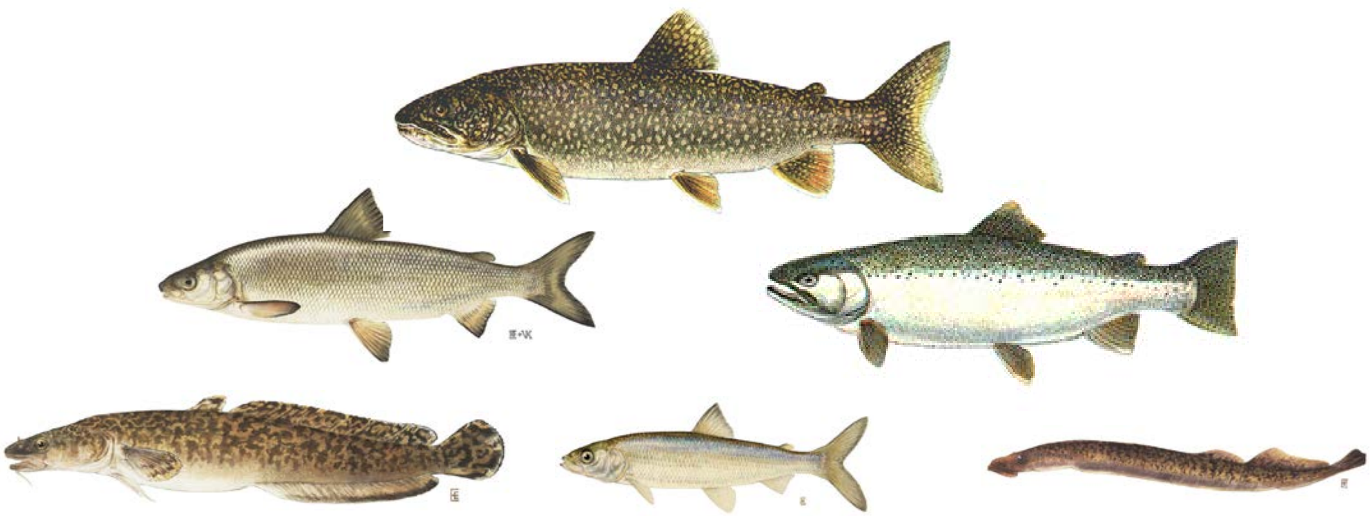
2018 REPORT OF THE LAKE ERIE COLDWATER TASK GROUP

March 2019

Presented to:
Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission



CWTG Members:

Tom MacDougall	Ontario Ministry of Natural Resources and Forestry (Co-Chair)
James Markham	New York Department of Environmental Conservation (Co-Chair)
Jim Boase	United States Fish and Wildlife Service
Jeff Braunscheidel	Michigan Department of Natural Resources
Andy Cook	Ontario Ministry of Natural Resources and Forestry
John Deller	Ohio Division of Wildlife
Chris Eilers	United States Fish and Wildlife Service
Mark Haffley	Pennsylvania Fish and Boat Commission
Chelsea May	Ontario Ministry of Natural Resources and Forestry
Chuck Murray	Pennsylvania Fish and Boat Commission
Kevin Tallon	Department of Fisheries and Oceans, Canada
Michael Thorn	Ontario Ministry of Natural Resources and Forestry
Chris Vandergoot	United States Geological Survey

Note: Data contained in this report is considered provisional. Use of data for external publication must be approved by the CWTG; please contact the CWTG Co-chairs for permission.

Citation:

Coldwater Task Group. 2019. 2018 Report of the Lake Erie Coldwater Task Group, March 2019. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Cover Art and Line Drawings from:

Raver, Duane. 1999. Duane Raver Art. U.S. Fish and Wildlife Service. Shepherdstown, West Virginia, USA.

Kraft, C.E., D.M. Carlson, and M. Carlson. 2006. *Inland Fishes of New York (Online)*, Version 4.0. Department of Natural Resources, Cornell University, and the New York State Department of Environmental Conservation.

TABLE OF CONTENTS

Reporting of 2018 – 2019 Coldwater Task Group Charges

Charge 1:	Coordinate annual standardized coldwater assessment among all eastern basin agencies and report upon the status of the coldwater fish community.	***7***
Charge 2:	Continue to assess and report on status of the Lake Whitefish fishery, including biological reference points, knowledge gaps, impediments and uncertainties required to provide advice to future management.	***16***
Charge 3:	Continue to participate in the IMSL process on Lake Erie to outline and prescribe the needs of the Lake Erie Sea Lamprey management program.	***27***
Charge 4:	Maintain an annual interagency electronic database of Lake Erie salmonid stocking for the STC, GLFC and Lake Erie agency data depositories.	***34***
Charge 5:	Report on the status of Steelhead and develop a proposal for mass marking, including lake wide and agency goals and objectives, a study plan, and logistics.	***39***
Acknowledgements		***44***
References		***45***

COLDWATER TASK GROUP EXECUTIVE SUMMARY REPORT MARCH 2019

Lake Erie Committee

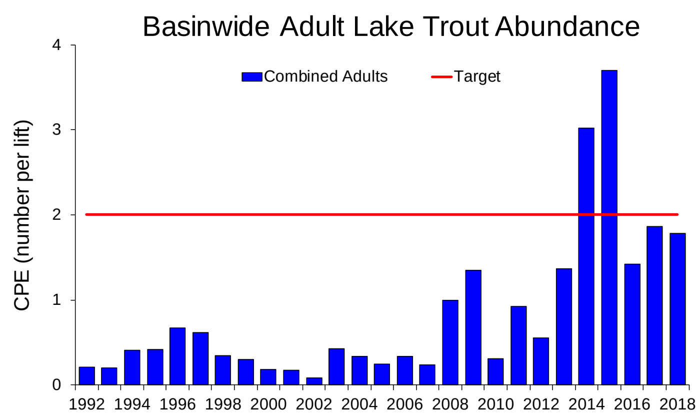
REPRESENTING THE FISHERY MANAGEMENT AGENCIES OF LAKE ERIE AND LAKE ST. CLAIR

Introduction

This year's Lake Erie Committee (LEC) Coldwater Task Group (CWTG) has produced an Executive Summary Report encapsulating information from the CWTG annual report. Five charges were addressed by the CWTG during 2018-2019: (1) Report on the status of the coldwater fish community; (2) Lake Whitefish fishery assessment and population biology; (3) Participation in Sea Lamprey assessment and control in the Lake Erie watershed; (4) Maintenance of an electronic database of Lake Erie salmonid stocking information, and (5) Status of Steelhead and development of a mass marking study. The complete report is available from the Great Lakes Fishery Commission's Lake Erie Committee Coldwater Task Group website at http://www.glfc.org/lakecom/lec/CWTG.htm, or upon request from an LEC or CWTG representative.

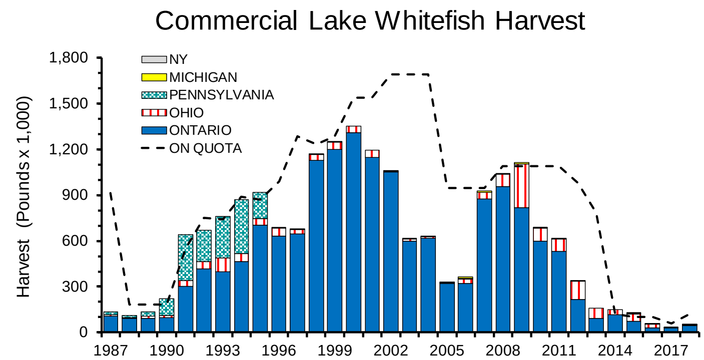
Lake Trout

A total of 403 Lake Trout were collected in 110 unbiased gill net lifts across the eastern basin of Lake Erie in 2018. Basin-wide Lake Trout abundance (weighted by area) was 2.9 fish per lift, which is near average for the time series but well below the rehabilitation target of 8.0 fish/lift. However, adult abundance (ages 5+) was at its fourth highest measure in the time series and slightly below the target of 2.0 fish/lift (see figure). Lake Trout ages 3, 6, 8, and 9 were the dominate cohorts; Lake Trout older than age-10 are increasing in abundance. Finger Lakes and Lake Champlain strain Lake Trout comprise the majority of the population. The Lake Erie Lake Trout population continues to be supported by binational stocking efforts; natural reproduction has not been documented in Lake Erie despite more than 30 years of restoration efforts.



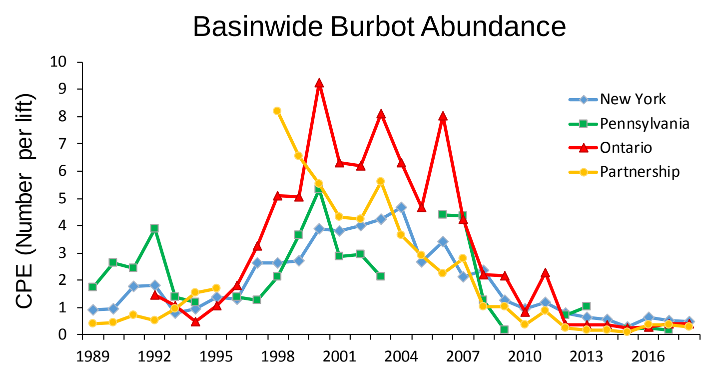
Lake Whitefish

Lake Whitefish harvest in 2018 was 52,722 pounds, distributed among Ontario (84%), Ohio (8%), Michigan (8%) and Pennsylvania (<1%). Harvest in 2018 was second lowest since 1987 but increased 67% from 2017. Gill net fishery age composition ranged from ages 3 to 15. The 2015 year class (age 3) comprised the largest fraction (65%) of the Lake Whitefish gill net fishery. Gill net surveys caught Lake Whitefish from age 0 to 33, with age 3 most abundant. Central and east basin bottom trawl surveys forecasted significant recruitment from 2014, 2015 and 2018 cohorts. These year classes are expected to improve Lake Whitefish status over the next several years. Continued, conservative harvest is recommended until the Lake Whitefish population recovers to moderate or higher levels.



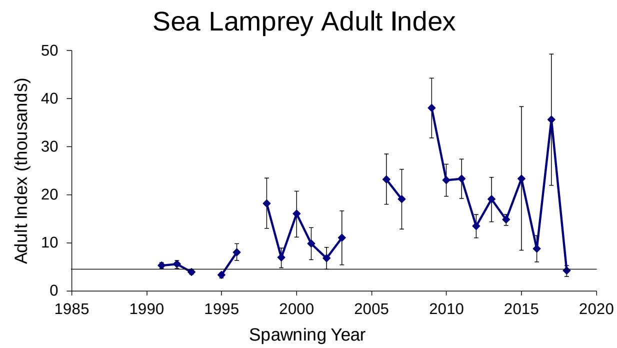
Burbot

Total commercial harvest of Burbot in Lake Erie in 2018 was 2,400 pounds. All harvest was incidental. Burbot abundance and biomass indices from annual Coldwater and Ontario Partnership Gillnet Assessment Surveys remained stable but at low levels compared to the highs in the early-2000s. The catch rate in the Interagency Coldwater Assessment Survey averaged 0.4 Burbot per lift and in the Ontario Partnership Assessment Survey averaged 0.3 Burbot per lift. Burbot in the Coldwater Assessment Survey ranged in age from 4 to 27 and mean age was 12.4 years. Round Goby was the dominant item in Burbot diets.



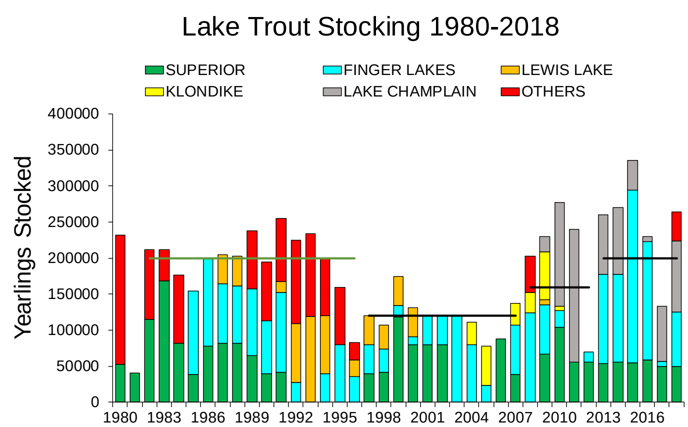
Sea Lamprey

The A1-A3 wounding rate on Lake Trout over 532 mm was 9.7 wounds per 100 fish in 2018. This was lower than the 10-year wounding rate (13.5 wounds/100 fish) but nearly 2 times the target rate of 5.0 wounds per 100 fish. Wounding rates have been above target for 22 of the past 23 years. Large Lake Trout over 635 mm continue to be the preferred targets for Sea Lamprey in Lake Erie. The Index of Adult Sea Lamprey Abundance (4,149) represents a substantial decrease compared to recent estimates and was below the target population of 4,435 for the first time since 1995. Comprehensive stream evaluations continued in 2018, including extensive detection surveys around the basin to inventory all sources contributing to the Lake Erie population.



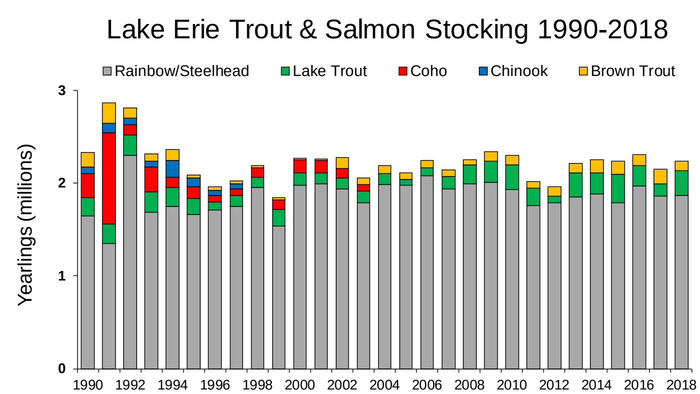
Lake Erie Salmonid Stocking

A total of 2,236,843 yearling salmonids were stocked in Lake Erie in 2018, which was near the long-term average (1990-2017). Lake Trout stocking was above targets for the fifth time in the past six years, and four different strains were stocked in 2018. By species, there were 270,275 yearling Lake Trout stocked in all three basins of Lake Erie, 98,966 Brown Trout stocked in Pennsylvania waters, 54,150 domestic Rainbow Trout stocked in New York waters, and 1,813,452 Steelhead stocked across all five jurisdictional waters.



Steelhead

All agencies stocked yearling Steelhead in 2018. The summary of Steelhead stocking in Lake Erie by jurisdictional waters for 2018 is: Pennsylvania (979,851; 54%), Ohio (478,408; 26%), New York (257,693; 14%), Michigan (62,000; 3%) and Ontario (35,500; 2%). Total Steelhead stocking in 2018 (1.87 million) was slightly above the long-term average. Annual stocking numbers have been consistently in the 1.7-2.0 million fish range since 1993. The summer open lake Steelhead harvest was estimated at 6,950 Steelhead across all US agencies in 2018, about an 23% decrease compared to 2017 estimates and below the long-term than average harvest of 8,600. Overall open lake catch rates remain near the long-term average, but reported effort remains small relative to percids. Tributary angler surveys, representing the majority (>90%) of the targeted fishery effort for Steelhead, found average catch rates of 0.56 fish/hour in 2017-18 in New York tributaries, which are among the highest in the country.



CHARGE 1: Coordinate annual standardized coldwater assessment among all eastern basin agencies and report upon the status of the coldwater fish community

James Markham (NYSDEC), Andy Cook (OMNRF), Chelsea May (OMNRF), Tom MacDougall (OMNRF), Chuck Murray (PFBC), Chris Vandergoot (USGS), Jim Boase (USFWS), Justin Chiotti (USFWS), Ed Roseman (USGS)

East Basin Cold Water Assessment Program

Two coldwater assessments are conducted each year: the inter-agency August Coldwater Assessment (hereafter referred to as the "Coldwater Assessment Survey") in New York, Ontario, and Pennsylvania waters of the eastern basin, and the Ontario Partnership Index Fishing Program (hereafter referred to as the "Partnership Survey") in Ontario waters.

The Coldwater Assessment Survey is a stratified, random, deep-water bottom set gill net assessment program conducted since 1986. The eastern basin of Lake Erie is divided into eight sampling areas (A1-A8; Figure 1.1). A1 and A2 have been the most consistently sampled areas across survey years while effort has varied in all other areas. Area A4 has been periodically sampled due to the lack of enough cold water to set gill nets according to the sampling protocol. Sampling was conducted in six of the eight areas in 2018 (Figure 1.1); areas A3 and A4 were not sampled due to vessels issues.

The Partnership Survey is a lakewide gill net survey of the Canadian waters that has provided a spatially robust assessment of fish species abundance and distribution since 1989. The Partnership Survey uses suspended and bottom set gill nets.

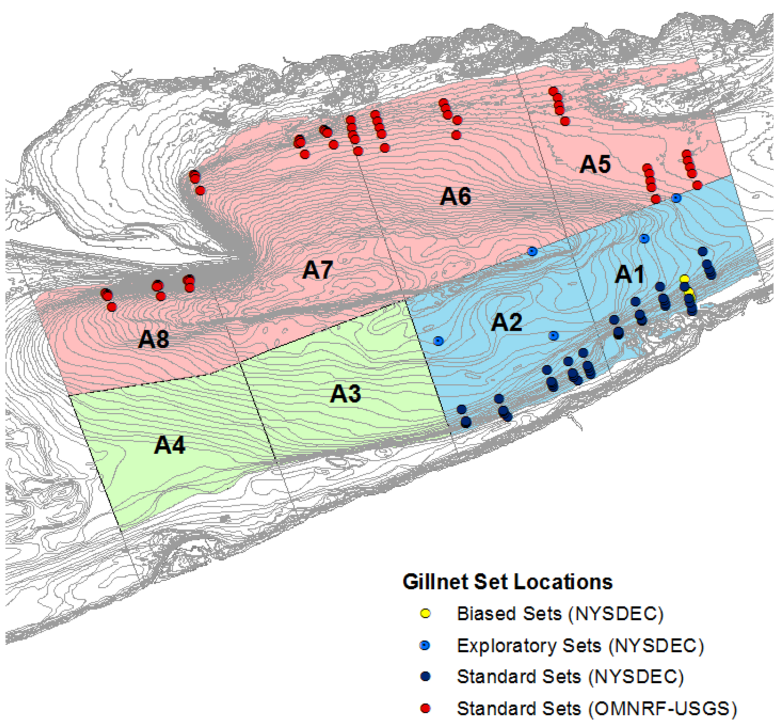


FIGURE 1.1. Standard sampling areas (A1-A8) used for assessment of assessment of coldwater species in the eastern basin of Lake Erie, 2018. Colored circles represent the location of all nets set in each sampling area.

LAKE TROUT REHABILITATION

Lake Trout Management Plan Objectives	Target	Long-term Average	2018
Lake Trout Abundance (all ages)	8 fish/lift	2.3 fish/lift	2.9 fish/lift
Lake Trout Abundance (age 5+)	2 fish/lift	0.8 fish/lift	1.8 fish/lift
Percent Females	25% age 5+		48%
Age classes	10+		18
Egg densities	25-500 eggs per m^2	Unknown	Unmeasured
Natural recruitment	Consistent contribution of wild age-1 Lake Trout	None	None

All Lake Trout in the Coldwater Assessment Survey are examined for total length, weight, sex, maturity, fin clips, and wounds by Sea Lamprey. Snouts from each Lake Trout are retained and coded-wire tags (CWT) are extracted in the laboratory to accurately determine age and genetic strain. Otoliths and genetic samples are also retained when the fish is not adipose fin-clipped. Stomach content data are usually collected as on-site enumeration or from preserved samples.

A total of 403 Lake Trout were caught in 110 unbiased lifts. Areas A1 and A2 again produced the highest catch per unit effort (CPE) values, coinciding with higher yearling Lake Trout stocking over time. Comparatively, Lake Trout catches were much lower in Ontario waters (A5-A8), where stocking did not commence until 2006. The large disparity in Lake Trout catches among east basin survey areas may indicate a lack of movement away from the stocking area, better available habitat, or a lower survival rate in Ontario waters.

Lake Trout captured in 2018 represented eighteen age-classes. Ages 3, 6, 8 and 9 cohorts were the most abundant and represented 71% of the total catch (Figure 1.2). The abundance of Lake Trout older than age-10 has increased in recent years but remains in relatively low abundance, comprising less than 10% of the overall catch.

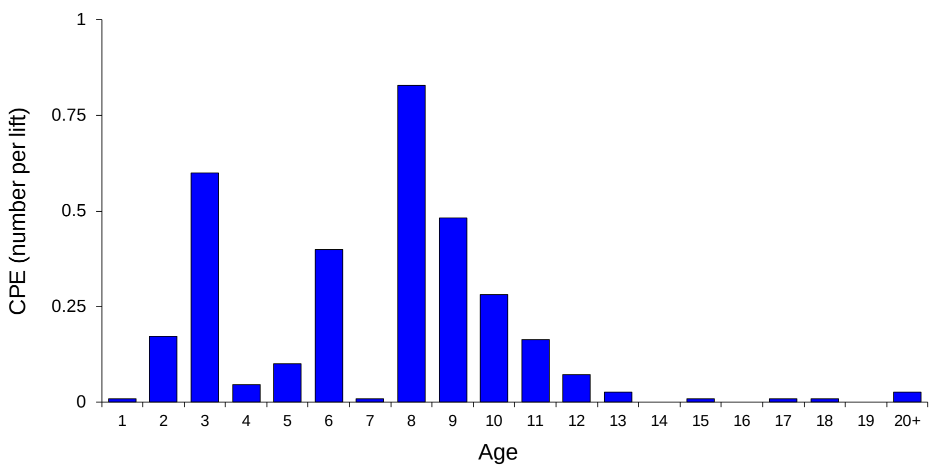


FIGURE 1.2. Relative abundance (number per lift) at age of Lake Trout sampled in standard assessment gill nets in the eastern basin of Lake Erie, August 2018.

Area-weighted mean CPE of Lake Trout caught in the eastern basin in 2018 was 2.9 fish per lift (Figure 1.3). This was above average for the time series but well below the rehabilitation target of 8.0 fish/lift (Markham et al. 2008).

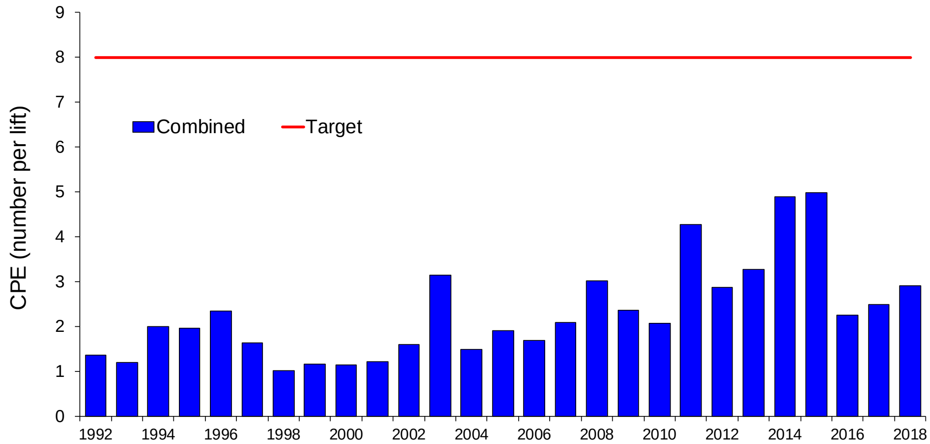


FIGURE 1.3. Mean combined CPE (number per lift, weighted by area) for Lake Trout sampled in standard assessment gill nets in the eastern basin of Lake Erie, 1992-2018. The red solid line represents the rehabilitation target of 8.0 fish per lift for all ages.

The relative abundance of adult (age-5 and older) Lake Trout caught in standard assessment gill nets (weighted by area) in the Coldwater Assessment Survey serves as an indicator of the size of the Lake Trout spawning stock in Lake Erie. Adult abundance decreased slightly in 2018 to 1.8 fish per lift but remains high for the time series, ranking as the fourth highest in 27 years (Figure 1.4). Adult abundance remains slightly below the basin-wide rehabilitation target of 2.0 fish/lift.

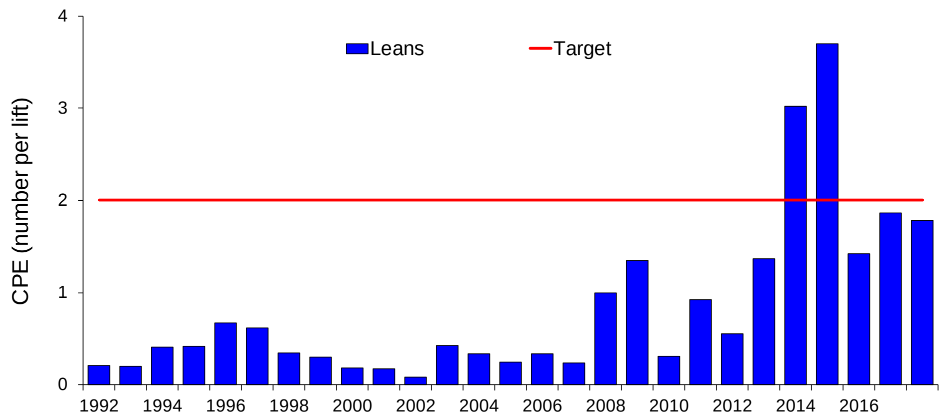


FIGURE 1.4. Relative abundance (number per lift, weighted by area) of age-5-and-older Lean strain and Klondike strain Lake Trout sampled in standard assessment gill nets in the eastern basin of Lake Erie, 1992-2018. The red solid line represents the adult rehabilitation target of 2.0 fish per lift.

Sixty-one (61) Lake Trout were caught in Partnership Survey index gear in the Pennsylvania Ridge (1) and the east basin (60). The 2018 Lake Trout index in the east basin (0.97 fish/lift) was above the time series mean (0.41 fish/lift) while the 2018 catch rate in the Pennsylvania Ridge survey (0.06) was below average (0.19 fish/lift) (Figure 1.5). Most (58) of the Lake Trout caught during 2018 were from nets fished on bottom, whereas 1 was caught in standard canned nets and 2 were caught in nets suspended within the thermocline. Five (5) additional Lake Trout were caught in auxiliary 50 mesh deep, 121 mm gill nets suspended in the water column of the east basin. From a total of 66 Lake Trout caught in index and auxiliary gear, strains of 57 fish were identified from coded wire tags: Finger Lakes (27, 41%), Slate Islands (19, 29%) and Lake Champlain (11, 17%). Tags were not detected or were not readable in 8 fish (12%), but adipose clips were present indicating a stocked origin. One (1) Lake Trout lacked fin clips and a coded wire tag, possibly indicating a natural origin. Ages derived from tagging dates ranged from 1 to 28, with age 3 comprising the largest fraction (29%).

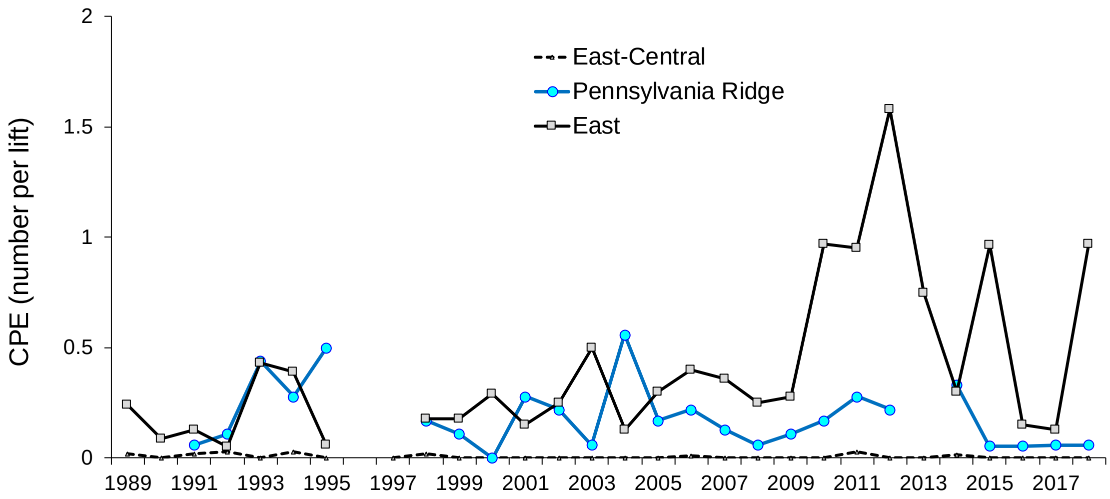


FIGURE 1.5. Lake Trout CPE (number per lift) by basin from the OMNRF Partnership Index Fishing Program, 1989-2018. Includes canned (suspended) and bottom gill net sets, excluding thermocline sets.

Harvest

Angler harvest of Lake Trout in Lake Erie remains very low. An estimated 358 Lake Trout were harvested in New York waters out of an estimated catch of 1,615 in 2018. Pennsylvania anglers harvested an estimated 245 fish from a total catch of 830 Lake Trout. (Figure 1.6).

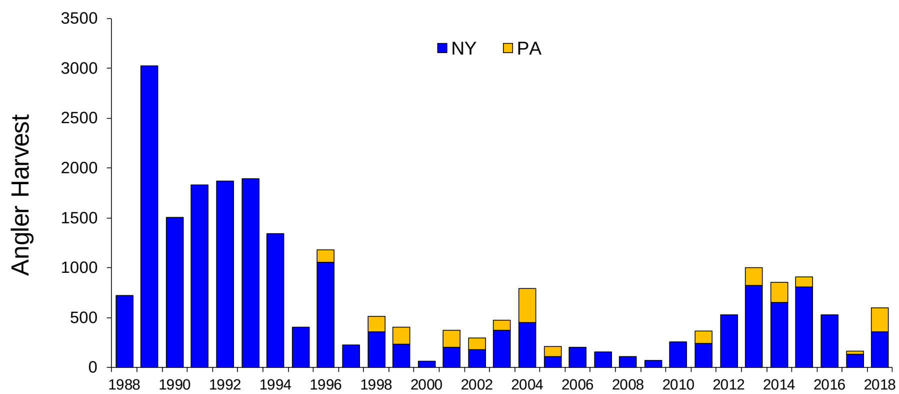


FIGURE 1.6. Estimated Lake Trout harvest by recreational anglers in the New York and Pennsylvania waters of Lake Erie, 1988-2018.

Natural Reproduction

Despite more than 30 years of Lake Trout stocking in Lake Erie, no naturally reproduced Lake Trout have been documented. Seven potentially wild fish (no fin clips; no CWT's) were caught in eastern basin coldwater gill net surveys in 2018, representing less than 2% of the fish captured. An additional non-clipped/non-tagged Lake Trout was caught in the Partnership Survey. This was the most non-marked Lake Trout caught in survey netting to date, and five of the unmarked fish were caught in one day and ranged between 355 and 422 mm TL. Altogether, a total of 76 potentially wild Lake Trout have been recorded over the past 18 years. Rates of unmarked fish remain similar to measures of unmarked fish in the hatchery. Otoliths are collected from Lake Trout found without CWTs or fin-clips and will be used in future stock discrimination studies.

Diet

Seasonal diet information for Lake Trout is not available based on current sampling protocols. Diet information was limited to fish caught during August 2018 in the coldwater gill net assessment surveys in the eastern basin of Lake Erie. Rainbow Smelt have traditionally been the main prey item for Lake Trout, comprising over 90% of Lake Trout diet items. However, Round Goby have become a common prey item since they invaded

the east basin of Lake Erie in the early 2000s (Figure 1.7). In years of lower adult Rainbow Smelt abundance, Lake Trout appear to prey more on Round Goby.

In 2018, Round Goby and Rainbow Smelt were equally prevalent diet items for Lake Trout, occurring in 58% and 57% of the stomachs, respectively (Figure 1.7). It should be noted that Round Goby were much more numerically abundant in Lake Trout diets compared to Rainbow Smelt; some stomachs contained in excess of 50 Round Goby compared to a few adult smelt. Other fish species comprised 15% of the diets, which is the highest occurrence in the time series. Yellow perch comprised the majority of this group (14%); other species included Morone sp. (white perch, white bass) (<1%), freshwater drum (<1%), and salmonids (<1%).

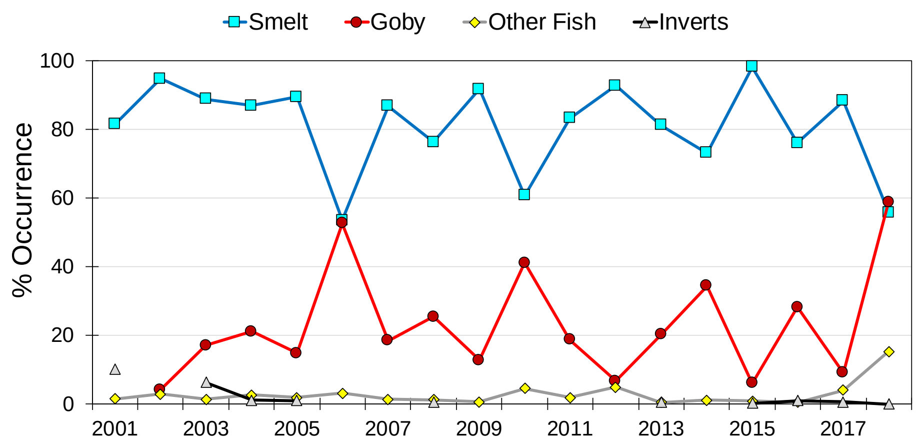


FIGURE 1.7. Percent occurrence in diet of Rainbow Smelt, Round Goby, all other fish species, and invertebrates from non-empty stomachs of Lake Trout caught in eastern basin assessment gill nets, August, 2001-2018.

BURBOT

Abundance and Distribution

Burbot are seasonally found in all the major basins of Lake Erie; however, the summer distribution of adult fish is restricted primarily to the 20-m and deeper thermally stratified regions of the eastern basin. During the early 1990s, Burbot abundance was low throughout the lake. It increased between 1993 and 1998, peaked in the early 2000s, and then declined. Since 2012, catch has been consistently low. Burbot catch rates in Partnership Survey nets fished on bottom during thermal stratification (0.1 fish/lift) are presented for comparison with CWA Burbot catch rates (0.4 fish/lift, Figure 1.8). Coldwater Assessment and Partnership Surveys east basin indices share similar trends and magnitudes with some annual variation.

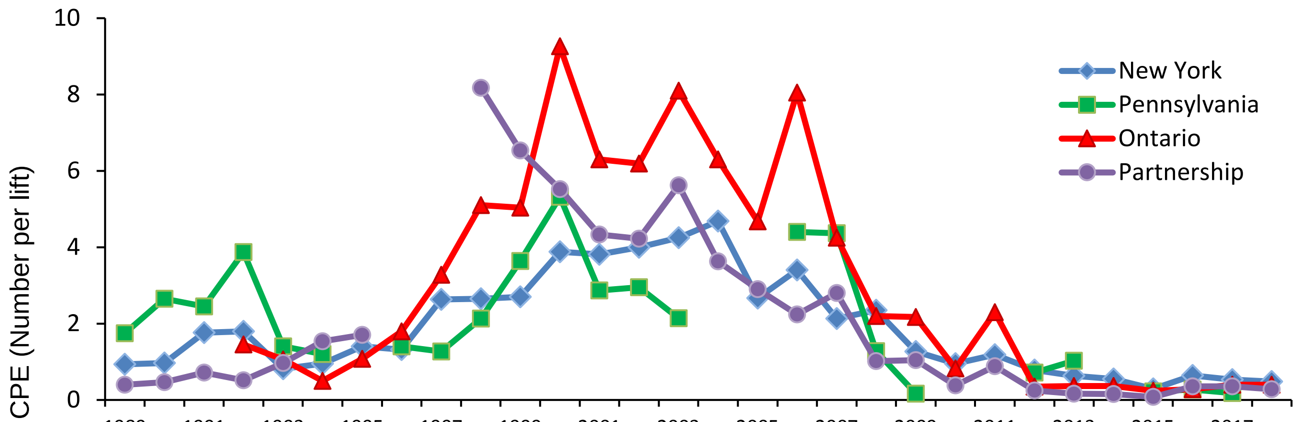


FIGURE 1.8. Burbot CPE (number per lift) by basin from the Interagency Coldwater Assessment and Ontario Partnership Surveys bottom set nets.

Most Burbot commercial harvest occurs in the eastern end of the lake, with minimal harvest occurring in Ohio waters and the western and central basins of Ontario waters. Historically, Burbot harvest was highest in Pennsylvania waters of Lake Erie. However, harvest decreased in Pennsylvania waters after 1995 following a shift from a gill net to a trap net commercial fishery, resulting in a substantial decrease of commercial effort (CWTG 1997). In 1999, a market was developed for Burbot in Ontario, leading the industry to actively target this species in 1999 and a concomitant increase was observed. However, this opportunistic market did not persist. Burbot catch is now incidental in nets targeting other species. The total commercial harvest for Lake Erie in 2018 was 2,401 pounds, up from 1,400 pounds in 2017. Catches were 1,054 pounds in Ontario, 1020 pounds in New York, 317 pounds in Pennsylvania and 10 pounds in Ohio.

In 2015, juvenile and adult Burbot were detected for the first time during U.S. Fish and Wildlife Service (USFWS) and U.S. Geological Survey (USGS) fisheries assessments in the St Clair - Detroit rivers. Since 2003, the USFWS and USGS have conducted annual surveys using a variety of gears (setlines, gillnets, hoop nets, and minnow traps) in an effort to measure fish response to artificial reefs that have been constructed in the two river systems. Assessment surveys since 2003 have resulted in over 4,000 gear deployment units of effort. Prior to 2015, juvenile and adult Burbot were undetected within the two rivers and since 2015, 29 Burbot of varying sizes have been captured. To date over 20 acres of artificial reefs have been constructed in these two river systems, and although not conclusive, 24 of the 29 Burbot were captured either on or near the artificial reefs

Pelagic larval burbot continue to be collected in the St. Clair-Detroit River System (SCDRS). In 2017, six larval burbot were captured during May and June sampling in the Detroit River. Most larval Burbot (5 of 6 fish) were captured during nighttime D-frame sampling near Belle Isle. We have thus far identified two larval Burbot from daytime bongo sampling in the south-west portion of Lake St. Clair early in the season (mid-May); although most larval fish sampled in 2018 have yet to be identified. Extensive larval sampling is planned for 2019 for the SCDRS and Lake Erie. We have consistently collected Burbot in the SCDRS since our larval sampling program began (McCullough et al. 2015; Tucker et al. 2018).

There were ten adult Burbot (>330 mm TL) were implanted with acoustic telemetry transmitters in spring and early summer of 2017 and then released into the St. Clair River. Preliminary data show most tagged fish remained in the St. Clair River during the initial months after released (http://glatos.glos.us/home/project/SDBUT).

Age and Recruitment

Burbot ages are estimated using otoliths for fish caught in the Interagency CWA Survey. The use of otolith thin-sections is recommended as the best approach for accurate age determination of Burbot (Edwards et al. 2011). Burbot ranged in age from 4 to 27 years in 2018 (N = 47, Figure 1.9). The mean age increased to 12.4 years in 2018, up from 8.3 years in the 2017 survey (Figure 1.10). Age four fish are used as an indicator of recruitment, and show a decline in burbot recruitment beginning in the late 1990s. Only one age four Burbot was caught in 2018.

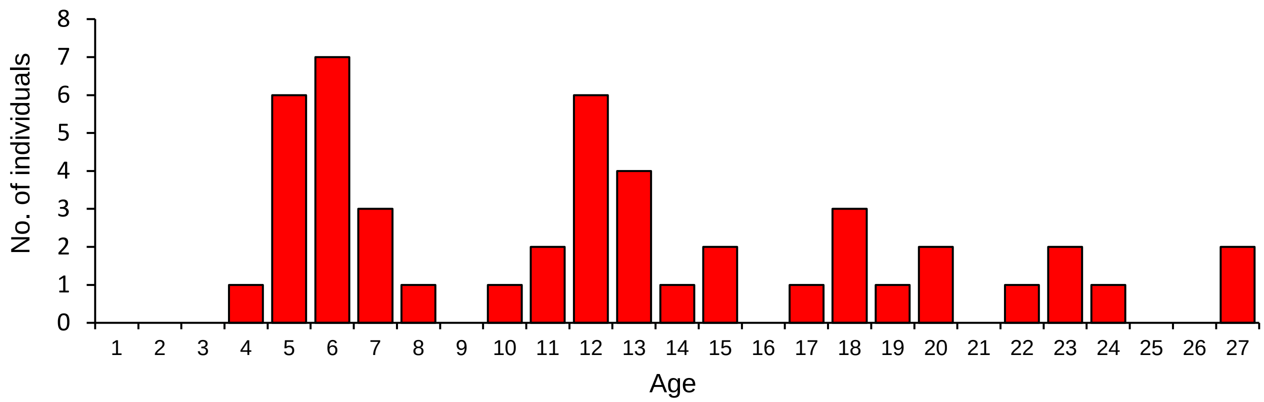


FIGURE 1.9. Age distribution of Burbot caught in the Interagency Coldwater Assessment Survey in eastern Lake Erie, 2018 (N=47).

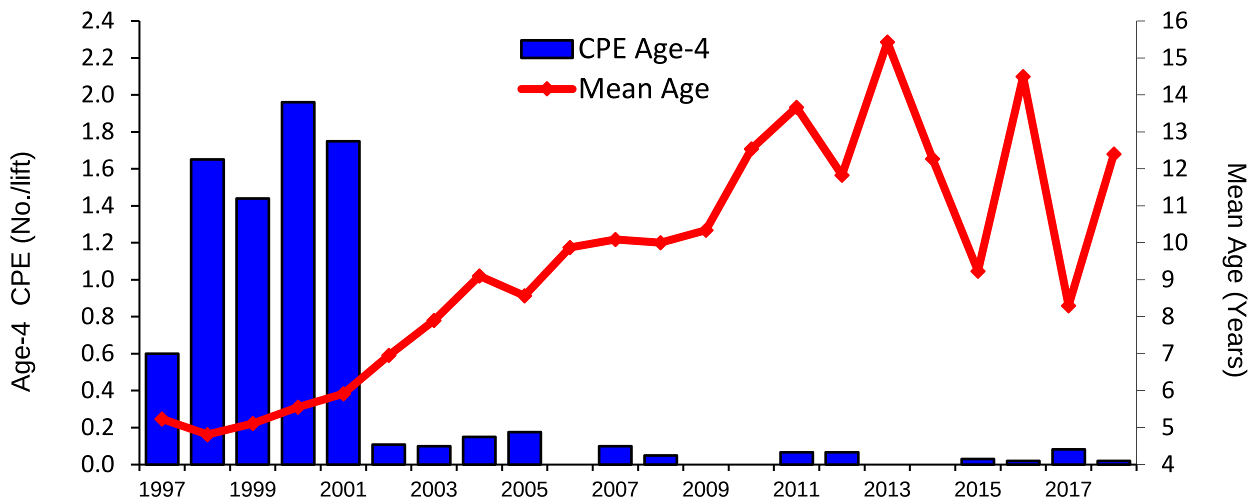


FIGURE 1.10. Mean age and average CPE of age-4 Burbot caught in the Interagency Coldwater Assessment Survey in eastern Lake Erie from 1997-2018.

Diet

Diet information was collected for Burbot caught in the 2018 Interagency CWA Survey. Analysis of stomach contents revealed a diet comprised mostly of fish (N=36). Burbot diets continue to be diverse, with five different identifiable fish species found in stomach samples. Round Goby was the dominant prey item, occurring in 69% of Burbot diet samples, followed by Rainbow Smelt (14%), Yellow Perch (11%), Gizzard Shad (6%) and White Perch (3%) (Figure 1.11). Round Goby have become the dominate prey species for Burbot in most years since 2003.

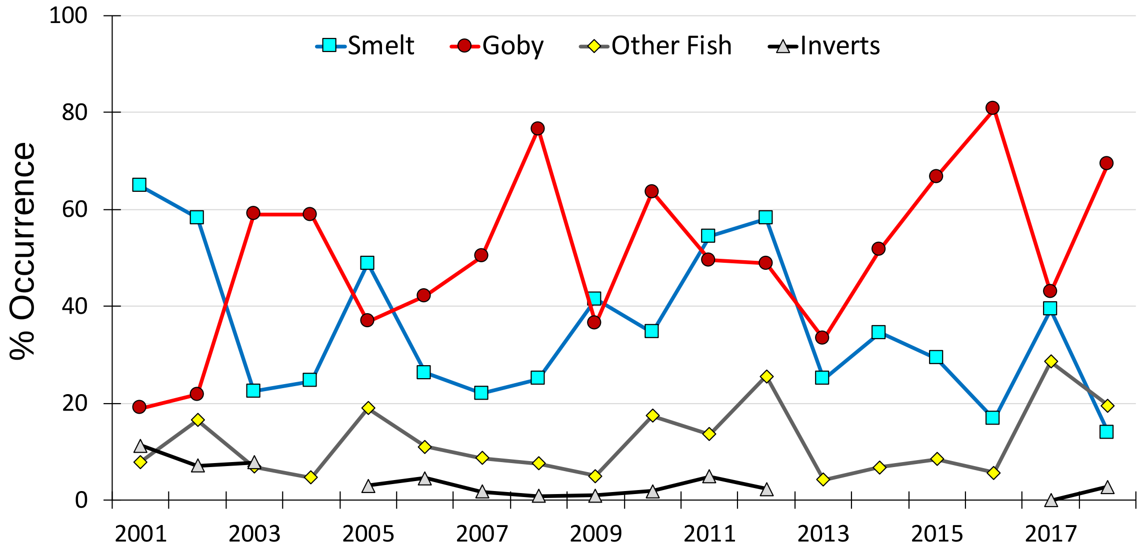


FIGURE 1.11. Percent occurrence in diet of Rainbow Smelt, Round Goby, all other fish species, and invertebrates from non-empty stomachs of Burbot caught in eastern basin assessment gill nets, August, 2001-2018.

CISCO

Once an abundant member of the coldwater fish community in Lake Erie, Cisco were reduced in number to a point where they were considered extirpated by the 1950s. Recognized as a desirable potential native forage, the CWTG has continued to report on their status based on the regular occurrence of small numbers of individuals, surrendered by the Ontario commercial fishing industry. Recent morpho-type and genetic investigations have revealed that most of the infrequently encountered herring-like fishes in the lake are not of the forms (*Coregonus artedi* or *albus*) historically associated with Lake Erie. These contemporary individuals are most like a deep-water form (*C. Hoyi*), possibly hybridized, found in Lake Huron. The presence of juvenile and larval *C. Hoyi* individuals from the Huron-Erie-Corridor, suggest that contemporary L. Erie samples are immigrants from the upper lakes. The CWTG document "Impediments to the Rehabilitation of Cisco (*Coregonus artedi*) in Lake Erie" (CWTG, 2017) reflects the likely source of contemporary Erie fish but emphasizes that within-Erie production cannot be ruled out.

In 2018-19, three additional individuals were surrendered by the Ontario commercial fishery. Of note, two of the individuals, a male and a female in spawning condition, were captured in association with western basin reefs, in early January 2019. The third individual, a developing but gravid female, was captured in the western basin in November 2018. These samples have been saved for future taxonomic analysis however a cursory examination suggests that they are of the deep-water hybrid form. Regardless of ability to reproduce, there is currently no indication that these forms are increasing in numbers or can thrive and play a significant role in Erie's coldwater fish community. Ongoing changes to the Lake Erie ecosystem, whether through food-web shifts, or climate associated changes, may affect the likelihood of this occurring in the future. The present availability of suitable oxygen and thermal habitat for Cisco (and other coldwater species) is currently being investigated by USGS (see below).

COLDWATER HABITAT RESEARCH

Currently, a project being led by the USGS seeks to addresses questions about the spatial distribution of summer refugia for coldwater species in Lake Erie. This project aims to determine how well existing water quality data (e.g., LTLA data from the Forage Task Group and EPA's Central Basin Hypoxia Survey data) delineates habitat for cold water species including: Lake Trout, Lake Whitefish, Burbot, Rainbow Smelt, and the extirpated Cisco according to oxygen and thermal parameters defined by Jacobson et al. (2010) and others. Preliminary models demonstrate that there is ample burbot, lake whitefish, and cisco habitat in the central and east basins even during the heat of the summer. On average, 50-60% of the water column is available across the central basin, while >80% of the water column is available in the east basin. For lake trout, habitat is much more restricted during late summer. There is virtually no habitat available in the central basin (<5% of the water column) and only about 50% -60% of the water column is available in the east basin, with exception of the deepest areas, where as much as 80% of the water column is available. Work is ongoing to add profiles from the west basin and to model spatiotemporal trends in habitat availability to determine when and where habitat is most limited. Future work will explore the relationship between oxythermal niche and surface temperature with the goal of determining how climate change may affect coldwater habitat availability in Lake Erie over the next decades.

CHARGE 2: Continue to assess and report on status of the Lake Whitefish fishery, including biological reference points, knowledge gaps, impediments and uncertainties required to provide advice to future management**.**

Andy Cook (OMNRF), Chris Vandergoot (USGS), John Deller (ODW),and Megan Belore (OMNRF)

Commercial Harvest

The total harvest of Lake Whitefish in Lake Erie during 2018 was 52,772 pounds (Figure 2.1). Ontario accounted for 84% of the lake-wide total, harvesting 44,624 pounds, followed by Ohio (8%; 4,020 pounds) and Michigan (8%; 4,100 lbs). Nominal commercial harvest occurred in Pennsylvania Yellow Perch trap nets (28 pounds) and no Lake Whitefish were harvested in New York waters (Figure 2.2). Total Whitefish harvest in 2018 was 67% higher than 2017. Lake Whitefish harvest increased in Ontario by 45% and in Ohio by several times. Michigan's Whitefish were harvested exclusively by seining in 2018, exceeding the previous five years.

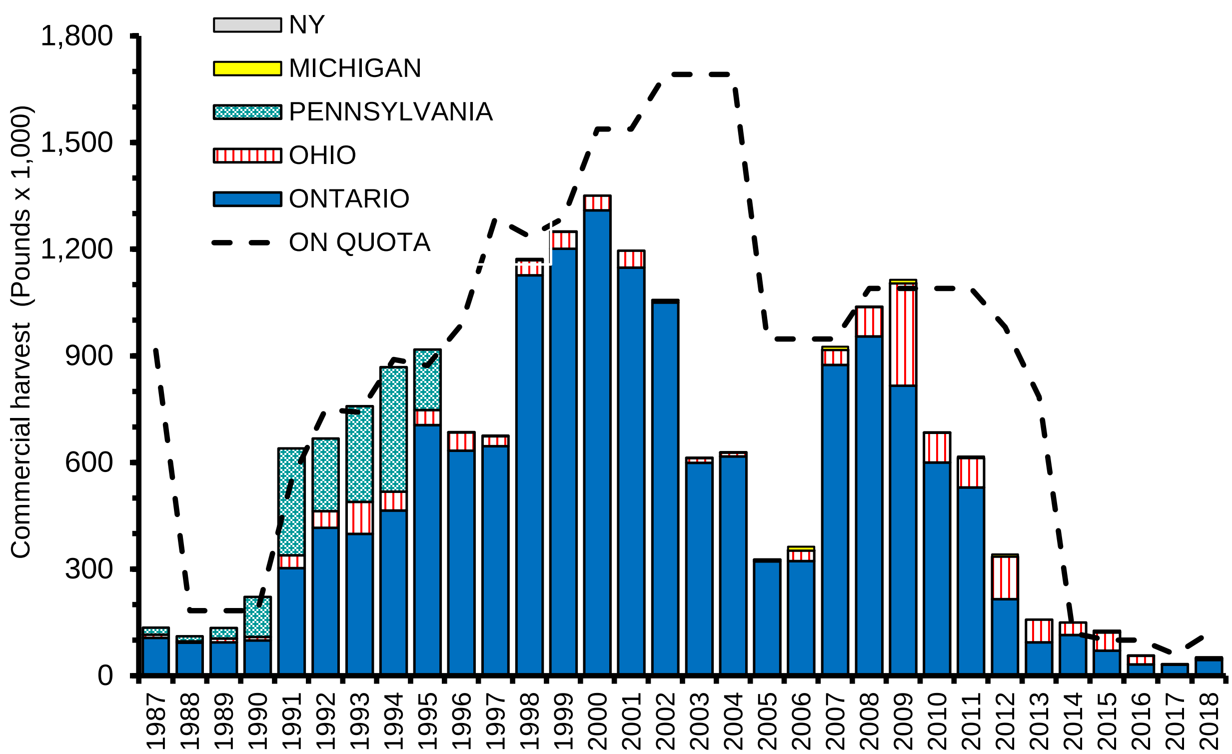


FIGURE 2.1. Lake Whitefish total harvest from 1987-2018 by jurisdiction in Lake Erie. Pennsylvania ceased gill netting in 1996. Ontario quota is presented as a dashed line.

Ontario's harvest in 2018 represented 37% of the quota (120,000 pounds). Almost all (99%) of Ontario's 2018 Lake Whitefish harvest was taken in gill nets. The remaining harvest of 284 pounds were caught in trawls targeting Rainbow Smelt (281 pounds) and impoundment gear (3 pounds). In addition to the Whitefish harvested, 256 pounds were surrendered to MNRF. The largest fraction of Ontario's Whitefish harvest (77%) was caught in the west basin (Ontario-Erie statistical district OE-1) followed by OE-2 (19%), with the remaining harvest distributed eastward among statistical districts OE-3 (3%), OE-4 (<1%) and OE-5 (<1%; Figure 2.2). Maximum harvest in 2018 was distributed west and north of Pelee Island (Figure 2.2). Harvest in OE-1 from October to December represented 74% of Ontario's Lake Whitefish harvest. Peak harvests occurred in OE-1 during November (15,098 pounds) and December (13,497 pounds); only 4% of OE-1 harvest occurred from March to May. Whitefish harvest in the central basin (OE2, OE3) was distributed evenly between spring and fall months. Only 676 pounds of Lake Whitefish were landed in eastern Lake Erie (OE-4 and OE-5) in 2018 with comparable harvest from gill nets (58%) and Smelt trawls (42%). There was no reported effort targeting Lake

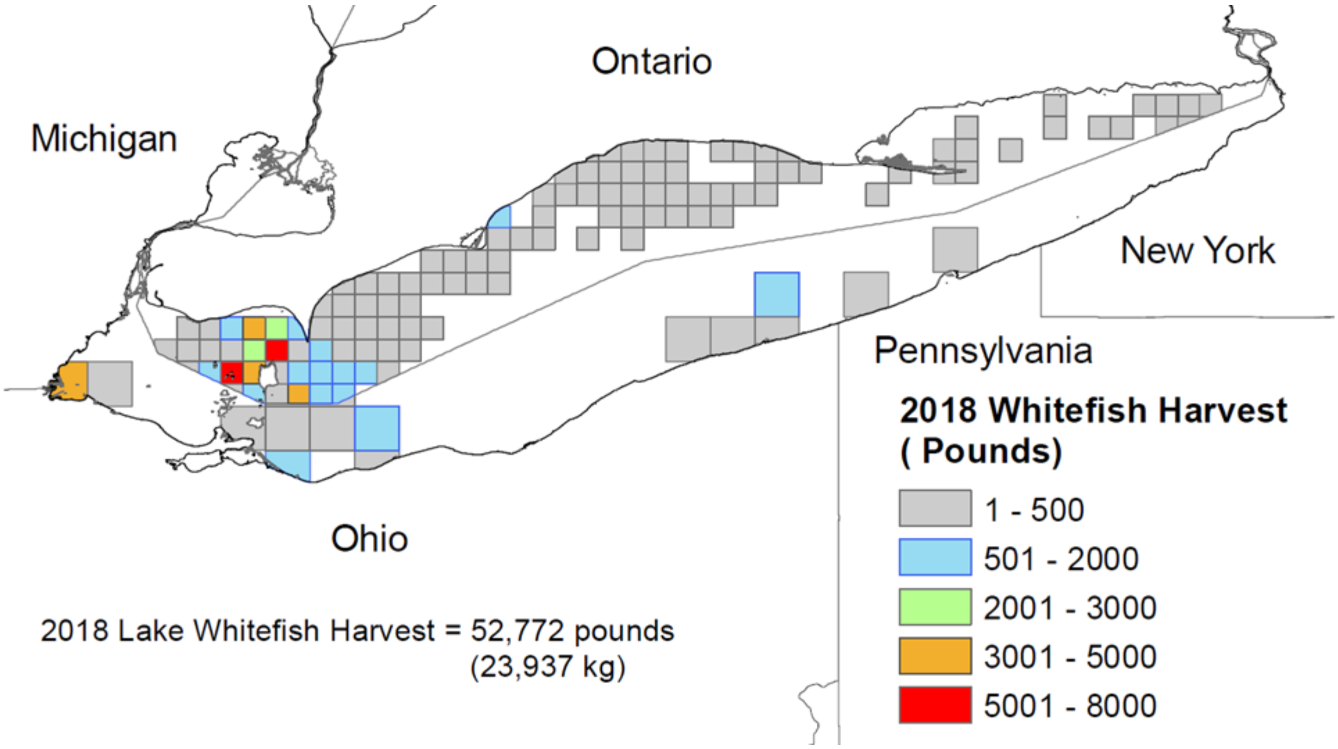


FIGURE 2.2. Commercial harvest of Lake Whitefish in Lake Erie during 2018 by 5-minute (Ontario) and 10-minute (U.S.) grids. Total harvest in 2018 = 52,772 pounds. Harvest in grid 801 at the mouth of the Maumee River was taken by seine nets in Michigan.

Whitefish during 2018 in Ontario waters of Lake Erie. Lake-wide, Ontario's Lake Whitefish harvest came from fisheries targeting Walleye (94%), White Bass (4%), Yellow Perch (1%), White Perch (<1%) and Rainbow Smelt (<1%).

As there was no reported targeted gill net harvest or effort in 2018, Ontario annual lake-wide commercial catch rates are presented in three forms (Figure 2.3). Along with a time series of targeted catch rates (kg/km) lacking 2014-2018 data, catch rates are presented based on all large mesh (>=76 mm or 3") gill net effort (kg/km) and large mesh gill net effort with Lake Whitefish in the catch (kg/km; the latter excludes zero catches). Catch rates based on all large mesh effort and effort with Lake Whitefish in the catch increased by 88% from 2017; similarly, catch rates based on effort with Lake Whitefish in the catch increased 87%. Although Whitefish harvest rates increased significantly in 2018, harvest rates were below average harvest rates (1998-2018) for all large mesh gill net (11.1 kg/km) and large mesh gill nets with Whitefish in the catch (28.5 kg/km).

All Lake Whitefish harvested in Ohio waters during 2018 came from commercial trap nets. Ohio Lake Whitefish harvest (4,020 pounds) in 2018 was distributed among the west (O-1 35%) and central basins (O-2 34%; O-3 31%). Lake Whitefish were harvested from 1,780 trap net lifts in 2018, with lifts distributed among District 1 (O-1) (38%), District 2 (O-2) (39%) and District 3 (O-3) (23%), respectively. More Lake Whitefish were caught in Ohio waters of the central basin (O-2, O-3) than in Ohio O-1, the west basin (Figure 2.2). Ohio trap net catch rates (pounds / lift with Whitefish in the catch) in 2018 (2.26 lbs/lift) increased 61% from 2017 (1.40 lbs/lift) but remained well below the mean (1996-2018) 30.7 lbs/lift (Figure 2.4).

Ohio's Lake Whitefish trap net fishery historically targeted Lake Whitefish during the spawning season, during November-December in the west basin, but harvest was 948 pounds in 2018. In years when Lake Whitefish were targeted, harvest was significant in OH grids 801, 802 and 804. The catch rate in OH grid 802 was very low in 2018 (6.7 lbs/lift) and no Lake Whitefish were landed in OH grids 801 and 804 in Ohio waters (Figure 2.2). Michigan harvested 4,100 pounds of Lake Whitefish from grid 801, near the mouth of the Maumee River, by seining during December 2018 (Figure 2.2). Pennsylvania's harvest rate from trap nets (0.09 lbs/lift) was approximately double the previous year's catch rate but remained well below the 1996-2018 mean (3.0 lbs/lift) (Figure 2.4).

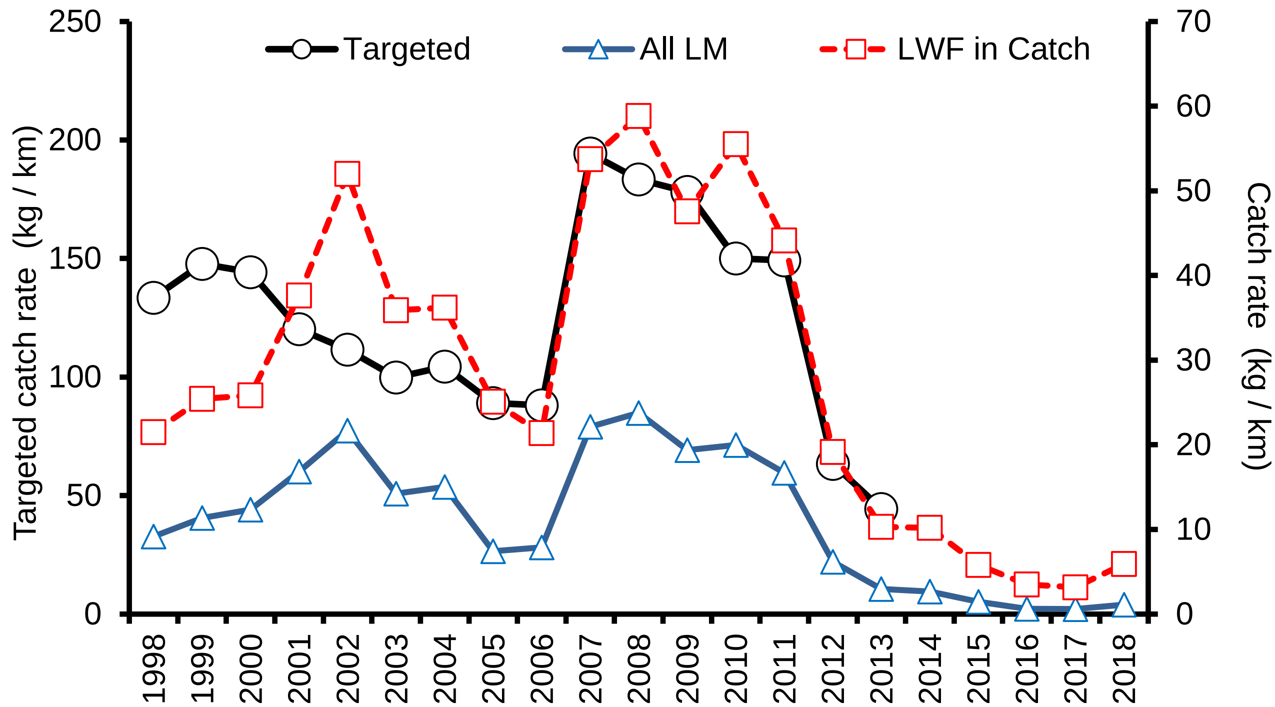


FIGURE 2.3. Lake-wide Ontario annual commercial large mesh gill net catch rates according to three forms of effort. Targeted Lake Whitefish catch rate (kg/km; left axis), catch rate relative to all large mesh gillnet fished (kg/km; right axis), and catch rates from large mesh effort with Lake Whitefish in the catch (kg/km; right axis). No targeted Lake Whitefish effort or harvest was reported in 2014 - 2018.

Ontario's west basin fall Lake Whitefish fishery in 2018 was dominated by younger fish, mainly ages 3 and 4 (Figure 2.5). The age composition of Lake Whitefish harvest from Ontario reflects fish caught in gill nets targeting Walleye. Based on standard harvest monitoring, Ontario's Whitefish gill net harvest in 2018 was comprised of ages 3 (65%), 4 (34%) and 15 (1%) (N=283). The age composition of Lake Whitefish harvested in U.S. waters was not assessed in 2018.

The landed value of Whitefish in Ontario during 2018 was $61,196 or $ 1.37 / lb CDN. The landed weight of roe from Ontario's 2018 Lake Whitefish fishery was 249 pounds, which came from OE1 and OE-2 in October and November. The approximate landed value of the roe was $ 388.90 or 1.56 / lb CDN.

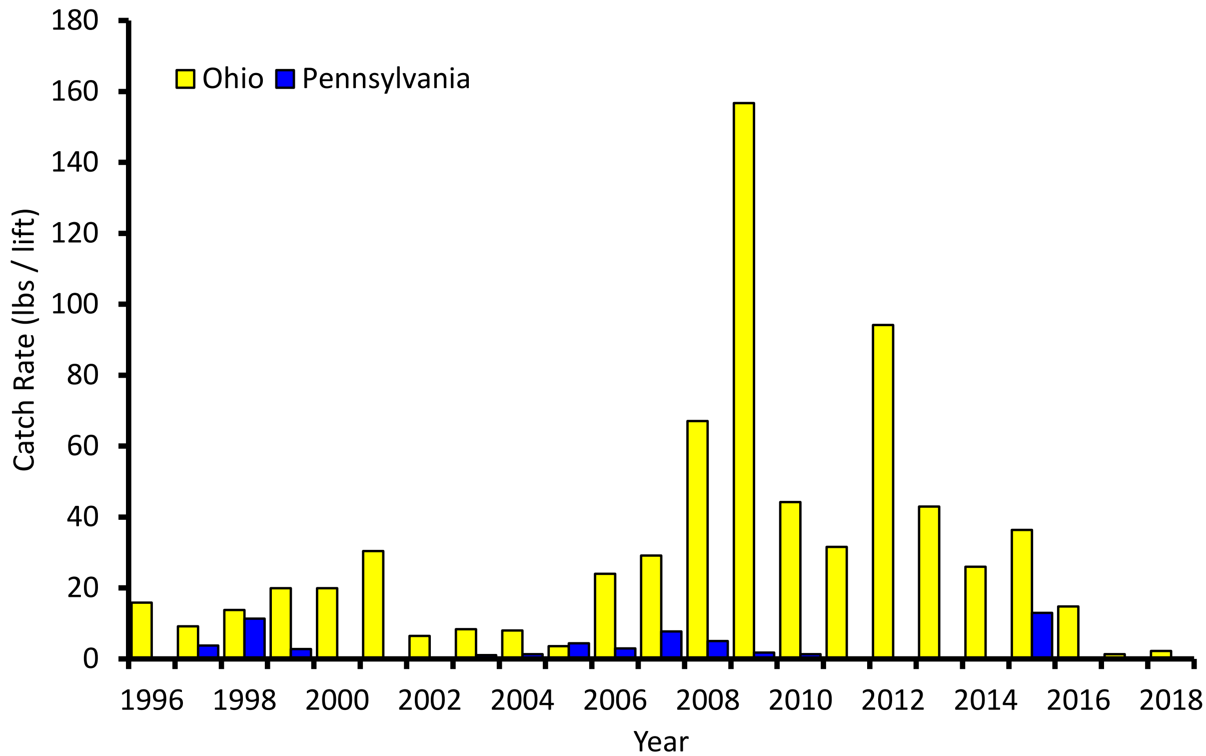


FIGURE 2.4. Lake Whitefish commercial trap net catch rates in Ohio and Pennsylvania (pounds per lift), 1996-2018. Zero harvest for PA in 2011-2014.

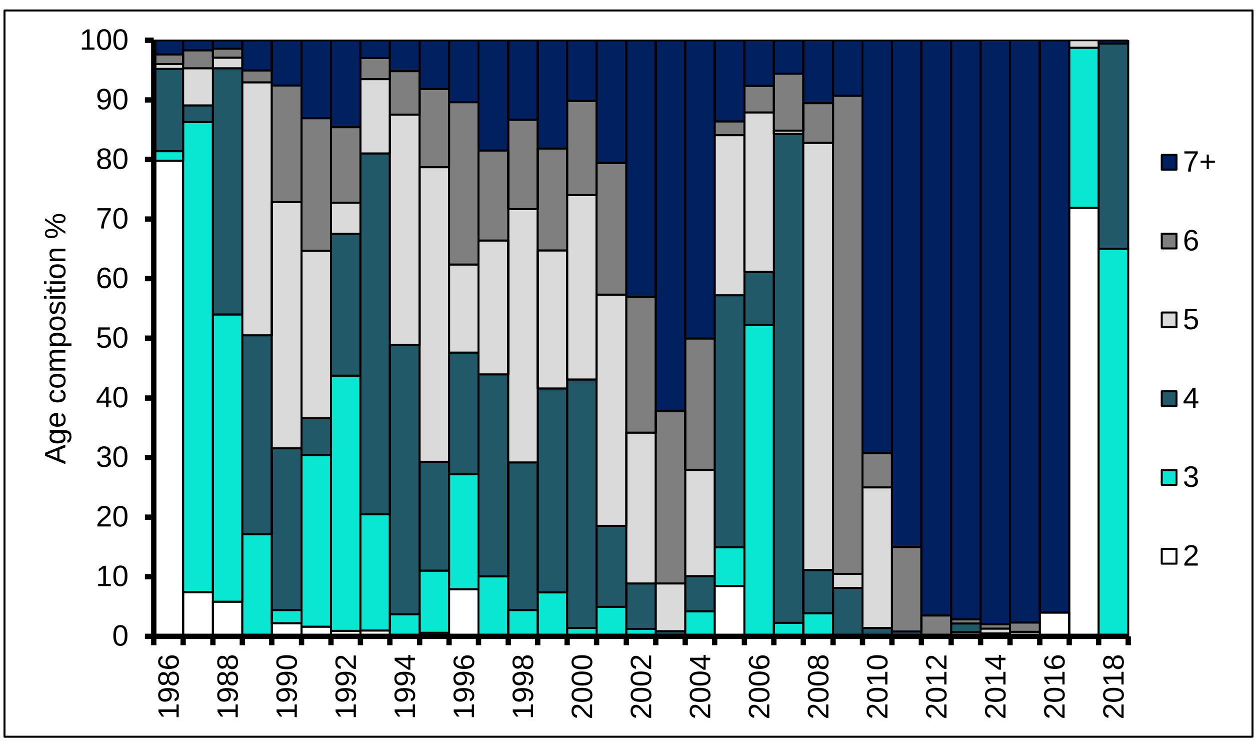


FIGURE 2.5. Ontario fall commercial Lake Whitefish harvest age composition in statistical district 1, 1986-2018, from effort with gill nets ≥3 inches, October to December. N=283 in 2018. Ages 7+ includes Whitefish ages 7 and older.

Assessment Surveys

Lake Whitefish gill net indices presented include east basin Cold Water Assessment (CWA) netting for Lake Trout conducted in New York, Ontario and Pennsylvania waters and also Ontario's combined central and east basin Partnership gill net surveys. Partnership survey catch rates were pooled despite differences in thermal stratification, and migratory behavior when east and central basin surveys occur. The combined Partnership surveys increase sample size and catches at the expense of introducing bias associated with temporal and spatial differences in catchability. The necessity of combining the Partnership surveys arises from variable, low catches observed among all basin-specific surveys. Partnership catch rates in 2018 are based on 111 sites with 222 gangs fished on bottom and at standard canned depths.

Lake Whitefish catch rates in CWA nets fished on bottom (110 lifts) during 2018 (1.5 LWF/lift) increased from 2017 (0.57 LWF/lift) and was ranked as the 64th percentile over the 34 year time series 1985-2018 (Figure 2.6). Among CWA surveys in 2018, catch rates in NY during 2017 were highest (1.94 LWF/lift), followed by ON (1.13 LWF/lift). Pennsylvania did not participate in CWA during 2018 as their research vessel was not operational.

Partnership catch rates of Lake Whitefish ages 0 to 2 was 0.03 LWF/gang in 2018, a drop from 2017 (Figure 2.6). Catch rates for age-3 and older Lake Whitefish caught in 2018 Partnership surveys increased to 0.30 LWF/gang from 0.11 LWF/gang in 2017 (Figure 2.6). Lake Whitefish (71) were caught in all areas of Lake Erie in 2018 except the west basin survey. The age composition of Lake Whitefish caught in Partnership Index gear ranged from ages 0 to 15, with ages 3 (68%; 2015 year class) and 4 (18%; 2014 year class; Figure 2.7) most abundant. Age 15 (2003 cohort) accounted for 3% of Lake Whitefish caught in index gear. Lake Whitefish mean age in Partnership gear was 3.4 reflecting recruitment of younger fish in the population. Of 71 Lake Whitefish examined, none had Sea Lamprey scars or wounds in 2018.

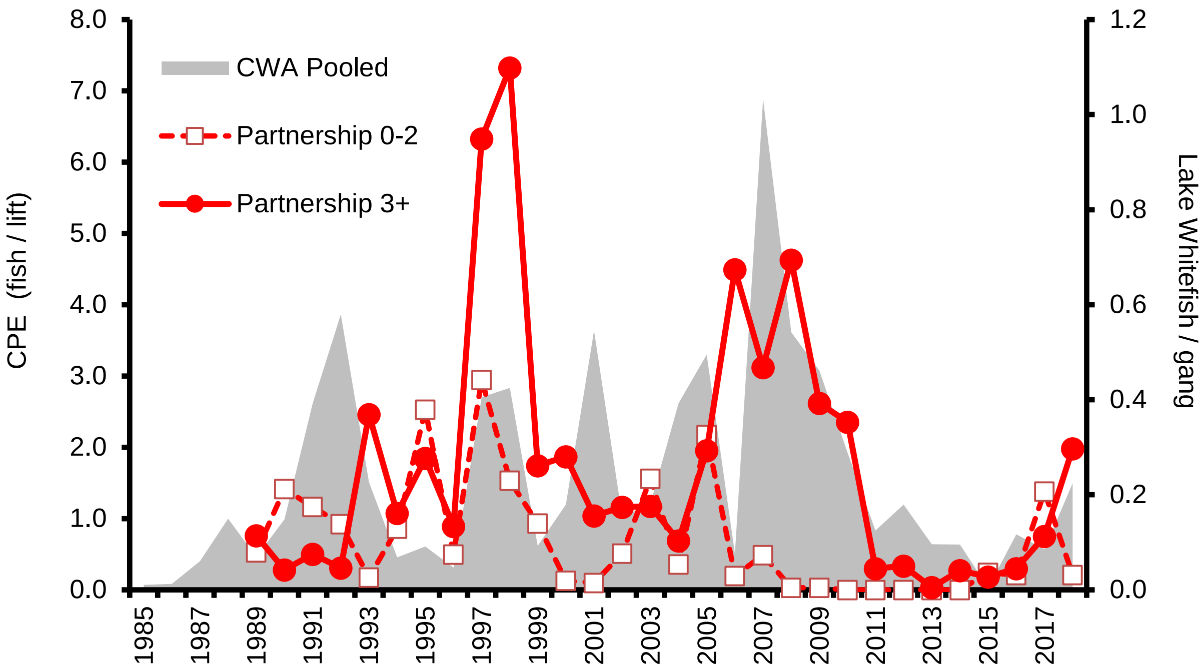


FIGURE 2.6. Catch per effort (number fish/lift) of Lake Whitefish caught in standard coldwater assessment gill nets (CWA) in New York, Ontario and Pennsylvania waters, weighted by number of lifts (grey area). Partnership index catch rates (WF/gang) for ages 0-2 (dots) and ages 3 and older (squares) (second axis).

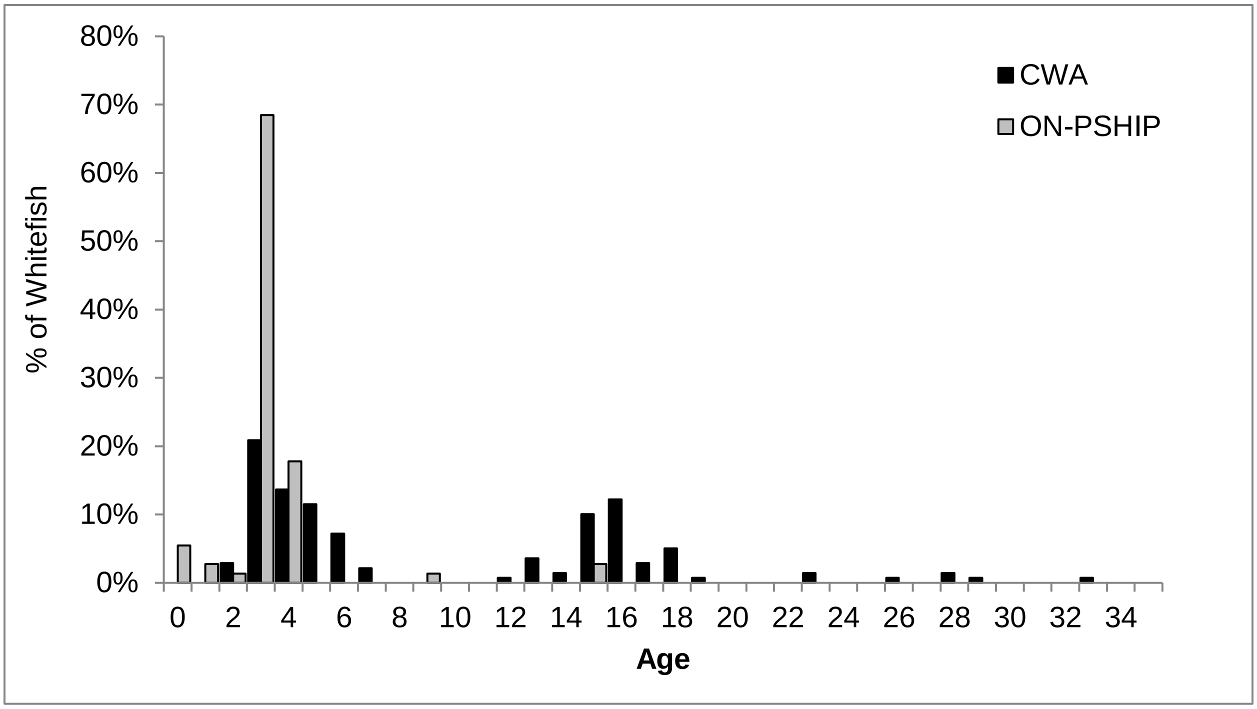


FIGURE 2.7. Age-frequency of Lake Whitefish collected from Cold Water Assessment (CWA) gill net surveys and Ontario Partnership index, 2018 (N=139, 71).

Lake Whitefish captured in CWA surveys by all agencies (N=139) ranged in age from 2 to 33. Ages 3 (21%) and 4 (14%) were most abundant, followed by ages 15 and 16 (10%,12% respectively) (Figure 2.7). Mean age of Lake Whitefish caught in CWA nets was 9.5 years. The older age composition of Lake Whitefish caught in CWA nets compared to the Partnership Index may be due to differences in study design. The CWA nets were fished exclusively in the east basin hypolimnion whereas Partnership nets were fished above and below the thermocline in Pennsylvania Ridge and east basin surveys and at all depths after fall turnover in the central basin.

Trawl surveys in Ohio waters of the central basin of Lake Erie (Ohio Districts 2 and 3 combined) encounter juvenile Lake Whitefish. June and October catch rates are presented in Figures 2.8 and 2.9 as indicators of year class strength. In 2018, age 0 Lake Whitefish catches were above average in June trawls (0.48 LWF/ha) but were below average (0.08 LWF/ha) in October trawls (Figure 2.8). Yearling Lake Whitefish were caught in June trawls (0.03 fish/ha) in 2018, but yearlings were not caught during October trawls in central (O-2, O-3) Lake Erie (Figure 2.9).

Pennsylvania bottom trawl surveys from May to November also describe year class strength of juvenile Lake Whitefish. The PA trawl survey did not take place in 2018 due to mechanical difficulties.

The New York east basin trawl survey indicated age 0 Lake Whitefish abundance in 2018 (0.63 LWF/ha) was above average (Figure 2.8). Historically, few Lake Whitefish have been encountered in deep, offshore fall bottom trawl assessment in Outer Long Point Bay. In 2018, however, one (1) young-of-the-year Lake Whitefish was caught during this survey.

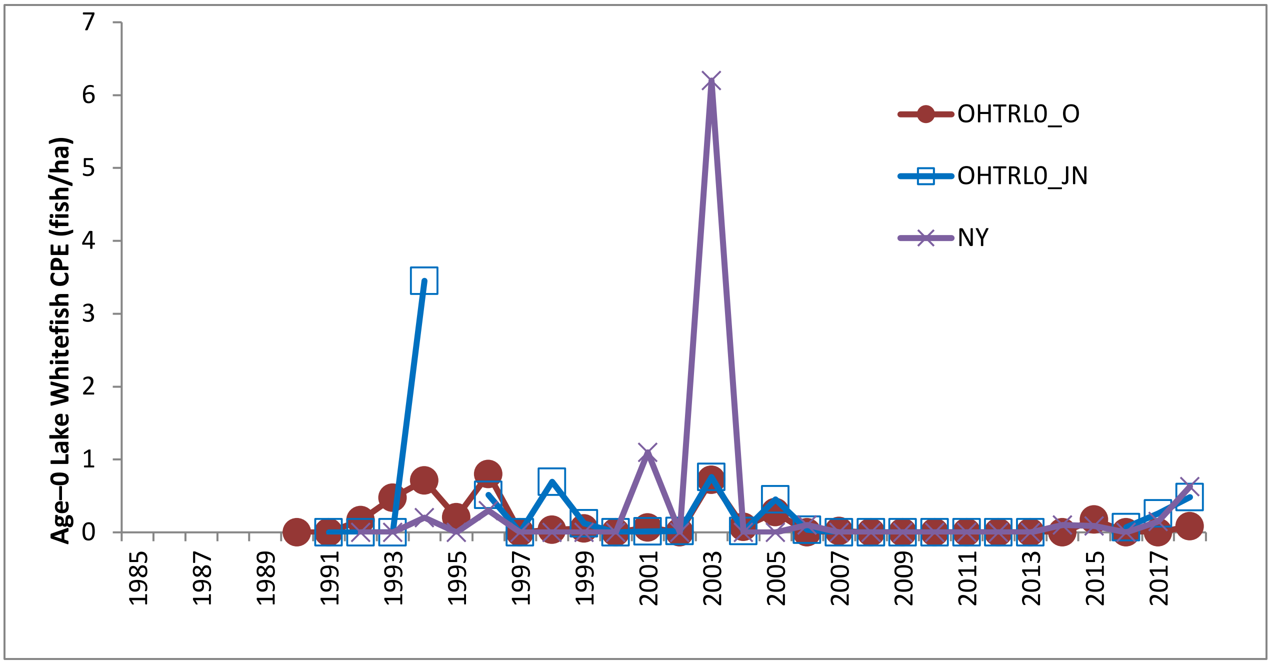


FIGURE 2.8. Mean age 0 Lake Whitefish catch per hectare in Ohio (central basin during June, October), and New York fall assessment trawls. Ohio data are means for October trawls in District 2 and 3. Pennsylvania did not conduct trawls during 2018.

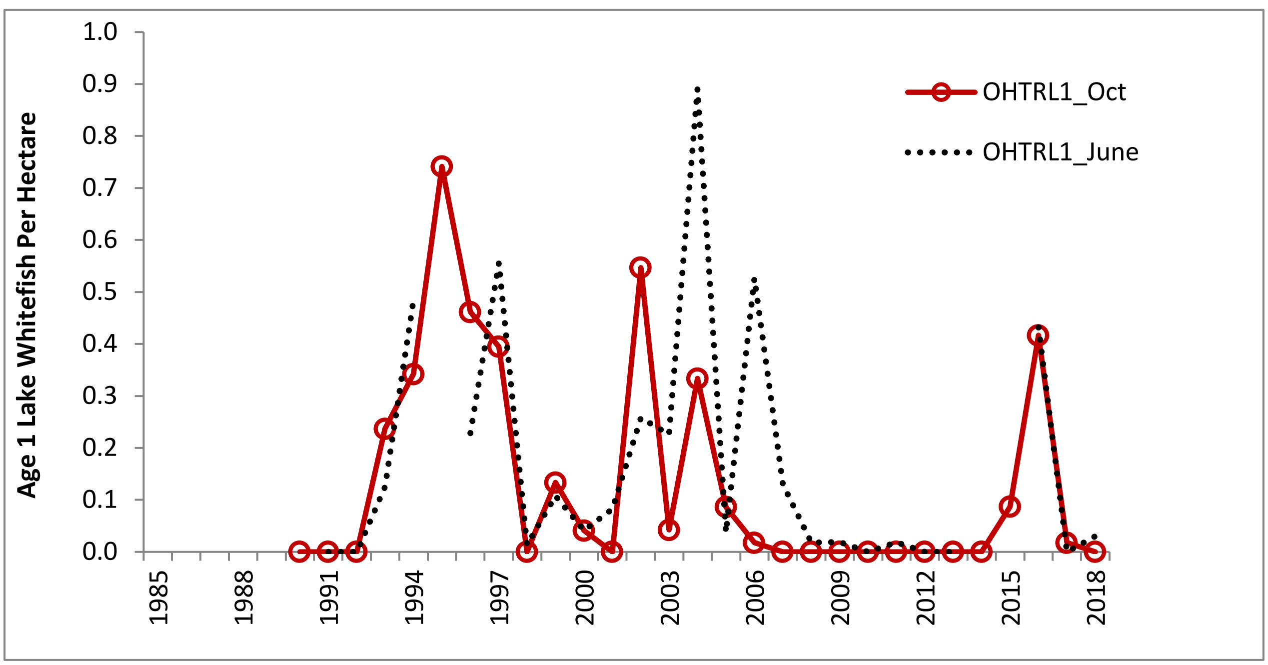


FIGURE 2.9. Age 1 Lake Whitefish trawl catch rates (number per ha) in Ohio waters during June (dotted line) and October (circles). Pennsylvania did not trawl in 2018.

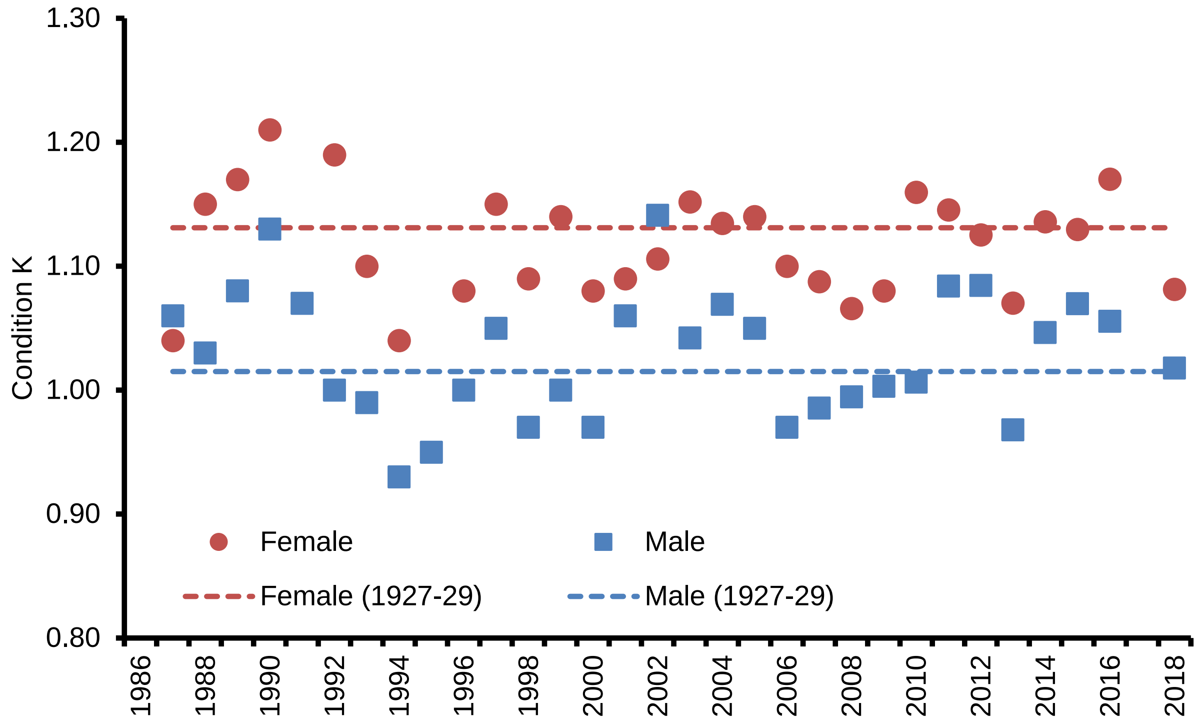


FIGURE 2.10. Mean condition (K) factor values of age 4 and older Lake Whitefish obtained from Ontario commercial, survey, and Ohio survey data (Oct-Dec) by sex from 1987-2018. Samples sizes in 2018 were: Males N=26 and Females N=27. Historic mean condition (1927-29) presented as dashed lines calculated from Van Oosten and Hile (1947).

Growth and Diet

Trends in condition are usually presented for Lake Whitefish sampled by ODNR and Ontario MNRF in relation to historic Lake Whitefish condition reported by Van Oosten and Hile's (1947). In 2018, samples were combined from Ontario commercial, partnership and ODNR surveys where the following selection criteria were met: ages 4 and older collected from Oct-Dec, excluding spawning and spent fish. Female condition was lower than the historic mean K whereas male condition was near average (Figure 2.10). The proportion of age 4 Whitefish may have contributed to the lower condition of females.

Stomach contents from 13 Lake Whitefish caught in Ohio waters of Lake Erie were examined in 2018. Dry weights of Whitefish diets varied by season. Whitefish collected in June (n=7) contained Isopods (64.9%) and Chironomids (34.2%). October diets (n=6) were primarily Daphnia (75.4%), Sphaeriidae (13.2%) and Isopods (8.4%)

Lake Whitefish in Lake Erie exhibit a high prevalence of Digean heart cysts from *Icthyocotylurus erraticus* (CWTG 2018[2]). In 2018, 97% of Lake Whitefish examined from commercial samples in 2018 had heart cysts while 78 % of Whitefish collected from the Partnership survey had heart cysts. This parasite is present in Lake Whitefish in the upper Great Lakes (Muzzal and Whelan, 2011). In Ireland, intermediate and final hosts of this parasite are snails and gulls respectively (Harrod and Griffiths 2005). Harrod and Griffiths (2005) reported that this parasite influenced gonad size of female Pollan with different effects on liver size and condition of males and females. This parasite was also identified in Rainbow Smelt in Lake Erie (Dechtiar and Nepszy, 1988). The impact of this parasite on Lake Whitefish in Lake Erie remains unknown.

Acoustic Telemetry

Lake Whitefish have been implanted with acoustic transmitters and tagged with external Floy tags from 2015 to 2018. This collaboration of USGS, ODNR, USFWS, OMNRF, GLFC, GLATOS and local partners seeks to describe Lake Whitefish movements during spawning and other seasons. From 2015 to 2018, 154 Lake Whitefish were tagged in areas including the Maumee River Ohio, west basin spawning reefs in Ohio and in Ontario waters and near the Detroit River mouth (Table 2.1). Since the project began, 11 tagged Lake Whitefish were caught by Ontario's commercial fishery. Lake Whitefish Movement is described from detections by acoustic receivers deployed throughout the Great Lakes. Detections were distributed lake-wide with the highest number of detections in the southern portion of the central basin. Fall spawning migrations to the west basin and movement eastward during thermal stratification were also observed. As data accumulates from this study, seasonal habitat use and population metrics such as mortality will inform Lake Whitefish population models and support Lake Whitefish management. Information about this project and other GLATOS projects is online: https://glatos.glos.us/.

TABLE 2.1. Number of Lake Whitefish tagged with internal acoustic transmitters and Floy tags by location 2015 – 2018. Number of tagged Whitefish recaptured by fisheries from 2015 – 2018.

			Recaptures By Year				
Tag Location	Year of Tagging	# Tagged	2015	2016	2017	2018	Total
Maumee River	2015	10	0	0	1	0	1
Hen/Little Chick	2016	37		3	0	0	3
OH Reefs, Hen/Little Chick	2017	105			6	1	7
Detroit River	2018	2				0	0
	Total	154	0	3	7	1	11

Statistical Catch at Age Analysis (SCAA) Population Model

A statistical catch-at-age (SCAA) model for Lake Whitefish (CWTG 2018[1,2]) was updated with 2018 fishery and survey data to estimate abundance at age from 1994 to 2018. The first model run with 2018 data raised concerns about the validity of the model configuration. Population trends up to 2018 did not reflect any trends of source data (fishery, survey catch rates). SCAA overestimates of abundance in 2017 and 2018 were attributed to low selectivity (age specific vulnerability to gear) estimates that did not take into account reduced gill net mesh sizes used by the Walleye gillnet fishery during 2017, 2018. This was addressed by adding a "selectivity block" for these recent two years. Ohio trapnet fishery age composition data in the model was adopted from Ontario gillnet data, excluding fish in samples that didn't meet the trap net minimum 17" length restriction. This assumption was not reasonable during 2017,2018 given the smaller fishery gill net mesh sizes that caught Lake Whitefish. This led to additional changes to the SCAA model configuration which included: removal of trap net fishery data; calculation of adjusted gill net effort to account for total harvest from all jurisdictions and adjusting total Whitefish catch at age based on the total harvest and gillnet age composition. The resulting model consisted of 2 gears (gillnet fishery catch and effort and partnership survey catch rates).

Using the third model configuration, abundance estimates for 2017 and 2018 were still higher than expected relative to fishery and survey performance (Figure 2.11). Principal components analyses (PCA) were used to consolidate 10 Lake Whitefish recruitment indices (Y. Zhao, personal communication, 2015) for use in linear regression with SCAA age 3 abundance estimates to forecast future recruitment (Table 2.2). The 2014 and

2015 cohort abundances estimated by SCAA were much higher than predicted by PCA – regression (Table 2.2, Figure 2.11). PCA-regression estimates of these year classes were used to forecast abundance and spawner biomass to 2021 assuming SCAA survival estimates from 2018. Forecasted spawner biomass from 2019 – 2021 was compared to unfished spawner biomass levels (SSB20%, SSB30%, SSB40%) (CWTG 2018[2]) to assess Lake Whitefish population status. Lake Whitefish spawner biomass levels may remain above the mean SSB40% for the next several years to 2021, provided fisheries remain conservative (Figure 2.12). Alternate SCAA model configurations will be explored in 2019-2020.

Summary

Lake Whitefish fishery and survey indicators showed modest improvements in 2018. Total Lake Whitefish harvest in 2018 (52,772 pounds) was the second lowest in 32 years. Ontario's incidental harvest in 2018 attained 37% of Lake Whitefish quota (120,000 pounds) with no targeted harvest of Lake Whitefish. Ohio trap net harvest (4,020 pounds) in 2018 was not targeting Lake Whitefish. The Lake Whitefish population will be dominated by age 4 and 5 fish in 2019, although the magnitude of these cohorts remains uncertain. Surveys indicated potential for the 2018 cohort to contribute to Lake Erie's Whitefish population in the future. To reduce Whitefish bycatch in the Walleye gill net fishery, Walleye quota transfers from the west basin (Quota Zone 1) to the central basin (Quota Zones 2 and 3) are permitted by Ontario. In 2018, 26% (1.05 million pounds) of Walleye quota in the west basin (MU1) was transferred to the central basin Walleye fisheries in 2018. The Coldwater Task Group recommends continued conservative management of Lake Whitefish until certainty of the population status improves.

TABLE 2.2. Age 3 abundance estimates from statistical catch at age analysis (SCAA) for 2014 and 2015 cohorts. Principal components analysis (PCA) for juvenile Whitefish indices (ages 0,1,2) used in linear regression with SCAA age 3 abundance estimates to estimate age 3 abundance of 2014 – 2018 cohorts. Number of surveys, ages and cumulative variance of 1st and 2nd principal components (P1,P2) presented for each cohort. Regression statistics R^2 and probability of significance (P>F).

	Age 3 Abundance Estimates		PCA			Regression	
Cohort	SCAA	PCA - REG	PCA # SURVEYS	PCA AGES	Cumulative Variance % P1, P2	R^2	Pr>F
2014	3,194,640	769,834	7	0,1,2	89	0.99	<0.0001
2015	17,433,900	3,335,898	9	0,1,2	87	0.98	<0.0001
2016	N/A	165,232	10	0,1,2	86	0.99	<0.0001
2017	N/A	475,616	8	0,1	82	0.98	<0.0001
2018	N/A	1,722,708	4	0	91	0.97	<0.0001

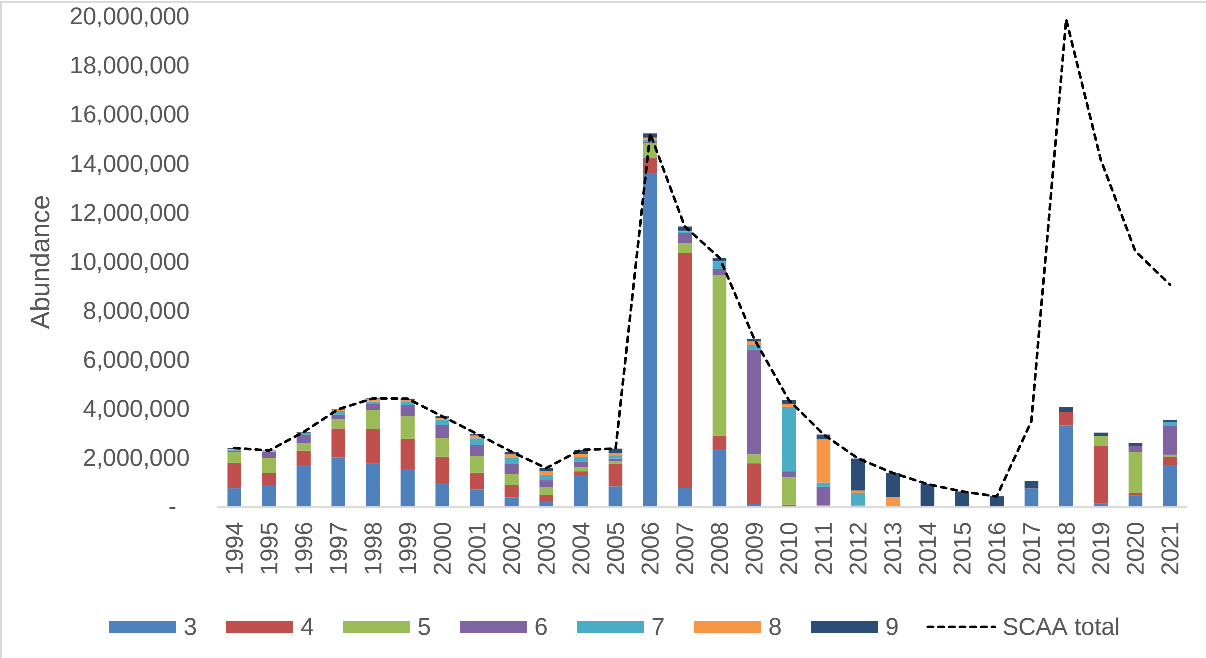


FIGURE 2.11. Lake Whitefish abundance estimates at age from SCAA and age 3 recruitment projections from PCA – regression estimates for cohorts 2014-2018. SCAA estimates of survival from 2018 assumed for 2019 – 2020. SCAA total abundance estimates (dotted line) for 2017, 2018 diverge due to higher SCAA estimates of 2014, 2015 cohorts compared to PCA-regression estimates. (see Table 2.2).

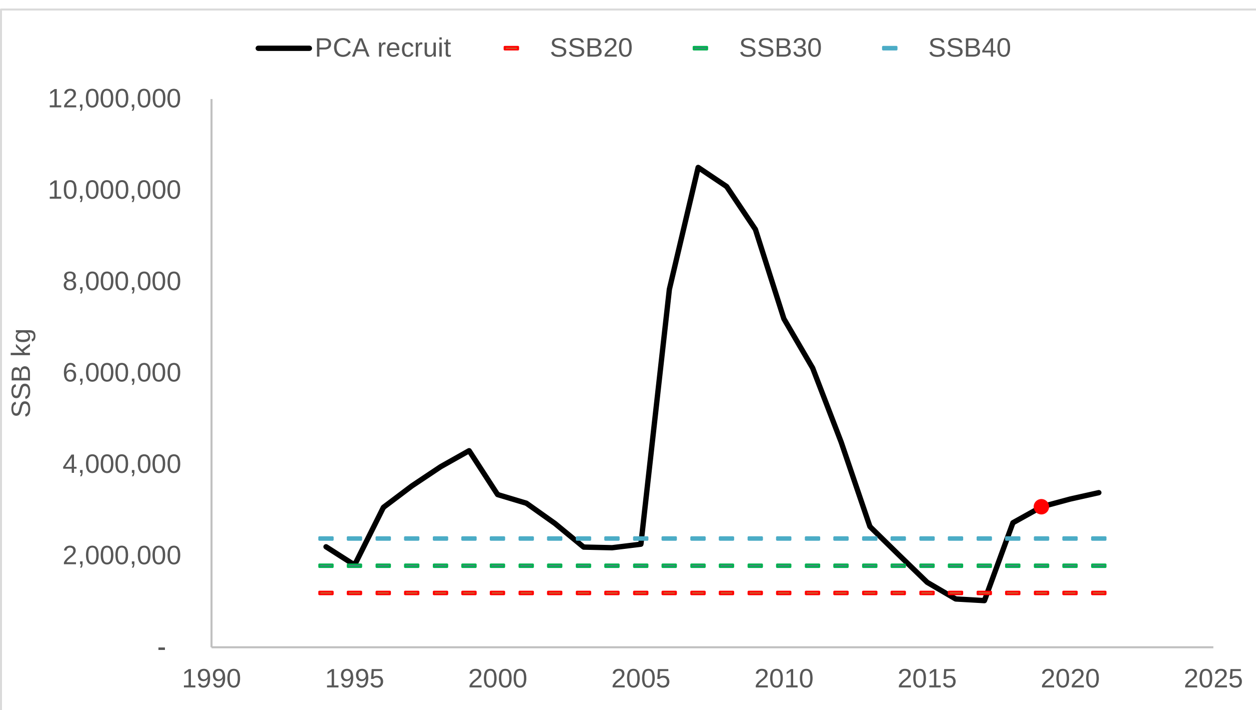


FIGURE 2.12. Lake Whitefish spawning stock biomass (SSB) estimates (kg - black line) projected to 2021 assuming constant survival from SCAA in 2018. Red dot indicates 2019 SSB. Biological reference points SSB20%, SSB30%, SSB40% of unfished population (SSB0) presented for reference.

CHARGE 3: Continue to participate in the IMSL process on Lake Erie to outline and prescribe the needs of the Lake Erie Sea Lamprey management program.

Chris Eilers (USFWS), Kevin Tallon (DFO), and James Markham (NYSDEC)

The Great Lakes Fishery Commission and its control agents (U.S. Fish and Wildlife Service and Fisheries and Oceans, Canada) continue to apply the Integrated Management of Sea Lamprey (IMSL) program in Lake Erie including selection of streams for lampricide treatment and implementation of alternative control methods. The Lake Erie Coldwater Task Group has provided the forum for the assemblage of Sea Lamprey wounding data used to evaluate and guide actions related to managing Sea Lamprey and for the discussion of ongoing Sea Lamprey and fishery management actions that impact the Lake Erie fish community.

Lake Trout Wounding Rates

A total of 38 A1-A3 wounds were found on 393 Lake Trout greater than 532 mm (21 inches) total length in 2018 during coldwater assessment gill netting, equaling a wounding rate of 9.7 wounds per 100 fish (Table 3.1; Figure 3.1). This was below than the average wounding rate from the previous 10 years (13.1 wounds/100 fish) but nearly twice the target rate of 5.0 wounds per 100 fish (Markham et al. 2008). Wounding rates have remained above target for 22 of the past 23 years. Large Lake Trout continue to be the preferred targets for Sea Lamprey; Lake Trout between 635-736 mm TL (25-29 inches) and greater than 736 mm (29 inches) had equal A1-A3 wounding rates (10.8 wounds/100 fish) (Table 3.1). Small Lake Trout less than 532 mm (21 inches) are rarely attacked when larger Lake Trout are available.

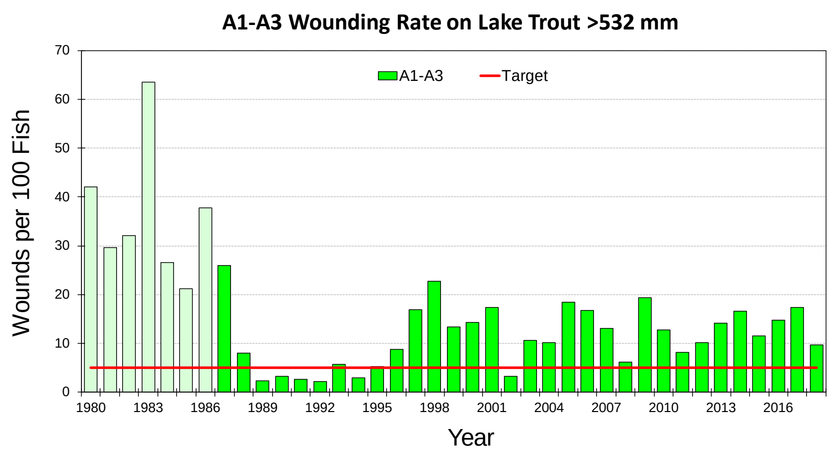


FIGURE 3.1. Number of fresh (A1-A3) Sea Lamprey wounds per 100 Lake Trout greater than 532 mm (21 inches) sampled in assessment gill nets in the eastern basin of Lake Erie, August-September, 1980-2018. The target rate (red solid line) is 5.0 wounds per 100 fish. Lighter shading indicates pre-treatment years.

TABLE 3.1. Frequency of Sea Lamprey wounds observed on several standard length groups of Lake Trout collected from assessment gill nets in the eastern basin of Lake Erie, August 2018.

Size Class Total Length (mm)	Sample Size	Wound Classification				No. A1-A3 Wounds Per 100 Fish	No. A4 Wounds Per 100 Fish
		A1	A2	A3	A4		
432-532	41	0	0	0	0	0.0	0.0
533-634	42	0	0	0	0	0.0	0.0
635-736	111	0	3	9	54	10.8	48.6
>736	240	1	4	21	259	10.8	107.9
>532	393	1	7	30	313	9.7	79.6

Finger Lakes (FL) and Lake Champlain (LC) strain Lake Trout were the most sampled strains in 2018, and they accounted for the majority of the fresh (A1-A3) and healed (A4) Sea Lamprey wounds (Table 3.2). A1-A3 wounding rates were similar between these two strains in 2018 while LC strain lake trout had a higher A4 wounding rate, most likely due to their higher abundance in the populations. The Klondike strain (KL) has higher wounding rates than FL and LC strain Lake Trout, indicative of higher susceptibility of this strain to Sea Lamprey attacks.

TABLE 3.2. Frequency of Sea Lamprey wounds observed on Lake Trout greater than 532 mm (21 inches), by strain, collected from assessment gill nets in the eastern basin of Lake Erie, August 2018. SI=Slate Island, FL=Finger Lakes, KL=Klondike, LC=Lake Champlain.

Lake Trout Strain	Sample Size	Wound Classification				No. A1-A3 Wounds Per 100 Fish	No. A4 Wounds Per 100 Fish
		A1	A2	A3	A4		
SI	14	0	0	0	3	0.0	21.4
FL	110	0	1	5	73	5.5	66.4
KL	6	1	1	2	5	66.7	83.3
LC	216	0	3	18	174	9.7	80.6

Burbot Wounding Rates

The Burbot population, once the most prevalent coldwater predator in the eastern basin of Lake Erie, has declined over 90% (in relative abundance) since 2004 (see Charge 1). Coincidentally, both A1-A3 and A4 wounding rates on Burbot have increased since 2004 in eastern basin waters of Lake Erie (Figure 3.2). In 2018, there was one fresh (A1-A3) and no healed (A4) wounds on the 53 Burbot sampled greater than 532 mm (21 inches) during coldwater assessment gill netting.

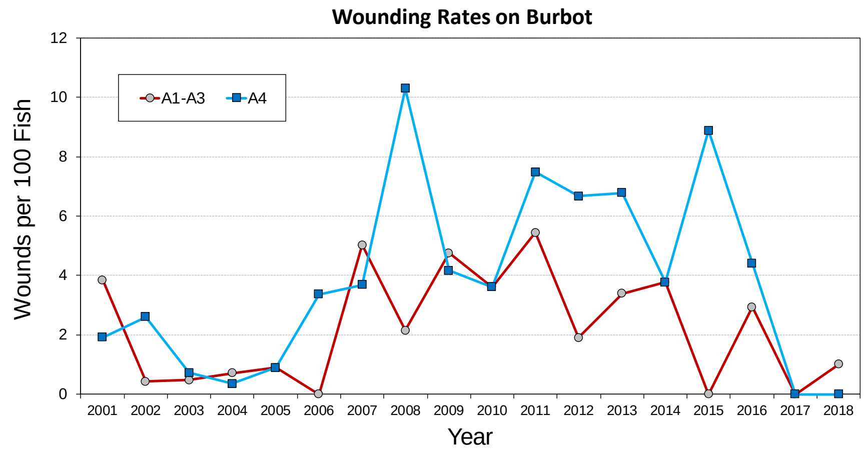


FIGURE 3.2. Number of A1-A3 and A4 Sea Lamprey wounds per 100 Burbot greater than 532 mm (21 inches) sampled in assessment gill nets in the eastern basin of Lake Erie, August, 2001-2018.

Lake Whitefish Wounding Rates

Reliable counts of Sea Lamprey wounds on Lake Whitefish have only been recorded since 2001. Wounds on Lake Whitefish were first observed in 2003, coincident with depressed adult Lake Trout abundance (see Charge 1). A total of 76 Lake Whitefish greater than 532 mm (21 inches) were checked for evidence of Sea Lamprey attacks in 2018 assessment netting; one of these fish had an A1-A3 wound (1.3 wounds/100 fish) while 2 had A4 wounds (2.6 wounds/100 fish) (Figure 3.3). Wounding rates on Lake Whitefish have generally remained consistent over the previous seven years with the exception of 2015 when only two fish were caught.

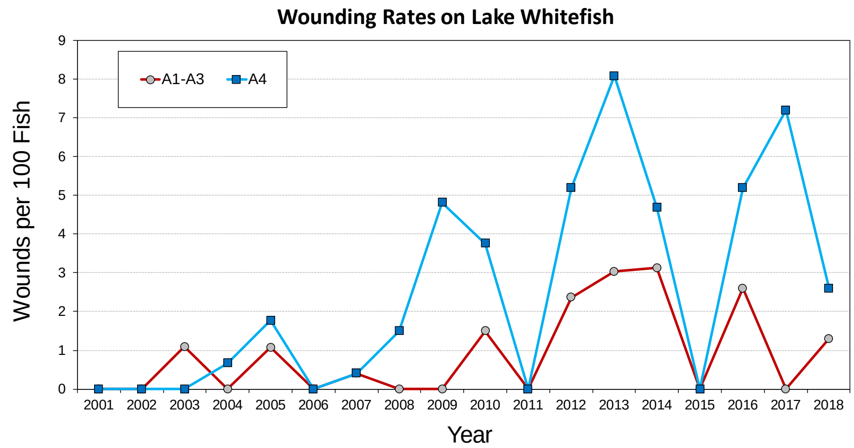


FIGURE 3.3. Number of A1-A3 and A4 Sea Lamprey wounds per 100 Lake Whitefish greater than 532 mm (21 inches) sampled in assessment gill nets in the eastern basin of Lake Erie, August, 2001-2018.

Ontario Partnership Program

The Ontario Partnership Index Fishing Program is an annual lake-wide gillnet survey of the Canadian waters of Lake Erie and provides an additional and spatially robust assessment of fish species abundance and distribution. Index gill nets were fished on bottom and suspended in the water column at 133 sites in 2018. Auxiliary gill nets (121 mm 50 meshes deep) were also fished suspended adjacent to index gear. Although Sea Lamprey wounds have been recorded on fish species since the survey began in 1989, detailed information on type and category of wound were not recorded until 2011.

A total of 66 Lake Trout (all sizes) were collected from index and auxiliary gear in 2018. One Lake Trout had an A-3 wound (2 / 100 fish) and 2 Lake Trout had type B scars (3 / 100 fish). No Sea Lamprey wounds or scars were detected on 71 Lake Whitefish. One of 11 Burbot examined had a type B scar (9 / 100 fish). No other species examined had Sea Lamprey scars or wounds. The spatial distribution of fish with Sea Lamprey wounds and scars in 2018 is shown in Figure 3.4.

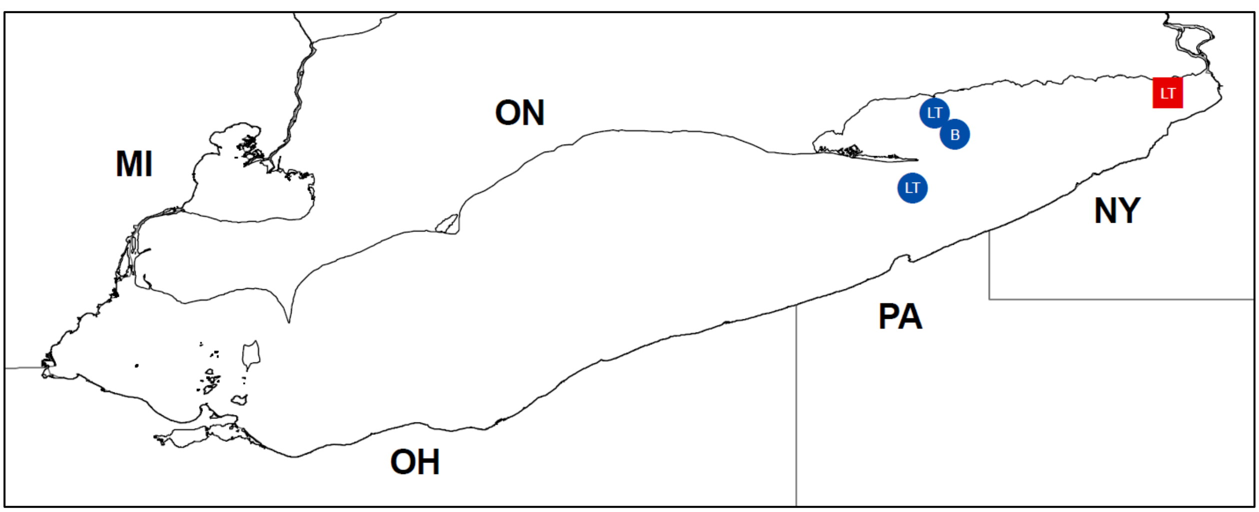


FIGURE 3.4. Individual fish with A3 wounds (red square) and B-type scars (blue dots). Lake Trout (LT) and Burbot (B) were the only species with wounds and scars observed during Lake Erie Partnership surveys in 2018. Includes index and auxiliary gear.

Summary of 2018 Actions and 2019 Plans for the Integrated Management of Sea Lampreys in Lake Erie

The Great Lakes Fishery Commission (Commission) and its control agents, the U.S. Fish and Wildlife Service (Service) and Department of Fisheries and Oceans, Canada (Department) continue to integrate the management of Sea Lamprey in Lake Erie including selection of streams for treatment, application of lampricides, implementation of alternative control methods such as low-head barriers and trapping to selected streams.

2018 Highlights

Lampricide Control

- Lampricide treatments were completed in three tributaries (one Canada, two U.S.).
- Silver Creek (Canada) and Conneaut Creek (U.S.) were successfully treated.
- The Huron River (Ohio) was treated for the first time ever.

Larval Assessment

- Larval assessments were conducted in 67 tributaries (20 Canada, 47 U.S.) and offshore of 2 U.S. tributaries.
- Surveys to detect new larval populations were conducted in 37 tributaries (7 Canada, 30 U.S.). No new Sea Lamprey populations were discovered in 2018.
- Post-treatment assessments were conducted in three tributaries (one Canada, two U.S.) to determine the effectiveness of treatments conducted during 2017 and 2018. Surveys indicated an infestation of Sea Lamprey persisting in the West Branch of Conneaut Creek. This tributary is scheduled for re-treatment during April 2019.
- Surveys to evaluate barrier effectiveness were conducted in five tributaries (two Canada, three U.S.). All barriers assessed were found to be effective in continuing to block Sea Lampreys.
- A total of 2.5 ha of the St. Clair River was surveyed with granular Bayluscide (gB), including the upper river and the three main delta channels. Eighty-two Sea Lampreys were captured throughout the river with no additional areas of high density detected.
- 0.6 ha of the Detroit River was surveyed with gB. Native lamprey larvae (Ichthyomyzon spp.) were collected at multiple sites. These are the first native lamprey collected on the U.S. side of the Detroit River since 1997, and may be indicative of improving habitat and water quality in the river.
- Larval assessment surveys were conducted in non-wadable lentic and lotic areas using 17.36 kg active ingredient of gB (6.16 Canada, 11.2 U.S.).

Juvenile Assessment

- Based on standardized fall assessment data, the marking rate during 2018 was 9.7 A1-A3 marks per 100 Lake Trout >532 mm (Figure 3). The marking rate has been greater than the target for the last 15 years.
- In cooperation with Walpole Island First Nation, the Commission and partners completed the fourth year of an annual index for out-migrating juvenile Sea Lampreys in the St. Clair River (SCR). Eight floating fyke nets were deployed on November 14, 2018. Due to United States Coast Guard (USCG) concerns surrounding proper function of aids to navigation and ice flow, the nets were retrieved early on December 15th. Over the collection period, 20 juvenile Sea Lampreys were captured. Despite attempts to standardize annual sampling effort, variation in net numbers and location due to USCG concerns continue to inhibit consistency.

Adult Assessment

- A total of 913 Sea Lampreys were trapped in 5 tributaries during 2018, all of which are index locations. Adult population estimates based on mark-recapture were obtained from 3 of the 5 index locations.

- The index of adult Sea Lamprey abundance was 4,149 (95% CI; 3,027 – 5,270), which was near the target 4,435 The three-year trend in abundance is above target and has been holding steady over the past 5 years (Figure 3.5).

- The adult Sea Lamprey migration was monitored in Cattaraugus Creek through a cooperative agreement with the Seneca Nation Tribe.

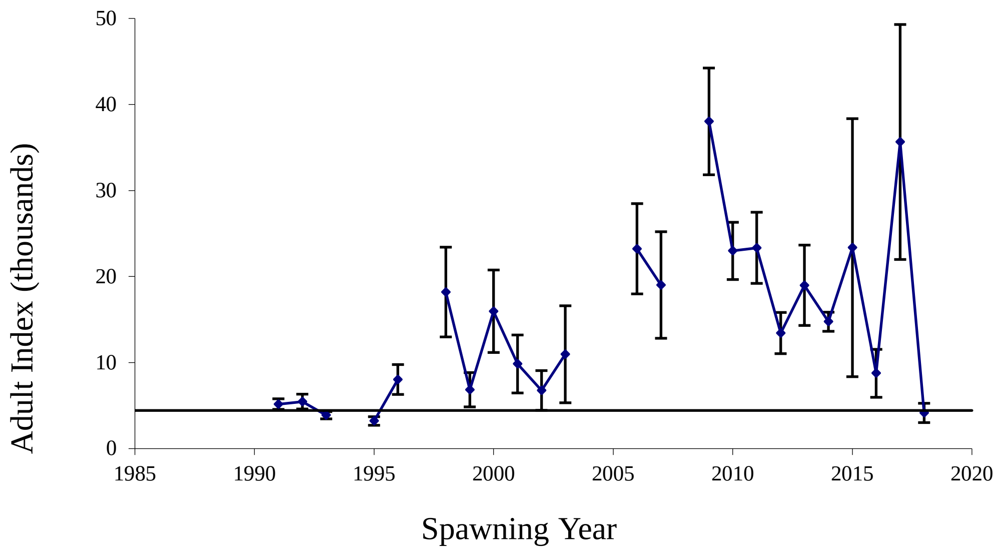


FIGURE 3.5. Index estimates with 95% confidence intervals (vertical bars) of adult Sea Lampreys. The adult index in 2018 was 4,149 with 95% confidence interval (3,027 – 5,270). The point estimate met the target of 4,435 (horizontal line). The index target was estimated as the mean of indices during a period with acceptable marking rates (1991-1995).

Barriers

- Field crews visited one structure on tributaries to Lake Erie to assess Sea Lamprey blocking potential and to improve the information in the Barrier Inventory and Project Selection System (BIPSS) database.

- Routine maintenance, spring start-up, and safety inspections were performed on 11 barriers (7 Canada, 2 U.S.).

- Cattaraugus Creek **–** The United States Army Corps of Engineers (USACE), along with project partners Erie County and New York Department of Environmental Conservation (NYDEC) have approved the selected plan for the Springville Dam Ecosystem Restoration Project. The Project Partnership Agreement (PPA) was completed in July 2017 and the study team has moved forward with the engineering and design phase of this project. The selected plan will lower the existing spillway from 38 to 13.5 feet to serve as a sea lamprey barrier. Requests from the National Historic Registry will be fulfilled by preserving a portion of the original spillway on both banks to show the original structure. A denil fishway with seasonal trapping and sorting operations is also included in the design. Construction is targeted for 2021 after the sea lamprey spawning run.

- Grand River – The USACE is the lead agency administering a project to construct a sea lamprey barrier to replace the deteriorated structure in the Grand River. Project partners include the Commission,

Service, Ohio Department of Natural Resources, and Ashtabula County. The USACE has selected an onsite rebuild as the preferred alternative and has completed the detailed project report. The PPA is in review by the USACE and the allocation agreement between the Commission and Ashtabula County has been signed. Design considerations for the barrier include an 18-inch drop between crest height and tailwater elevations and tailwater velocities capable of preventing sea lamprey passage during flooding events. Barrier design is currently under review. A Value Added Engineering Workshop was completed in February 2017 and several cost saving measures were identified, including constructing the dam during one season. The construction contract was awarded in August 2018. Construction of the dam began fall 2018 and will be completed during 2019.

- One consultation to ensure blockage at barriers was conducted with partner agencies during 2018 (Table 3.3).

Table 3.3. Status of concurrence requests for barrier removals, replacements, or fish passage projects in Lake Erie tributaries.

Mainstream	Tributary	Lead Agency	Project	SLCP Position	Position Rationale
Clinton River	-	Clinton River Watershed Council	Yates Mill Dam	Concur	Barrier repair

Risk Management

- The Risk Management Team (RMT) participated with partner agencies and local community volunteers to conduct non-target surveys in Ohio waters of Conneaut Creek during the April lampricide treatment.

- The RMT participated with the Ohio EPA to conduct non-target surveys in the Huron River during the May lampricide treatment.

- In situ tests were conducted in the St. Clair River to evaluate the toxicity of niclosamide to the Eastern pondmussel (*Ligumia nasuta*) and Eastern lampmussel (*Lampsilis radiata*) when exposed to granular Baylucide.

2019 Plans

Lampricide Control

- Lampricide treatments are planned for four tributaries; Buffalo River (including Cayuga Creek, Cazenovia Creek, and Buffalo Creek), Cattaraugus Creek, Crooked Creek, and the West Branch of Conneaut Creek (U.S.).

Larval Assessment

- Typical larval assessments (detection, distribution, and evaluation surveys) are planned for the 2019 field season.

- At least 1.2 ha of gB assessment is planned for the lower St. Clair River and channels to monitor the population and delineate areas for potential future treatment activities.

Juvenile Assessment

- Assessment for out-migrating juvenile Sea Lampreys in the St. Clair River is planned for the fifth consecutive year by Walpole Island First Nation, in cooperation with the Commission and other partners.

Adult Assessment

- Adult assessment traps will be operated on five tributaries identified for inclusion in the adult Sea Lamprey index.

Barriers

- Conduct routine maintenance and operation of all Commission purpose built barriers in Lake Erie waters of the U.S. and Canada.

- Continue working with the USACE, NYDEC, and other stakeholder groups on the Springville Dam Ecosystem Restoration Project and providing input on barrier and fishway design from a sea lamprey control perspective.

Risk Management

- Tests will be conducted in the RMT's bioassay trailer to determine the toxicity and sub-lethal effects of niclosamide to the Eastern lampmussel (*Lampsilis radiata*) during June 11-20 on the St. Clair River (Michigan). The mussels will be exposed to the equivalent of gB applied in the field (FAR: Field Application Rate) and ¼FAR, ½FAR, 2FAR, 4FAR. The tests will take place streamside in flow-through aquaria with St. Clair River water and sediment.

Research

- Ongoing pilot study by Chris Holbrook, USGS (*Feasibility of acoustic telemetry to describe the spatial distribution of adult Sea Lampreys in the Huron-Erie Corridor*) is designed to provide information needed to design future studies aimed at understanding the spatial and temporal dynamics of adult Sea Lamprey migration in the Huron-Erie Corridor.

- Ongoing project by Nick Johnson titled: Survival and Metamorphosis of Larval Sea Lampreys in Lake Erie Tributaries. During 2016, 2017, and 2018, Nick Johnson, et al. released coded wire tagged sea lamprey larvae into the St. Clair River, Cattaraugus Creek, and Big Creek to estimate survival and metamorphosis rates. The underlying question is: How fast do larvae grow in the St. Clair and how likely is it that a transformer from the St. Clair survives to the adult stage relative to other Erie tributaries? Researchers expect to recover their first tags from adult stage lamprey during spring 2019. Preliminary results and trends will likely not be available until 2020 or 2021. The number of tags recovered each year will be reported to the GLFC through research progress reports.

CHARGE 4: Maintain an annual interagency electronic database of Lake Erie salmonid stocking and current projections for the STC, GLFC and Lake Erie agency data depositories.

Chuck Murray (PFBC) and James Markham (NYSDEC)

In 2018, over 2.2 million yearling trout were stocked in Lake Erie, including Rainbow/Steelhead Trout, Brown Trout and Lake Trout (Figure 4.1). Total 2018 salmonid stocking increased almost 4% from 2017 and equal to the long-term average (1990-2017). Annual summaries for each species stocked within individual state and provincial areas are summarized in Table 4.1 and are standardized to yearling equivalents.

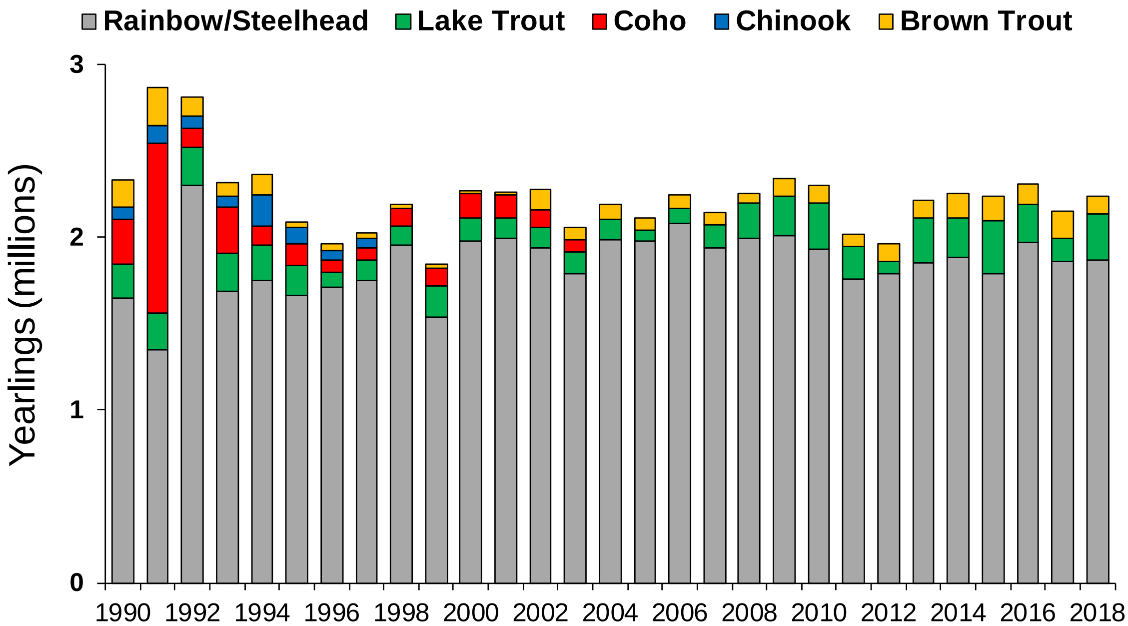


FIGURE 4.1. Annual stocking of all salmonid species (in yearling equivalents) in Lake Erie by all agencies, 1990-2018.

Lake Trout Stocking

A total of 247,305 yearling Lake Trout were stocked in Lake Erie in 2018 (Figure 4.2). The USFWS stocked 79,230 in Ohio, 39,660 in Pennsylvania, and 79,035 yearling Lake Trout in the eastern basin waters of New York. In addition, the Ontario Ministry of Natural Resources and Forestry (OMNRF) stocked 49,380 yearlings at Nanticoke Shoal. All Lake Trout stocked in U.S. waters came from the USFWS Allegheny National Fish Hatchery located in Warren, PA, and were Finger Lakes, Lake Champlain, and Huron-Perry Sound strains. The yearlings stocked in Ontario waters were Slate Island strain. In addition to the yearlings, a total of 40,024 fall fingerling Lake Trout (Finger Lakes strain) were stocked into Cattaraugus Creek in early November 2018. This was the first year of a three-year pilot stocking initiative to determine if stream stocked Lake Trout can survive and return to the stream to spawn. Ontario also stocked 16,000 Finger Lakes strain fall fingerlings in November. The combined yearling and fall fingerling yearling equivalents totaled 270,275 yearlings, which exceeded the current Lake Trout stocking goal of 200,000 yearlings for fifth time in the past six years.

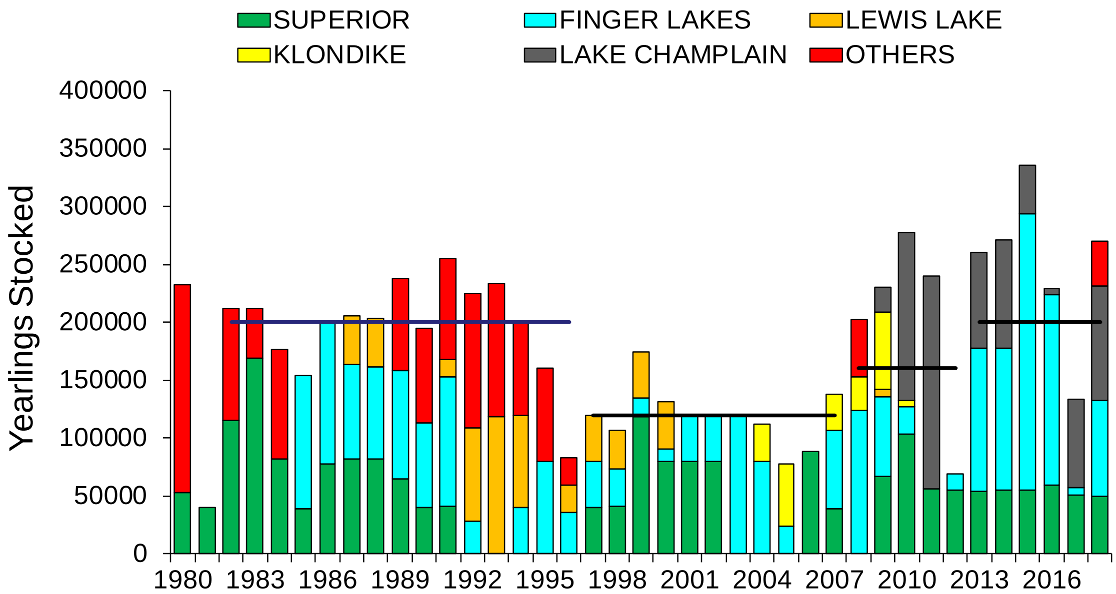


FIGURE 4.2. Lake Trout (in yearling equivalents) stocked by all jurisdictions in Lake Erie, 1980-2018, by strain. Stocking goals through time are shown by black lines dark lines; the current stocking goal is 200,000 yearlings per year. Superior includes Superior, Apostle Island, Traverse Island, Slate Island, and Michipicoten strains; Others include Clearwater Lake, Lake Ontario, Lake Erie, and Lake Manitou strains. 1 fall fingerling = 0.41 yearling equivalents.

Steelhead Stocking

All Lake Erie jurisdictions stocked Steelhead or lake-run Rainbow Trout (hereafter steelhead) in 2018 (Table 4.2). Based on these efforts, a total of 1,813,452 yearling Steelhead and 54,150 domestic strain Rainbow Trout were stocked in 2018, nearly equal to 2017 and slightly above the long-term (1990-2017) average. Nearly all (97%) of the Steelhead stocked in Lake Erie originated from West Coast strains naturalized to the Great Lakes. A Lake Erie strain accounted for 50% of the strain composition, followed by a Washington strain (17%), Manistee River strain (3%), Ganaraska River strain (2%), and a mixture of Manistee River; Chamber's Creek and Ganaraska River which are stocked in equal ratios by ODOW. Less than 3% of the Rainbow Trout stocked are domestic strain and are stocked by the NYSDEC.

State fisheries management agencies are responsible for 94% of all Steelhead stocking effort in Lake Erie. Approximately 6% of the Steelhead stocking is through sportsmen's organizations (NGO's) in Pennsylvania (72,022 yearlings) and Ontario (35,500 yearlings). Fisheries agency stocking of spring yearlings took place between 20 February and 7 May, with smolts averaging about 180 mm in length (Table 4.3).

Brown Trout Stocking

Brown Trout stocking in Lake Erie totaled 98,966 yearlings in 2018. This was a 38% decrease from 2017 but still 13% above the long-term (1990-2017) average (87,579 yearlings). All Brown Trout stocking took place in Pennsylvania waters. Between 13 April and 26 May, about 34,800 adult Brown Trout were stocked by the PFBC and a few NGO hatcheries to provide catchable trout for the opening of the 2018 Pennsylvania trout season and an additional 600 adult Brown Trout were stocked in December in support of late season trout fishing. In a continued effort to provide a put-grow-take trophy Brown Trout program that began in 2009, Pennsylvania NGO's hatcheries stocked about 36,000 yearlings and the PFBC stocked about 27,000 yearling Brown Trout in 2018. This program was implemented through the annual donation of 100,000 certified IPN-free eggs from the NYSDEC. The PFBC has now developed a captive brood egg source for this program to decrease the reliance on New York Brown Trout eggs. Brown Trout stocking levels for catchable trout as well as the trophy program are expected to continue at the current rates in Pennsylvania.

TABLE 4.1. Summary of salmonid stockings in numbers of yearling equivalents, Lake Erie, 1990-2018.

Year	Jurisdiction	Lake Trout	Coho	Chinook	Brown Trout	Rainbow/Steelhead	Total
1990	ONT.	--	--	--	--	31,530	31,530
	NYS DEC	113,730	5,730	65,170	48,320	160,500	393,450
	PFBC	82,000	249,810	5,670	55,670	889,470	1,282,620
	ODNR	--	--	--	--	485,310	485,310
	MDNR	--	--	--	51,090	85,290	136,380
	1990 Total	**195,730**	**255,540**	**70,840**	**155,080**	**1,652,100**	**2,329,290**
1991	ONT.	--	--	--	--	98,200	98,200
	NYS DEC	125,930	5,690	59,590	43,500	181,800	416,510
	PFBC	84,000	984,000	40,970	124,500	641,390	1,874,860
	ODNR	--	--	--	--	367,910	367,910
	MDNR	--	--	--	52,500	58,980	111,480
	1991 Total	**209,930**	**989,690**	**100,560**	**220,500**	**1,348,280**	**2,868,960**
1992	ONT.	--	--	--	--	89,160	89,160
	NYS DEC	108,900	4,670	56,750	46,600	149,050	365,970
	PFBC	115,700	98,950	15,890	61,560	1,485,760	1,777,860
	ODNR	--	--	--	--	561,600	561,600
	MDNR	--	--	--	--	14,500	14,500
	1992 Total	**224,600**	**103,620**	**72,640**	**108,160**	**2,300,070**	**2,809,090**
1993	ONT.	--	--	--	650	16,680	17,330
	NYS DEC	142,700	--	56,390	47,000	256,440	502,530
	PFBC	74,200	271,700	--	36,010	973,300	1,355,210
	ODNR	--	--	--	--	421,570	421,570
	MDNR	--	--	--	--	22,200	22,200
	1993 Total	**216,900**	**271,700**	**56,390**	**83,660**	**1,690,190**	**2,318,840**
1994	ONT.	--	--	--	--	69,200	69,200
	NYS DEC	120,000	--	56,750	--	251,660	428,410
	PFBC	80,000	112,900	128,000	112,460	1,240,200	1,673,560
	ODNR	--	--	--	--	165,520	165,520
	MDNR	--	--	--	--	25,300	25,300
	1994 Total	**200,000**	**112,900**	**184,750**	**112,460**	**1,751,880**	**2,361,990**
1995	ONT.	--	--	--	--	56,000	56,000
	NYS DEC	96,290	--	56,750	--	220,940	373,980
	PFBC	80,000	119,000	40,000	30,350	1,223,450	1,492,800
	ODNR	--	--	--	--	112,950	112,950
	MDNR	--	--	--	--	50,460	50,460
	1995 Total	**176,290**	**119,000**	**96,750**	**30,350**	**1,663,800**	**2,086,190**
1996	ONT.	--	--	--	--	38,900	38,900
	NYS DEC	46,900	--	56,750	--	318,900	422,550
	PFBC	37,000	72,000	--	38,850	1,091,750	1,239,600
	ODNR	--	--	--	--	205,350	205,350
	MDNR	--	--	--	--	59,200	59,200
	1996 Total	**83,900**	**72,000**	**56,750**	**38,850**	**1,714,100**	**1,965,600**
1997	ONT.	--	--	--	1,763	51,000	52,763
	NYS DEC	80,000	--	56,750	--	277,042	413,792
	PFBC	40,000	68,061	--	31,845	1,153,606	1,293,512
	ODNR	--	--	--	--	197,897	197,897
	MDNR	--	--	--	--	71,317	71,317
	1997 Total	**120,000**	**68,061**	**56,750**	**33,608**	**1,750,862**	**2,029,281**
1998	ONT.	--	--	--	--	61,000	61,000
	NYS DEC	106,900	--	--	--	299,610	406,510
	PFBC	--	100,000	--	28,030	1,271,651	1,399,681
	ODNR	--	--	--	--	266,383	266,383
	MDNR	--	--	--	--	60,030	60,030
	1998 Total	**106,900**	**100,000**	**0**	**28,030**	**1,958,674**	**2,193,604**
1999	ONT.			--		85,235	85,235
	NYS DEC	143,320		--		310,300	453,620
	PFBC	40,000	100,000	--	20,780	835,931	996,711
	ODNR			--		238,467	238,467
	MDNR			--		69,234	69,234
	1999 Total	**183,320**	**100,000**	**0**	**20,780**	**1,539,167**	**1,843,267**
2000	ONT.	--	--	--	--	10,787	10,787
	NYS DEC	92,200	--	--	--	298,330	390,530
	PFBC	40,000	137,204	--	17,163	1,237,870	1,432,237
	ODNR	--	--	--	--	375,022	375,022
	MDNR	--	--	--	--	60,000	60,000
	2000 Total	**132,200**	**137,204**	**0**	**17,163**	**1,982,009**	**2,268,576**
2001	ONT.	--	--	--	100	40,860	40,960
	NYS DEC	80,000	--	--	--	276,300	356,300
	PFBC	40,000	127,641	--	17,000	1,185,239	1,369,880
	ODNR	--	--	--	--	424,530	424,530
	MDNR	--	--	--	--	67,789	67,789
	2001 Total	**120,000**	**127,641**	**0**	**17,100**	**1,994,718**	**2,259,459**
2002	ONT.	--	--	--	4,000	66,275	70,275
	NYS DEC	80,000	--	--	72,300	257,200	409,500
	PFBC	40,000	100,289	--	40,675	1,145,131	1,326,095
	ODNR	--	--	--	--	411,601	411,601
	MDNR	--	--	--	--	60,000	60,000
	2002 Total	**120,000**	**100,289**	**0**	**116,975**	**1,940,207**	**2,277,471**

TABLE 4.1. (Continued) Summary of salmonid stockings in number of yearling equivalents, 1990-2018.

Year	Jurisdiction	Lake Trout	Coho	Chinook	Brown Trout	Rainbow/Steelhead	Total
2003	ONT.	--	--	--	7,000	48,672	55,672
	NYS DEC	120,000	--	--	44,813	253,750	418,563
	PFBC	--	69,912	--	22,921	866,789	959,622
	ODNR	--	--	--	--	544,280	544,280
	MDNR	--	--	--	--	79,592	79,592
	2003 Total	**120,000**	**69,912**	**0**	**74,734**	**1,793,083**	**2,057,729**
2004	ONT.	--	--	--	--	34,600	34,600
	NYS DEC	111,600	--	--	36,000	257,400	405,000
	PFBC	--	--	--	50,350	1,211,551	1,261,901
	ODNR	--	--	--	--	422,291	422,291
	MDNR	--	--	--	--	64,200	64,200
	2004 Total	**111,600**	**0**	**0**	**86,350**	**1,990,042**	**2,187,992**
2005	ONT.	--	--	--	--	55,000	55,000
	NYS DEC	62,545	--		37,440	275,000	374,985
	PFBC	--	--	--	35,483	1,183,246	1,218,729
	ODNR	--	--	--	--	402,827	402,827
	MDNR	--	--	--	--	60,900	60,900
	2005 Total	**62,545**	**0**	**0**	**72,923**	**1,976,973**	**2,112,441**
2006	ONT.	88,000	--	--	175	44,350	132,525
	NYS DEC		--	--	37,540	275,000	312,540
	PFBC	--	--	--	35,170	1,205,203	1,240,373
	ODNR	--	--	--	--	491,943	491,943
	MDNR	--	--	--	--	66,514	66,514
	2006 Total	**88,000**	**0**	**0**	**72,885**	**2,083,010**	**2,243,895**
2007	ONT.	--	--	--		27,700	27,700
	NYS DEC	137,637	--	--	37,900	272,630	448,167
	PFBC	--	--	--	27,715	1,122,996	1,150,711
	ODNR	--	--	--	--	453,413	453,413
	MDNR	--	--	--	--	60,500	60,500
	2007 Total	**137,637**	**0**	**0**	**65,615**	**1,937,239**	**2,140,491**
2008	ONT.	50,000	--	--	--	36,500	86,500
	NYS DEC	152,751	--	--	36,000	269,800	458,551
	PFBC		--	--	17,930	1,157,968	1,175,898
	ODNR		--	--		465,347	465,347
	MDNR		--	--		65,959	65,959
	2008 Total	**202,751**	**0**	**0**	**53,930**	**1,995,574**	**2,252,255**
2009	ONT.	50,000	--	--	--	18,610	68,610
	NYS DEC	173,342	--	--	38,452	276,720	488,514
	PFBC	6,500	--	--	64,249	1,186,825	1,257,574
	ODNR	--	--	--	--	458,823	458,823
	MDNR	--	--	--	--	70,376	70,376
	2009 Total	**229,842**	**0**	**0**	**102,701**	**2,011,354**	**2,343,897**
2010	ONT.	126,864	--	--		33,447	160,311
	NYS DEC	144,772	--	--	38,898	310,194	493,864
	PFBC	1,303	--	--	63,229	1,085,406	1,149,938
	ODNR	--	--	--		433,446	433,446
	MDNR	--	--	--		66,536	66,536
	2010 Total	**272,939**	**0**	**0**	**102,127**	**1,929,029**	**2,304,095**
2011	ONT.	--	--	--	--	36,730	36,730
	NYS DEC	184,259	--	--	38,363	305,780	528,401
	PFBC	--	--	--	36,045	1,091,793	1,127,838
	ODNR	--	--	--	--	265,469	265,469
	MDNR	--	--	--	--	61,445	61,445
	2011 Total	**184,259**	**0**	**0**	**74,408**	**1,761,217**	**2,019,883**
2012	ONT.	55,330	--	--	--	21,050	76,380
	NYS DEC	--	--	--	35,480	260,000	295,480
	PFBC	--	--	--	65,724	1,018,101	1,083,825
	ODNR	17,143	--	--	--	425,188	442,331
	MDNR	--	--	--	--	64,500	64,500
	2012 Total	**72,473**	**0**	**0**	**101,204**	**1,788,839**	**1,962,516**
2013	ONT.	54,240	--	--	--	2,000	56,240
	NYS DEC	41,200	--	--	32,630	260,000	333,830
	PFBC	82,400	--	--	71,486	1,072,410	1,226,296
	ODNR	82,200	--	--	--	455,678	537,878
	MDNR	--	--	--	--	62,400	62,400
	2013 Total	**260,040**	**0**	**0**	**104,116**	**1,852,488**	**2,216,644**
2014	ONT.	55,632	--	--		56,700	112,332
	NYS DEC	40,691	--	--	38,707	258,950	338,348
	PFBC	53,370	--	--	97,772	1,070,554	1,221,696
	ODNR	83,885	--	--		428,610	512,495
	MDNR	--	--	--		67,800	67,800
	2014 Total	**233,578**	**0**	**0**	**136,479**	**1,882,614**	**2,252,671**
2015	ONT.	55,370	--	--	--	70,250	125,620
	NYS DEC	81,867	--	--	37,840	153,923	273,630
	PFBC	82,149	--	--	103,173	1,079,019	1,264,341
	ODNR	85,433	--	--	--	421,740	507,173
	MDNR	--	--	--	--	64,735	64,735
	2015 Total	**304,819**	**0**	**0**	**141,013**	**1,789,667**	**2,235,499**
2016	ONT.	60,005	--	--	--	4,324	64,329
	NYS DEC	51,461	--	--	38,110	407,111	496,682
	PFBC	32,500	--	--	83,249	1,074,849	1,190,598
	ODNR	75,650	--	--	--	416,593	492,243
	MDNR	--	--	--	--	66,000	66,000
	2016 Total	**219,616**	**0**	**0**	**121,359**	**1,968,877**	**2,309,852**
2017	ONT.	50,982				59,750	110,732
	NYS DEC	76,456			36,480	267,166	380,102
	PFBC				123,186	1,032,421	1,155,607
	ODNR					442,228	442,228
	MDNR					60,706	60,706
	2017 Total	**127,438**	**0**	**0**	**159,666**	**1,862,271**	**2,149,375**
2018	ONT.	55,940				35,500	91,440
	NYS DEC	95,445				311,843	407,288
	PFBC	39,660			98,966	979,851	1,118,477
	ODNR	79,230				478,408	557,638
	MDNR					62,000	62,000
	2018 Total	**270,275**	**0**	**0**	**98,966**	**1,867,602**	**2,236,843**

TABLE 4.2 Steelhead stocking by jurisdiction and location for 2018.

Jurisdiction	Location	Strain	Number	Life Stage	Yearling Equivalents	
Michigan	Huron River	Manistee River, L. Michigan	62,000	Yearling	62,000	
					62,000	**Sub-Total**
Ontario	Mill Creek	Ganaraska River, L. Ontario / Wild	35,500	Yearlings	35,500	
					35,500	**Sub-Total**
Pennsylvania	Conneaut Creek	Trout Run, L. Erie	75,006	Yearling	75,006	
	Crooked Creek	Trout Run, L. Erie	63,174	Yearling	63,174	
	Elk Creek	Trout Run, L. Erie	234,766	Yearling	234,766	
	Fourmile Creek	Trout Run, L. Erie	25,840	Yearling	25,840	
	Godfrey Run	Trout Run, L. Erie	18,689	Yearling	18,689	
	Lake Erie	Trout Run, L. Erie	70,000	Yearling	70,000	
	Presque Isle Bay	Trout Run, L. Erie	61,477	Yearling	61,477	
	Raccoon Creek	Trout Run, L. Erie	28,385	Yearling	28,385	
	Sevenmile Creek	Trout Run, L. Erie	20,204	Yearling	20,204	
	Sixteenmile Creek	Trout Run, L. Erie	16,380	Yearling	16,380	
	Trout Run	Trout Run, L. Erie	46,252	Yearling	46,252	
	Twelvemile Creek	Trout Run, L. Erie	33,728	Yearling	33,728	
	Twentymile Creek	Trout Run, L. Erie	107,517	Yearling	107,517	
	Walnut Creek	Trout Run, L. Erie	178,433	Yearling	178,433	
					979,851	**Sub-Total**
Ohio	Ashtabula River	Manistee River/Chamber's Creek/Ganaraska River	69,928	Yearling	69,928	
	Chagrin River	Manistee River/Chamber's Creek/Ganaraska River	90,008	Yearling	90,008	
	Conneaut Creek	Manistee River/Chamber's Creek/Ganaraska River	75,079	Yearling	75,079	
	Grand River	Manistee River/Chamber's Creek/Ganaraska River	90,076	Yearling	90,076	
	Rocky River	Manistee River/Chamber's Creek/Ganaraska River	90,114	Yearling	90,114	
	Vermillion River	Manistee River/Chamber's Creek/Ganaraska River	63,203	Yearling	63,203	
					478,408	**Sub-Total**
New York	Buffalo Creek	Washington	15,000	Yearling	15,000	
	Buffalo River - Net Pens	Washington	10,000	Yearling	10,000	
	Canadaway Creek	Washington	20,000	Yearling	20,000	
	Canadaway Creek	Domestic	11,200	Fall Fingerling	11,200	
	Cattaraugus Creek	Washington	90,000	Yearling	90,000	
	Cattaraugus Creek	Domestic	16,200	Fall Fingerling	16,200	
	Caygua Cfeek Creek	Washington	10,000	Yearling	10,000	
	Chautauqua Creek	Washington	50,000	Yearling	50,000	
	Chautauqua Creek	washington	76,291	Fall Fingerling	2,693	
	Chautauqua Creek	Domestic	11,200	Fall Fingerling	11,200	
	Eighteenmile Creek	Washington	40,000	Yearling	40,000	
	Eighteenmile Creek	Domestic	4,350	Yearling	4,350	
	Eighteenmile Creek	Domestic	11,200	Fall Fingerling	11,200	
	Silver Creek	Washington	10,000	Yearling	10,000	
	Walnut Creek	Washington	10,000	Yearling	10,000	
					311,843	**Sub-Total**
					1,867,602	**Grand Total**

TABLE 4.3. Stocking summaries of yearling steelhead by fisheries agency for 2018.

Agency	Range of Dates Stocked	mean length (mm)	N of yearlings stocked
Michigan Dept. of Natural Resources	13 April - 14 April	193	62,000
New York Dept. of Environmental Conservation	12 April - 7 May	126	255,000
Ohio Division of Wildlife	24 April - 5 May	191	478,408
Pennsylvania Fish and Boat Commission	20 February - 11 April	186	909,851
		180	1,705,259

CHARGE 5. Report on the status of steelhead in Lake Erie and develop a proposal for mass marking, including lake wide and agency goals and objectives, a study plan, and logistics

Chuck Murray (PFBC), Tom MacDougall (OMNRF), and James Markham (NYSDEC)

Tributary Angler Surveys

Steelhead are mainly a pelagic species in the open waters of Lake Erie and are not sampled efficiently in any of the long-term assessment surveys. Because of this, populations metrics of the population, such as age structure and estimates of abundance, are not practical. The best measures of the status of the Lake Erie Steelhead population are provided through comprehensive tributary angler surveys. Initial measures of the fishery were conducted in the 1980's and showed average steelhead catch rates of 0.10 fish per angler hour (Figure 5.1). Beginning in 2003-04, the NYSDEC began conducting tributary angler surveys to monitor catch, effort, and harvest of the New York steelhead fishery. These surveys were initially conducted in consecutive years, and at 3-year intervals since then. Coincidentally, the PFBC conducted a similar survey on their Steelhead fishery in 2003-04, and ODNR on theirs in 2008-09 and 2009-10. Results of these surveys showed high tributary catch rates that averaged 0.60 fish/angler hour in the mid-2000's, but then declined in more recent years to 0.35 fish/hour. The most recent NYSDEC angler survey conducted in 2017-18 found tributary steelhead catch rates of 0.56 fish/angler hour, which were similar to the catch rates recorded in the mid-2000's and are among the best catch rates for Steelhead in the country.

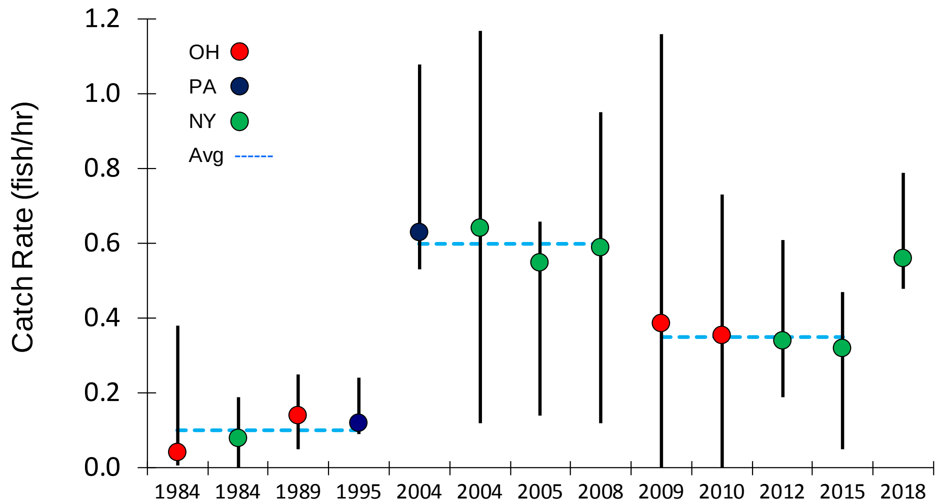


FIGURE 5.1. Targeted average Steelhead catch rates (fish/angler hour) in Lake Erie tributary angler surveys by year and jurisdiction, 1984-2018. Vertical wiskers represent the range of individual tributary catch rates in the survey year.

Exploitation

While Steelhead trout harvest by boat anglers represents only a fraction of the total estimated harvest, it remains the only annual estimate of Steelhead harvest tabulated by most Lake Erie agencies. All agencies provide annual measurements of open lake summer harvest by boat anglers, whether by creel surveys or angler diary reports. These can provide some measure of the relative abundance of adult Steelhead in Lake Erie. The 2018 estimated Steelhead harvest from the summer open-water boat angler fishery totaled 6,950 fish across all US agencies, about a 23% decrease from 2017 (Table 5.1). The majority of the harvest occurred in Ohio waters (77%) with lesser amounts in Pennsylvania (12%) and New York (11%). The Ontario Ministry of Natural Resources and Forestry (OMNRF) has intermittently conducted open lake boat angler creel surveys, but no data was collected in 2018. Pennsylvania and Ohio harvest decreased 52% and 22%, respectively, from 2017 while New York harvest increased 52%. No Steelhead harvest has been reported from Michigan waters since 2013.

TABLE 5.1 Estimated harvest by open lake boat anglers in Lake Erie, 1999-2018.

Year	Ohio	Pennsylvania	New York	Ontario	Michigan	Total
1999	20,396	7,401	1,000	13,000	100	41,897
2000	33,524	11,011	1,000	28,200	100	73,835
2001	29,243	7,053	940	15,900	3	53,139
2002	41,357	5,229	1,600	75,000	70	123,256
2003	21,571	1,717	400	N/A*	15	23,703
2004	10,092	2,657	896	18,148	0	31,793
2005	10,364	2,183	594	N/A*	19	13,160
2006	5,343	2,044	354	N/A*	0	7,741
2007	19,216	4,936	1,465	N/A*	68	25,685
2008	3,656	1,089	647	N/A*	39	5,431
2009	7,662	857	96	N/A*	150	8,765
2010	3,911	5,155	109	N/A*	3	9,178
2011	2,996	1,389	92	N/A*	3	4,480
2012	6,865	2,917	374	N/A*	9	10,165
2013	3,337	1,375	482	N/A*	53	5,247
2014	3,516	2,552	419	4,165	0	10,652
2015	4,622	1,165	673	N/A*	0	6,460
2016	3,577	806	452	N/A*	0	4,835
2017	6,804	1,727	516	N/A*	0	9,047
2018	5,330	837	783	N/A*	0	6,950
mean	12,529	3,330	637	25,736	33	24,656

* no creel data collected by OMNRF in 2003, 2005-2013, 2015, 2016, 2017, 2018

A small amount of targeted effort for Steelhead occurs in the open lake. While the harvest rate statistics are based on a small number of interviews that limit the application of these results, the harvest rates do provide some measure of the overall performance of the Steelhead fishery. Compared to 2017, the 2018 Steelhead harvest rates increased considerably in Pennsylvania and declined moderately in Ohio, with both near the combined agency long-term average of 0.12 Steelhead/angler hr. Steelhead boat angler harvest rates in 2018 were 0.11 Steelhead harvested per angler hour in Ohio waters, a 27% decline from 2017, and 0.15 Steelhead harvested per angler hour in Pennsylvania waters, an 85% increase from 2017. The combined catch rate for 2017 (0.13 fish/angler hr.) was near the long-term average of 0.12 Steelhead harvested/angler hr. (Figure 5.2)

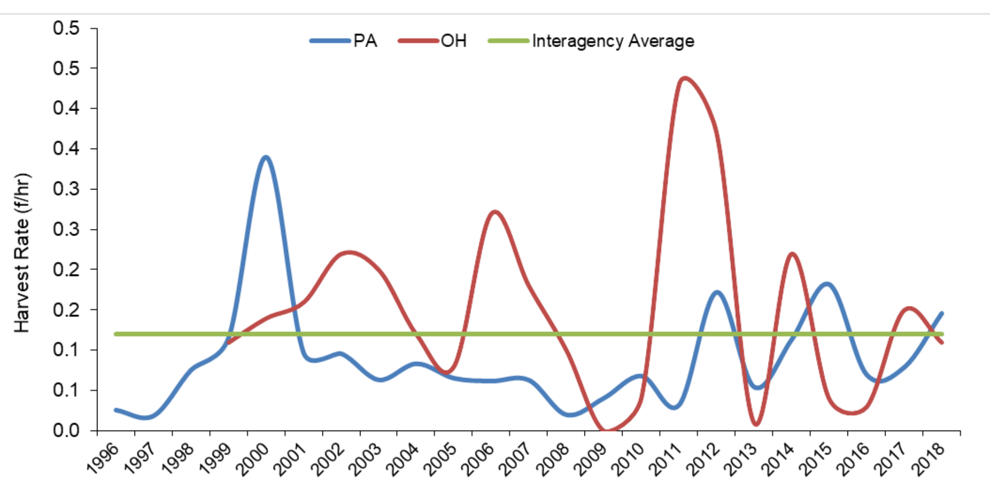


FIGURE 5.2. Targeted Steelhead catch rates (fish caught/angler hr.) in Lake Erie by open lake boat anglers in Ohio and Pennsylvania 1996-2018.

The OMNRF collected open water angler diary reports that can detail trends over time by area of the lake. In 2018, diarists reported 54 targeted Steelhead angler trips in west-central basin and 27 targeted trips in the east-central basin waters of Lake Erie. Fourteen trips targeting Steelhead were recorded through the diary program in the east basin for 2018. West-central basin angler diary reports show that rod-hours for Steelhead in 2018 (1,067) declined 45% from 2017 and were 59% below the 28-year (1990-2017) mean of 2,611 hours (Figure 5.3). The 2018 Steelhead catch rates in the west central basin (0.088 fish per rod-hour) represented a 49% decline from 2017, and were 40% below than the long-term average of 0.148 Steelhead/rod-hr. The 587 rod-hours of effort recorded by anglers fishing the east-central basin for Steelhead in 2018 was a 55% decrease from 2017 and 57% below the 28-year average of 1,351 rod-hours (Figure 5.4). The 2018 east-central catch rate of 0.022 f/rod-hr dropped 70% from 2017 and was 69% below the long-term average of 0.072 Steelhead/rod-hr.

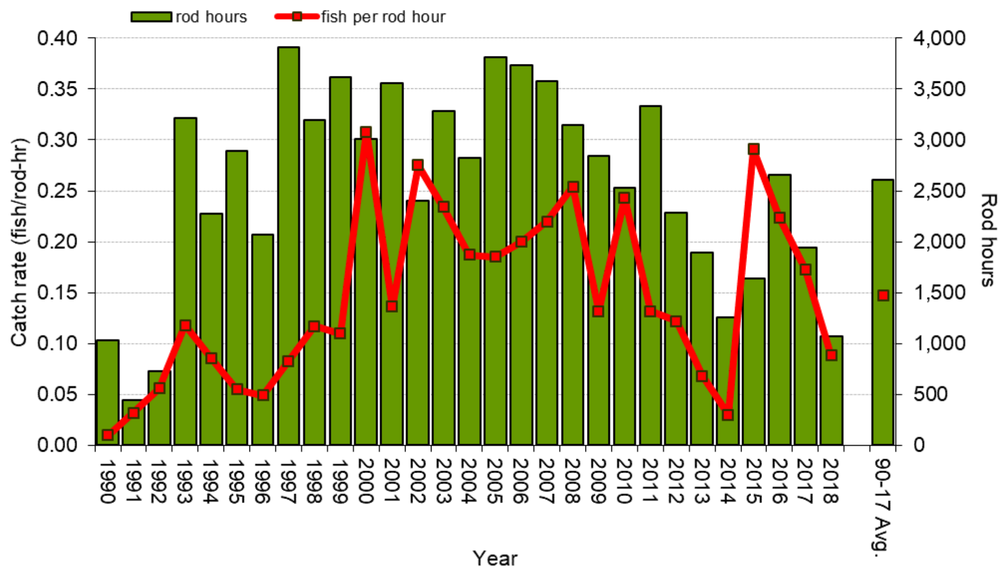


FIGURE 5.3. Targeted steelhead effort and catch rates in Lake Erie’s west-central basin as reported in angler diaries by open lake boat anglers in Ontario from 1990-2018.

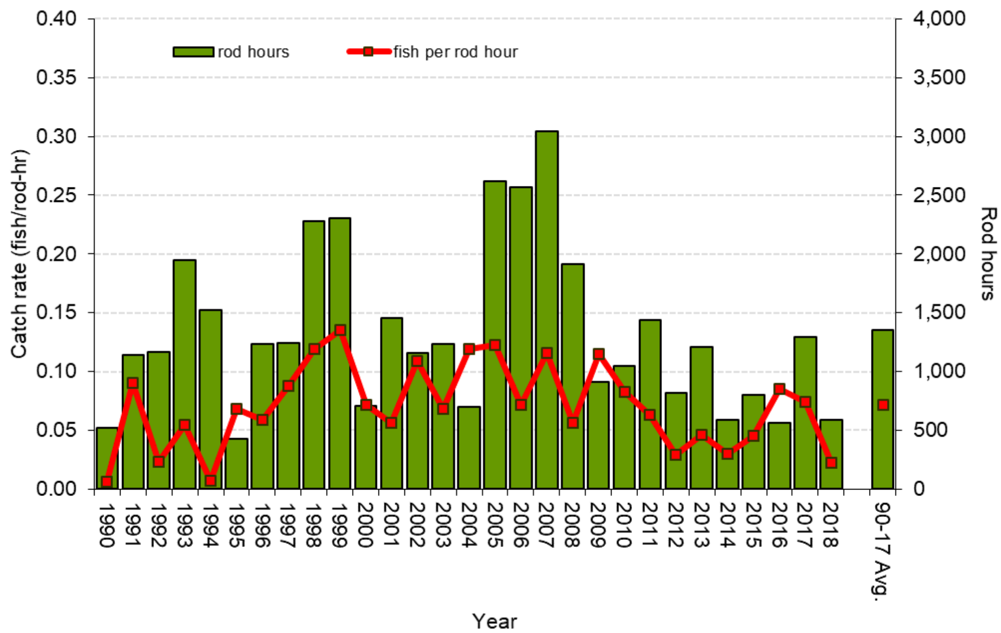


FIGURE 5.4. Targeted steelhead effort and catch rates in Lake Erie’s east-central basin as reported in angler diaries by open lake boat anglers in Ontario from 1990-2018.

Mass Marking

Steelhead represent the major trout fishery on Lake Erie, accounting for 87% of all stocked salmonids. Additionally, more Steelhead are stocked in Lake Erie than in any of the other Great Lakes. Recognizing the prominence of this fishery and the potential impact of stocking so many fish, the Lake Erie Committee has expressed an interest in knowing more about the influence of this species in the fish community and specifically their impact on the forage base. Managers are also interested in how their stocking efforts are performing and what can be done to improve tributary sport fisheries. During this reporting period, the CWTG was charged with developing a proposal for mass marking, including lake wide and agency goals and objectives, a study plan, and logistics.

Lake wide goals

A common goal among all jurisdictions is a better understanding of Steelhead population dynamics, including total abundance, wild recruitment, survival, natural and fishing mortality, growth, maturation and life history. Several attempts have been made over the years to quantify Steelhead abundance, but without key information such as survival and mortality estimates and some age-based population structure, a population model was difficult to develop.

Agency goals

Agencies share the same lake wide goals, but also want an opportunity to evaluate their respective Steelhead programs to see if improvements can be made to maximize juvenile survival, reduce straying, increase adult returns, maximize the time span of the spawning runs, and generally improve their angling fisheries. Otolith microchemistry work on Lake Erie Steelhead also suggests that there is also the potential to fine tune returns to specific areas of the streams in which they are stocked using sequential imprinting (Bohler et al., 2012). NYSDEC (Markham 2017)) and PFBC (CWTG 2016) have been evaluating stocking practices, including smolt size and release location in hope of increasing adult returns. All agencies are interested in determining optimal size to stock smolts. The range of currently stocked Steelhead smolts will provide an excellent spectrum of relative survival based on size at stocking. This could be coupled by smaller size-at-stocking studies within a local watershed which may provide an opportunity for a finer scale evaluation of size related stocking success. There is also interest in describing behavior of the strains being stocked to see if they are performing as expected, based on seasonal contributions to the fishery, growth and longevity.

Study plan

A detailed mass marking plan will be developed by the CWTG to address the common objectives as well as the individual agency goals of the study. Crucial to success of the analysis is the collection of tags from adult Steelhead. Availability, source and abundance of tags will vary by jurisdiction. Samples should be available through the summer boat and tributary fisheries, but fisheries independent sources of information will be needed as well. These samples can be collected through hatchery brood collections, fish used in disease screening, electrofishing or experimental netting. Tags will be taken from all sources, but some collections will need to be directed at specific lots of tagged fish or study locations dictated by the study design. Agency specific research related to tag recoveries could be coordinated internally to minimize costs.

Logistics

Mass marking using CWT technology has been widely used to mark pacific salmon on the great lakes since 2006 (Bronte et al., 2012). Current stocking objectives are about 1.875 million yearling Steelhead smolts annually. Based on these combined target stocking levels, it would cost about $218,700 ($0.117/fish) to clip and tag all Steelhead stocked in Lake Erie (C. Bronte, 2017).

Mass marking involves bringing the tagging trailers to each individual hatchery during a period when the fish are in the optimal size range for tagging and clipping in the machines. This would involve the Salmon River State Fish Hatchery in NY, the Castalia State Fish Hatchery in OH, the Wolf Lake State Fish Hatchery in MI, the Tionesta and Fairview Fish Culture Stations in PA, as well as several cooperative sportsman's hatcheries in Pennsylvania and Ontario. Logistically, it should be a priority to clip and tag at the larger hatcheries and transfer clipped/tagged fish to the smaller cooperative NGO hatcheries. Due to the size variability in hatchery Steelhead fry, optimal tagging size would be when juvenile Steelhead range in size from 62mm-142mm with a mean size of about 80mm in total length (James Webster, USFWS, personal communication). Tagging also assumes that each hatchery facility is equipped to handle the tagging trailer in terms of electrical and water needs, which may not be the case for every hatchery. Time spent at each hatchery will vary depending upon the number of fish that need to be tagged and clipped. If we assume that 50,000 fish can be tagged per day, then NY would require a maximum of 5 working days, PA 20 days, OH 8 days, and two days each for MI and ON.

ACKNOWLEDGMENTS

Coldwater task group members wish to thank the following people for their support during the past year:

- Ann Marie Gorman, Brian Schmidt of the Ohio Department of Natural Resources,
- Division of Wildlife;
- Megan Belore, Karen Soper and Dr. Yingming Zhao of the Ontario Ministry of Natural Resources and Forestry
- Todd Wills, Michigan Department of Natural Resources;
- Mike Hosack of the Pennsylvania Fish and Boat Commission
- Joseph Schmitt of the US Geological Survey

The CWTG report could not be completed without the contributions of all Lake Erie staff from the Michigan Department of Natural Resources, Ohio Division of Wildlife, Pennsylvania Fish and Boat Commission, New York Department of Environmental Conservation, US Geological Survey – Biological Resources Division, and the Ontario Ministry of Natural Resources and Forestry. In addition, the CWTG expresses our thanks to the Great Lakes Fishery Commission and GLATOS for their continued support.

REFERENCES

Boehler, C T., Miner, J .G., Farver J. R., and Freyer, B. J. (2012). Within-stream release-site fidelity of steelhead trout from Lake Erie hatchery stocks. Journal of Great Lakes Research. 38:251-259.

Bronte, C. R., Walch, K. A., Dettmers, J. M., Gaden, M., Connerton, M J. Daniels, M. E., and Newcomb, T. J. 2012. A Coordinated Mass Marking Program for Salmonines Stocked into the Laurentian Great Lakes. American Fisheries Society Symposium 76:27–42, 2012.

Coldwater Task Group. 2016. Report of the Lake Erie Coldwater Task Group, March 2017. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Coldwater Task Group. 1997. Report of the Coldwater Task Group to the Standing Technical Committee of the Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Coldwater Task Group. 2018[1]. Report of the Lake Erie Coldwater Task Group, March 2018. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Coldwater Task Group 2018[2]. MacDougall, T., J. Markham, Z. Biesinger, J. Braunscheidel, A. Cook, C. Eilers, R. Kraus, S. Marklevitz, C. Murray, M. Rogers, G. Steinhart, K. Tallon, J. Trumpickas, C. Vandergoot, J. Boase, P. Penton, M. Belore, M. Faust, T. Hartman, K. Soper, A. Gorman and R. Drouin. Charge 8. The current state of knowledge of Lake Whitefish populations in Lake Erie, including knowledge gaps, impediments, uncertainties, and recommendations for strategies to advise management. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

CWTG. 2017. Impediments to the rehabilitation of Cisco (*Coregonus artedi*) in Lake Erie. Presented to the Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Dechtiar, A.O. and S. Nepszy 1988. Survey of selected parasite fauna of selected fish species from Lake Erie 1970-75. In Parasites of Fishes in the Canadian Waters of the Great Lakes. Great Lakes Fishery Commission Technical Report No. 51.

Edwards, W.H., M.A. Stapanian, A.T. Stoneman. 2011. Precision of Two Methods for Estimating Age from Burbot Otoliths. Journal of Applied Ichthyology 27 (Supplement 1): 43-48.

Harrod, C. and D. Griffiths. 2005. *Ichthyocotylurus erraticus* (Digenea:Strigeidae): factors affecting infection intensity and the effects of infection on pollan (*Coregonus autumnalis*), a glacial relict fish. Parasitology. 131 511-519.

Jacobson, P. C., Stefan, H. G., and D. L. Pereira. 2010. Coldwater fish oxythermal habitat in Minnesota lakes: influence of total phosphorus, July air temperature, and relative depth. Canadian Journal of Fisheries and Aquatic Sciences 67(12): 2002-2013.

Markham, J.L. 2015. Stocked steelhead emigration study. Section J in NYSDEC 2015, Lake Erie 2014 Annual Report. New York State Department of Environmental Conservation, Albany, New York, USA.

Markham, J.L. 2017. Stocked steelhead emigration study. Section J in NYSDEC 2017, Lake Erie 2016 Annual Report. New York State Department of Environmental Conservation, Albany, New York, USA.

Markham, J.L., Cook, A., MacDougall, T., Witzel, L., Kayle, K., Murray, M., Fodale, M., Trometer, E., Neave, F., Fitzsimons, J., Francis, J., and Stapanian, M. 2008. A strategic plan for the rehabilitation of Lake Trout in Lake Erie, 2008-2020. Great Lakes Fish. Comm. Misc. Publ. 2008-02.

McCullough, D., E.F. Roseman, K.M. Keeler, R.L. DeBruyne, J.J. Pritt, P.A. Thompson, S. Ireland, J. Ross, D. Bowser, R.D. Hunter, D. Castle, J. Fischer, and S. Provo. 2015. Abundance, Distribution, and Diet of Transient Larval Burbot in the St. Clair-Detroit Rivers System. Invited to special issue on Burbot Biology and Management, Hydrobiologia 757(1): 21-34.

Muzzall, P.M. and Whelan, G. 2011. Parasites of Fish from the Great Lakes: A Synopsis and Review of the Literature, 1871-2010. Great Lakes Fish. Comm. Misc. Publ. 2011-01.

Tucker, T., E.F. Roseman, J. Pritt, D. Hondorp, R.L. DeBruyne, and D. Bennion. 2018. Long-term assessment of ichthyoplankton in a large North American river system reveals changes in fish community dynamics Canadian Journal of Fisheries and Aquatic Sciences, 75(12): 2255-2270.

Van Oosten, J. and R. Hile. 1947. Age and growth of the Lake Whitefish, *Coregonus clupeaformis* (Mitchill), in Lake Erie. Transactions of the American Fisheries Society 77: 178-249.

Webster, James, USFWS Tagging Operations Supervisor. 2018. Personal Communication. United States Fish and Wildlife Service. Green Bay Fish and Wildlife Conservation Office. Green Bay Wisconsin.