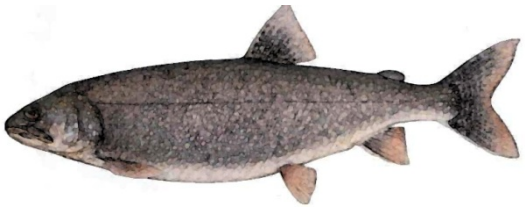
Technical Fisheries Committee Administrative Report 2018: Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron, and Michigan, with Recommended Yield and Effort Levels for 2018



A Report Submitted by the Modeling Subcommittee to the Technical Fisheries Committee

S.J. Lenart (United States Fish and Wildlife Service)
D.C. Caroffino (Michigan Department of Natural Resources)

Editors

Recommended citation formats:

Entire report: Modeling Subcommittee, Technical Fisheries Committee. 2018. Technical Fisheries Committee Administrative Report 2018: Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan, with Recommended Yield and Effort Levels for 2018. http://www.michigan.gov/greatlakesconsentdecree

Section: Lenart, S.J. and Caroffino, D.C. 2018. Executive Summary *in* Lenart, S.J. and Caroffino, D.C., eds. Technical Fisheries Committee Administrative Report 2018: Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan, with Recommended Yield and Effort Levels for 2018. http://www.michigan.gov/greatlakesconsentdecree

Table of Contents

EXECUTIVE SUMMARY

Prepared by Stephen J. Lenart and David C. Caroffino

This document outlines the status of Lake Trout and Lake Whitefish stocks in the 1836 Treaty (hereafter "Treaty") waters of the Great Lakes as assessed by the 2000 Consent Decree's (Decree) Modeling Subcommittee (MSC). The main purposes of this report are to 1) describe the status of each managed stock in the context of establishing harvest limits according to the terms of the Decree; and 2) document important technical changes in the stock assessment process. For more in-depth technical detail on stock-assessment structure, see the 2012 version of this report available at https://www.michigan.gov/documents/dnr/2012StatusStocksReport_403608_7.pdf

Except in a few cases, statistical catch-at-age (SCAA) models have been developed for each management unit where the provisions of the Decree apply. Estimates from the SCAA models are used in projection models that incorporate the mortality target and allocation rules of the Decree to calculate model-recommended yield limits for these units. Annual mortality rate targets for Lake Trout are either 40 or 45%, depending on the area, and a 65% annual mortality target has been established for Lake Whitefish, though a complementary rule reduces mortality below the target rate if the spawning potential ratio (SPR) falls below 0.2. Model-derived yield limits, along with the actual yield and effort limits for 2018, are provided in Table 1.

Table 1. 2018 yield and effort limits

Species	Lake	Management unit	Model-generated yield limit (lb)	Actual yield limit (lb)	Gill net limit (ft)
Lake Trout	Superior	MI-5	170,209	170,209	NA
		MI-6	195,888	195,888	3,089,000
		MI-7	172,993	172,993	11,024,000
	Huron	MH-1	851,545	TBD	TBD
		MH-2	656,753	TBD	NA
	Michigan	MM-123	441,779	630,000	10,380,000
		MM-4	126,603	171,500	957,000
		MM-5	82,930	98,000	244,000
		MM-67	165,352	230,216	NA
Lake Whitefish	Superior	WFS-04	87,000	87,000	NA
		WFS-05	286,900	286,900	NA
		WFS-06	NA	210,000	NA
		WFS-07	689,200	689,200	NA
		WFS-08	294,700	294,700	NA
	Huron	North Huron	438,700	379,900	NA
		WFH-05	654,500	394,000	NA
	Michigan	WFM-01	2,131,600	2,131,600	NA
		WFM-02	699,200	362,300	NA
		WFM-03	800,400	800,400	NA
		WFM-04	427,200	427,200	NA
		WFM-05	352,200	352,200	NA
		WFM-06	117,200	125,000	NA
		WFM-07	NA	350,000	
		WFM-08	353,300	500,000	NA

In instances where the actual yield limit for a Lake Trout or shared-allocation Lake Whitefish unit (WFS-04, WFS-05, WFM-01, WFM-06 and WFM-08) differs from model-generated yield limit, a brief explanation is provided below. For non-shared-allocation whitefish units, where the tribes have exclusive commercial fishing opportunities, harvest regulation guidelines (HRGs), as established by the Chippewa-Ottawa Resource Authority (CORA), serve as final yield limits - these may differ from the model-generated limits. SCAA models for Lake Whitefish are on a one-year lag, so estimates reported here are derived from data through 2016. Estimates from SCAA models for Lake Trout are derived from data through 2017.

Lake Trout

In Lake Superior, lean Lake Trout are self-sustaining, and the SCAA models and target mortality rates apply to these wild fish in three management areas (MI-5, MI-6, and MI-7). There has been no effort to construct an assessment model for Lake Trout in unit MI-8 due to its status as a deferred area. Unit MI-5 spans waters in both 1836 and 1842 Treaty areas - to date, commercial harvest of Lake Trout from unit MI-5 has occurred exclusively in 1842 Treaty waters.

Modest increases in recruitment appear to have stabilized population levels in MI-5 after a decade-long decline that began in the late-1990s. Abundance levels appear to be have been more stable in units MI-6 and MI-7 during this period. A more pronounced increase in recruitment is evident in MI-7 in recent years and estimated abundance is now comparable to levels not observed since the late 1980s. Estimated mortality rates of lean Lake Trout are generally low throughout the 1836 waters of Lake Superior and, aside from natural mortality, sea lamprey-induced mortality (SLIM) remains the largest individual source of mortality in all modeled Superior units. Average SLIM rates are higher in units MI-6 and MI-7 (0.08 y^{-1}) than unit MI-5 (0.02 y^{-1}).

Both commercial (<0.05 y^{-1}) and recreational (<0.03 y^{-1}) fishing mortality remains low throughout the Treaty waters of Lake Superior, despite harvest nearing the time series high for both the commercial (44K lb) and recreational (28K lb) fisheries in unit MI-6 during 2017. Total fishery yield of lean Lake Trout has only rarely eclipsed 50K lb in any modeled unit since the inception of the Decree and mortality of lean Lake Trout remains below the maximum target rate of 45% throughout Lake Superior Treaty waters.

Wild Lake Trout continue to recruit to the adult stock in Lake Huron and most cohorts younger than age 12 are dominated by naturally produced fish. Roughly 40% of the mature stock in North-Central Lake Huron (NCLH) is of wild origin. As detailed in the 2017 report, a single stock assessment is now used to model the Lake Trout population in MH-1, MH-2 and adjacent Ontario waters. The structural changes and revised methodological approaches implemented last year remained largely unchanged in 2018.

The most recent NCLH assessment estimates that natural mortality (0.09 y^{-1}) has generally been the single largest source of mortality in NCLH since 2001, despite the substantial fishery harvest that occurs in the unit. Yield of Lake Trout from commercial fisheries in NCLH has averaged 405K lb during 2012-2017, with the majority (57-70%) of the yield associated with CORA fisheries operating in statistical district MH-1 and the remainder coming from Ontario waters. Estimated commercial fishing mortality rates associated with these yield levels are below 0.1 y^{-1}. During 2006 to 2013, yield from recreational fisheries in the US waters of NCLH was fairly consistent (range 36-52K lb per year); recreational yields have since increased markedly, exceeding 125K lb in both 2016 and 2017. Recreational fishing mortality was estimated to be below 0.03 y^{-1} in 2017. SLIM has been below 0.06 y^{-1} since 2001 and the 2016 estimate (0.01 y^{-1}) was the lowest in the time series.

Total annual mortality is estimated to be stable, and quite low, in NCLH – the current assessment suggests that annual mortality has remained below 22% since 2001. This lower mortality regime allowed spawning biomass to build almost linearly during 2002-2010. Adult biomass leveled off over the subsequent five years but has since increased to a time-series high in 2017, driven by higher recruitment associated with the 2009-2012 year classes. As of this

writing, 2018 harvest limits for MH-1 and MH-2 have not been established.

The Lake Michigan Lake Trout SCAA models apply only to stocked fish. Although wild fish are becoming more abundant in discrete areas of the lake, as a whole, Lake Trout recovery in Lake Michigan is well behind that of the other lakes. Recent observations suggest a decline in the survival of stocked fish in units MM-123, MM-4, and MM-5, a pattern that bears watching. Mortality rates referenced below represent averages for Lake Trout ages 6-11.

During 2000-2013, estimated annual mortality on Lake Trout in northern Lake Michigan unit MM-123 averaged 61% and the adult stock remained at depressed levels. Sea lamprey were a significant factor during this period - SLIM exceeded 0.2 y^{-1} in most years, reaching as high as 0.33 y^{-1} in 2007. Increased stocking helped the abundance of young fish build after 2009 and improved sea lamprey control (SLIM < 0.1 y^{-1} during 2014-2016) has contributed to increased spawning biomass levels during the past five years. Fishery yield and mortality remain substantial, however. Commercial fishing is the largest source of mortality in MM-123 (average $F_C = 0.3\ y^{-1}$ during 2015-2017) and recreational fishery yield has eclipsed 40K lb for three consecutive years (avg $F_R = 0.06\ y^{-1}$). Reduced predation by sea lamprey (SLIM <0.05 y^{-1}) have helped keep estimated annual mortality in the 45% range for the past three years. The Parties agreed to continue the 630K lb limit for Lake Trout established by a Decree amendment in 2017.

In unit MM-4, fisheries have harvested between 150-200K lb of Lake Trout annually since 2009 and during this period annual mortality has been above the 45% target. In 2017, recreational fishing mortality was on par with commercial fishing mortality (~0.3 y^{-1}), the highest observed since the inception of the Decree. As in the north, mortality from sea lamprey has declined substantially, reaching a time-series low during 2016 (0.01 y^{-1}). Increased recruitment has helped maintain spawning biomass in the 90K lb range over the past five years. A 2009 amendment to the Decree establishes base harvest limits in this unit, and it includes a transfer provision that increases CORA's harvest limit by the amount that the state remained below its harvest limit the prior year.

Mortality rates in units MM-5 and MM-67 are below target and natural mortality is the largest individual source of mortality in these units. Annual fishery yield of Lake Trout from MM-5 has been consistent (80-100K lb) for the past five years, with the recreational fishery responsible for roughly 70% of the yield. Estimated total fishing mortality has averaged 0.12 y^{-1} during this period. Mortality from sea lamprey predation has been below 0.02 y^{-1} in four of the past five years and estimated spawning biomass has been stable around 200K lb since 2011. Despite meeting the sea lamprey reduction target provided in the 2009 Decree amendment, the Parties agree to establish harvest limits in MM-5 at levels consistent with the amendment. The commercial fishery in MM-67 has largely been absent since 2012 and commercial fishing mortality has been below 0.02 y^{-1} for the entire modeled time series. Recreational fishery yield eclipsed 100K lb the past two years, the highest levels observed since the early 2000s. Fishing mortality rates associated with these recent yield levels are in the 0.1 y^{-1} range. As in other Michigan units, SLIM has declined substantially in recent years (<0.02 y^{-1} the past two years) and spawning biomass increased markedly in MM-67 during the decade that followed implementation of the Decree, peaking around 2010. After a slight decline, estimated spawning biomass in MM-67 is once again on a positive trajectory. The Decree's 15% rule was implemented in MM-67, limiting the decline in the harvest limit to a level 15% below the 2017 limit.

Lake Whitefish

Lake Whitefish populations are supported by natural reproduction throughout the Treaty-ceded waters and projected harvest limits are allocated to CORA- and, where applicable, State-licensed commercial fisheries. The assessment model for Lake Superior unit WFS-06 has not been updated since the mid- 2000s due to the small fishery and a lack of commercial monitoring data. There has been no attempt to fit an assessment model for Lake Michigan unit WFM-07, where no harvest has occurred in the past five years. No information is provided for these units in the section that follows. Lake Superior unit WFS-04

spans waters in both 1836 and 1842 Treaty areas – most of the commercial harvest of Lake Whitefish occurs in the latter. In contrast to Lake Trout mortality rates referenced in the preceding section, mortality rates that follow are for the age class most vulnerable to fisheries.

Lake Whitefish populations in Lake Superior are among the most stable in 1836 Treaty waters, primarily as a result of more consistent recruitment relative to lakes Michigan and Huron. Fishery yields in western Lake Superior Treaty units (WFS-04 and WFS-05) have generally remained in the 50-100K lb range throughout the Decree and recent fishing mortality rates on the most vulnerable age class have been below 0.3 y^{-1}. Estimated annual mortality was nearly identical (33%), and well below target, in these units during 2016. Fishery catch rates are generally stable in these units and patterns of adult biomass showed a similar upward pattern during the mid- to late-2000s. Patterns diverge after 2010, with WFS-05 showing increased recruitment and biomass, in contrast to WFS-04. Additional observations will be required to ascertain whether these disparate patterns continue. In eastern Lake Superior (WFS-07 and WFS-08), fisheries are more intense, and mortality is higher. Yields from WFS-07 have ranged between 400-500K lb since 2010 and fishing mortality has increased during this period. The 2016 estimate was >0.8 y^{-1} on the most vulnerable age class. Yields had been similarly consistent, though lower in scale, in adjacent WFS-08 during 2010-2015, but 2016 yield exceeded 200K lb for the first time in the modeled time series and annual mortality (72%) exceeded the target rate. Fishery monitoring data suggest a strong contribution from the 2010 year class in these eastern units and model estimates of this cohort's abundance at age 6 are among the highest in the time series; as a result adult biomass is estimated to be stable to increasing, despite the high mortality. The progression of this age class through the fishery should be of particular interest to managers.

In northern Lake Huron Treaty waters (WFH-01 thru WFH-04), dramatic declines in recruitment that commenced in the early 2000s and substantial sea lamprey and fishing mortality have combined to drive Lake Whitefish stocks down to their lowest levels since the late 1970s. This area produced an average of 1.71M lb of yield during the 1990s, and as recently as 2006, yield exceeded 1M lb. Roughly 180K lb of whitefish were harvested from northern Lake Huron in 2016 and catch rates are approximately 10% of those observed during the peak of the fishery. The latest version of the assessment suggests that annual mortality has exceeded the 65% target through much of the model time series – a distinct departure from previous assessments and likely a product of structural changes to the model (see unit summary). A slight uptick in estimated recruitment at the end of the time series (as in eastern Lake Superior, associated with the 2010 cohort) halted the near 20-year decline in estimated biomass, which bottomed out in 2013 at more than three-times below the 1995 peak. Similar patterns in recruitment and sea lamprey mortality are evident in adjacent unit WFH-05, though estimated fishing and sea lamprey mortality are lower here than in the north. Nonetheless, fishery yield has declined in WFH-05 for nine consecutive years and less than 34K lb of Lake Whitefish were harvested in WFH-05 during 2016, a 75% decline from the previous low established in 2015. Trap-net effort was 142 lifts in 2016, a time series low.

Lake Whitefish recruitment patterns in northern Lake Michigan (WFM-01 thru WFM-04) are fairly synchronous and similar to those in Lake Huron, with similarly predictable consequences: declining abundance, fishery yields and catch rates. Less than one million pounds of whitefish were harvested in these four northern units combined during 2016, the lowest yield since the late 1970s. Trap-net effort has not declined as it has in Lake Huron, though reported gill-net effort declined by 24% in 2016 from the roughly 10 million feet reported in 2013-2015 for units WFM-02-WFM-04 combined. Annual mortality rates are below target in these northern units (range 25-39%) and the overall mortality scale is lower than in previous assessments, in large part to the way natural mortality was estimated during this assessment cycle (see *Technical Changes* section). As in eastern Lake Superior and northern Lake Huron, a signal exists in most northern Lake Michigan units for a modestly strong 2010 year class.

Recruitment patterns in unit WFM-05 mirror those in the north, peaking in the early 2000s, but

biomass declines have been muted by increased growth and lower overall fishing mortality through time. Fisheries are fairly minor here (yield range 35-60K lb during 2011-2016) and fishing mortality has been below 0.04 y^{-1} since 2011. Total annual mortality was estimated at 22% in WFM-05 during 2016, the lowest in Treaty waters. Similarly low mortality rates were estimated in unit WFM-06 (24%), but here recruitment patterns suggest the presence of a strong mid-2000s year class not evident in the north – likely a product of recruitment from the south (WFM-08), which shows a similar pattern. Yield of whitefish from WFM-06 in 2016 was the lowest in the time series at roughly 13K lb and fishery effort continues to decline, diminishing prospects for future modeling efforts. The aforementioned mid-2000 year class appeared to carry the fishery in unit WFM-08 for a few additional years when compared to the north, but recruitment and biomass has declined markedly since then. Fishery yields and catch rates have increased modestly the last two years, but the fishery continues to be supported by older fish, with no signal for recent recruits. Nonetheless, estimated fishing mortality was modest (0.15 y^{-1}) in 2016 and annual mortality (32%) remained well below the established maximum target. The TFC recommended continuance of the conditional constant catch policy for units WFM-06 and WFM-08 in 2018, with harvest limits consistent with the reduced levels established during 2017.

Technical Changes

Information in this section is generally reserved for technical changes that were implemented across multiple assessments for a particular species. The individual unit summaries provide detail on major structural changes or assumptions that affect a particular assessment; for this reason, certain individual unit summaries provide more detail than others.

Natural Mortality estimation in Lake Whitefish assessments

For Lake Whitefish assessments, the prior used to inform estimation of natural mortality (*M*) during model fitting derives from an assumed relationship between natural mortality and growth and water temperature (Pauly 1980). In most assessments, the assigned standard deviation around this prior was sufficiently small (0.01 or lower) so that the estimate would not deviate meaningfully from the Pauly-derived prior. In instances where empirical estimates were available, these may have been used to inform the estimate, though with a similarly restrictive standard deviation. During the most recent assessment cycle for Lake Whitefish, we evaluated the consequences of loosening the standard deviation, allowing greater deviation from the Pauly-prior during model fitting. In assessments for lakes Huron and Michigan, this loosening of the prior had the effect of consistently reducing the estimate of *M*, often to levels (<=0.2 yr^{-1}) that were well below the range of published empirical estimates (>0.3 yr^{-1}). These reduced estimates are more in line with a recent conceptual model that natural mortality must be lower, given that otolith aging routinely reveals fish >age 20 in broad areas of these lakes, even in more heavily fished stocks. Furthermore, the assessments tended to perform better, with much reduced scaling, when *M* fell in this lower range. A more explicit evaluation and justification is warranted on this topic; nonetheless we have tentatively adopted a revised approach that allows *M* to depart further from the Pauly-derived prior. A workgroup has been formed and tasked with conducting a literature review of available empirical estimates and the methodology employed in their derivation.

MANAGEMENT UNIT DESCRIPTIONS

The Great Lakes are divided into spatially explicit management units, which differ for Lake Trout and Lake Whitefish. The provisions of the 2000 Consent Decree apply to each of the individual management units either partially or wholly contained within the 1836 Treaty-ceded (Treaty) waters of the Great Lakes. What follows are descriptions of the nine Lake Trout management units (Figure 1) and 15 Lake Whitefish management units (Figure 2) that are assessed by the Modeling Subcommittee, with an emphasis on major physical features and landmarks. Table 2 provides area estimates for each management unit as derived from spatial analysis of available shapefile layers in ArcGIS™ (ESRI).

Lake Trout Management Units

MI-5: Lake trout management unit MI-5 extends from Pine River Point (west of Big Bay) to Laughing Fish Point (east of Marquette). This management unit includes Stannard Rock, an offshore shoal about 72 km north of Marquette, and is in both the 1836 (250,000 ha) and 1842 Treaty waters (124,000 ha). The 1836 Treaty area extends east from the north-south line established by the western boundaries of grids 1130, 1230, 1330, 1430, and 1530. This unit has a wide bathymetric range with depths beyond 235 m.

MI-6: Lake trout management unit MI-6 extends from Laughing Fish Point (east of Marquette) to Au Sable Point (east of Munising). This management unit includes Big Reef, an offshore reef complex about 32 km northeast of Munising. This management unit contains the deepest waters of Lake Superior with soundings deeper than 400 m.

MI-7: Lake trout management unit MI-7 extends from Au Sable Point (west of Grand Marais) to Little Lake Harbor (east of Grand Marais). This management unit has complex bathymetry with many lacustrine ridges, trenches, and slopes.

MH-12: Lake trout assessment unit MH-12 comprises Lake Huron statistical districts MH-1 and MH-2 and includes biological data from adjacent Ontario quota management areas 4-1, 4-2, and 4-3. MH-1 is located in northern Lake Huron and extends from the Mackinac Bridge south to the border between grids 607 and 608. The management unit has a wide bathymetric range with areas in grids 407 and 408 as deep as 130 m. This statistical district lies completely within 1836 Treaty waters. On the Michigan shore this district encompasses the ports of Saint Ignace, Mackinaw City, Cheboygan, Hammond Bay, and Rogers City. The St. Marys River, connecting Lakes Superior and Huron, flows into Lake Huron in grid 306. The majority of Lake Huron's historically important Lake Trout spawning reefs and shoals are located in MH-1. The Drummond Island Refuge is located in grids 307, the northern ½ of grid 407, and Michigan waters of grids 308, 408, 409, and 410, and covers 72,000 ha of 1836 Treaty waters. Retention of Lake Trout in the refuge is prohibited. Statistical district MH-2 lies directly to the south of MH-1 and includes both 1836 Treaty waters and non-treaty waters, divided by a NE line running near the tip of Thunder Bay's North Point to the international border. The Michigan ports of Presque Isle and Alpena are contained in this statistical district. MH-2 also has a wide bathymetric range, with areas in grids 714 and 814 deeper than 210 m. District MH-2 contains a limited number of historically important nearshore Lake Trout spawning reefs and shoals. These reefs are located near Middle Island and along Thunder Bay's North and South Points. Six Fathom Bank, a large offshore reef complex, bisects districts MH-2 and MH-3. A portion of the Six Fathom Bank Refuge is contained in unit MH-2, covering the eastern half of grid 913 grid 914 and Michigan waters of grid 915. Retention of Lake Trout is prohibited in the refuge. Canadian waters adjacent to the refuge are a commercially protected area where commercial fishers are prohibited from fishing in waters shallower than 40 fathoms.

MM-123: Management unit MM-123 is made up of statistical districts MM-1, MM-2 and

MM-3 and encompasses Michigan's waters of northern Lake Michigan and northern Green Bay. Water depths in the northern portion of the unit are generally less than 45 m. In southern portions of the unit, depths can be greater than 170 m. Most of the historically important Lake Trout spawning reefs in Lake Michigan are located in MM-123. The unit contains many islands including the Beaver Island complex (Beaver, Hat, Garden, Whiskey, Trout, High and Squaw Islands), North and South Fox Islands, and Gull Island in Lake Michigan. Another series of islands form a line separating Green Bay from Lake Michigan; these include Little Gull, Gravely, St. Martins, Big and Little Summer and Poverty Islands. Except for the southern one-half of MM-1 in Green Bay, this management unit is entirely in 1836 Treaty waters, and contains a Lake Trout refuge. The "northern refuge" is nearly 233,000 ha and occupies the southern ½ of grids 313 and 314, grids 413, 414, 513-516, the northwest quarter of grid 517, grid 613, and the northern ½ of grid 614. Retention of lake trout by sport or commercial fisheries is prohibited in the refuge. Both commercial and subsistence gill-net fishing are prohibited in the refuge, while commercial trap-net operations are permitted to harvest Lake Whitefish.

MM-4: Lake trout management unit MM-4 encompasses the Grand Traverse Bay region of Lake Michigan. There are two islands in this management unit, Bellow and Marion Island. A large peninsula bisects the southern half of the bay. For the most part water depths in the bay range up to 85 m. However, waters on either side of the peninsula are much deeper, ranging to 134 m in the west arm and 195 m in the east arm. This management unit is entirely in 1836 Treaty waters. There are no refuge areas allocated, however commercial fishing is prohibited in the southern most portion of the bay (grids 915 and 916). Based on estimates from historical commercial catch rates only a small amount of Lake Trout spawning habitat is located in the management unit.

MM-5: Lake trout management unit MM-5 is located in eastern central Lake Michigan and corresponds to the MM-5 statistical district. This area constitutes an area of high use by both Tribal and State interests. The unit includes Michigan's waters of Lake Michigan from Arcadia north to the tip of the Leelanau Peninsula, extending to the state line bisecting the middle of the lake. There are two islands in this management unit, the North and South Manitou Islands. Some of the deepest waters and largest drop-offs in Lake Michigan occur in MM-5. Water depths range to 250 m and for the most part are greater than 120 m. The entire area is in 1836 Treaty waters and there are no refuges allocated within the management unit. Only a small amount of Lake Trout spawning habitat is located here, most of which is located in the near shore zone and around the North and South Manitou Islands.

MM-67: Lake trout management unit MM-67 is located in eastern central Lake Michigan, comprising statistical districts MM-6 and MM-7. The area covers Michigan's waters of Lake Michigan from Arcadia to Holland, extending to the state line bisecting the middle of the lake. The northern section of the region (MM-6) is deeper, with depths up to 275 m, and is characterized by greater slope than the southern section (MM-7). For the most part, water depths in MM-7 are less than 122 m. There are no islands or structures in southern treaty waters, and there is little Lake Trout spawning habitat, with the exception of offshore deep-water spawning reefs located within the mid-lake refuge. The southern treaty management unit is not entirely comprised of 1836 waters- the northern section (MM-6) is entirely treaty ceded territory while only the northern two-thirds of the southern section (MM-7) is within treaty territory. A total of 179,000 ha in the unit are outside treaty waters. A line running parallel to the northern side of the Grand River (located approximately ¾ of the way through grids in the 1900 series) out to the state line in the middle of the lake delineates the southern boundary of treaty territories in the unit. Management unit MM-67 contains a portion of the mid-lake Lake Trout refuge, which comprises 850 square miles of the unit (grids 1606, 1607, 1706, 1707, 1806, 1807, 1906 and 1907). It is illegal for recreational, commercial and subsistence fishers to retain Lake Trout when fishing in the refuge area. Gill-net fishing (both commercial and subsistence) is prohibited in the refuge, State- and Tribal-licensed commercial trap-net operations are permitted to fish in the refuge; however, the retention of Lake Trout is prohibited.

Lake Whitefish Management Units

WFS-04: Lake whitefish unit WFS-04 is located in Lake Superior near Marquette, roughly between Big Bay and Laughing Fish Point. Near shoreline features of this zone include many points, bays, islands, and in-flowing rivers. Habitat suitable for Lake Whitefish growth and reproduction is associated with many of these features. This unit holds waters both within and outside the 1836 Treaty area. Based partly on the number of statistical grids on either side of the 1836 treaty line and partly on established protocol for a similar situation with Lake Trout, 70% of WFS-04 is considered to be in 1836 waters.

WFS-05: The WFS-05 Lake Whitefish management unit extends approximately from Laughing Point to Au Sable Point in Michigan waters of Lake Superior. Several bays (Shelter Bay, Au Train Bay, South Bay, and Trout Bay) and islands (Au Train Island, Wood Island, Williams Island, and Grand Island) are prominent in this area, providing substrate and depth contours suitable for Lake Whitefish habitat and spawning. Different whitefish stocks exist within this unit, including a smaller, slower-growing stock identified in Munising (South) Bay.

WFS-06: The Grand Marais stock of Lake Whitefish is probably one of the smallest in the 1836 ceded waters, certainly the smallest in terms of harvest levels in Lake Superior waters. There are typically only small aggregations of spawning Lake Whitefish in WFS-06, based on anecdotal information from commercial fishers that have regularly fished WFS-06 throughout the year.

WFS-07: WFS-07 is located in the Whitefish Bay area of Lake Superior. There is a substantial commercial fishery in adjacent Canadian management unit 33. WFS-07 contains a single, large stock of whitefish that spawns in the southwest portion of Whitefish Bay.

WFS-08: WFS-08 is located in the southeast portion of Whitefish Bay, Lake Superior. WFS-08 is spatially the smallest of the management units in the 1836 ceded waters of Lake Superior. A substantial commercial fishery targeting whitefish also exists in adjacent Canadian management units 33 and 34. It is thought that four reproductively isolated stocks of whitefish contribute to the commercial fishery in WFS-08. There are two spawning areas in WFS-08, a probable contributing spawning population in Canadian waters of management unit 34, as well as contributions from spawning fish in WFS-07 directly west of WFS-08.

Northern Huron (WFH-01 thru WFH-04): Management unit WFH-01 is located in the northwest portion of the main basin of Lake Huron. Management unit WFH-02 is located along the northern shore of the main basin of Lake Huron. Much of WFH-02 is deeper than 45 m and maximum depth is slightly more than 90 m. WFH-02 is a small unit made up of only three statistical grids. The unit has an irregular shoreline with many small, rocky points, small bays, and scattered boulders. Management unit WFH-03 is small and encompasses only the area around Drummond Island. A Lake Trout refuge is located along the south shore of Drummond Island where large-mesh gill-net fishing is prohibited and retention of Lake Trout by trap-net fisheries is prohibited. The south side of WFH-03 is deep. with much of the water exceeding 45 m in depth, whereas the north and west sides of Drummond Island are relatively shallow. WFH-03 contains six statistical grids. WFH-04 is the largest whitefish management unit in the 1836 Treaty waters of Lake Huron. Spawning concentrations of whitefish are scattered throughout the unit with concentrations being found from Cheboygan to Hammond Bay.

WFH-05: WFH-05 extends from Presque Isle south to the southern end of grids 809-815 in US waters and includes some waters of Lake Huron that lie outside the 1836 Treaty waters. WFH-05 contains multiple spawning aggregates, most of which are likely associated with the numerous islands (Crooked, Gull, Middle, Sugar and Thunder Bay) or small embayments that are found in the southern part of the unit.

WFM-01: Lake whitefish management unit WFM-01 is located in the 1836 Treaty waters of northern Green Bay. Prominent features of this area include two large bays (Big and Little Bay de Noc), numerous small embayments, several islands (including St. Martins Island, Poverty Island, Summer Island, Little Summer Island, Round Island, Snake Island, and St. Vital Island), as well as various shoal areas (Gravelly Island Shoals, Drisco Shoal, North Drisco Shoal,

Minneapolis Shoal, Corona Shoal, Eleven Foot Shoal, Peninsula Point Shoal, Big Bay de Noc Shoal, Ripley Shoal, and shoals associated with many of the islands listed above). Little Bay de Noc is the embayment delineated by statistical grid 306. Shallow waters characterize the northern end and nearshore areas, but there is a 12- to 30-m deep channel that runs the length of the bay. Rivers that flow into Little Bay de Noc include the Whitefish, Rapid, Tacoosh, Days, Escanaba, and Ford. Big Bay de Noc is a larger embayment delineated by statistical grids 308 and 309. Big Bay de Noc is relatively shallow with over half the area less than 10-m deep and a maximum depth of 21 m. Rivers that empty into Big Bay de Noc include the Big, Little, Ogontz, Sturgeon, Fishdam, and Little Fishdam. Only grids 308, 309, 407 and 408 are entirely within 1836 Treaty waters

WFM-02: WFM-02 is located in the northwest portion of Lake Michigan. The only known spawning population of whitefish in the management unit is located in Portage Bay; this population is not as abundant as other stocks in Lake Michigan. Many of the whitefish inhabiting WFM-02 move into the unit from adjacent units.

WFM-03: WFM-03 is located in northern Lake Michigan. The unit extends from the Straits of Mackinac west to Seul Choix Point and is bounded on the south by Beaver Island and a complex of shoals and islands surrounding it. Nearly the entire unit is shallow water less than 27 m deep.

WFM-04: WFM-04 is located in central northern Lake Michigan and contains a very diverse range of habitat. The Beaver Island archipelago, which consists of eight named islands, is the dominant feature of the unit. These islands, located mainly along the northern edge of the unit, are associated with a large, rocky reef complex that extends about 15 miles west from Waugoshance Point near the northwestern tip of Michigan's Lower Peninsula. This northern reef complex is shallow, ranging from 2- to 9-m deep. Many smaller submerged reefs extend from the northern reef complex to the south, running along the east and west sides of Beaver Island, a 14,245 ha landmass that bisects the unit. These latter reefs are surrounded by deep water.

WFM-05: Management unit WFM-05 encompasses the area from Little Traverse Bay through Grand Traverse Bay and offshore waters of Lake Michigan north and west of the Leelanau Peninsula. Much of WFM-05 contains water greater than 80-m deep, including both the east and west arms of Grand Traverse Bay. The deepest parts of WFM-05 exceed 183 m, both in the offshore waters west of the Leelanau Peninsula, as well as within the east arm of Grand Traverse Bay. Several small shallow reef areas are located in the offshore waters, and there is an extensive shallow water area associated with the Fox Islands. Seventeen statistical grids make up WFM-05. Much of the offshore waters of WFM-05 are part of the northern Lake Michigan Lake Trout refuge.

WFM-06: Lake whitefish management unit WFM-06 is located in 1836 Treaty waters west of the Leelanau Peninsula from about Cathead Point south to Arcadia. These waters of Lake Michigan include Good Harbor Bay, Sleeping Bear Bay, and Platte Bay. Two large islands, North Manitou and South Manitou, are contained in this management zone, as are three large shoal areas including North Manitou Shoal, Pyramid Point Shoal, and Sleeping Bear Shoal. Major rivers flowing into WFM-06 include the Platte and the Betsie. Betsie Lake is a drowned river mouth formed where the Betsie River flows into Lake Michigan. Except for areas near shore or around the islands, most of the waters in WFM-06 are deep (greater than 60 m). Bays, islands, and shoal areas offer the best habitat for Lake Whitefish spawning in this management area.

WFM-07: Lake whitefish management unit WFM-07 is located within the 1836 Treaty Ceded Waters of eastern central Lake Michigan from Arcadia in the north to just south of Stony Lake, and west to the Michigan/Wisconsin state line bisecting the middle of the lake. This Lake Whitefish management unit includes part or all of grids 1107-1111, 1207-1211, 1306-1310, 1406-1410, 1506-1510 and 1606-1609. There are several inflows from the Big Manistee, Little Manistee, Big Sable, Pere Marquette, and Pentwater Rivers, and drowned river mouths at Manistee Lake, Pere Marquette Lake, and Pentwater Lake.

WFM-08: Management unit WFM-08 is the Lake Michigan whitefish zone that extends from Montague south past Port Sheldon; only those waters north of the Grand River lie within 1836

Treaty waters. Apart from the shoreline, and inflows from the White, Muskegon, and Grand Rivers, and drowned river mouths at White Lake, Muskegon Lake, Mona Lake, and Pigeon Lake, this area has few other distinguishing features relevant to Lake Whitefish biology. Depth gradients west from shore are relatively gradual, but most of the waters in WFM-08 are 61-m deep or deeper.

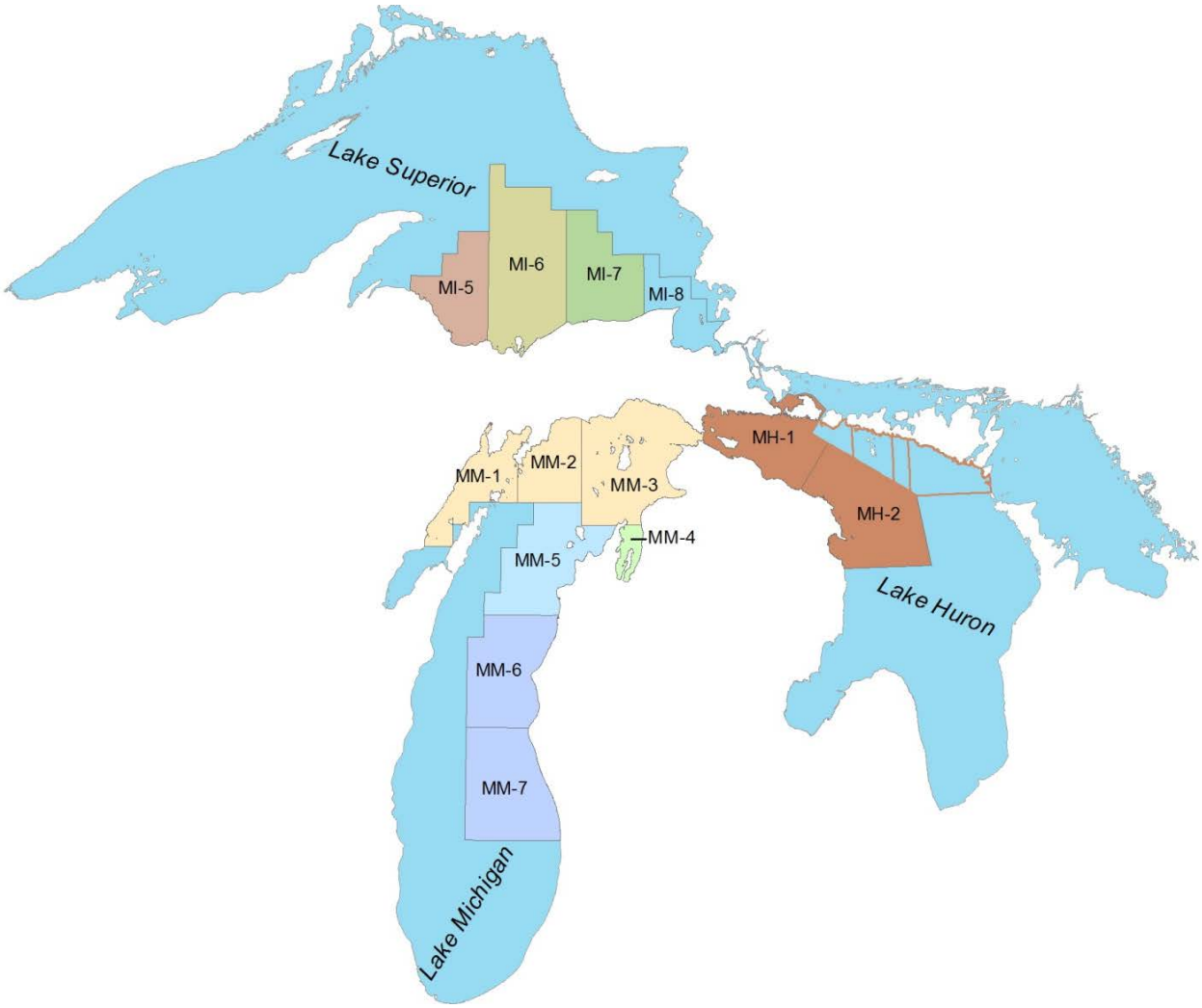


Figure 1. Lake Trout Management Units. Shading denotes units subject to provisions of the 2000 Consent Decree. Like shading indicates where statistical districts have been combined into a single management unit for stock assessment purposes. In the case of Lake Huron, outlined areas adjacent to statistical districts MH-1 and MH-2 denote where fishery data from Ontario waters are included in the stock assessment for Lake Huron. No stock assessment has been developed for Lake Superior unit MI-8.

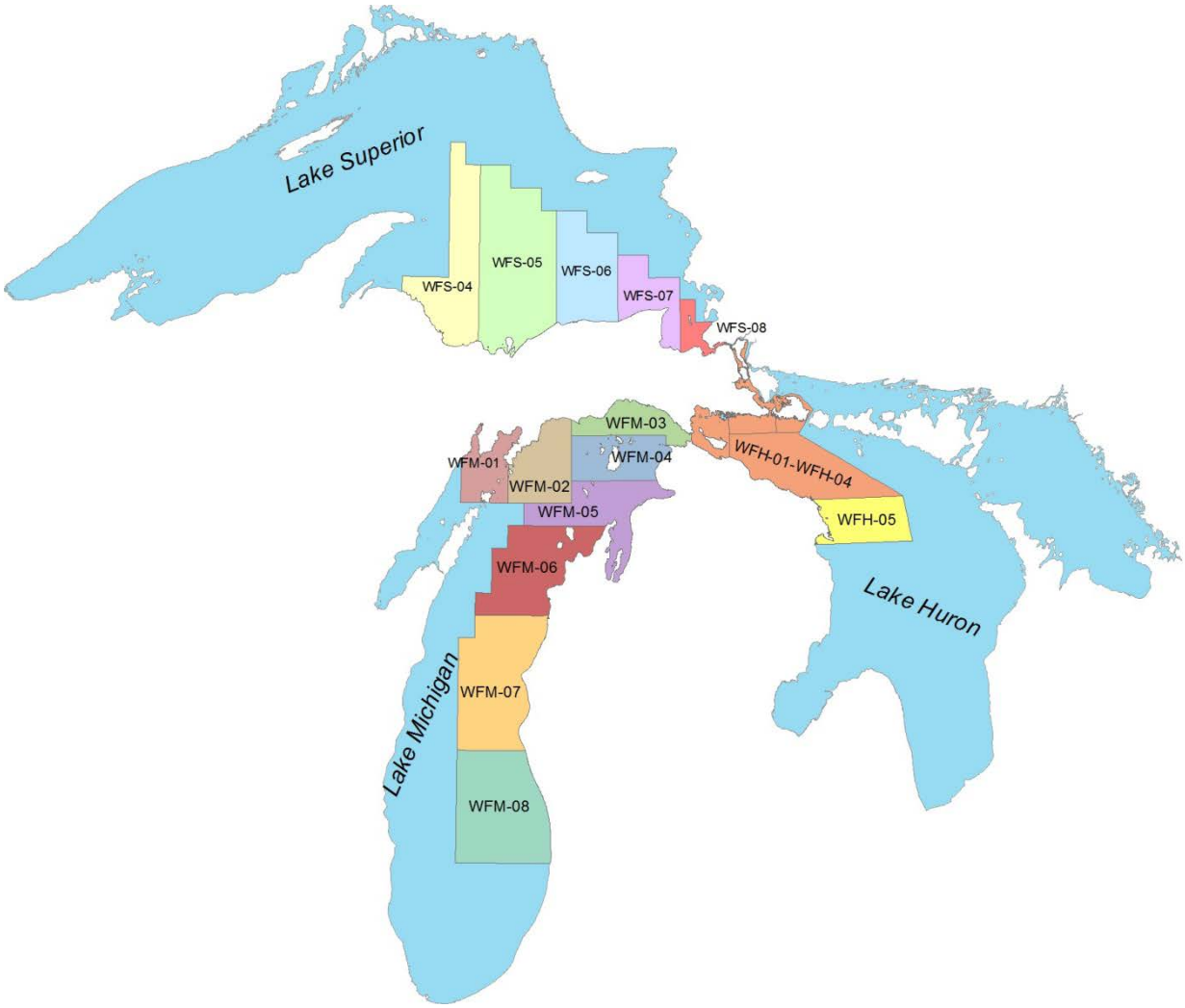


Figure 2. Lake Whitefish Management Units. Shading denote units subject to provisions of the 2000 Consent Decree. Like shading indicates where units have been combined into a single management area for stock assessment purposes. No stock assessment model has been developed for Lake Michigan unit WFM-07 and the stock assessment model for Lake Superior unit WFS-06 has not been populated since 2006 due to a paucity of available data.

Table 2. Surface area estimates for Lake Trout and Lake Whitefish management units associated with 1836 waters of the Great Lakes.

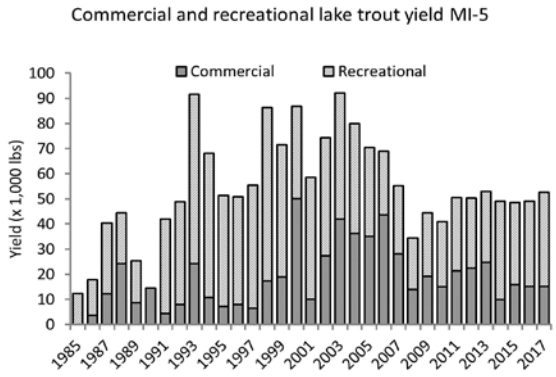
Species	Lake	Management unit	Total Area (ha)	Area<= 80m (ha)
Lake Trout	Superior	MI-5	374,100	117,000
		MI-6	803,300	105,100
		MI-7	459,300	157,800
	Huron	MH-12	1,073,800	563,000
		OH-1*	353,800	196,300
	Michigan	MM-123	1,293,200	910,200
		MM-4	66,100	50,200
		MM-5	548,000	125,400
		MM-67	1,155,500	270,200
Lake Whitefish	Superior	WFS-04	396,300	116,800
		WFS-05	730,000	96,400
		WFS-06	416,900	123,200
		WFS-07	239,200	148,800
		WFS-08	78,200	70,400
	Huron	North Huron	677,300	385,700
		WFH-05	262,700	86,300
	Michigan	WFM-01	190,700	190,700
		WFM-02	293,000	146,800
		WFM-03	200,500	200,500
		WFM-04	259,200	228,900
		WFM-05	366,100	174,100
		WFM-06	475,300	116,600
		WFM-07	643,800	117,800
		WFM-08	656,800	145,700

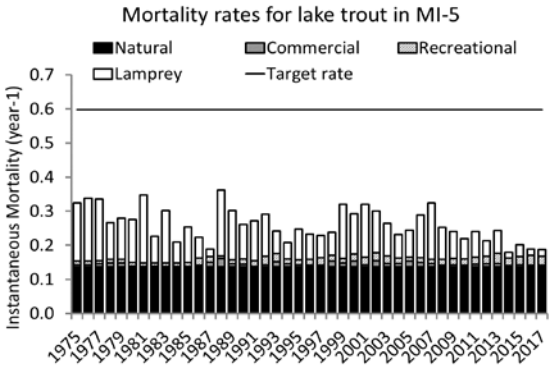
*Ontario statistical district OH-1 presented as a surrogate for the three Ontario quota-management areas (4-1, 4-2 and 4-3) included in the North-Central Lake Huron (MH-12) model.

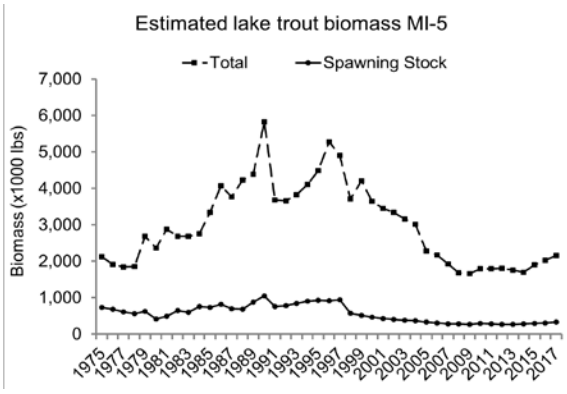
STATUS OF LAKE TROUT POPULATIONS

Lake Superior

MI-5 (Marquette) **Shawn Sitar**







Parameter[(1)]	Value
Base SSBR	7.01 lb
Current SSBR	3.19 lb
Target SSBR	0.40 lb
Current SPR	0.46
M	0.13 y^{-1}
F, Commercial (2015-2017)	0.01 y^{-1}
F, Recreational (2015-2017)	0.03 y^{-1}
Sea Lamprey Mort (2014-2016)	0.02 y^{-1}
Z (2017)	0.19 y^{-1}
Recommended TAC	170,209 lb
Actual TAC	170,209 lb
Model Rating	Medium

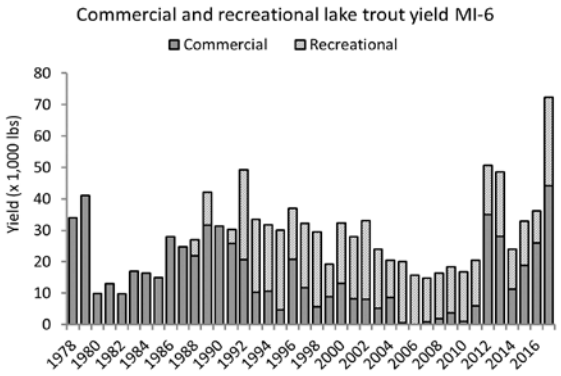
(1) For this table and all subsequent tables in this section, mortality rates represent averages for Lake Trout ages 6-11.

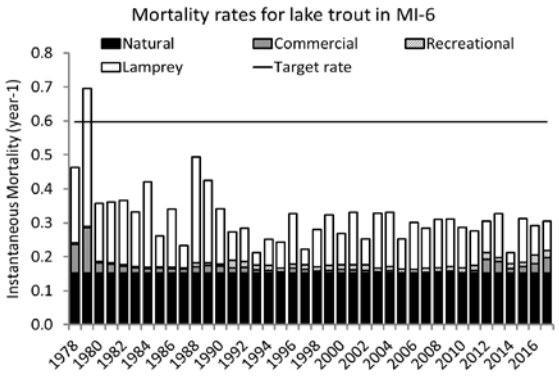
Notable Stock Dynamics and Model Changes:

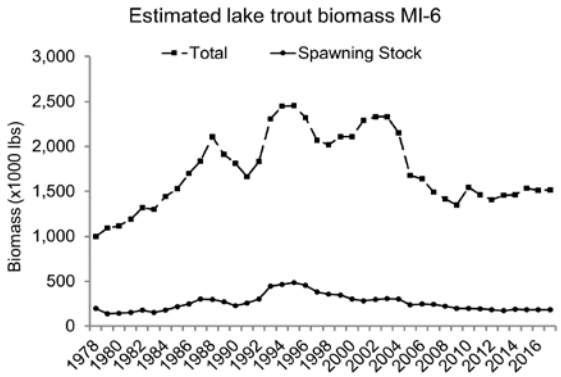
Recruitment and growth drive lake trout biomass, and both progressively declined during the 1990s and 2000s before stabilizing in recent years. Sea lamprey-induced mortality has declined since 2007 and is low comparable to the mid-1990s. Recreational harvest averaged 9,700 fish during 2015-2017. Commercial yield declined by 50% between 2013 and 2014 and averaged 13,800 lb during 2014-2016. The 2018 model does not have actual 2017 commercial yield, effort, and age composition data. The assessment was based on assuming that 2017 commercial

fishery data were equal to 2016. Total annual mortality for age 6-11 lake trout averaged 18% in the last three years. The harvest limit in 2018 increased 0.4% from 2017.

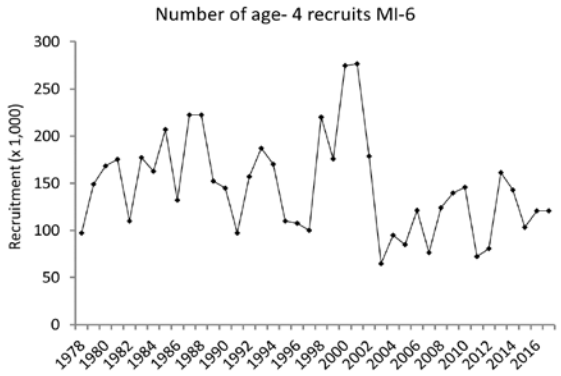
MI-6 (Munising) Shawn Sitar







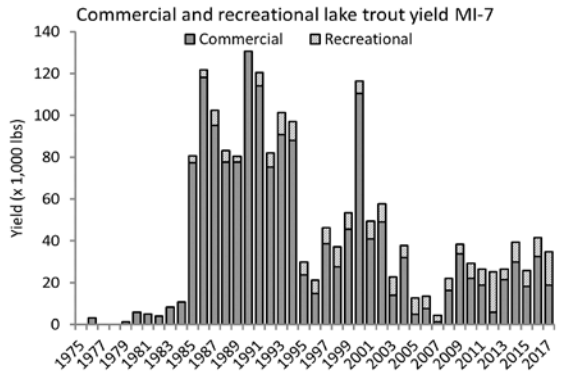
Parameter	Value
Base SSBR	5.46 lb
Current SSBR	1.43 lb
Target SSBR	0.59 lb
Current SPR	0.26
M	0.15 y^{-1}
F, Commercial (2015-2017)	0.03 y^{-1}
F, Recreational (2015-2017)	0.02 y^{-1}
Sea Lamprey Mort (2014-2016)	0.08 y^{-1}
Z (2017)	0.30 y^{-1}
Recommended TAC	195,888 lb
Actual TAC	195,888 lb
Model Rating	Medium

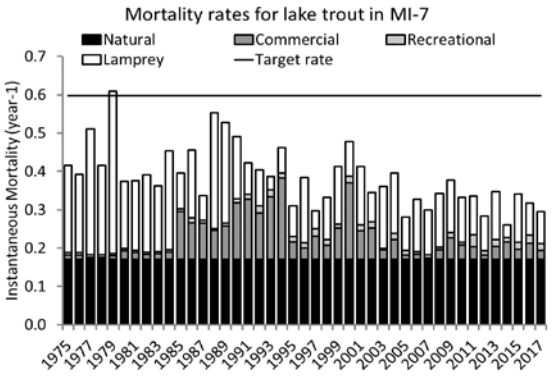


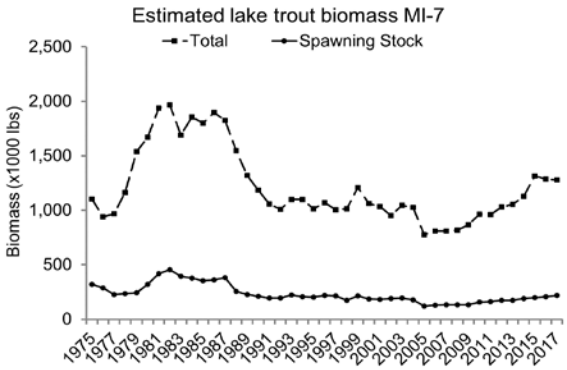
Notable Stock Dynamics and Model Changes:

Abundance has been generally stable in MI-6 since 2010. With the exception of 2014, total mortality has not varied much in the last 10 years and is mostly driven by sea lamprey predation. Recent commercial landings have been low; however, in 2012 and 2013 yield increased five-fold to the highest levels since 1980 and was 44,200 lb in 2017. Total annual mortality for age 6-11 lake trout averaged 26% in the last three years. The 2018 TAC for MI-6 increased by 9% from last year due to a slight reduction in sea lamprey-induced mortality.

MI-7 (Grand Marais) Shawn Sitar





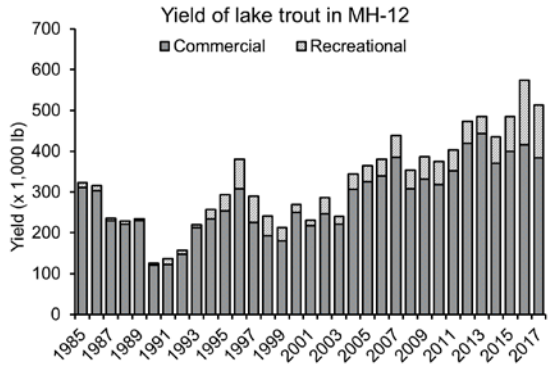


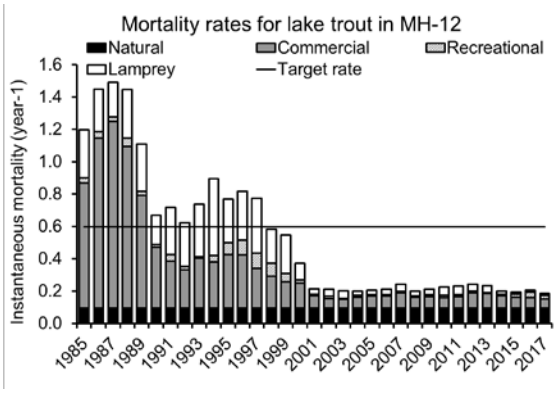
Parameter	Value
Base SSBR	5.99 lb
Current SSBR	2.05 lb
Target SSBR	1.15 lb
Current SPR	0.34
M	0.17 y^{-1}
F, Commercial (2015-2017)	0.03 y^{-1}
F, Recreational (2015-2017)	0.02 y^{-1}
Sea Lamprey Mort (2014-2016)	0.08 y^{-1}
Z (2017)	0.29 y^{-1}
Recommended TAC	172,922 lb
Actual TAC	172,933 lb
Model Rating	Medium

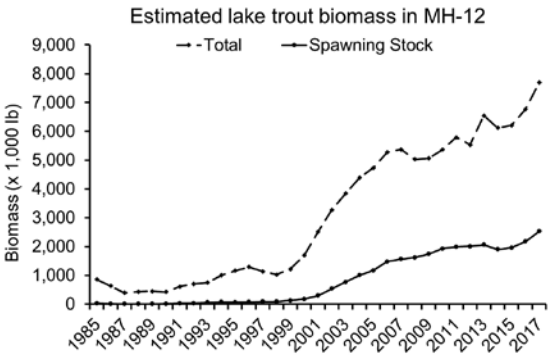
<u>Notable Stock Dynamics and Model Changes:</u>

A full assessment was conducted for MI-7 in 2018. Since the last assessment in 2015, adult abundance and recruitment increased. Commercial yield averaged 23,000 lb during 2015-2017. Average recreational harvest in the last three years was 3,400 fish. Sea lampreys continue to be the highest mortality source and have been since 2001. Total mortality is low and averaged 27% in the last three years. The 2018 harvest limit for MI-7 was 72% higher than in 2017 due to significant increases in estimated abundance and recruitment.

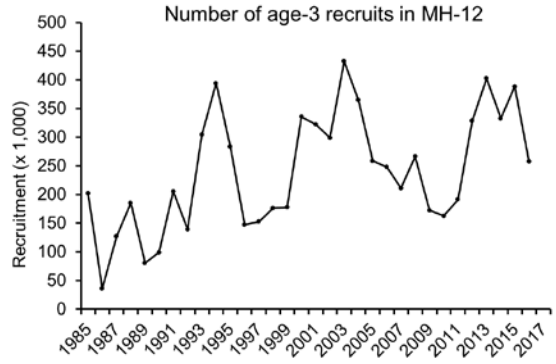
Lake Huron
MH-1 and MH-2 (Northern and North-central Lake Huron) Ji He







Parameter	Value
Base SSBR	30.06 lb
Current SSBR	10.74 lb
Target SSBR	1.54 lb
Current SPR	0.36
M	0.09 y^{-1}
F, Commercial (2015-2017)	0.07 y^{-1}
F, Recreational (2015-2017)	0.03 y^{-1}
Sea Lamprey Mort (2014-2016)	0.01 y^{-1}
Z (2016)	0.18 y^{-1}
Recommended TAC	1,508,298 lb
Actual TAC	N/A
Model Rating	Low



<u>Notable Stock Dynamics and Model Changes:</u>

The 16-year trend in increasing catch and catch rates in both the commercial and recreational fisheries continued in 2017. There were no clear treads in survey CPUE, with all ages and sizes included. However, juvenile CPUE declined during 2001 through 2009, followed by increases to the recent peak in 2016. Adult CPUE increased since 1990, but there were no clear trends since 2001. Changes in catchability and selectivity were estimated by the assessment model.

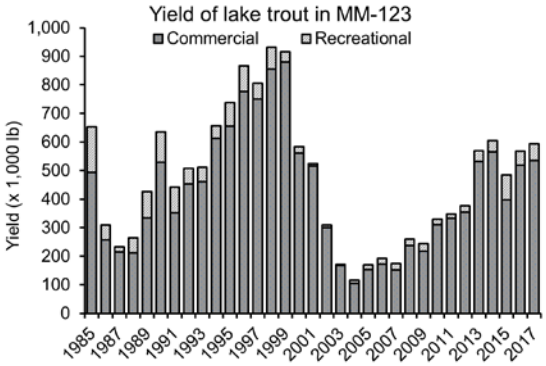
Fishery harvest and fishing mortality peaked at age 7. Based on modelled 2005-2015 survey data, 50% of female lake trout are mature by age 7. Mortality has not exceeded 0.3 yr^{-1} on any age since 2001 and the observed maximum age in the data sources

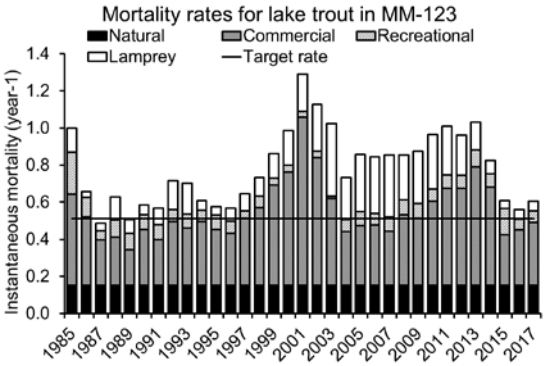
expanded from less than 15 to over 25. Estimated female spawning stock biomass increased from 293,629 lb in 2001 to 2,530,655 lb in 2017. The increases after 2005 were almost all from wild lake trout.

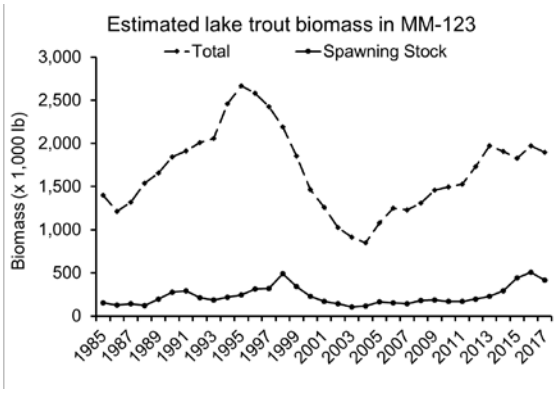
The youngest age routinely observed from the survey and fisheries was age 3. Annual recruitment of stocked fish at age 3 was estimated to be between 200,000 and 400,000 fish during 2000 to 2015. With the addition of wild recruits, total recruitment at age 3 was estimated between 500,000 to 600,000 for 2012 to 2015.

There were no major changes to the assessment model structure or assumptions. For each data source (survey and commercial and recreational fishery) the maximum effective sample size (ESS) for fitting the wild ratio was set at 50% of the maximum ESS for fitting age composition, which differed among time-periods. Before 2000, the maximum ESS for all data source was set at 200. Between 2001 and 2011, the maximum ESS for all data sources was set below 100 because aging procedures were in transition as fin clips alone were no longer a reliable basis for assigning ages to old and large lake trout and assigning ages to wild lake trout required calcified structures. The final ESS of 80 was decided after evaluation of maximum gradients from multiple runs of the model. After 2011, the maximum age in age composition is much older than in earlier years, and the maximum ESS was set at 150 based on evaluation of maximum gradients of multiple runs of the model. The model often did not converge when data from recent years were excluded in retrospective analyses.

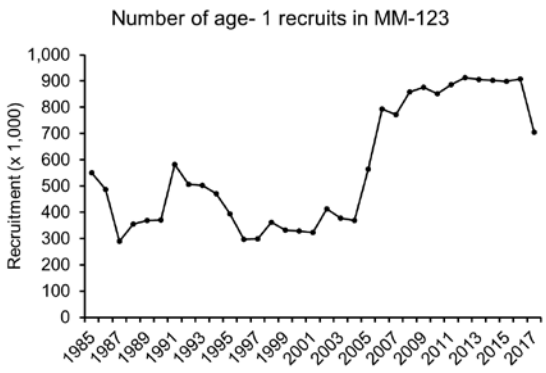
Lake Michigan
MM-123 (Northern Treaty Waters) Ted Treska







Parameter	Value
Base SSBR	3.20 lb
Current SSBR	0.43 lb
Target SSBR	0.78 lb
Current SPR	0.14
M	0.15 y^{-1}
F, Commercial (2015-2017)	0.30 y^{-1}
F, Recreational (2015-2017)	0.09 y^{-1}
Sea Lamprey Mort (2014-2016)	0.05 y^{-1}
Z (2017)	0.61 y^{-1}
Recommended TAC	441,729 lb
Actual TAC	630,000 lb
Model Rating	Medium

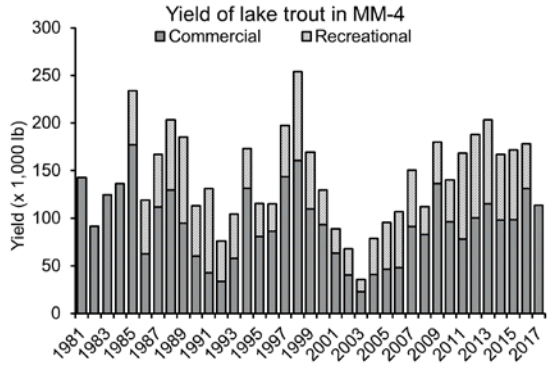


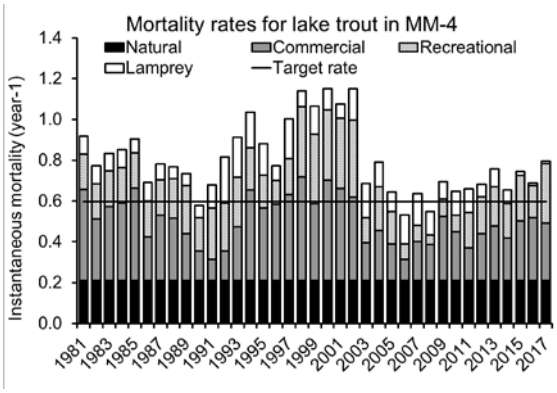
Notable Stock Dynamics and Model Changes:

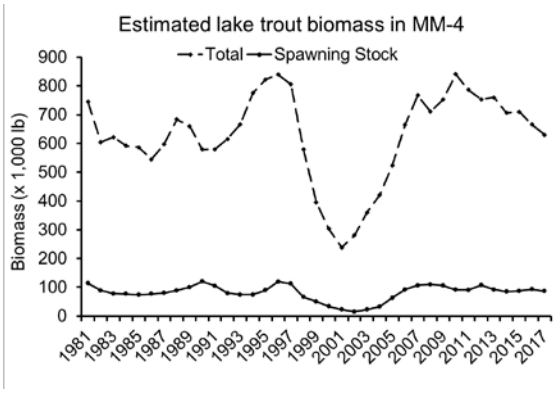
Aside from adding 2017 data, the only change to this model for 2018 is the revision of the maturity matrix, consistent with the rest of the Lake Michigan units. The model recommended harvest limit increased from 2017 and was 441,729 lb. A dramatic decrease in estimated sea lamprey mortality over the last few years has resulted in increased abundance estimates, though fishery signals in 2017 indicate larger proportions of these fish are ages 5-7 rather than the younger ages (3-5) that were strongest in the previous 10 years. Overall, harvest in 2017 was very similar to 2016, with an uptick in both recreational and commercial harvest. Effort in both fisheries increased slightly in 2017. Annual mortality

rates have recently declined, but remain above target at 45%.

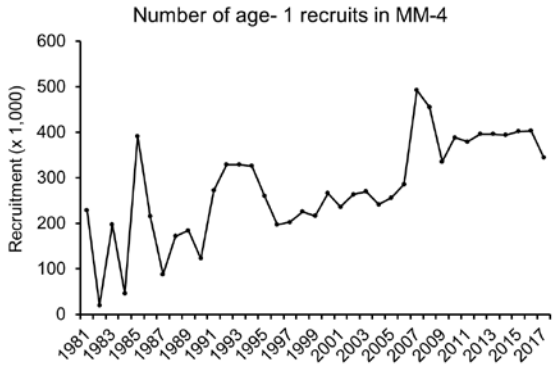
MM-4 (Grand Traverse Bay) Stephen Lenart







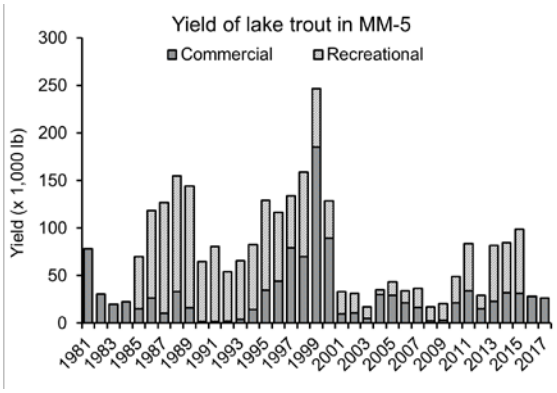
Parameter	Value
Base SSBR	1.98 lb
Current SSBR	0.25 lb
Target SSBR	0.36 lb
Current SPR	0.13
M	0.21 y^{-1}
F, Commercial (2015-2017)	0.29 y^{-1}
F, Recreational (2015-2017)	0.22 y^{-1}
Sea Lamprey Mort (2014-2016)	0.03 y^{-1}
Z (2016)	0.77 y^{-1}
Recommended TAC	126,603 lb
Actual TAC	171,500 lb
Model Rating	Medium

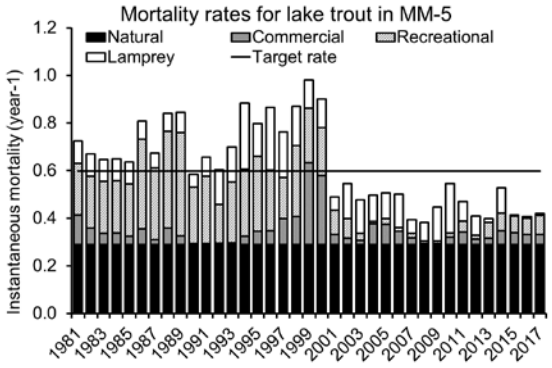


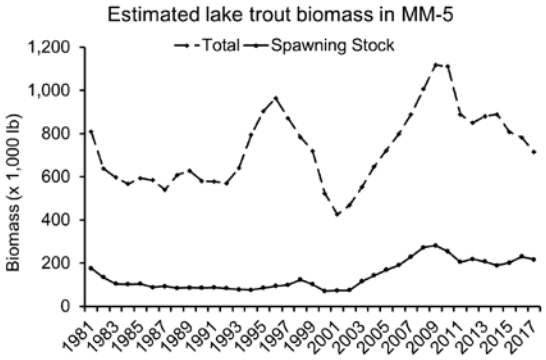
<u>Notable Fishery Dynamics and Model Changes:</u>
No changes were made to the structure of the MM-4 assessment. As in all Lake Michigan units, female maturity-at-age was re-estimated for the entire time series (five-year running average beginning in 2003, time blocks for prior periods). The model estimated a slight increase in total abundance in the last year, ending the trend of declining abundance that began in 2009. Estimated sea lamprey-induced mortality declined for the third consecutive year to the lowest estimate in the time series (avg 0.01 $y^{-1}$for fish ages 6-11); despite this, spawning biomass has remained flat, a product of increased fishing mortality rates. Total annual mortality for fish ages 6-11 (55% in 2017) was above the target rate for the ninth consecutive year. Lower projections of sea lamprey mortality

resulted in a 10% increase in the harvest limit, despite mortality rates remaining above target. Changes to the maturity schedule had very little influence (<0.1%) on the harvest limit.

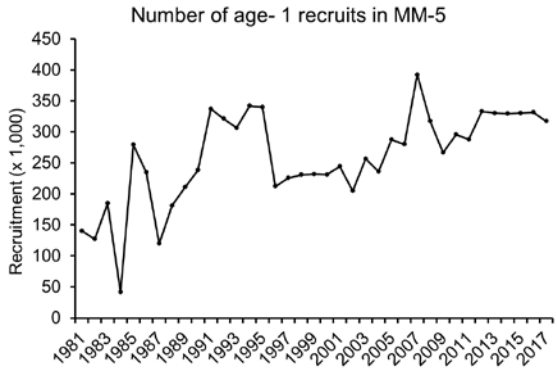
MM-5 (Leelanau Peninsula to Arcadia) Stephen Lenart







Parameter	Value
Base SSBR	0.49 lb
Current SSBR	0.23 lb
Target SSBR	0.19 lb
Current SPR	0.46
M	0.29 y^{-1}
F, Commercial (2015-2017)	0.05 y^{-1}
F, Recreational (2015-2017)	0.07 y^{-1}
Sea Lamprey Mort (2014-2016)	0.04 y^{-1}
Z (2017)	0.42 y^{-1}
Recommended TAC	82,930 lb
Actual TAC	98,000 lb
Model Rating	Low

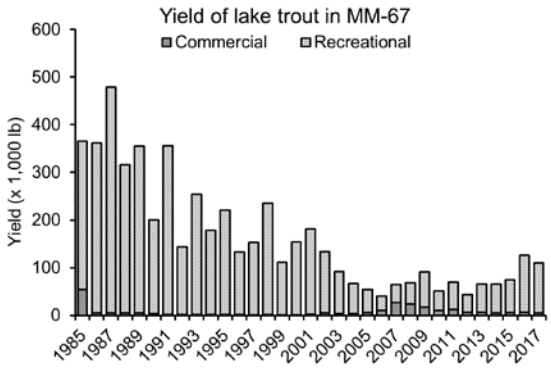


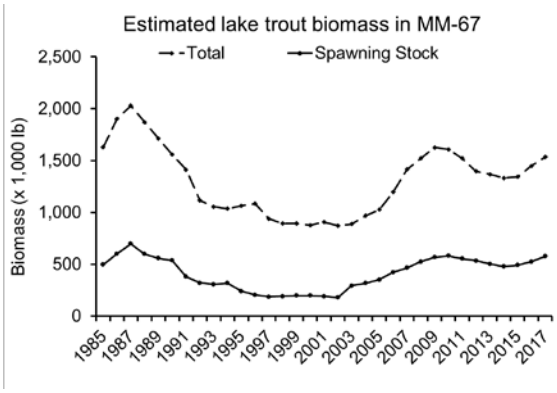
Notable Fishery Dynamics and Model Changes:

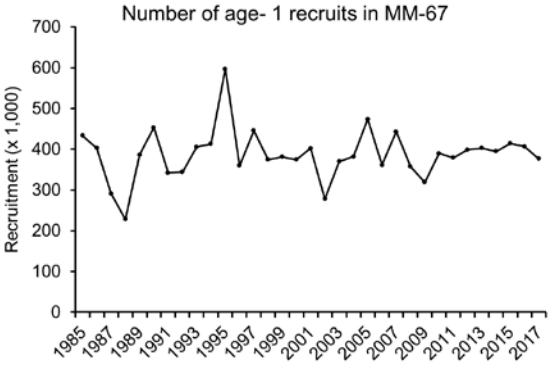
The only structural change made to the MM-5 assessment was the integration of an iterative process for assigning effective sample size (ESS) to the age composition data. This change was precipitated by unsatisfactory diagnostics and model instability. Although this change only modestly improved diagnostics, the process for assigning ESS using an iterative approach is supported by published work and should be viewed as less arbitrary than the previously accepted method. The performance of the MM-5 model received a low rating due to less than satisfactory diagnostics and inconsistent data signals related to the abundance of young fish in the populations. Nonetheless, the model reached a stable solution and population trends (declining overall abundance and spawning biomass) are

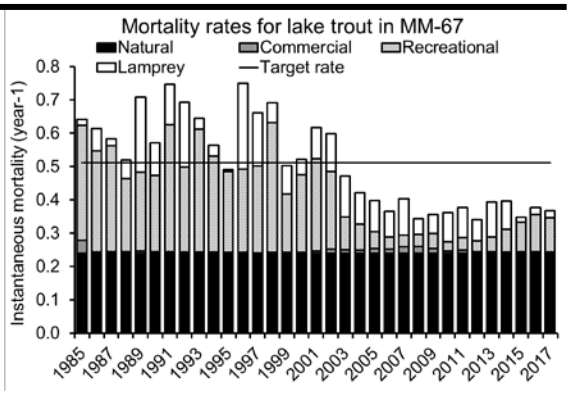
somewhat similar to the 2017 version, but these declines were much more muted in the ESS version. As in unit MM-4, sea lamprey-induced mortality was at a time-series low (<0.01 yr^{-1}) in the most recent year and overall mortality (*A*=34% in 2017) has remained stable for the past three years. The harvest limit produced by the ESS version of the model was nearly 50% higher than the base version, resulting in an 8% increase overall from last year.

MM-67 (Southern Treaty Waters) Mike Seider









Parameter	Value
Base SSBR	2.61 lb
Current SSBR	1.40 lb
Target SSBR	0.99 lb
Current SPR	0.54
M	0.24 y^{-1}
F, Commercial (2015-2017)	0.00 y^{-1}
F, Recreational (2015-2017)	0.10 y^{-1}
Sea Lamprey Mort (2014-2016)	0.04 y^{-1}
Z (2017)	0.37 y^{-1}
Recommended TAC	165,352 lb
Actual TAC	230,216 lb
Model Rating	Medium

Notable Fishery Dynamics and Model Changes:

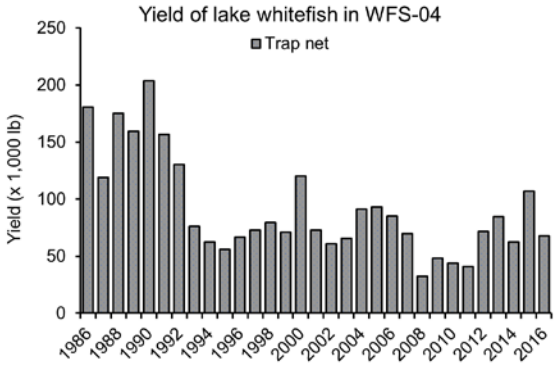
The lake trout fishery in MM-67 is composed almost exclusively of recreational angling. Sport harvest in 2017 was approximately 16,000 lake trout, the second highest value since 2002. Total annual mortality has remained below the target maximum value since 2002. Sport fishing mortality has gradually increased since 2012. The annual mortality rate for the most vulnerable age class was 32% in 2017. No significant structural changes were made to the assessment model in 2018 and the estimated population characteristics were generally similar to last year. Survey data were used to correct previous estimates of female lake trout maturity since 1998. These changes lowered the assumed proportion of mature fish at ages 3-7 and lowered the estimated spawning biomass. The new maturity schedule caused a slight increase in the total

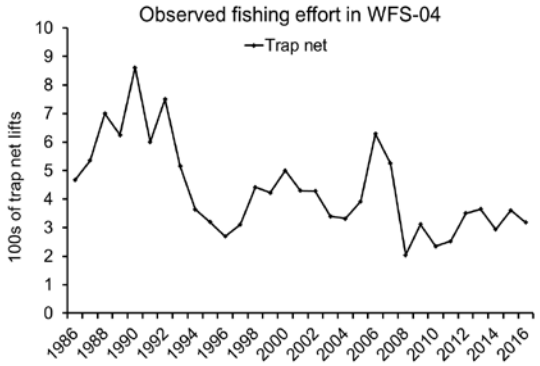
allowable catch by reducing the target spawning stock biomass per recruit. The most noteworthy change since last year was a third consecutive year of low estimated sea lamprey mortality rates. Projected lamprey mortality was reduced by almost 50%, which increased the total allowable catch. The model showed very little parameter sensitivity, no concerning retrospective patterns, and was rated medium. The 2018 harvest limit was calculated to be 165,000 lb, which is 69% higher than 2017.

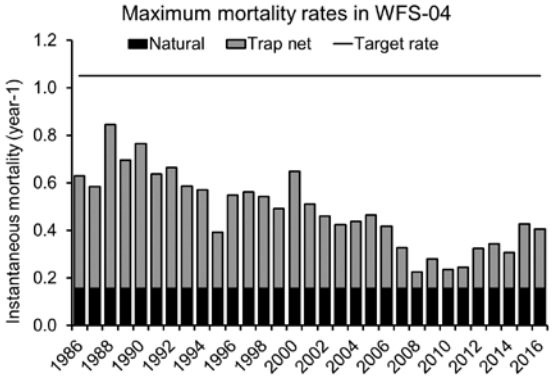
STATUS OF LAKE WHITEFISH POPULATIONS

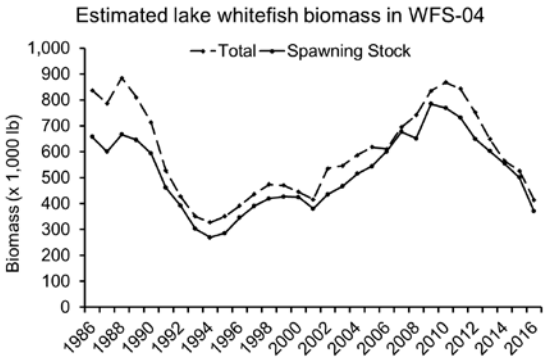
Lake Superior

WFS-04 (Marquette-Big Bay) Mike Seider









Parameter[(2)]	Value
Base SSBR	8.29 lb
Current SSBR	1.66 lb
Target SSBR	1.32 lb
Current SPR	0.20
M	0.16 y^{-1}
F, trap net (2014-2016)	0.22 y^{-1}
Z (2016)	0.41 y^{-1}
Recommended TAC	87,000 lb
Actual TAC	87,000 lb
Model Rating	Medium

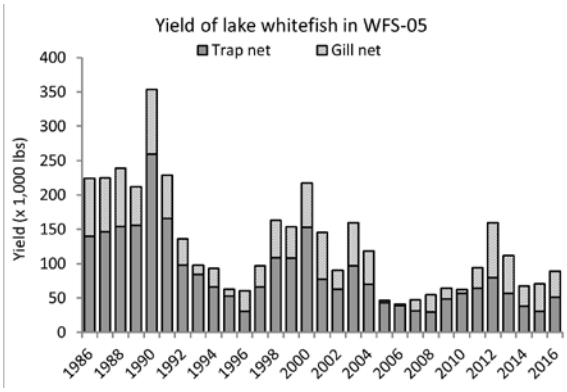
(2) For this table and all subsequent tables in this section, mortality rates represent averages for Lake Whitefish ages 6-11.

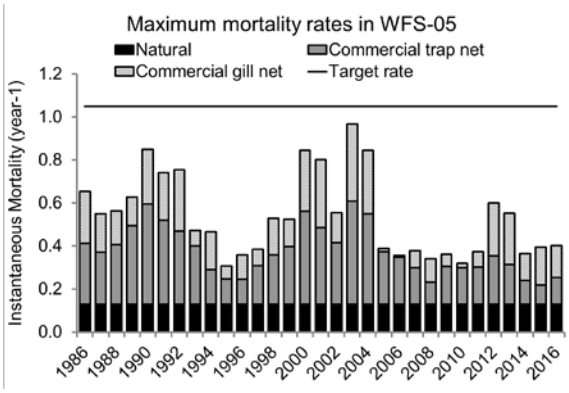
Notable Fishery Dynamics and Model Changes:

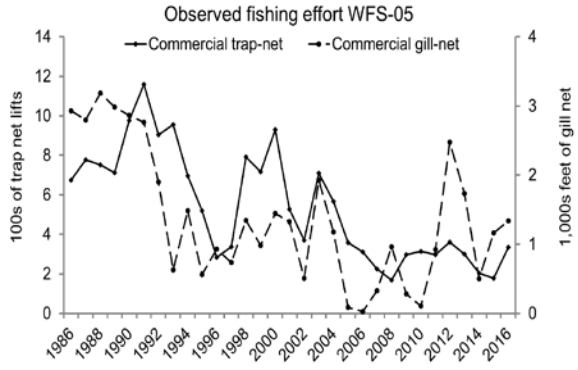
Lake whitefish biomass in WS-04 has declined since the late-2000s, due to declining abundance and weight-at-age. Fishing mortality has increased during the same timeframe; however maximum total

mortality rates were well below the target value. Annual mortality (*A*) for the most vulnerable age class was 38% in 2016. Estimated recruitment has been generally declining since the mid-2000s. This assessment model has long suffered from retrospective patterns and poor MCMC distributions due to lack of biological data collected from the gill-net fishery. The contribution of the gill-net fishery to total lake whitefish harvest varies from 20-50% annually. Prior attempts to adjust the effective sample size and time varying selectivity for the gill-net fishery did not resolve poor model diagnostics. For 2018, an alternative model was developed where gill-net harvest was combined with the trap-net fishery and trap-net effort was adjusted based on catch per effort (as is done in other management units). In addition, trap-net selectivity was held constant for the entire time period. These changes significantly improved retrospective patterns and MCMC distributions yet resulted in model outputs that were similar to past assessments. Unfortunately, by combining gill and trap net harvest we can only track changes in total fishing mortality and not mortality from the two fisheries independently.

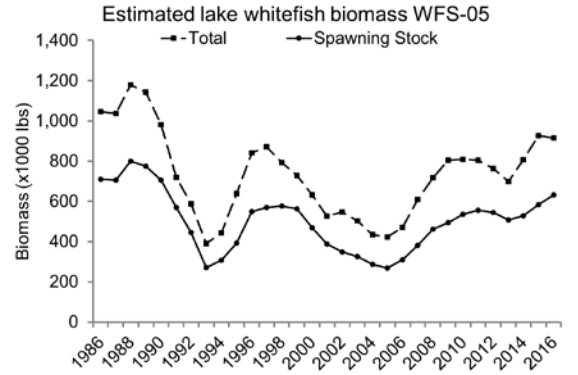
WFS-05 (Munising) Shawn Sitar







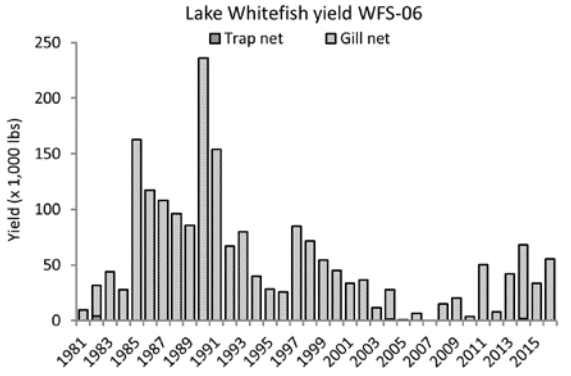
Parameter	Value
Base SSBR	4.41 lb
Current SSBR	1.41 lb
Target SSBR	1.14 lb
Current SPR	0.32
M	0.13 y^{-1}
F, trap net (2014-2016)	0.11 y^{-1}
F, gill net (2014-2016)	0.15 y^{-1}
Z (2016)	0.40 y^{-1}
Recommended TAC	286,900 lb
Actual TAC	286,900 lb
Model Rating	Medium

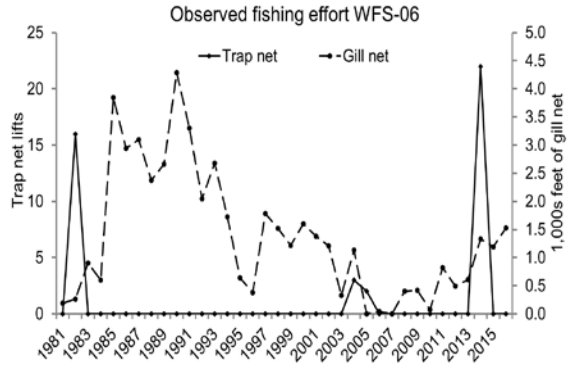


<u>Notable Fishery Dynamics and Model Changes:</u>

The 2018 recommended Lake Whitefish harvest limit 8% lower than 2017. The slight decline in TAC was due to an overall lower stock size estimate and slightly higher mortality rates in the current model than in the prior model. There were no key changes to the model structure. The mortality rate on the most vulnerable age class in 2016 was 33%. Trap-net yield in 2016 increased 70% from 2015 and gill-net yield declined by 6%. The model has good diagnostics and performance consistent with prior models.

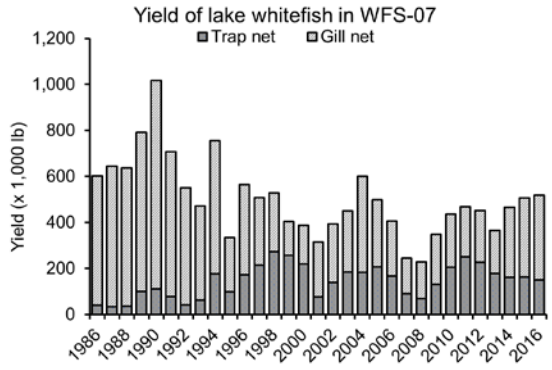
WFS-06 (Grand Marais)

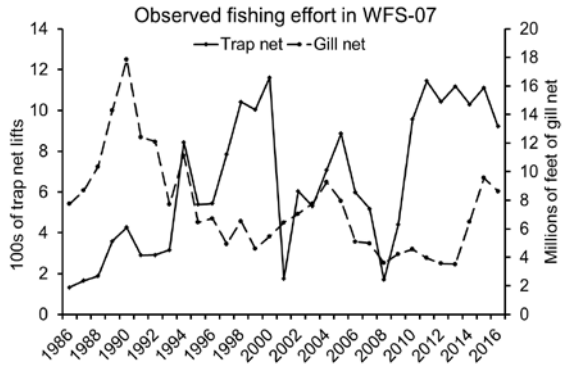


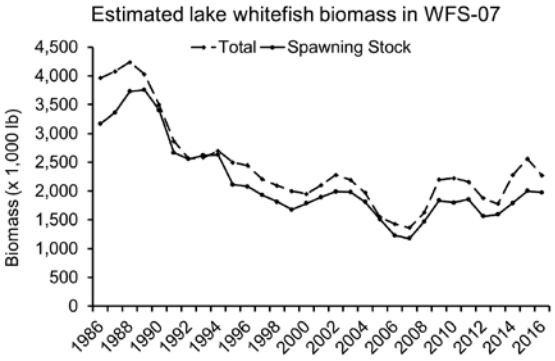


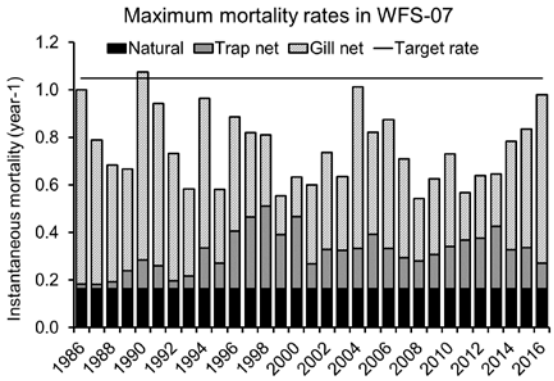
There is no current stock assessment model for WFS-06. Low levels of effort and harvest and a lack of fishery monitoring data since the early 2000s limit the ability to produce an assessment model for this unit. The HRG for this unit remains 210,000 lb.

WFS-07 (Tahquamenon Bay) Ian Harding









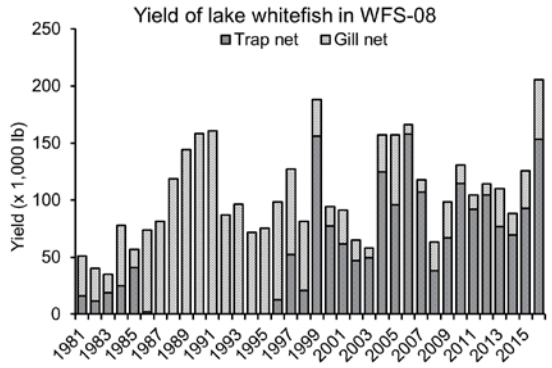
Parameter	Value
Base SSBR	4.32 lb
Current SSBR	1.07 lb
Target SSBR	0.50 lb
Current SPR	0.25
M	0.16 y^{-1}
F, trap net (2014-2016)	0.15 y^{-1}
F, gill net (2014-2016)	0.55 y^{-1}
Z (2016)	0.98 y^{-1}
Recommended TAC	689,200 lb
Actual TAC	689,200 lb
Model Rating	Medium

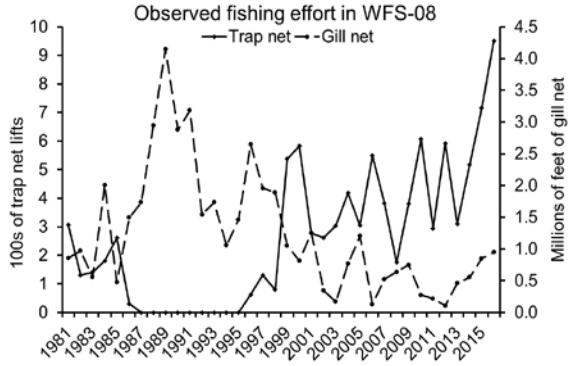
Notable Fishery Dynamics and Model Changes:

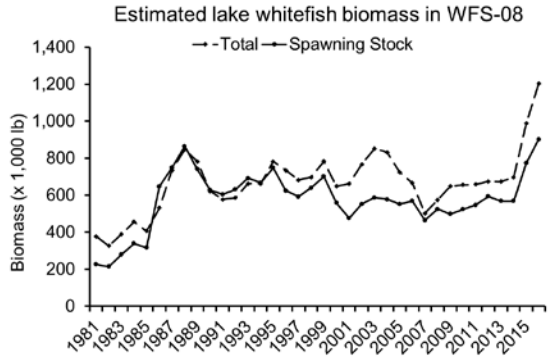
The model recommended harvest limit for 2018 is 689,200 lb, up 43% from 2017. All values for the .dat file were re-estimated because many data errors were found and corrected, such as mismatched grid/management unit, wrong study code, and outliers in length, weight, and age. The previous year's model started in 1976 and was changed to 1986 for the 2018 model. A growth model was also used to estimate lengths-at-age opposed to using raw means for length-based selectivity. These changes had a minor influence on abundance predictions from 1986-2012; however, the new model predicts increasing abundance after 2012 while last year's model predicts a modest increase until 2014 then a decline in 2015. Recruitment estimates were similar between both models. Harvest has been

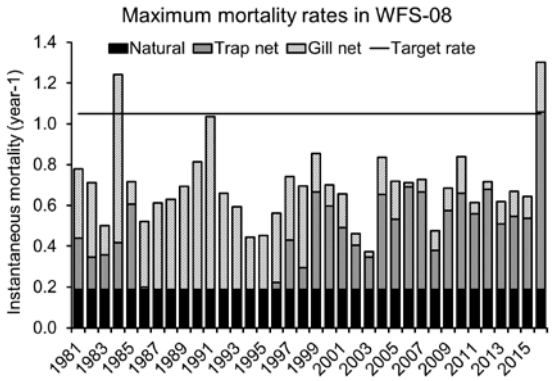
increasing in WFS-07 since 2013. The gill-net fishery has been the predominant fishery for 26 out of 31 years (1986-2016) and currently constitutes 71% of the catch. Gill-net effort was slightly lower in 2016 relative to 2015, but has been increasing since 2013. Fishing effort by the trap-net fishery increased from 2009 to the second highest effort on record in 2011, then has made minor oscillations through 2016. The number of age-4 recruits in 2014 was the second highest predicted during the time series (1986-2016). This is validated by increases in the proportion of age-4, -5, and -6 fish in 2014, 2015, and 2016, respectively. Similar observations were made in unit WFS-08, which suggests the presence of a strong year class in Whitefish Bay. Both spawning and total biomass increased from 2013-2015, but slightly declined in 2016. Total biomass in 2016 is 54% of the maximum total biomass estimated in 1988 for this unit. Fits to catch, and age composition data, effort residuals, MCMCs, and retrospective analyses ranged from satisfactory to superior.

WFS-08 (Brimley) Ian Harding









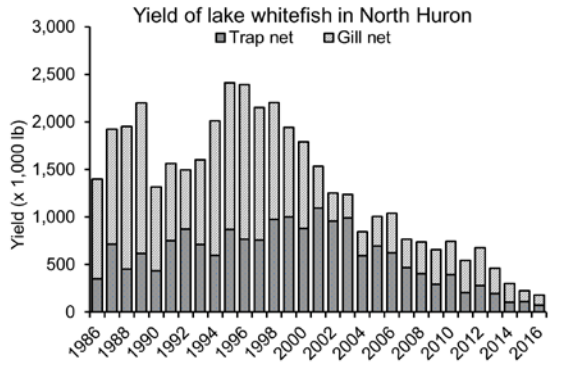
Parameter	Value
Base SSBR	2.77 lb
Current SSBR	1.01 lb
Target SSBR	1.00 lb
Current SPR	0.37
M	0.19 y^{-1}
F, trap net (2014-2016)	0.53 y^{-1}
F, gill net (2014-2016)	0.16 y^{-1}
Z (2016)	1.30 y^{-1}
Recommended TAC	294,700 lb
Actual TAC	294,700 lb
Model Rating	Medium

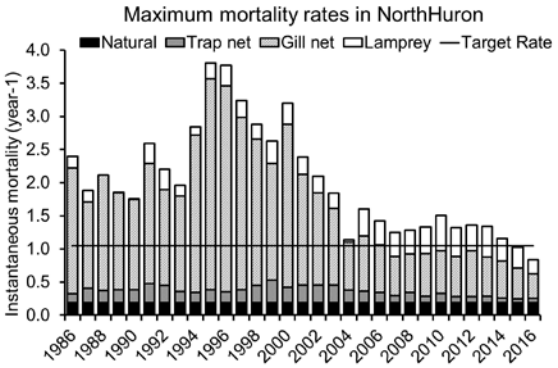
Notable Fishery Dynamics and Model Changes:

The model recommended harvest limit for 2018 is 294,700 lb, up 32% from 2017. All values for the .dat file were re-estimated because many data errors were found and corrected, such as mismatched grid/management unit, wrong study code, and outliers in length, weight, and age. These data changes had a minor influence on model predictions. The only change to last year's model structure was allowing the random walk of trap-net selectivity to run from the start of the time series as opposed to 1996. Harvest has been increasing in WFS-08 since 2014 and harvest in 2016 was the highest on record. The trap-net fishery has been the predominant fishery since 1999. Trap-net effort has been increasing since 2013 and 2016 was the highest on record. Gill-net effort has been increasing since 2012, but

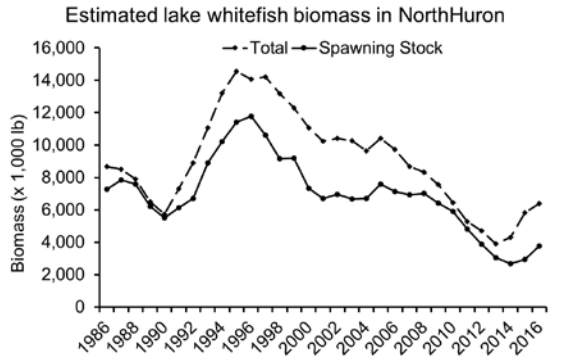
effort in 2016 is still only 23% of the maximum that was observed in 1989. The number of age-4 recruits has been increasing since 2012 and 2014-2016 represent the highest predictions of recruitment for the modeling period. A sharp increase in the proportion of age-5 fish in 2015 is evident in both fisheries and suggests an increase in age-4 recruits in 2014; however, strong recruitment events in 2015 and 2016 are not well supported by the proportion-at-age data and could be spurious model estimates. Both spawning and total biomass have been increasing since 2014 and are currently the highest on record. Fit to catch, fit to age, effort residuals, MCMCs, and retrospective analyses ranged from marginal to superior for this model.

Lake Huron
Northern Huron (WFH-01 to WFH-04) Stephen Lenart





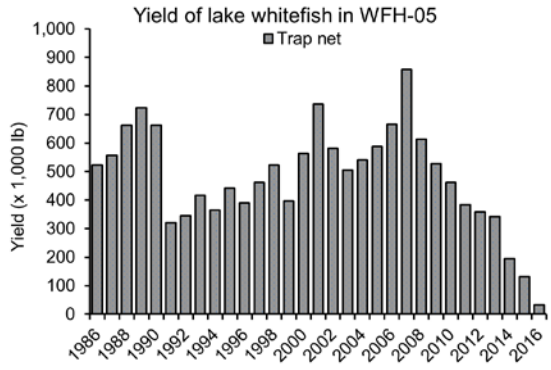
Parameter	Value
Base SSBR	3.55 lb
Current SSBR	1.23 lb
Target SSBR	1.47 lb
Current SPR	0.35
M	0.19 y^{-1}
F, trap net (2013-2015)	0.06 y^{-1}
F, gill net (2013-2015)	0.46 y^{-1}
Z (2015)	0.83 y^{-1}
Recommended TAC	438,700 lb
Actual TAC	379,900 lb
Model Rating	Low

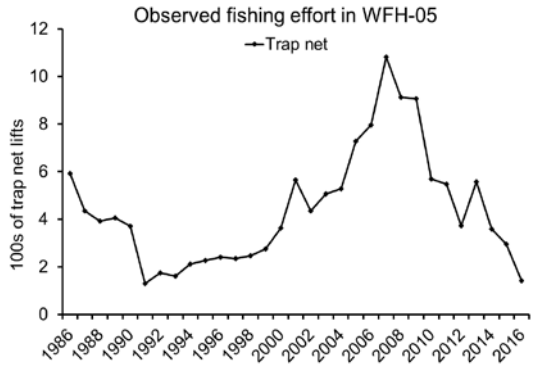


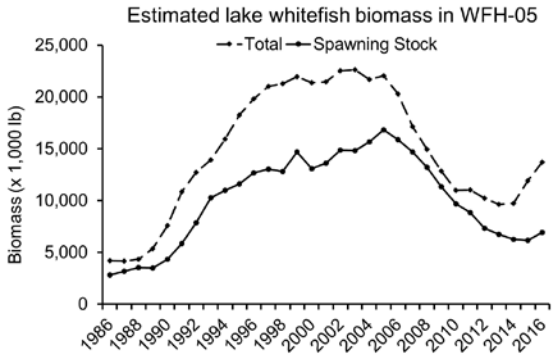
<u>Notable Fishery Dynamics and Model Changes:</u>

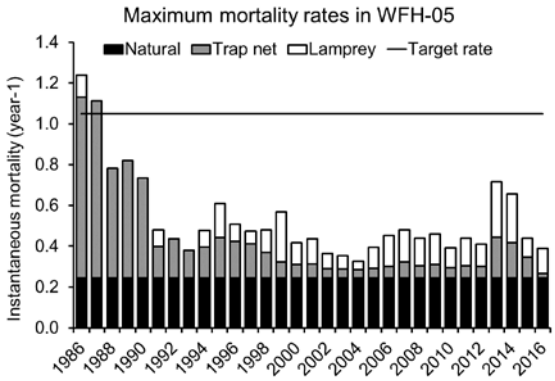
After a nearly two-decade decline, estimated spawning biomass increased modestly from the historic low of 2.7M lb observed in 2014. This increase is mostly attributed to a large (by recent standards) 2010 cohort that entered the fishery in 2016. The absolute size of this cohort is uncertain and additional observations will be necessary to confirm. Estimated mortality remains high at 56% and sea lamprey is still a significant source of mortality in this unit. The model produces limits in the range of 400-700K lb, depending on assumptions related to catchability and the weighting of the age composition data. Substantial changes were made to the assessment, including a change to the method used to model gill-net selectivity (fixed-

parameter double logistic to freely estimated lognormal), an expansion of the spatial information used to estimate maturity and growth (all Huron Treaty water data), a reduction in the weighting of the age composition data (effective sample size reduced from 100 to 50) and an increase in the aforementioned standard deviation associated with the Pauly prior for *M*. Nonetheless, certain diagnostics remain problematic. This factor, coupled with the variability in TACs produced, resulted in the low model rating. The 438,700 lb limit represents an 8% decrease from the 2017 model limit and is primarily driven by higher projected fishing mortality.









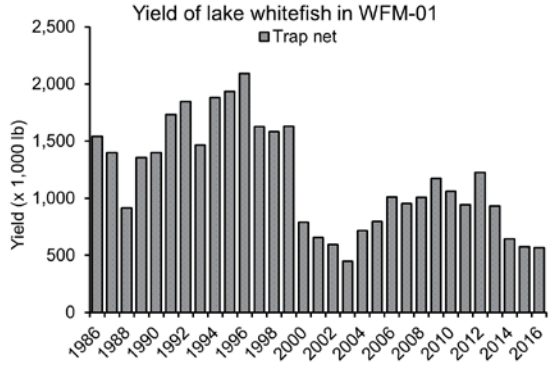
Parameter	Value
Base SSBR	2.03 lb
Current SSBR	0.99 lb
Target SSBR	1.22 lb
Current SPR	0.49
M	0.24 y^{-1}
F, trap net (2014-2016)	0.10 y^{-1}
Z (2016)	0.39 y^{-1}
Recommended TAC	654,500 lb
Actual TAC	394,000 lb
Model Rating	Low

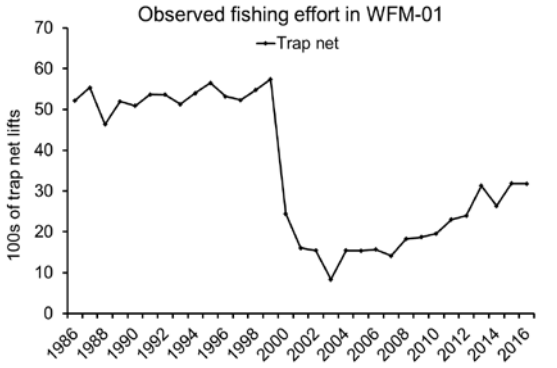
Notable Fishery Dynamics and Model Changes:

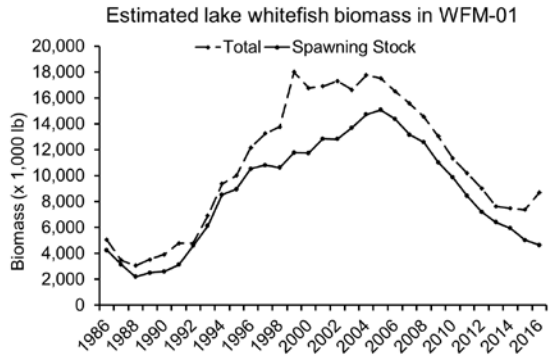
As is the case in North Huron, a slight increase in spawning biomass at the end of the time series is attributed to increased recruitment associated with cohorts from the 2008-2010 time period. The size of these cohorts remains uncertain. Mortality on the most vulnerable age classes was low (*A*=32%) but stock size remains depressed compared to the early 2000s peak due to the decline in recruitment that occurred since then. Various structural changes (see description in North Huron section) to the model were the primary reason for the 24% decrease in the 2018 model limit compared to 2017. Most diagnostics remain problematic and the model struggles to fit to the age composition data, which continue to show increased contributions from fish greater than age 20. Structural changes were not as significant here as in adjacent North Huron

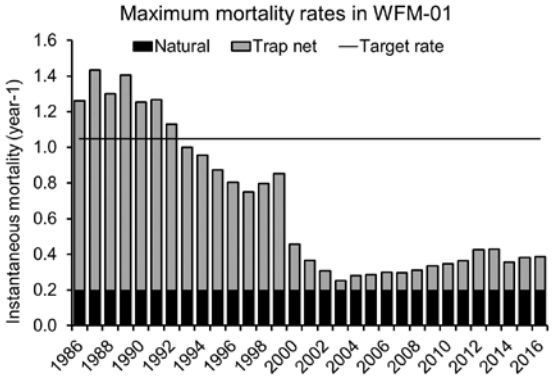
but, similarly, the model remains sensitive to assumptions about the weighting of the age composition and the flexibility given to changes in fishery catchability over time. Model performance is poor according to most diagnostic standards, yet stock sizes produced by various iterations of the assessment are similar.

WFM-01 (Bays De Noc) — Dave Caroffino









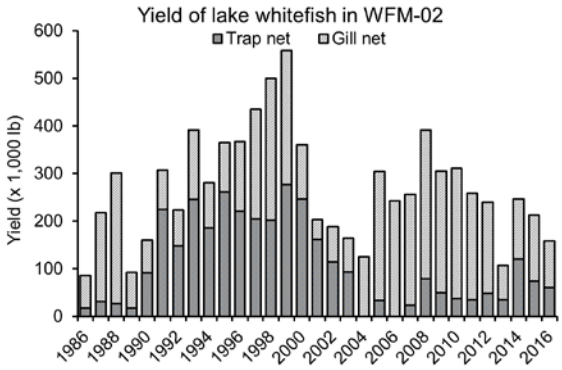
Parameter	Value
Base SSBR	3.15 lb
Current SSBR	0.66 lb
Target SSBR	0.66 lb
Current SPR	0.21
M	0.19 y^{-1}
F, trap net (2014-2016)	0.18 y^{-1}
Z (2016)	0.39 y^{-1}
Recommended TAC	2,131,600 lb
Actual TAC	2,131,600 lb
Model Rating	Low

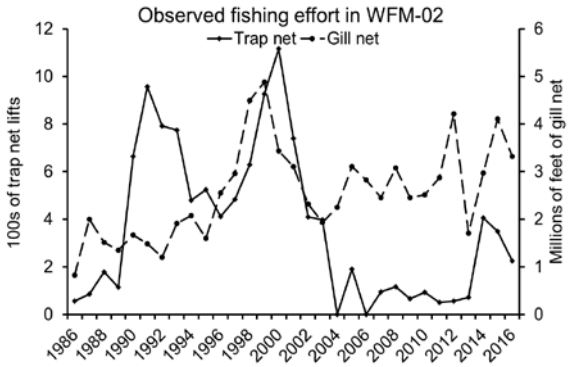
Notable Fishery Dynamics and Model Changes:

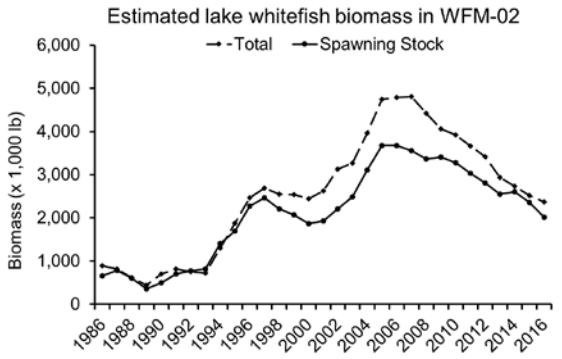
This model underwent numerous evaluations and modifications to bring it in line with other assessment models in Lake Michigan. Conceptually, the MSC felt that utilizing constant selectivity was most appropriate, as was modeling the purse seine as a separate fishery. Both changes were evaluated, but neither resulted in a stable model. The structure thus reverted to combining purse seine and trap-net data and allowing for time-varying selectivity. As more data are collected these changes will be reevaluated. Other items that were updated include using standard values for reference length and rhos and a reduction in the effective sample size from 100 to 50. The time series was also reduced to begin in 1986, consistent with other models throughout the lake. The

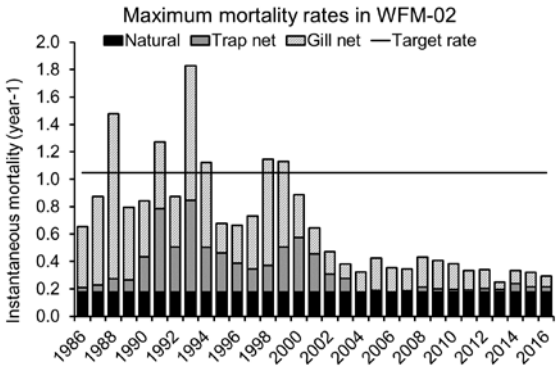
maturity matrix was updated, as was the prior and standard deviation used for natural mortality, which caused a reduction in the estimate from 0.3 to 0.19. A growth model was run to update lengths- and weights-at-age; however, results in the last year were problematic and need further scrutiny by the MSC before use. Raw data averages, which produce results consistent with past years, were used in the final assessment model. Overall, this model represents four different fisheries (gill net, trawl, trap net, and purse seine), three age structures (scales, spines, and otoliths), 3 labs and aging protocols (SSM, DNR-CHX, and DNR-MQT), and numerous individuals collecting information over the past 30 years. There is substantial noise in the data inputs, which will inherently result in some degree of model instability, which is why this unit will retain a low rating. A positive sign is that 40% of the catch is comprised of fish age 7 or under, suggesting recruitment is higher than in many other areas of Lake Michigan. The final version of the 2018 assessment model is not truly comparable to 2017 due to the model updates and provides a harvest limit of 2.13 million lb.

WFM-02 (Manistique) Ted Treska









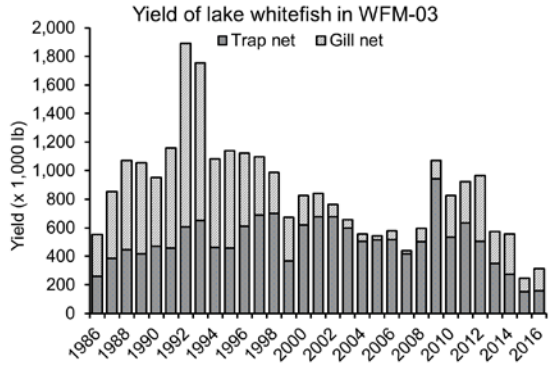
Parameter	Value
Base SSBR	4.12 lb
Current SSBR	0.81 lb
Target SSBR	0.84 lb
Current SPR	0.20
M	0.18 y^{-1}
F, trap net (2014-2016)	0.05 y^{-1}
F, gill net (2014-2016)	0.09 y^{-1}
Z (2016)	0.29 y^{-1}
Recommended TAC	699,200 lb
Actual TAC	362,300 lb
Model Rating	Medium

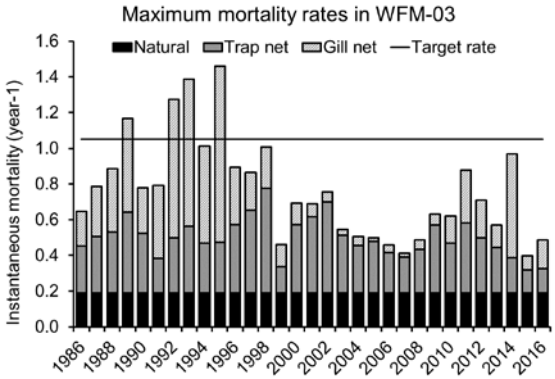
Notable Fishery Dynamics and Model Changes:

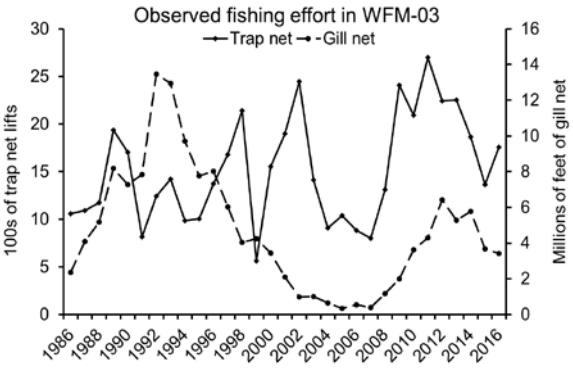
The model provides a harvest of 699,200 lb for 2018, an almost two-fold increase from the previous year. This year saw many substantial changes to the model. Included in this list is a reduction in the effective sample size for both fisheries from 100 to 50, the replacement of the maturity matrix with a standard version created for Lake Michigan, and an increase to the reference length of the trap-net fishery to 532 mm from 450 mm. There were also changes to the way natural mortality (*M*) was handled as was the case in most models, with an increase in the SD for *M*, along with the establishment of a starting value of 0.2, a value commonly used in fisheries. The average age of a harvested fish in this unit continues to increase, with a value of 10-11 for both fisheries. Agreement in proportions at age in the modeled and

observed catch are good, though the model is having trouble matching data from recent years, which is very erratic and drawn out over many age classes. This model incorporates mean length-at-age to estimate selectivity, the variance-ratio approach, and a random walk structure for catchability. This model has better diagnostics than past years and trends similar to its neighboring units.

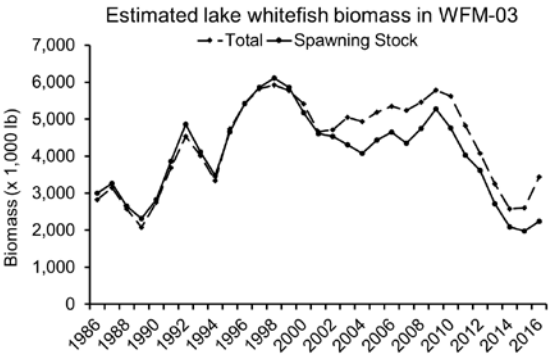
WFM-03 (Naubinway) Ted Treska







Parameter	Value
Base SSBR	3.59 lb
Current SSBR	1.13 lb
Target SSBR	1.13 lb
Current SPR	0.32
M	0.19 y^{-1}
F, trap net (2014-2016)	0.16 y^{-1}
F, gill net (2014-2016)	0.27 y^{-1}
Z (2016)	0.49 y^{-1}
Recommended TAC	800,400 lb
Actual TAC	800,400 lb
Model Rating	Medium

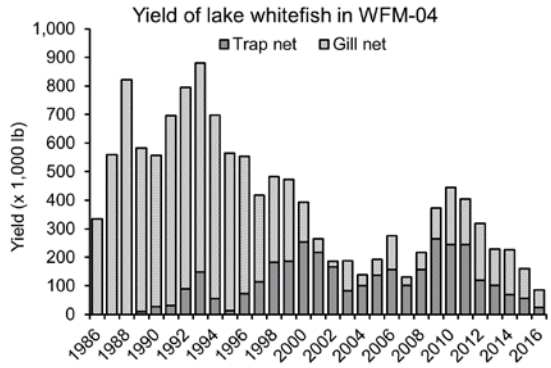


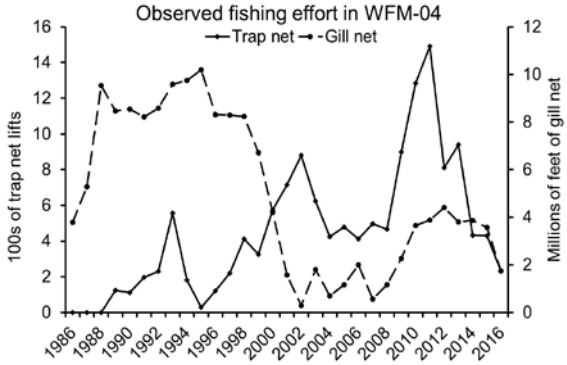
<u>Notable Fishery Dynamics and Model Changes:</u>

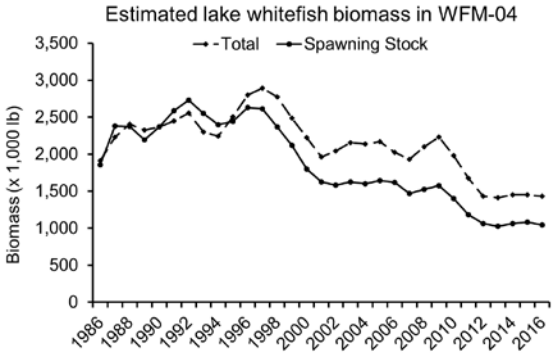
The recommended harvest level of 800,400 lb is a 10% decrease over last year's value of 887,100 lb. This year saw many substantial changes to the model. Included in this list is a reduction in the effective sample size for both fisheries from 100 to 50, the replacement of the maturity matrix with a standard version created for Lake Michigan, and an increase to the reference length of the trap-net fishery to 532 mm from 455. There were also changes to the way natural mortality (*M*) was handled as was the case in most models, with an increase in the SD for *M*, along with the establishment of a starting value of 0.2, a value commonly used in fisheries. Given the changes to natural mortality, the model estimated a much lower *M* value at 0.19 rather than the highly inflated value used in the past, and this new value

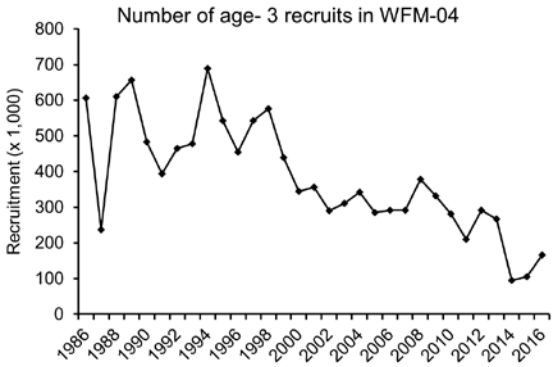
seems more appropriate given the older fish present in the unit and the fact that many previous studies of *M* were based on scale ages. The average age of fish harvested in the fisheries has increased from about age 5-6 during 1986-1997 or so, to nearly age 8-9 since late 2000s, though there is some indication that this might be declining again. This model incorporates mean length-at-age to estimate selectivity, the variance-ratio approach, and a random walk structure for selectivity and catchability. The model fit to age compositions continues to be strong, with good agreement in the recent years. Issues with covariance persist from the previous year and could not be remedied. Minor adjustments were made to the tacalc file (code correction) and meshes deep values (standardization) but had minor impacts on the model output. Overall, the model showed improved diagnostics and performance over prior years.

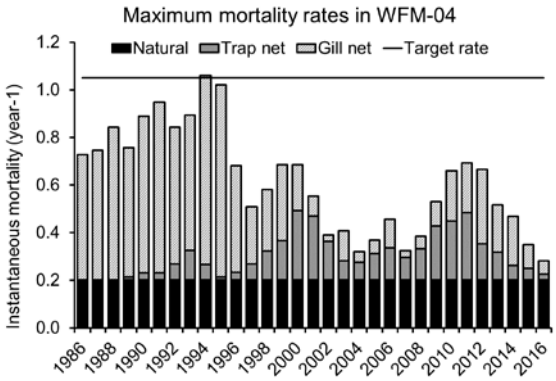
WFM-04 (Beaver Island) Kevin Donner











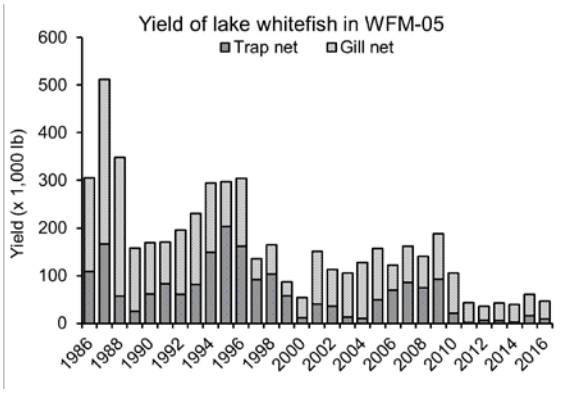
Parameter	Value
Base SSBR	3.64 lb
Current SSBR	0.73 lb
Target SSBR	0.40 lb
Current SPR	0.20
M	0.20 y^{-1}
F, trap net (2014-2016)	0.04 y^{-1}
F, gill net (2014-2016)	0.12 y^{-1}
Z (2016)	0.28 y^{-1}
Recommended TAC	427,200 lb
Actual TAC	427,200 lb
Model Rating	Medium

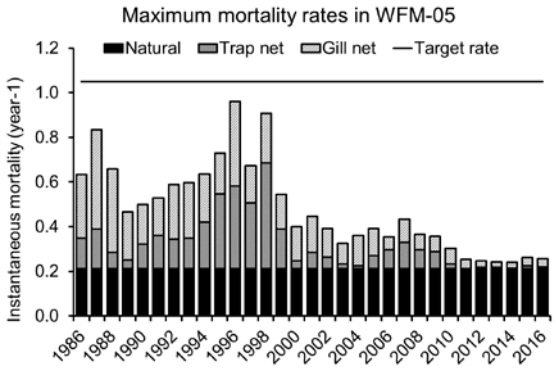
Notable Fishery Dynamics and Model Changes:

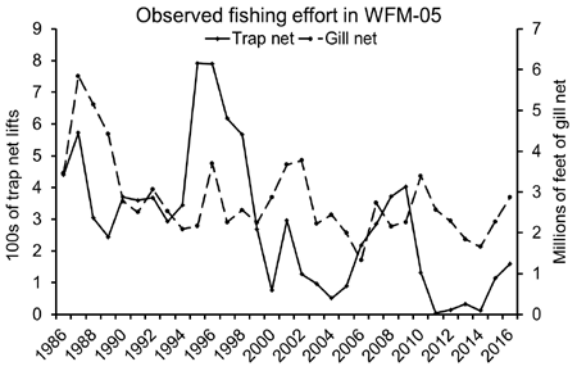
The 2018 model-generated harvest limit for WFM-04 is 427,200 lb. This estimate is 29% lower than the 2017 model limit and mostly attributable to changes to the model structure but also consistent with declines in biomass in the unit. Gill-net selectivity is estimated using a lognormal function of length and selectivity is now constant to address scaling issues that were estimating abundances beyond reasonable bounds. Effective sample size has been reduced from 75 to 25 per MSC discussion. The most substantial change this year was an increase in the deviation associated with the Pauly equation from 0.001 to 0.24. This change resulted in reduced estimates of natural mortality (*M*; 0.2 in the current model vs 0.28 in last year's model) that are likely more appropriate for the stock. A literature review and discussion

by the MSC determined that in most whitefish stocks where age is estimated using otoliths, *M* typically ranges between 0.15 and 0.25. Catch curves from WFM-04 fishery dependent and independent sources indicated that total mortality (*Z*) was consistently less than 0.3, also supporting a reduced estimate of *M*. Population trends (declining biomass, abundance, etc) estimated in past years and observed in adjacent management units are similar to those observed in the current model. The model exhibited good fit, almost no retrospective patterns, and decent MCMC results.

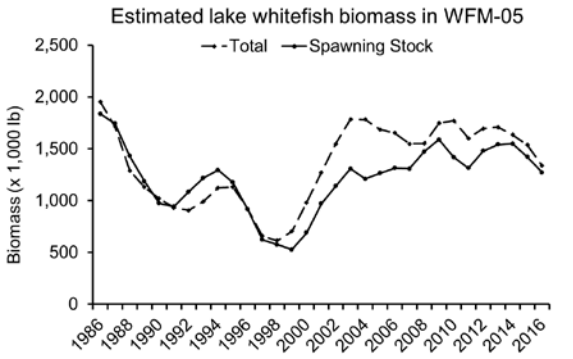
WFM-05 (Grand Traverse Bay) Nathan Barton







Parameter	Value
Base SSBR	3.37 lb
Current SSBR	0.67 lb
Target SSBR	0.44 lb
Current SPR	0.20
M	0.21 y^{-1}
F, trap net (2014-2016)	0.01 y^{-1}
F, gill net (2014-2016)	0.03 y^{-1}
Z (2016)	0.26 y^{-1}
Recommended TAC	352,200 lb
Actual TAC	352,200 lb
Model Rating	Medium

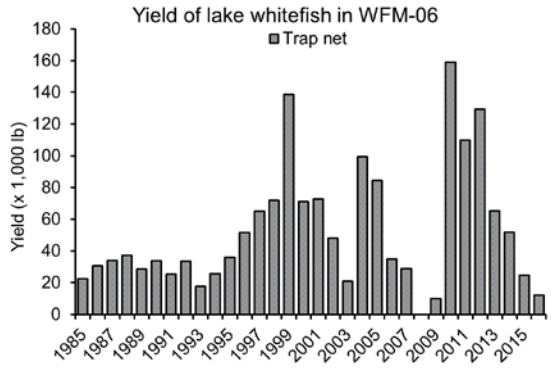


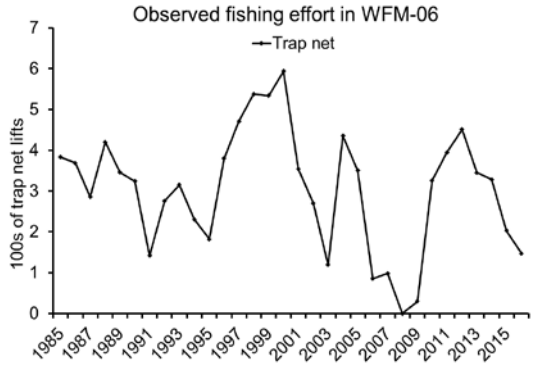
Notable Fishery Dynamics and Model Changes:

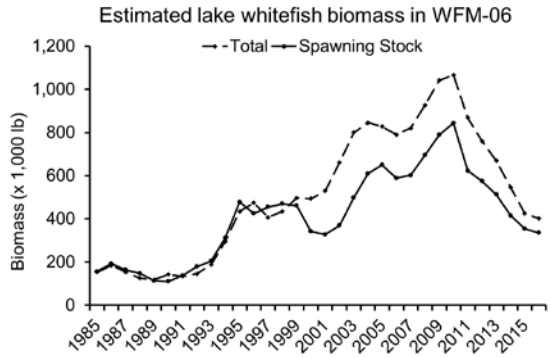
The 2018 model-generated harvest limit for WFM-05 is 32% lower than the 2017 model limit and is largely attributed to declining stock sizes and a few modifications to data inputs. First, the maturity matrix was updated for this model and standardized across the entire modeled waters of Lake Michigan. Second, the first five years of data (1981-1985) were removed from the model. These data represented an essentially unfished resource, and was not representative of contemporary stock sizes, and nearly every other model begins in 1986. Third, the parameters constraining the estimate of *M* was relaxed, allowing the model to more freely estimate *M*, which resulted in a decrease in the estimate, closer to 0.2 yr^{-1}. In keeping with the recent transition in this unit from scales to otoliths as the major aging

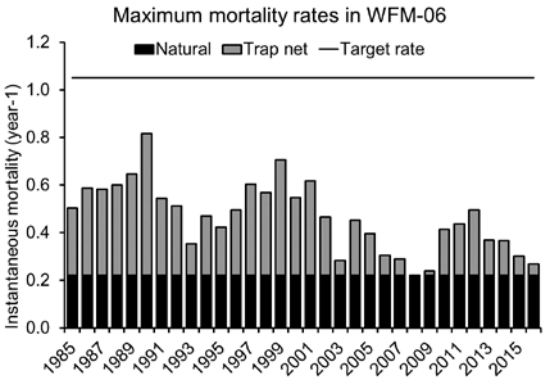
structure, the 2016 age composition data were again skewed toward older ages, causing a divergence in the last two years of retrospective patterns.

WFM-06 (Leland) Dave Caroffino









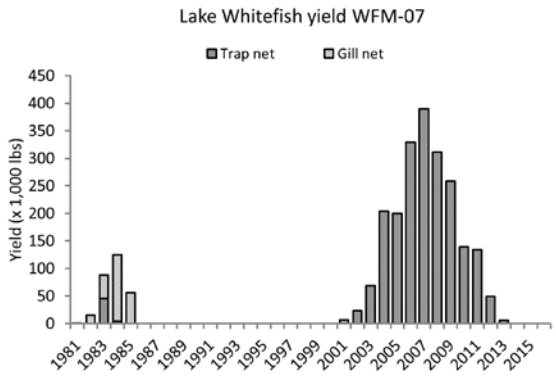
Parameter	Value
Base SSBR	3.86 lb
Current SSBR	0.77 lb
Target SSBR	0.45 lb
Current SPR	0.20
M	0.22 y^{-1}
F, trap net (2014-2016)	0.09 y^{-1}
Z (2016)	0.27 y^{-1}
Recommended TAC	117,200 lb
Actual TAC	125,000 lb
Model Rating	Medium

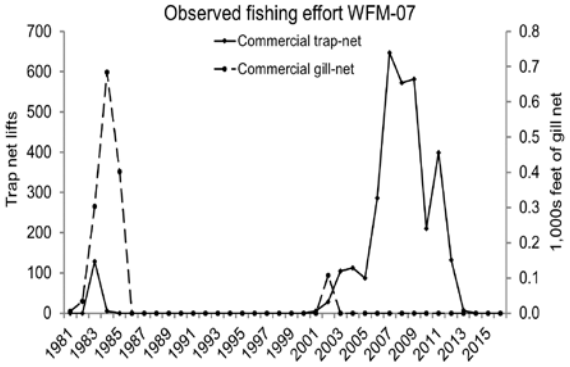
Notable Fishery Dynamics and Model Changes:

The changes to the WFM-06 model for the 2018 cycle were consistent with those made for other models in Lake Michigan – a new maturity matrix, a reduction in effective sample size, and increased freedom to estimate natural mortality. The estimate of natural mortality declined from 30% in prior years to 22% in this model. In the prior modeling cycle, gill-net data were dropped as a separate modeled fishery, simply due to a lack of information. Ironically, in 2016 more gill-net samples were collected than trap-net samples and the gill-net sample size was higher than it's been since 2004. These data were used as part of the modeled trap-net fishery and weighted with the trap-net data, according to the proportion of total extraction by each gear. Model performance was adequate and the trends unchanged from recent years. Biomass and recruitment both

remain low and fishery catch rate continues to decline. The conditional constant catch quota was halved last year from 250,000 lb to 125,000 lb and it is recommended this lower value be continued.

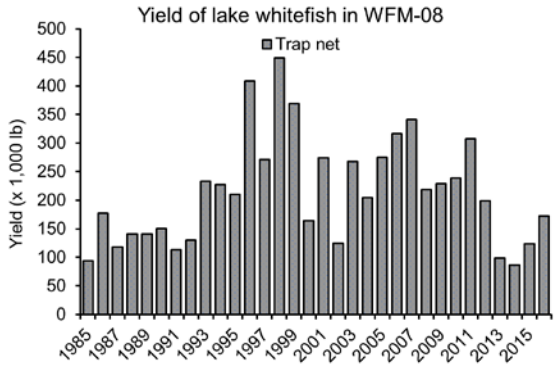
WFM-07 (Manistee to Pentwater)

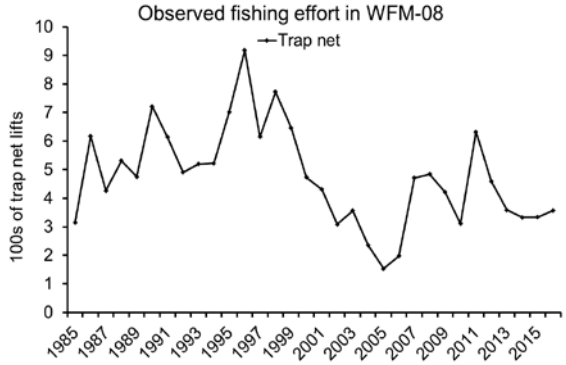


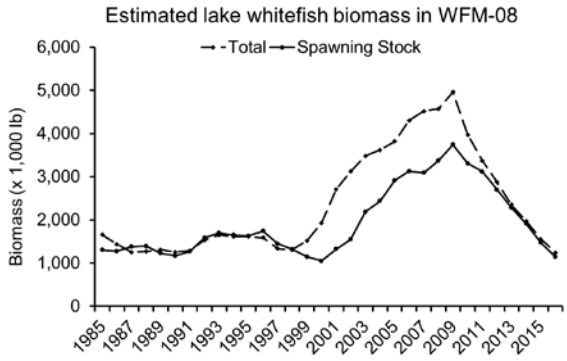


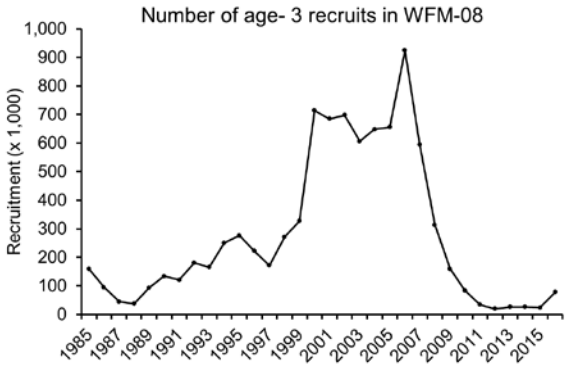
No stock assessment model has been developed for WFM-07. When the Consent Decree was initially signed, this unit lacked the necessary time series of data to populate a model. Fishing effort and yield in this unit peaked in 2007 and ceased in 2013. The HRG was reduced from 500,000 lb to 350,000 lb in 2016 and that reduced limit remains in place for 2018.

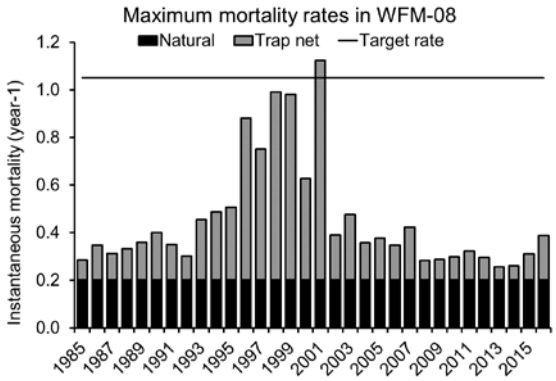
WFM-08 (Muskegon) Dave Caroffino











Parameter	Value
Base SSBR	3.88 lb
Current SSBR	0.78 lb
Target SSBR	0.73 lb
Current SPR	0.20
M	0.20 y^{-1}
F, trap net (2014-2016)	0.12 y^{-1}
Z (2016)	0.39 y^{-1}
Recommended TAC	353,300 lb
Actual TAC	500,000 lb
Model Rating	Medium

Notable Fishery Dynamics and Model Changes:

The changes to the WFM-08 model for the 2018 cycle were consistent with those made for other models in Lake Michigan – a new maturity matrix, a reduction in effective sample size, and increased freedom to estimate natural mortality. The estimate of natural mortality declined from 34% in prior years to 20% in this model. Stock size is equivalent to levels of the 1980s and 1990s, but that represents a 69% decline from the peak in 2009. This decline is driven by recruitment, which for a period of 8 years averaged 700,000 age-3 fish per year; however, in the five most recent years for which data are available, recruitment of age-3 fish has averaged 26,000 fish per year. The conditional constant catch quota was reduced by 64% in 2017 down to 500,000 lb, and it is recommended it remain at that level for 2018.