!!
#this also transposes the matrices into the Yr X Age format that can be fed into SCAA models

for(m2 in 1:length(MUs))
 for(a2 in 1:(length(ages)-1))
   for(y2 in 1:length(years))
   {
    if(y2<length(years)) {adjSLMort2[y2,a2,m2]=SLMort2[a2+1,y2+1,m2]} else #fill in all regular values
with  age+1/yr+1 value
       {adjSLMort2[y2,a2,m2]=SLMort2[a2+1,y2,m2]}  #fill in last yr with copy of prev year
    if(a2==(length(ages)-1)) {adjSLMort2[y2,(a2+1),m2]=adjSLMort2[y2,a2,m2]}  #fill in last age with
copy of prev age
   }


##################################################################
#Save the resulting lamprey mortality matrices, appended to the original file
#Save first MU sea lamprey Matrix to another sheet, then others if they exist, labeled with MU number
gc()   #for good measure, was having java memory issues
```

APPENDIX 13 cont’d

```
write.xlsx(adjSLMort2[,,1], file=Path, sheetName= paste0("LampreyMort MU",as.character(MUs[1])), col.names=TRUE, row.names=TRUE, append=TRUE)
#this will write to up to 5 total tabs for multiple MUs
if (length(MUs)>=2) write.xlsx(adjSLMort2[,,2], file=Path, sheetName= paste0("LampreyMort MU",as.character(MUs[2])), col.names=TRUE, append=TRUE)
if (length(MUs)>=3) write.xlsx(adjSLMort2[,,3], file=Path, sheetName= paste0("LampreyMort MU",as.character(MUs[3])), col.names=TRUE, append=TRUE)
if (length(MUs)>=4) write.xlsx(adjSLMort2[,,4], file=Path, sheetName= paste0("LampreyMort MU",as.character(MUs[4])), col.names=TRUE, append=TRUE)
if (length(MUs)>=5) write.xlsx(adjSLMort2[,,5], file=Path, sheetName= paste0("LampreyMort MU",as.character(MUs[5])), col.names=TRUE, append=TRUE)



##########################################################################################################################
# Notes:  LS uses different bins than LM, so has been switched (from starting at 440 to 430mm).  Also, incoporated >750mm
# bin into analysis, with wounding rates, sea lamprey mortalities rates (were copies of 730-750 bin).
#
#INPUT FILE FORMAT
#Excel Input Sheet names & headings, 1 workbook, 3 worksheets.  See previous versions
#NAME:      LengthAtAge                 ADMBoutputs                 LakeName
#FIELDS     Year  MU  Age  Length           Year  MU  Alpha  Beta  Theta


#generic function to write whatever to the clipboard
write.table(as.table(Wounding[,,1]),"LM wounding.csv")
write.table(as.table(adjSLMort2[,,1]),"LM lampmort.csv")
write.table(as.table(SLMort2[,,1]),"clipboard")
write.table(as.table(PropAge[,,37,1]),"clipboard")
```

APPENDIX 14 – AGE- AND YEAR-SPECIFIC SEA LAMPREY MORTALITY RATES, 1986-2017

WI345 Instantaneous Sea Lamprey Mortality Rate

	Age Class																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.0000	0.0008	0.0058	0.0152	0.0348	0.0489	0.0598	0.0675	0.0731	0.0770	0.0796	0.0815	0.0829	0.0840	0.0840	0.0840	0.0840	0.0840	0.0840	0.0840
1987	0.0000	0.0002	0.0013	0.0049	0.0087	0.0146	0.0181	0.0209	0.0229	0.0244	0.0255	0.0263	0.0269	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273
1988	0.0000	0.0009	0.0060	0.0174	0.0324	0.0420	0.0519	0.0569	0.0601	0.0624	0.0644	0.0656	0.0665	0.0671	0.0671	0.0671	0.0671	0.0671	0.0671	0.0671
1989	0.0000	0.0107	0.0922	0.1357	0.1711	0.1981	0.2122	0.2262	0.2329	0.2381	0.2378	0.2394	0.2406	0.2415	0.2415	0.2415	0.2415	0.2415	0.2415	0.2415
1990	0.0000	0.0020	0.0067	0.0378	0.0556	0.0724	0.0872	0.0958	0.1049	0.1102	0.1133	0.1159	0.1178	0.1190	0.1190	0.1190	0.1190	0.1190	0.1190	0.1190
1991	0.0000	0.0025	0.0171	0.0326	0.0795	0.0970	0.1109	0.1218	0.1281	0.1349	0.1379	0.1405	0.1426	0.1437	0.1437	0.1437	0.1437	0.1437	0.1437	0.1437
1992	0.0000	0.0017	0.0183	0.0610	0.0905	0.1557	0.1776	0.1941	0.2082	0.2156	0.2218	0.2259	0.2293	0.2314	0.2314	0.2314	0.2314	0.2314	0.2314	0.2314
1993	0.0000	0.0002	0.0027	0.0101	0.0185	0.0225	0.0298	0.0319	0.0336	0.0351	0.0358	0.0363	0.0367	0.0370	0.0370	0.0370	0.0370	0.0370	0.0370	0.0370
1994	0.0000	0.0002	0.0020	0.0095	0.0194	0.0262	0.0292	0.0340	0.0354	0.0365	0.0375	0.0380	0.0385	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388
1995	0.0000	0.0002	0.0006	0.0015	0.0026	0.0035	0.0040	0.0042	0.0046	0.0047	0.0049	0.0050	0.0050	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051
1996	0.0000	0.0028	0.0313	0.0722	0.1355	0.1970	0.2375	0.2611	0.2708	0.2878	0.2952	0.3014	0.3055	0.3089	0.3089	0.3089	0.3089	0.3089	0.3089	0.3089
1997	0.0000	0.0045	0.0212	0.0658	0.0957	0.1257	0.1488	0.1624	0.1700	0.1732	0.1791	0.1819	0.1841	0.1856	0.1856	0.1856	0.1856	0.1856	0.1856	0.1856
1998	0.0000	0.0002	0.0055	0.0235	0.0494	0.0732	0.0902	0.1017	0.1095	0.1146	0.1180	0.1205	0.1223	0.1236	0.1245	0.1253	0.1258	0.1262	0.1273	0.1273
1999	0.0000	0.0001	0.0029	0.0127	0.0271	0.0405	0.0503	0.0570	0.0615	0.0644	0.0664	0.0679	0.0689	0.0696	0.0702	0.0706	0.0710	0.0712	0.0718	0.0718
2000	0.0000	0.0002	0.0044	0.0199	0.0449	0.0696	0.0882	0.1012	0.1101	0.1159	0.1200	0.1229	0.1249	0.1265	0.1276	0.1284	0.1291	0.1295	0.1309	0.1309
2001	0.0000	0.0002	0.0041	0.0176	0.0379	0.0569	0.0708	0.0803	0.0868	0.0910	0.0939	0.0959	0.0974	0.0985	0.0993	0.0999	0.1004	0.1007	0.1016	0.1016
2002	0.0000	0.0003	0.0059	0.0257	0.0549	0.0823	0.1023	0.1159	0.1251	0.1311	0.1352	0.1382	0.1403	0.1419	0.1430	0.1439	0.1446	0.1450	0.1464	0.1464
2003	0.0000	0.0003	0.0080	0.0334	0.0692	0.1015	0.1245	0.1400	0.1504	0.1572	0.1618	0.1651	0.1674	0.1692	0.1704	0.1714	0.1722	0.1726	0.1742	0.1742
2004	0.0000	0.0001	0.0029	0.0119	0.0244	0.0355	0.0434	0.0487	0.0522	0.0545	0.0560	0.0572	0.0579	0.0585	0.0589	0.0593	0.0595	0.0597	0.0602	0.0602
2005	0.0000	0.0005	0.0113	0.0450	0.0891	0.1265	0.1523	0.1693	0.1806	0.1878	0.1927	0.1962	0.1987	0.2005	0.2018	0.2029	0.2037	0.2042	0.2058	0.2058
2006	0.0000	0.0004	0.0086	0.0317	0.0584	0.0792	0.0926	0.1011	0.1067	0.1102	0.1126	0.1143	0.1155	0.1163	0.1169	0.1174	0.1178	0.1180	0.1188	0.1188
2007	0.0000	0.0005	0.0106	0.0389	0.0719	0.0975	0.1141	0.1246	0.1315	0.1358	0.1388	0.1409	0.1423	0.1434	0.1442	0.1448	0.1453	0.1455	0.1465	0.1465
2008	0.0000	0.0004	0.0079	0.0314	0.0618	0.0875	0.1051	0.1167	0.1244	0.1293	0.1327	0.1351	0.1367	0.1380	0.1389	0.1396	0.1401	0.1405	0.1416	0.1416
2009	0.0000	0.0002	0.0054	0.0213	0.0422	0.0600	0.0722	0.0802	0.0856	0.0890	0.0913	0.0930	0.0942	0.0950	0.0957	0.0962	0.0965	0.0968	0.0975	0.0975
2010	0.0000	0.0001	0.0030	0.0119	0.0238	0.0340	0.0411	0.0458	0.0489	0.0509	0.0523	0.0532	0.0539	0.0544	0.0548	0.0551	0.0553	0.0554	0.0559	0.0559
2011	0.0000	0.0004	0.0086	0.0332	0.0640	0.0892	0.1061	0.1171	0.1244	0.1290	0.1321	0.1344	0.1360	0.1371	0.1379	0.1386	0.1391	0.1394	0.1404	0.1404
2012	0.0000	0.0003	0.0059	0.0235	0.0462	0.0654	0.0786	0.0872	0.0929	0.0966	0.0991	0.1009	0.1021	0.1031	0.1037	0.1043	0.1047	0.1049	0.1057	0.1057
2013	0.0000	0.0003	0.0064	0.0247	0.0474	0.0659	0.0783	0.0864	0.0917	0.0951	0.0974	0.0990	0.1002	0.1010	0.1016	0.1021	0.1025	0.1027	0.1035	0.1035
2014	0.0000	0.0002	0.0048	0.0174	0.0320	0.0433	0.0506	0.0552	0.0581	0.0600	0.0613	0.0622	0.0629	0.0633	0.0636	0.0639	0.0641	0.0642	0.0647	0.0647
2015	0.0000	0.0002	0.0033	0.0119	0.0214	0.0286	0.0332	0.0361	0.0380	0.0392	0.0400	0.0405	0.0409	0.0412	0.0414	0.0416	0.0417	0.0418	0.0420	0.0420
2016	0.0000	0.0001	0.0023	0.0084	0.0153	0.0205	0.0239	0.0260	0.0274	0.0283	0.0289	0.0293	0.0296	0.0298	0.0299	0.0300	0.0301	0.0302	0.0304	0.0304
2017	0.0000	0.0001	0.0023	0.0084	0.0153	0.0205	0.0239	0.0260	0.0274	0.0283	0.0289	0.0293	0.0296	0.0298	0.0299	0.0300	0.0301	0.0302	0.0304	0.0304

APPENDIX 14 cont'd

WIIM Instantaneous Sea Lamprey Mortality Rate																				
	Age Class																			
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.0000	0.0008	0.0058	0.0152	0.0348	0.0489	0.0598	0.0675	0.0731	0.0770	0.0796	0.0815	0.0829	0.0840	0.0840	0.0840	0.0840	0.0840	0.0840	0.0840
1987	0.0000	0.0002	0.0013	0.0049	0.0087	0.0146	0.0181	0.0209	0.0229	0.0244	0.0255	0.0263	0.0269	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273
1988	0.0000	0.0009	0.0060	0.0174	0.0324	0.0420	0.0519	0.0569	0.0601	0.0624	0.0644	0.0656	0.0665	0.0671	0.0671	0.0671	0.0671	0.0671	0.0671	0.0671
1989	0.0000	0.0107	0.0922	0.1357	0.1711	0.1981	0.2122	0.2262	0.2329	0.2381	0.2378	0.2394	0.2406	0.2415	0.2415	0.2415	0.2415	0.2415	0.2415	0.2415
1990	0.0000	0.0020	0.0067	0.0378	0.0556	0.0724	0.0872	0.0958	0.1049	0.1102	0.1133	0.1159	0.1178	0.1190	0.1190	0.1190	0.1190	0.1190	0.1190	0.1190
1991	0.0000	0.0025	0.0171	0.0326	0.0795	0.0970	0.1109	0.1218	0.1281	0.1349	0.1379	0.1405	0.1426	0.1437	0.1437	0.1437	0.1437	0.1437	0.1437	0.1437
1992	0.0000	0.0017	0.0183	0.0610	0.0905	0.1557	0.1776	0.1941	0.2082	0.2156	0.2218	0.2259	0.2293	0.2314	0.2314	0.2314	0.2314	0.2314	0.2314	0.2314
1993	0.0000	0.0002	0.0027	0.0101	0.0185	0.0225	0.0298	0.0319	0.0336	0.0351	0.0358	0.0363	0.0367	0.0370	0.0370	0.0370	0.0370	0.0370	0.0370	0.0370
1994	0.0000	0.0002	0.0020	0.0095	0.0194	0.0262	0.0292	0.0340	0.0354	0.0365	0.0375	0.0380	0.0385	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388
1995	0.0000	0.0002	0.0006	0.0015	0.0026	0.0035	0.0040	0.0042	0.0046	0.0047	0.0049	0.0050	0.0050	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051
1996	0.0000	0.0028	0.0313	0.0722	0.1355	0.1970	0.2375	0.2611	0.2708	0.2878	0.2952	0.3014	0.3055	0.3089	0.3089	0.3089	0.3089	0.3089	0.3089	0.3089
1997	0.0000	0.0045	0.0212	0.0658	0.0957	0.1257	0.1488	0.1624	0.1700	0.1732	0.1791	0.1819	0.1841	0.1856	0.1856	0.1856	0.1856	0.1856	0.1856	0.1856
1998	0.0003	0.0062	0.0254	0.0560	0.0869	0.1114	0.1295	0.1418	0.1506	0.1565	0.1608	0.1639	0.1661	0.1680	0.1693	0.1703	0.1711	0.1717	0.1732	0.1732
1999	0.0001	0.0021	0.0082	0.0177	0.0268	0.0340	0.0391	0.0426	0.0451	0.0468	0.0480	0.0488	0.0494	0.0500	0.0503	0.0506	0.0508	0.0510	0.0514	0.0514
2000	0.0002	0.0045	0.0176	0.0372	0.0561	0.0706	0.0811	0.0881	0.0931	0.0965	0.0989	0.1006	0.1018	0.1029	0.1036	0.1042	0.1046	0.1050	0.1058	0.1058
2001	0.0002	0.0042	0.0171	0.0375	0.0578	0.0739	0.0856	0.0936	0.0993	0.1031	0.1059	0.1079	0.1094	0.1106	0.1114	0.1121	0.1126	0.1130	0.1139	0.1139
2002	0.0003	0.0052	0.0203	0.0427	0.0641	0.0804	0.0922	0.1000	0.1056	0.1094	0.1121	0.1140	0.1154	0.1166	0.1174	0.1180	0.1185	0.1189	0.1198	0.1198
2003	0.0005	0.0110	0.0420	0.0861	0.1267	0.1570	0.1785	0.1928	0.2029	0.2097	0.2145	0.2179	0.2205	0.2226	0.2240	0.2252	0.2260	0.2267	0.2283	0.2283
2004	0.0003	0.0055	0.0222	0.0483	0.0741	0.0943	0.1090	0.1189	0.1261	0.1309	0.1344	0.1368	0.1387	0.1402	0.1412	0.1420	0.1427	0.1431	0.1443	0.1443
2005	0.0005	0.0109	0.0399	0.0787	0.1124	0.1367	0.1536	0.1647	0.1725	0.1776	0.1813	0.1839	0.1858	0.1874	0.1885	0.1894	0.1900	0.1905	0.1917	0.1917
2006	0.0005	0.0099	0.0375	0.0763	0.1115	0.1376	0.1561	0.1683	0.1770	0.1827	0.1868	0.1897	0.1919	0.1937	0.1949	0.1959	0.1967	0.1972	0.1986	0.1986
2007	0.0003	0.0054	0.0212	0.0445	0.0666	0.0834	0.0955	0.1035	0.1093	0.1131	0.1159	0.1178	0.1193	0.1205	0.1213	0.1220	0.1225	0.1229	0.1238	0.1238
2008	0.0003	0.0067	0.0242	0.0473	0.0671	0.0813	0.0911	0.0975	0.1020	0.1049	0.1071	0.1086	0.1097	0.1106	0.1112	0.1117	0.1121	0.1124	0.1131	0.1131
2009	0.0003	0.0065	0.0226	0.0421	0.0579	0.0688	0.0761	0.0808	0.0840	0.0862	0.0877	0.0887	0.0895	0.0902	0.0906	0.0910	0.0912	0.0914	0.0919	0.0919
2010	0.0003	0.0066	0.0234	0.0445	0.0620	0.0742	0.0825	0.0879	0.0916	0.0941	0.0958	0.0971	0.0980	0.0987	0.0992	0.0997	0.1000	0.1002	0.1008	0.1008
2011	0.0003	0.0063	0.0217	0.0406	0.0559	0.0665	0.0736	0.0781	0.0813	0.0834	0.0848	0.0859	0.0866	0.0873	0.0877	0.0880	0.0883	0.0885	0.0890	0.0890
2012	0.0002	0.0043	0.0156	0.0303	0.0428	0.0517	0.0578	0.0618	0.0646	0.0665	0.0678	0.0687	0.0694	0.0700	0.0703	0.0707	0.0709	0.0711	0.0715	0.0715
2013	0.0002	0.0047	0.0169	0.0324	0.0454	0.0545	0.0608	0.0649	0.0677	0.0696	0.0709	0.0719	0.0725	0.0731	0.0735	0.0738	0.0741	0.0742	0.0747	0.0747
2014	0.0002	0.0038	0.0143	0.0289	0.0419	0.0516	0.0584	0.0628	0.0660	0.0681	0.0696	0.0706	0.0714	0.0721	0.0725	0.0729	0.0732	0.0734	0.0739	0.0739
2015	0.0001	0.0013	0.0051	0.0106	0.0158	0.0198	0.0226	0.0245	0.0258	0.0267	0.0274	0.0278	0.0282	0.0285	0.0286	0.0288	0.0289	0.0290	0.0292	0.0292
2016	0.0001	0.0012	0.0046	0.0095	0.0139	0.0173	0.0197	0.0213	0.0224	0.0231	0.0237	0.0240	0.0243	0.0246	0.0247	0.0249	0.0249	0.0250	0.0252	0.0252
2017	0.0001	0.0012	0.0046	0.0095	0.0139	0.0173	0.0197	0.0213	0.0224	0.0231	0.0237	0.0240	0.0243	0.0246	0.0247	0.0249	0.0249	0.0250	0.0252	0.0252

APPENDIX 15 – R-SCRIPT FOR LINEAR MIXED EFFECTS MODELS OF LWAP CATCH-PER-UNIT EFFORT

```
#Mixed model analyses to estimates survey CPE and SD
library(nlme)
library(lme4)
library(dplyr)
library(readxl) #for reading in excel spreadsheets
library(ggplot2)

#Load workbook
wd <-"C:/Users/User/Documents/LAT Model Lake Michigan/"
xl <- "WIIM LWAP & LATSPAWN Catch_effort.xlsx" #excel workbook with data

#Biologcial data from the spring survey
d1 <- read_excel(paste0(wd,xl), sheet="LWAPdatabase") #read in specifc worksheet

#check to make sure data were read in correctly
str(d1)

#Select lifts from a specific unit
modunit="WIIM"

d1 <- d1 %>%
  filter(ModelUnit=="WIIM") %>%
  filter(Year>1997) %>% #Added to ignore data before 1998
  select(Grid,Year,Month,Stock_CPUE) %>%
  mutate(ln.cpe=log(Stock_CPUE+0.01))

#Change variables to factors
d1$YR.fc<-factor(d1$Year) #year
d1$GD.fc<-factor(d1$Grid)  #grid
d1$MT.fc<-factor(d1$Month) #month
#d1$SD.fc<-factor(d1$LTUnit) #stat dist for mm-123

#Create interaction terms
d1$YG.fc<-factor(d1$YR.fc:d1$GD.fc) #year X Grid interaction
d1$YM.fc<-factor(d1$YR.fc:d1$MT.fc) #year X month interaction
d1$GM.fc<-factor(d1$GD.fc:d1$MT.fc) #grid X month interaction

#remove rows that are missing grid (from LRB)
d1 <- filter(d1,Grid!='NA')

n.lift <- d1 %>%
  group_by(Year) %>%
  summarize(Count=length(ln.cpe))
n.lift
```

APPENDIX 15 cont'd

```
#Subset the data into two time periods
#d2 <- filter(d1, Year <= 1990)
#d3 <- filter(d1, Year >= 1997)

#Choose which data set to run through models
mod.dat <- d1

#linear mixed effects model
#year and grid fixed effects, year X grid interaction
#lme.0 <- lme(ln.cpe~YR.fc-1+GD.fc,random=list(YG.fc=~1),mod.dat,method="ML")

#lme.1 <- lme(ln.cpe ~ YR.fc-1,random=list(GD.fc=~1),mod.dat, method="ML")

lme.2 <- lme(ln.cpe ~ YR.fc-1,random=list(GD.fc=~1,YG.fc=~1),mod.dat, method="ML")

# lme.3 <- lme(ln.cpe ~ YR.fc-1,random=list(GD.fc=~1,YG.fc=~1),mod.dat, method="ML",
#           weights = varIdent(form = ~1| GD.fc),correlation = corAR1())

# lme.4 <- lme(ln.cpe ~ YR.fc-1,random=list(GD.fc=~1),mod.dat, method="ML",
#           weights = varIdent(form = ~1| GD.fc),correlation = corAR1())
#
# lme.5 <- lme(ln.cpe ~ YR.fc-1,random=list(GD.fc=~1),mod.dat, method="ML",
#           weights = varIdent(form = ~1| GD.fc),correlation = corARMA(p=1,q=1))

#Best performing model for commercial gill nets (w/out boat size and license holder) from Deroba and
Bence
#(tried it for comparison)
#lme.5 <- lme(ln.cpe~YR.fc+MT.fc-1, random=list(YM.fc=~1), mod.dat, method="ML")

#year and month as fixed, grid as random (#previous version w/ month as fixed)
lme.6 <- lme(ln.cpe~YR.fc+MT.fc-1, random=list(GD.fc=~1), mod.dat, method="ML")

#lme.6.1 <- lme(ln.cpe~YR.fc+MT.fc-1, random=list(GD.fc=~1),correlation = corAR1(), mod.dat,
method="ML")

#add grid X month interaction- **this is the one we use**
lme.7 <- lme(ln.cpe~YR.fc+MT.fc-1, random=list(GD.fc=~1,GM.fc=~1), mod.dat, method="ML")

#add year X month interaction
lme.8 <- lme(ln.cpe~YR.fc+MT.fc-1, random=list(GD.fc=~1,GM.fc=~1,YM.fc=~1), mod.dat, method="ML")

#add year X grid interaction
lme.9 <- lme(ln.cpe~YR.fc+MT.fc-1, random=list(GD.fc=~1,GM.fc=~1,YM.fc=~1,YG.fc=~1), mod.dat,
method="ML")

#Ji's model (w/out depth)
lme.10 <- lme(ln.cpe~YR.fc-1, random=list(GM.fc=~1),correlation = corAR1(), mod.dat, method="ML")
```

APPENDIX 15 cont'd

```
#Grab the CPEs and SDs
sum0 <- data.frame(summary(lme.2)$tTable) #1 for reference to plots
sum1 <- data.frame(summary(lme.6)$tTable)
sum2 <- data.frame(summary(lme.7)$tTable)
sum3 <- data.frame(summary(lme.8)$tTable)
sum4 <- data.frame(summary(lme.9)$tTable)
sum5 <- data.frame(summary(lme.10)$tTable) #6 for reference to plots

#Compare models
anova(lme.2,lme.6,lme.7,lme.8,lme.9,lme.10)

#Model version used previously
mod.list <- list(sum0,sum1,sum2,sum3,sum4,sum5)

#cpe.df <- matrix(nrow=0,ncol=4)
cpe.df <- data.frame()
datalist = list()

for (i in 1:length(mod.list)){
  var1 <- i
  output1 <- mod.list[[i]]
  yrs <- c(1998:2017) #change this as years added
  yrlen <- length(yrs)
  cpe <- round(output1$Value[1:yrlen],4)
  sd <- round(output1$Std.Error[1:yrlen],4)
  cpe.out <- cbind(var1,yrs,cpe,sd)
  datalist[[i]] <- cpe.out
}

#Data frame with all the model CPEs and SDs
cpe.comp <- data.frame(do.call(rbind, datalist))

#plot cpes
p <- ggplot(cpe.comp, aes(x=yrs,y=cpe, group=factor(var1), colour=factor(var1))) + geom_line()
p <- p + labs(x="Year",y="CPE",title="") #+ scale_colour_hue(guide=FALSE)
p

#plot SDs
p <- ggplot(cpe.comp, aes(x=yrs,y=sd, group=factor(var1), colour=factor(var1))) + geom_line()
p <- p + labs(x="Year",y="SD",title="") #+ scale_colour_hue(guide=FALSE)
p

#Write out file with data
file.name <- paste0(wd,modunit,".mixmodcpe_compare_1998-2017.csv")
write.csv(cpe.comp, file=file.name)
```

APPENDIX 16 – AGE COMPOSITION OF LWAP SURVEY CATCHES WIIM AND WI345, 1998-2017

Age composition LWAP surveys WIIM																		
	Age Class																	
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1998	0.0690	0.1379	0.0345	0.1724	0.2759	0.0345	0.0345	0.1379	0.0345	0.0345	0.0000	0.0000	0.0000	0.0000	0.0000	0.0345	0.0000	0.0000
1999	0.0000	0.2143	0.2857	0.1429	0.1429	0.1429	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2000	0.1645	0.2039	0.2303	0.2303	0.0461	0.0461	0.0197	0.0263	0.0132	0.0066	0.0132	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	0.0800	0.2500	0.2700	0.1600	0.0700	0.0400	0.0200	0.0600	0.0000	0.0100	0.0000	0.0000	0.0000	0.0400	0.0000	0.0000	0.0000	0.0000
2002	0.0461	0.2928	0.1842	0.1118	0.1250	0.0888	0.0658	0.0362	0.0362	0.0000	0.0132	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2003	0.0455	0.1616	0.4394	0.1263	0.0404	0.0455	0.0960	0.0051	0.0051	0.0303	0.0051	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2004	0.1145	0.2169	0.2651	0.1566	0.0783	0.0422	0.0422	0.0301	0.0181	0.0241	0.0000	0.0120	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2005	0.1344	0.1781	0.2188	0.1938	0.1313	0.0531	0.0250	0.0219	0.0125	0.0063	0.0031	0.0125	0.0063	0.0031	0.0000	0.0000	0.0000	0.0000
2006	0.0431	0.2069	0.2931	0.1897	0.0948	0.0603	0.0129	0.0172	0.0560	0.0129	0.0043	0.0043	0.0043	0.0000	0.0000	0.0000	0.0000	0.0000
2007	0.0533	0.1667	0.2767	0.1633	0.1300	0.0767	0.0300	0.0200	0.0167	0.0400	0.0200	0.0033	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000
2008	0.0141	0.0763	0.3785	0.2373	0.1328	0.0480	0.0593	0.0141	0.0000	0.0198	0.0028	0.0085	0.0000	0.0000	0.0056	0.0000	0.0000	0.0028
2009	0.0161	0.1254	0.2251	0.3408	0.1608	0.0482	0.0289	0.0161	0.0096	0.0129	0.0032	0.0064	0.0032	0.0000	0.0000	0.0000	0.0032	0.0000
2010	0.0000	0.0497	0.1511	0.2526	0.3085	0.1118	0.0538	0.0269	0.0166	0.0145	0.0062	0.0062	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000
2011	0.0090	0.0113	0.1244	0.2851	0.1674	0.2534	0.0860	0.0271	0.0068	0.0090	0.0113	0.0023	0.0023	0.0045	0.0000	0.0000	0.0000	0.0000
2012	0.0301	0.0767	0.0521	0.2110	0.1918	0.1342	0.1808	0.0712	0.0274	0.0110	0.0055	0.0027	0.0000	0.0027	0.0000	0.0027	0.0000	0.0000
2013	0.0183	0.0823	0.0518	0.0488	0.1402	0.2104	0.1250	0.1921	0.0549	0.0305	0.0213	0.0030	0.0030	0.0061	0.0030	0.0000	0.0000	0.0091
2014	0.0526	0.1316	0.2368	0.1842	0.0000	0.0526	0.1053	0.0000	0.1316	0.1053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2015	0.0000	0.1111	0.1111	0.1481	0.1481	0.0741	0.0000	0.0000	0.1481	0.1852	0.0000	0.0741	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2016	0.0181	0.1156	0.2154	0.2041	0.1202	0.0612	0.0295	0.0476	0.0454	0.0340	0.0703	0.0159	0.0068	0.0045	0.0000	0.0091	0.0000	0.0023
2017	0.0305	0.0891	0.2545	0.2188	0.1450	0.0458	0.0254	0.0280	0.0204	0.0382	0.0153	0.0407	0.0178	0.0051	0.0051	0.0025	0.0025	0.0153

APPENDIX 16 cont'd

Age composition LWAP survey WI345																			
	Age class																		
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1998	0.0087	0.0232	0.0841	0.2145	0.2377	0.1565	0.0812	0.0435	0.0232	0.0174	0.0232	0.0203	0.0203	0.0087	0.0058	0.0058	0.0058	0.0058	0.0145
1999	0.0060	0.0179	0.0478	0.1731	0.2597	0.1433	0.1194	0.0418	0.0299	0.0209	0.0299	0.0269	0.0209	0.0119	0.0090	0.0060	0.0090	0.0060	0.0209
2000	0.0055	0.0820	0.1175	0.1721	0.2240	0.1339	0.0765	0.0683	0.0328	0.0137	0.0191	0.0164	0.0082	0.0082	0.0055	0.0055	0.0027	0.0027	0.0055
2001	0.0060	0.0422	0.2108	0.2831	0.1566	0.1265	0.0241	0.0060	0.0422	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0482
2002	0.0000	0.0367	0.0847	0.3362	0.2684	0.1130	0.0593	0.0311	0.0226	0.0085	0.0085	0.0056	0.0028	0.0028	0.0028	0.0028	0.0113	0.0000	0.0028
2003	0.0000	0.0293	0.1506	0.1967	0.2134	0.1632	0.0962	0.0711	0.0335	0.0167	0.0126	0.0084	0.0042	0.0042	0.0000	0.0000	0.0000	0.0000	0.0000
2004	0.0000	0.0511	0.1183	0.3522	0.2957	0.0457	0.0296	0.0296	0.0269	0.0134	0.0161	0.0081	0.0027	0.0000	0.0027	0.0000	0.0000	0.0027	0.0054
2005	0.0061	0.0729	0.1307	0.2492	0.2584	0.1641	0.0517	0.0243	0.0091	0.0152	0.0061	0.0030	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030
2006	0.0000	0.0068	0.0405	0.2534	0.2331	0.1588	0.0608	0.0304	0.0541	0.0169	0.0338	0.0203	0.0405	0.0372	0.0068	0.0034	0.0034	0.0000	0.0000
2007	0.0000	0.0186	0.0590	0.1957	0.2857	0.1366	0.0963	0.0528	0.0373	0.0217	0.0217	0.0342	0.0062	0.0093	0.0031	0.0062	0.0062	0.0000	0.0093
2008	0.0000	0.0078	0.0259	0.1943	0.2435	0.1891	0.0907	0.0881	0.0415	0.0181	0.0285	0.0155	0.0207	0.0052	0.0130	0.0104	0.0026	0.0026	0.0026
2009	0.0000	0.0000	0.0000	0.0000	0.4830	0.2381	0.0748	0.0408	0.0272	0.0204	0.0136	0.0204	0.0068	0.0136	0.0000	0.0068	0.0272	0.0204	0.0068
2010	0.0000	0.0094	0.0283	0.1085	0.1651	0.2358	0.1981	0.1085	0.0472	0.0330	0.0283	0.0142	0.0094	0.0047	0.0047	0.0000	0.0000	0.0000	0.0047
2011	0.0000	0.0139	0.0833	0.1910	0.1806	0.1389	0.1389	0.0868	0.0556	0.0347	0.0278	0.0139	0.0139	0.0069	0.0035	0.0035	0.0000	0.0000	0.0069
2012	0.0021	0.0063	0.0545	0.1866	0.2096	0.1153	0.0922	0.1279	0.0734	0.0398	0.0210	0.0147	0.0147	0.0168	0.0042	0.0021	0.0042	0.0000	0.0147
2013	0.0000	0.0038	0.0639	0.1880	0.2444	0.1165	0.1541	0.0714	0.0752	0.0301	0.0113	0.0188	0.0113	0.0075	0.0000	0.0000	0.0000	0.0038	0.0000
2014	0.0000	0.0070	0.0490	0.1224	0.1294	0.1853	0.1399	0.1189	0.0769	0.0769	0.0175	0.0245	0.0210	0.0105	0.0105	0.0035	0.0035	0.0035	0.0000
2015	0.0042	0.0336	0.0588	0.1639	0.1471	0.0546	0.1134	0.0588	0.0714	0.0420	0.0672	0.0252	0.0126	0.0252	0.0168	0.0126	0.0168	0.0084	0.0672
2016	0.0023	0.0164	0.0656	0.1382	0.1663	0.1897	0.1218	0.0937	0.0632	0.0398	0.0211	0.0398	0.0117	0.0047	0.0047	0.0047	0.0023	0.0000	0.0141
2017	0.0096	0.0096	0.0192	0.0673	0.0769	0.1538	0.1538	0.0769	0.0577	0.0913	0.0625	0.0192	0.0240	0.0144	0.0288	0.0144	0.0096	0.0144	0.0962
2018	0.0000	0.0135	0.0000	0.0270	0.1622	0.1892	0.1622	0.0676	0.0811	0.0135	0.1216	0.0405	0.0270	0.0676	0.0000	0.0000	0.0000	0.0135	0.0135
2019	0.0000	0.0063	0.0532	0.1367	0.2557	0.2949	0.1215	0.0544	0.0177	0.0139	0.0165	0.0101	0.0038	0.0013	0.0063	0.0025	0.0025	0.0000	0.0025

APPENDIX 17 – AGE-LENGTH KEY CWT-MARKED LAKE TROUT WI345 ALL FISHERIES 1986-2017

Length	Age class																												
bin	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
420	0.032787	0.245902	0.540984	0.147541	0.032787	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
430	0.04	0.2	0.626667	0.08	0.026667	0.013333	0.013333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
440	0.044776	0.208955	0.537313	0.164179	0.044776	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
450	0	0.162791	0.569767	0.209302	0.046512	0	0.011628	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
460	0.010753	0.053763	0.602151	0.268817	0.053763	0.010753	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
470	0.015385	0.115385	0.576923	0.223077	0.061538	0	0.007692	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
480	0.014815	0.074074	0.459259	0.377778	0.044444	0.014815	0.014815	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
490	0.023256	0.087209	0.476744	0.325581	0.05814	0.011628	0.011628	0.005814	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0.005025	0.090452	0.336683	0.477387	0.065327	0.025126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
510	0.008264	0.082645	0.31405	0.483471	0.078512	0.008264	0.020661	0.004132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
520	0.003876	0.062016	0.306202	0.527132	0.065891	0.027132	0.003876	0.003876	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
530	0.003745	0.089888	0.277154	0.501873	0.116105	0.011236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
540	0.004219	0.088608	0.189873	0.548523	0.130802	0.025316	0.012658	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
550	0.004082	0.077551	0.22449	0.473469	0.187755	0.012245	0.016327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
560	0.010638	0.053191	0.265957	0.468085	0.159574	0.026596	0.010638	0.005319	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
570	0	0.086957	0.192547	0.521739	0.149068	0.024845	0.018634	0.006211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
580	0	0.04023	0.333333	0.367816	0.206897	0.045977	0	0	0.005747	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
590	0	0.072289	0.337349	0.313253	0.204819	0.042169	0.018072	0.012048	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
600	0	0.040698	0.325581	0.290698	0.226744	0.081395	0.034884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
610	0	0.044872	0.269231	0.314103	0.217949	0.083333	0.044872	0.019231	0.00641	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
620	0	0.012422	0.248447	0.285714	0.254658	0.142857	0.037267	0.006211	0.006211	0.006211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
630	0	0.005181	0.150259	0.341969	0.26943	0.119171	0.082902	0.020725	0.005181	0.005181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
640	0	0.004762	0.157143	0.280952	0.257143	0.161905	0.085714	0.019048	0.019048	0.009524	0	0.004762	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
650	0	0.008368	0.079498	0.292887	0.305439	0.179916	0.104603	0.020921	0.004184	0.004184	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
660	0	0	0.087273	0.236364	0.287273	0.221818	0.094545	0.04	0.014545	0.003636	0.003636	0	0	0.003636	0	0.003636	0.003636	0	0	0	0	0	0	0	0	0	0	0	0	0
670	0	0	0.053333	0.19	0.293333	0.236667	0.13	0.046667	0.016667	0.02	0.006667	0.003333	0	0	0	0	0	0.003333	0	0	0	0	0	0	0	0	0	0	0	0
680	0	0.003115	0.024922	0.165109	0.283489	0.249221	0.149533	0.065421	0.021807	0.009346	0.006231	0.006231	0.003115	0.006231	0.006231	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690	0	0	0.018405	0.122699	0.297546	0.242331	0.147239	0.092025	0.033742	0.018405	0.01227	0.003067	0.003067	0	0	0.003067	0	0.003067	0	0.003067	0	0	0	0	0	0	0	0	0	0
700	0	0.002786	0.011142	0.114206	0.203343	0.250696	0.197772	0.094708	0.052925	0.044568	0.008357	0.005571	0.002786	0	0.008357	0	0	0.002786	0	0	0	0	0	0	0	0	0	0	0	0
710	0	0	0	0.112532	0.184143	0.204604	0.186701	0.130435	0.066496	0.028133	0.028133	0.028133	0.012788	0.005115	0.007673	0	0	0	0.002558	0	0	0.002558	0	0	0	0	0	0	0	0
720	0	0	0	0.04336	0.149051	0.243902	0.200542	0.173442	0.086721	0.04607	0.01355	0.01355	0.00542	0.00271	0.01355	0.00542	0	0	0	0	0	0.00271	0	0	0	0	0	0	0	0
730	0	0	0.018634	0.024845	0.124224	0.270186	0.195652	0.145963	0.074534	0.062112	0.049689	0.018634	0.006211	0.006211	0	0	0	0	0	0.003106	0	0	0	0	0	0	0	0	0	0
740	0	0.002778	0	0.027778	0.105556	0.180556	0.216667	0.161111	0.083333	0.102778	0.041667	0.027778	0.013889	0.013889	0.008333	0.005556	0.002778	0.002778	0	0.002778	0	0	0	0	0	0	0	0	0	0
750	0	0	0	0.00974	0.074675	0.181818	0.181818	0.194805	0.116883	0.113636	0.045455	0.019481	0.029221	0.006494	0.00974	0.003247	0.003247	0.003247	0.003247	0	0	0.003247	0	0	0	0	0	0	0	0
760	0	0.003003	0	0.009009	0.054054	0.102102	0.141141	0.186186	0.168168	0.096096	0.078078	0.039039	0.048048	0.033033	0.018018	0.006006	0	0.015015	0	0	0	0	0	0.003003	0	0	0	0	0	0
770	0	0.003356	0.006711	0.003356	0.013423	0.100671	0.11745	0.171141	0.161074	0.114094	0.107383	0.063758	0.030201	0.020134	0.016779	0.030201	0.010067	0.013423	0.010067	0	0.006711	0	0	0	0	0	0	0	0	0
780	0	0	0	0.003279	0.013115	0.062295	0.108197	0.186885	0.137705	0.163934	0.114754	0.055738	0.042623	0.04918	0.019672	0.009836	0.016393	0.006557	0	0	0.006557	0	0.003279	0	0	0	0	0	0	0
790	0	0	0.003745	0	0.018727	0.052434	0.089888	0.104869	0.183521	0.17603	0.134831	0.048689	0.048689	0.044944	0.022472	0.014981	0.029963	0.007491	0.007491	0.003745	0.003745	0	0.003745	0	0	0	0	0	0	0
800	0	0	0.004739	0	0.014218	0.037915	0.090047	0.094787	0.109005	0.189573	0.137441	0.080569	0.066351	0.037915	0.023697	0.033175	0.009479	0.033175	0.004739	0.009479	0.018957	0.004739	0	0	0	0	0	0	0	0
810	0	0	0.004762	0	0	0.009524	0.057143	0.066667	0.157143	0.166667	0.128571	0.085714	0.090476	0.071429	0.052381	0.02381	0.019048	0.014286	0.019048	0.009524	0.009524	0.009524	0	0.004762	0	0	0	0	0	0
820	0	0	0	0	0.005747	0.045977	0.028736	0.051724	0.103448	0.201149	0.16092	0.08046	0.08046	0.028736	0.068966	0.057471	0.017241	0.011494	0.011494	0.005747	0.017241	0.011494	0.005747	0	0	0.005747	0	0	0	0
830	0	0	0	0	0.006993	0.013986	0.034965	0.06993	0.104895	0.195804	0.181818	0.118881	0.076923	0.041958	0.041958	0	0.020979	0.013986	0.020979	0	0.020979	0.013986	0.020979	0	0	0	0	0	0	0
840	0	0	0	0	0	0.007692	0.007692	0.030769	0.069231	0.138462	0.169231	0.169231	0.1	0.053846	0.053846	0.030769	0.030769	0.061538	0.030769	0.015385	0.007692	0	0.007692	0.007692	0	0	0	0	0	0.007692
850	0	0	0	0	0.008475	0	0.016949	0	0.076271	0.161017	0.161017	0.194915	0.050847	0.042373	0.059322	0.067797	0.033898	0.025424	0.008475	0.025424	0.016949	0.016949	0.008475	0.008475	0	0.008475	0	0.008475	0	0
860	0	0	0	0	0	0	0.010989	0.021978	0.065934	0.197802	0.186813	0.131868	0.087912	0.032967	0.043956	0.065934	0.043956	0.010989	0	0.032967	0.021978	0.010989	0.021978	0	0.010989	0	0	0	0	0
870	0	0	0	0	0	0	0	0	0.098592	0.126761	0.169014	0.014085	0.098592	0.042254	0.084507	0.056338	0.084507	0.070423	0.028169	0.014085	0.028169	0.042254	0.028169	0	0.014085	0	0	0	0	0
880	0	0	0	0	0	0.015152	0.015152	0.015152	0.030303	0.075758	0.106061	0.151515	0.121212	0.106061	0.075758	0.045455	0.045455	0.060606	0	0.075758	0.030303	0.015152	0	0	0	0	0	0.015152	0	0
890	0	0	0	0	0	0	0.03125	0	0.09375	0.15625	0.15625	0.140625	0.015625	0.046875	0.046875	0.0625	0.03125	0.046875	0.0625	0.015625	0.03125	0.03125	0.03125	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0.081081	0.162162	0.027027	0.162162	0.081081	0.081081	0.054054	0.081081	0.054054	0	0.054054	0.027027	0.054054	0.081081	0	0	0	0	0	0	0
910	0	0	0	0	0	0	0	0	0	0.095238	0.190476	0.190476	0.047619	0.047619	0.047619	0.095238	0	0.047619	0	0.047619	0.047619	0.095238	0	0.047619	0	0	0	0	0	0
920	0	0	0	0	0.066667	0	0	0	0	0.2	0.266667	0.2	0	0.066667	0	0	0.066667	0	0	0.066667	0	0	0	0	0	0	0	0	0	0.066667
930	0	0	0	0	0	0	0	0	0	0	0.090909	0	0.090909	0	0.090909	0	0	0.272727	0.090909	0.090909	0.090909	0.090909	0.090909	0	0	0	0	0	0	0
940	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0	0	0	0	0	0.2	0	0.2	0	0	0	0	0.2	0	0
950	0	0	0	0	0	0	0	0	0	0.125	0	0.125	0	0	0	0.125	0.25	0.125	0	0.125	0	0	0.125	0	0	0	0	0	0	0
960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0
970	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.4	0	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0
>979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 18 – PROPORTION WILD 1971-2016 YEAR CLASSES

Year	WI345			WIIM		
class	stocked	wild	%wild	stocked	wild	%wild
1971	1	0	0.0%	0	0	
1972	0	0		0	0	
1973	4	0	0.0%	0	0	
1974	6	0	0.0%	0	0	
1975	8	0	0.0%	0	0	
1976	18	0	0.0%	0	0	
1977	34	0	0.0%	0	0	
1978	68	0	0.0%	0	0	
1979	82	0	0.0%	0	0	
1980	105	2	1.9%	0	0	
1981	177	3	1.7%	0	0	
1982	133	1	0.7%	0	0	
1983	51	3	5.6%	0	0	
1984	564	1	0.2%	54	1	1.8%
1985	199	1	0.5%	77	0	0.0%
1986	92	0	0.0%	76	0	0.0%
1987	79	7	8.1%	44	0	0.0%
1988	110	1	0.9%	129	3	2.3%
1989	858	3	0.3%	363	2	0.5%
1990	1525	6	0.4%	286	0	0.0%
1991	1638	3	0.2%	532	3	0.6%
1992	835	12	1.4%	366	2	0.5%
1993	434	8	1.8%	200	3	1.5%
1994	669	8	1.2%	724	0	0.0%
1995	456	7	1.5%	503	3	0.6%
1996	601	9	1.5%	376	4	1.1%
1997	524	13	2.4%	343	2	0.6%
1998	665	11	1.6%	550	2	0.4%
1999	827	8	1.0%	407	1	0.2%
2000	442	7	1.6%	482	5	1.0%
2001	493	1	0.2%	533	9	1.7%
2002	462	5	1.1%	764	13	1.7%
2003	571	8	1.4%	1036	7	0.7%
2004	151	17	10.1%	681	9	1.3%
2005	288	33	10.3%	514	12	2.3%
2006	301	15	4.7%	293	12	3.9%
2007	226	24	9.6%	96	14	12.7%
2008	133	31	18.9%	177	15	7.8%
2009	212	41	16.2%	217	23	9.6%
2010	300	29	8.8%	465	34	6.8%
2011	251	12	4.6%	425	50	10.5%
2012	309	18	5.5%	257	67	20.7%
2013	153	4	2.5%	99	48	32.7%
2014	28	3	9.7%	47	45	48.9%
2015	7	9	56.3%	35	43	55.1%
2016	0	0		4	9	69.2%

APPENDIX 19 – PROPORTI0N WILD LAKE TROUT AT AGE 1986-2017

WI345																		
Year	Age Class																	
class	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1987	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1988	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1989	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1990	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1991	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1993	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1994	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1995	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000
1996	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000	0.0000
1997	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000	0.0000
1998	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000	0.0000
1999	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187	0.0000
2000	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167	0.0187
2001	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075	0.0167
2002	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556	0.0075
2003	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018	0.0556
2004	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050	0.0018
2005	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000	0.0050
2006	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814	0.0000
2007	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090	0.0814
2008	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035	0.0090
2009	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039	0.0035
2010	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018	0.0039
2011	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142	0.0018
2012	0.1621	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181	0.0142
2013	0.0881	0.1621	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118	0.0181
2014	0.0456	0.0881	0.1621	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151	0.0118
2015	0.0550	0.0456	0.0881	0.1621	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148	0.0151
2016	0.0255	0.0550	0.0456	0.0881	0.1621	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242	0.0148
2017	0.0968	0.0255	0.0550	0.0456	0.0881	0.1621	0.1890	0.0960	0.0475	0.1028	0.1012	0.0138	0.0107	0.0020	0.0156	0.0096	0.0163	0.0242

APPENDIX 19 Cont'd

WIIM																		
Year	Age Class																	
class	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1986	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1987	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1988	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1989	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1990	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1991	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1993	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1994	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1995	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1997	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1998	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1999	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000
2000	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000
2001	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000	0.0000
2002	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000	0.0000
2003	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182	0.0000
2004	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000	0.0182
2005	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000	0.0000
2006	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000	0.0000
2007	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227	0.0000
2008	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055	0.0227
2009	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000	0.0055
2010	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056	0.0000
2011	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054	0.0056
2012	0.0958	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148	0.0054
2013	0.0681	0.0958	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000	0.0148
2014	0.1053	0.0681	0.0958	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059	0.0000
2015	0.2068	0.1053	0.0681	0.0958	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105	0.0059
2016	0.3265	0.2068	0.1053	0.0681	0.0958	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058	0.0105
2017	0.4891	0.3265	0.2068	0.1053	0.0681	0.0958	0.0781	0.1273	0.0393	0.0228	0.0130	0.0067	0.0167	0.0166	0.0103	0.0025	0.0036	0.0058