Sub-Indicator: Sea Lamprey

Overall Assessment

Status: Fair

10-Year Trend: Improving

Long-term Trend (1985-2020): Improving

Rationale: Annual Sea Lamprey control activities in the Great Lakes have successfully suppressed Sea Lamprey populations from levels by about 90% since pre-control efforts. Currently, 3-year average adult Sea Lamprey indices are meeting targets in Lakes Michigan, Erie, and Ontario and are above targets in Lakes Superior and Huron. The basin-wide 10-year and long-term adult Sea Lamprey abundance trends are declining. More suppression is needed to bring Sea Lamprey populations to targets in all lakes.

Lake-by-Lake Assessment

Lake Superior

Status: Poor

10-Year Trend: Deteriorating

Long-term Trend (1986 – 2020): Deteriorating

Rationale: Adult Sea Lamprey index is above target and deteriorating.

Lake Michigan

Status: Good

10-Year Trend: Improving

Long-term Trend (1995-2020): Improving

Rationale: Adult Sea Lamprey index is meeting the target and improving.

Lake Huron (including St. Marys River)

Status: Fair

10-Year Trend: Improving

Long-term Trend (1985-2020): Improving

Rationale: Adult Sea Lamprey index is above target and improving.

Lake Erie (including St. Clair-Detroit River Ecosystem)

Status: Good

10-Year Trend: Improving

Long-term Trend (1991-2020): Unchanging

Rationale: Adult Sea Lamprey index is meeting target and improving.

Lake Ontario (including Niagara River and International section of the St. Lawrence River)

Status: Good

10-Year Trend: Improving

Long-term Trend (1987-2020): Unchanging

Rationale: Adult Sea Lamprey index is meeting the target and improving.

Status Assessment Definitions

Good: Adult Sea Lamprey index is below target (see lake-specific targets below)

Fair: Adult Sea Lamprey index is above target, but the 10-year trend is improving

Poor: Adult Sea Lamprey index is above target and the 10-year trend is deteriorating

Trend Assessment Definitions

Improving: Adult Sea Lamprey index shows a change toward acceptable conditions

Unchanging: Adult Sea Lamprey index shows no change

Deteriorating: Adult Sea Lamprey index shows a change away from acceptable conditions

Endpoints and/or Targets

Endpoints for this sub-indicator refer to the adult Sea Lamprey index targets, which correspond to the fish community objectives for each lake. Index targets were agreed upon by the cooperating fisheries management agencies on each lake committee and represent index levels during periods where mortality caused by Sea Lampreys was tolerable and would allow attainment of critical fish community objectives including restoration and maintenance of native species populations and valuable fisheries. Index targets remain the same from year-to-year unless a new index stream is added and/or removed, or estimator methodology changes.

Lake Superior: Suppress Sea Lampreys to population levels that cause only insignificant mortality on adult Lake Trout. The adult Sea Lamprey index target in Lake Superior is 10,000 Sea Lampreys.

Lake Michigan: Suppress the Sea Lamprey to allow the achievement of other fish-community objectives. The adult Sea Lamprey index target in Lake Michigan is 32,000 Sea Lampreys.

Lake Huron: Reduce Sea Lamprey abundance to allow the achievement of other fish-community objectives. The adult Sea Lamprey index target in Lake Huron is 31,000 Sea Lampreys.

Lake Erie: The fish community objectives for Lake Erie does not include a specific Sea Lamprey objective, however it does acknowledge that effective Sea Lamprey control is needed to support the fish-community objectives for Lake Erie. The adult Sea Lamprey index target in Lake Erie is 3,300 Sea Lampreys.

Lake Ontario: Suppress abundance of Sea Lamprey to levels that will not impede achievement of objectives for Lake Trout and other fish. The adult Sea Lamprey index target in Lake Ontario is 14,000 Sea Lampreys.

Sub-Indicator Purpose

- To estimate and track the relative adult Sea Lamprey abundance for each lake.
- To monitor the damage caused by Sea Lamprey to the aquatic ecosystem.
- To monitor the success of Sea Lamprey control actions.

Ecosystem Objective

This sub-indicator supports Great Lakes Fishery Commission (GLFC) and fishery management agencies fish community objectives that were established under "A Joint Strategic Plan for the Management of Great Lakes Fisheries" (Great Lakes Fishery Commission - Joint Strategic Plan Committees (glfc.org)). Fish community objectives call for suppressing Sea Lamprey populations to levels that cause only insignificant mortality on fish to achieve objectives for Lake Trout and other members of the fish community.

This sub-indicator best supports work towards General Objective #7 of the 2012 Great Lakes Water Quality Agreement, which states that the Waters of the Great Lakes should "be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes."

Measure

Indices of adult Sea Lamprey abundance are currently calculated as the sum of the spawning run estimates for a subset of streams in a given lake basin (called index streams; Figure 1). The number of adult Sea Lampreys migrating into each index stream are estimated with traps using an adjusted pooled Petersen estimator (~90% of estimates) or are derived from a lake-specific, weighted least squares, two-way analysis of variance (ANOVA) with main effects only (~10% of estimates). More detail on the current methodology used to calculate adult Sea Lamprey indices can be found in Adams et al. (2021).

The GLFC assesses the status of sea lamprey populations in each lake (http://www.glfc.org/status.php) by comparing the 3-year average adult Sea Lamprey index to its lake-specific target (meeting or above target) and evaluating the 5-year linear trend in abundance (decreasing, increasing, or steady); 3-year averages and 5-year trends are used to address variability in the annual point estimates that may not be reflective of the actual population. 3-year average adult Sea Lamprey indices and 5-year trends are updated on an annual basis. For the purposes of this sub-indicator report 3-year average adult Sea Lamprey indices relative to targets and 10-year and long-term trends are used to assess the status of sea lamprey populations in each lake.

Before 2015, this indicator encompassed whole-lake adult Sea Lamprey abundances calculated as the sum of spawning run estimates for all Sea Lamprey-producing streams in a given basin. Abundances were obtained in streams with traps using a modified Schaefer estimator or extrapolation from previous trap capture efficiency estimates, and in streams without traps using a model that relates spawning run size to stream discharge, larval abundance, and year since last treatment (spawner model; Mullett et al., 2003). The majority of the abundances were obtained using the spawner model. In 2015, the GLFC changed its adult Sea Lamprey monitoring protocols by switching from the spawner model to an adult Sea Lamprey index on a subset of streams in a given basin. The change was made because of the high amount of uncertainty inherent to the spawner model. The index provides a means to track adult Sea Lamprey populations using best available data - actual population assessment data, and

providing a better method to track adult Sea Lamprey populations and assess the impacts of the Sea Lamprey control program. In 2017, the GLFC made an additional change to its Sea Lamprey monitoring protocols by switching from a modified Schaefer estimator to an adjusted pooled Petersen estimator. The pooled Petersen estimator performs better than the modified Schaefer and other estimators in terms of accuracy and precision with large sample sizes and was more accurate than the modified Schaefer estimator with small sample sizes. See Adams et al. (2021) for more detail on these methodological changes. The current method to calculate the indices has been applied to historic data to promote comparisons across the time series.

Ecological Condition

The Sea Lamprey is a non-native species and a lethal parasite of many fish species in the Great Lakes (e.g. Bergstedt and Schneider 1988; Kitchell 1990), and has caused ecologic and economic tragedy in terms of its impact on the Great Lakes fish communities and ecosystem (Smith and Tibbles 1980). Before control, Sea Lampreys killed an estimated 103 million pounds (47 million kilograms) of fish per year with the average Sea Lamprey killing up to 40 pounds (18 kg) of fish during its parasitic stage. Sea Lampreys prefer trout, salmon, whitefish, and Lake Sturgeon but they also parasitize smaller fish like cisco, Walleye, and Yellow Perch (GLFC 2015). The first complete round of stream treatments with the lampricide TFM (as early as 1960 in Lake Superior) successfully suppressed Sea Lamprey populations to about 10% of pre-control abundances in all of the Great Lakes except Lake Erie, and subsequent lampricide treatments conducted on a regular basis across the Great Lakes have successfully maintained Sea Lamprey populations at this level in all lakes except Lake Erie. The Sea Lamprey, however, continues to be a significant source of mortality for many fish species (Bergstedt and Schneider 1988; Kitchell 1990) and its continued control is needed to restore and maintain the Great Lakes fish communities and ecosystem.

Indices of adult Sea Lamprey abundance relative to lake-specific targets are the primary performance indicators of the Sea Lamprey control program (Figure 2). Index estimates are calculated as the sum of the spawning run estimates for a subset of streams in a given lake basin. The numbers of adult Sea Lampreys migrating into each index stream are estimated with traps using mark/recapture methods. Index estimates are updated on an annual basis.

On all lakes except Huron and Michigan, index targets are the average index estimate in each lake during times when lake-wide Sea Lamprey wounding rates on Lake Trout were tolerable, that is, causing less than 5% annual mortality (or when Lake Trout wounding rates were less than or equal to five wounds per 100 fish). For Lake Huron, Lake Trout wounding rates have not been at tolerable levels for five consecutive years, so the index target is set at 25% of the average index estimate during the late 1980s. For Lake Michigan, Sea Lamprey index estimates are not available during times when Lake Trout wounding rates were tolerable, so the index target is set using index data from the late 1990s corrected for the higher than tolerable Lake Trout wounding rates. Index targets are only updated when an index stream is either added and/or removed from the estimation procedure or if estimator methodology changes.

Sea Lamprey wounding rates on Lake Trout have also been previously included as another measure of the abundance of Sea Lamprey in relation to their prey. However, wounding rates were not used directly to assess Sea Lamprey abundance in previous Sea Lamprey indicator reports. Lake Trout wounding rate trends do not always match Sea Lamprey abundance trends. Lake Trout wounding rates are dependent on Sea Lamprey abundance and abundances of ALL host fish. These relationships are hard to reconcile because of the lack of abundance data on hosts other than Lake Trout, which leads to inconsistencies between Sea Lamprey abundance and Lake Trout wounding rates (e.g., a Lake Trout wounding rate can increase in the presence of a steady Sea Lamprey population if the abundance of other host fish declines). However, Sea Lamprey wounding rates on Lake Trout for each lake

along with their targets are graphically summarized in Figure 3 to show some of the impact Sea Lamprey have on Great Lakes fish, specifically Lake Trout.

Lake Superior

In Lake Superior, the 2020 adult Sea Lamprey index could not be calculated because of the COVID-19 pandemic. The 3-year average adult Sea Lamprey index is above target and has been deteriorating over the past 10 years. Sources of Sea Lampreys that are of concern include the Bad and Sturgeon rivers and lentic (estuaries, bays, and slower moving tributaries) populations in the Kaministiquia, Nipigon, Gravel, and Batchawana rivers where populations are sparsely distributed and lampricide treatments are less effective. Overall, lampricide control effort has increased since 2005 with additional tributary and lentic areas being treated. Intensive lampricide treatment effort was focused on Lake Superior during 2016 and 2019.

Lake Michigan

In Lake Michigan, the 2020 adult Sea Lamprey index could not be calculated because of the COVID-19 pandemic. The 3-year average adult Sea Lamprey index is meeting target and has been improving over the past 10 years. Sources of Sea Lampreys that are of concern include the Manistique River, other productive tributaries in the northern and eastern parts of the lake, and the St. Marys River (Lake Huron). Lampricide control effort has increased starting in 2006, and intensive lampricide treatment effort was focused on Lake Michigan during 2017. In addition, the Manistique River has been treated seven times since 2003. Reductions in Sea Lamprey abundance during the past ten years are likely a result of increased lampricide treatment efforts.

Lake Huron

In Lake Huron, the 2020 adult Sea Lamprey index was calculated. The 3-year average adult Sea Lamprey index is above target and has been improving over the past 10 years. Sources of Sea Lampreys that are of concern include the St. Marys River, other productive tributaries in the northern part of the lake (e.g. Garden and Mississagi rivers), and the Manistique River (Lake Michigan). Lampricide control effort has increased starting in 2006 with additional treatments. A large-scale effort to treat the North Channel area of Lake Huron (including the St. Marys River) occurred from 2010-2011 along with geographically expanded treatment in the northern parts of Lakes Huron and Michigan in 2012-2013 and 2014-2015. Application of this strategy successfully reduced larval Sea Lampreys in the St. Marys River to historically low levels.

Lake Erie

In Lake Erie, the 2020 adult Sea Lamprey index estimate was calculated, but is partially based on ANOVA modeling estimates due to the COVID-19 pandemic. The 3-year average adult Sea Lamprey index is meeting target and has been improving over the past 10 years. Sources of Sea Lampreys that are of concern include hard-to-treat tributaries (e.g. Cattaraugus Creek), tributaries with non-target species of concern (Conneaut Creek), and the St. Clair and Detroit River System. Lampricide control effort dramatically increased during 2008-2010 with the implementation of a large-scale treatment strategy where all known Sea Lamprey-producing tributaries to Lake Erie were treated in consecutive years. Increased control effort was also applied during 2013 with the treatment of twelve tributaries. Assessment and treatment strategies continue to be developed for the St. Clair and Detroit River System, which could be a significant contributor of Sea Lamprey to Lake Erie.

Lake Ontario

In Lake Ontario, the 2020 adult Sea Lamprey index estimate was calculated. The 3-year average adult Sea Lamprey index is meeting the target and has been improving over the past 10-years. A source of Sea Lampreys that is of concern is the Niagara River – the larval Sea Lamprey population is currently small, but could become an issue with

improved habitat and water quality. Steady lampricide control effort on Lake Ontario has maintained the adult Sea Lamprey index at or near the target.

Linkages

Lake Trout; Walleye; and Lake Sturgeon

Sea Lampreys remain a significant source of mortality (basin-wide and/or locally) on many fish species of the Great Lakes including Atlantic, Chinook, and Coho Salmon, Burbot, ciscoes, Lake Sturgeon (threatened in some parts of the Great Lakes basin), Lake Trout, Lake Whitefish, Steelhead, Walleye, etc. Short lapses in Sea Lamprey control can result in rapid increases in Sea Lamprey abundance and the damage they inflict on fish. Continued stream and lentic area treatments are necessary to overcome the reproductive potential of the Sea Lamprey and to ensure the achievement of population management objectives for many different species, and to preserve functioning ecosystems.

Aquatic Habitat Connectivity; Water Quality

The potential for Sea Lampreys to colonize new locations is increased with improved aquatic habitat connectivity through the removal of dams and improved water quality. For this reason, improvements in habitat connectivity must be weighed with the costs of potential increases in Sea Lamprey habitat. The failure of the Manistique River Dam to block Sea Lampreys and the subsequent Sea Lamprey production from the river is an example of the linkages between Sea Lamprey and aquatic habitat connectivity. Additionally, as water quality improves, streams and lentic areas once inhospitable to Sea Lampreys may become viable spawning and nursery habitats. During the mid-2000s, a significant larval population requiring regular lampricide treatment was established for the first time in the estuary of the Kaministiquia River (Lake Superior) after a local paper mill began tertiary treatment of its effluent. The establishment of larval populations in the St. Marys, St. Clair, and Lower Niagara rivers followed concerted efforts to improve water quality, and with observations of successful reproduction by Lake Sturgeon, Lake Whitefish, and Brindled Madtom, evidence of Sea Lamprey reproduction in the Detroit River is likely inevitable.

Climate Change

Rising water temperatures in the Great Lakes have recently been associated with increasing size of adult Sea Lampreys (Kitchell et al. 2014). As water temperatures rise, Sea Lampreys may grow larger increasing metabolism and becoming more fecund (fertile), which may increase the number of Sea Lampreys and the damage they cause to host fish. Increased precipitation amounts can cause dam failures such as those experienced on the Tittabawassee River (Michigan) during 2020, allowing passage of sea Lamprey into new locations. Precipitation events can also move Sea Lamprey larvae downstream or into lentic areas where treatment is more difficult. See Lennox et al. (2020) for a recent review of the potential impacts of climate change on sea lamprey in the Great Lakes.

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin	X			
Data obtained from sources within the U.S. are comparable to those from Canada	X			
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report	X			
Data used in assessment are openly available and accessible	No			

Data Limitations

- Adult Sea Lamprey trapping and index estimations, Lake Trout population assessments, and Lake Trout wounding data collections were all impacted by COVID-19 during 2020. Estimates may not be available, may be based on modeling instead of actual catches, or may be based on a smaller sample size or geographic sampling area than is typical. These limitations are noted above.
- There are no direct measures of Sea Lampreys during the period when they are parasitic on Great Lakes fish. Adult Sea Lamprey indices are used as a surrogate. Relating adult Sea Lamprey indices to the parasitic population assumes insignificant or at least constant mortality between the parasitic and adult life stages.
- Adult Sea Lamprey indices are limited to streams where it is possible to trap migrating adult Sea Lampreys and generate a mark/recapture population estimate. Consequently, the adult Sea Lamprey indices only use a subset of streams in a given lake basin.
- Direct mark/recapture data for parasitic or newly metamorphosed Sea Lampreys might provide better estimates of damage to other fishes, but these direct estimates may only be obtained with confidence when large numbers of individuals can be recaptured. To date, assumptions of mark/recapture methods, particularly the assumption of equal survival among marked and unmarked individuals, cannot be met and estimates of juvenile Sea Lamprey are highly uncertain.
- Sea Lamprey wounding rates on other important fish species could also inform the impacts of Sea Lamprey to the Great Lakes ecosystem, but are excluded from this sub-indicator for the sake of simplicity because:

1) Lake-wide wounding rates are currently only available for Lake Trout. Lake Trout are considered the most vulnerable and preferred species, thus making them a good indicator species.

2) The observations of wounding rates are hard to interpret because they are influenced by the abundance of fish in the suitable size range for Sea Lampreys and may vary depending on the mix of these fishes in an area.

3) Classification of Sea Lamprey wounds (i.e., marks, Type A or Type B) is subjective and may vary among individuals and agencies making the observation.

4) The relationship between an observed wound and the mortality caused by Sea Lampreys involves understanding the lethality of an attack. Experimental and observational data regarding the probability of trout and salmon surviving an attack is available. However, these experimental observations are limited and verification of lethality in the field will improve understanding of Sea Lamprey mortality.

Additional Information

Increases in lampricide treatments have reduced 3-year average adult Sea Lamprey indices to within target ranges in three of the five Great Lakes (Michigan, and Ontario). The effects of increased lampricide treatments are observed in index estimates beginning two years after they occur. Efforts to identify new/unidentified sources of Sea Lampreys also need to continue. In addition, research to better understand Sea Lamprey/host interactions, recruitment dynamics, population dynamics of Sea Lampreys that survive treatment, and refinement of and research into other control methods are all keys to achieving and maintaining adult Sea Lamprey indices at targets.

Acknowledgments

Authors

Michael J. Siefkes and Lisa M. Walter, Great Lakes Fishery Commission, 2200 Commonwealth Blvd., Suite 100, Ann Arbor, MI 48105. Phone: (734) 669-3013 (Siefkes); (734)669-3002 (Walter). Email: msiefkes@glfc.org; lwalter@glfc.org

Contributors

Jean V. Adams, U.S. Geological Survey, Great Lakes Science Center, 223 East Steinfest Road, Antigo, WI 54409. Phone: (715) 627-4317 ext. 3125. Email: jvadams@usgs.gov
Pete Hrodey, U.S. Fish and Wildlife Service, Marquette Biological Station, 3090 Wright Street, Marquette, MI 49855. Phone: (906) 226-1225. Email: pete_hrodey@usfws.gov
Gale Bravener, Department of Fisheries and Oceans Canada, Sea Lamprey Control Centre, 1219 Queen Street East, Sault Ste. Marie ON P6A 2E5. Phone: (705) 941-2625. Email: gale.bravener@dfo-mpo.gc.ca

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List of Figures

Figure 1. Adult Sea Lamprey index streams.

Source: Great Lakes Fishery Commission

Figure 2. 3-year average adult Sea Lamprey indices plotted on Sea Lamprey spawning year. Horizontal lines represent the targets for each lake. Note the scale differences for each lake.

Source: Great Lakes Fishery Commission

Figure 3. 3-year average A1-A3 Sea Lamprey wounds per 100 Lake Trout > 532 mm (Superior, Huron, Michigan, and Erie) and 3-year average A1 Sea Lamprey wounds per 100 Lake Trout > 432 mm (Ontario) from standardized assessments. Horizontal lines represent the wounding rate target for each lake. Note the scale differences for each lake.

Source: Great Lakes Fishery Commission

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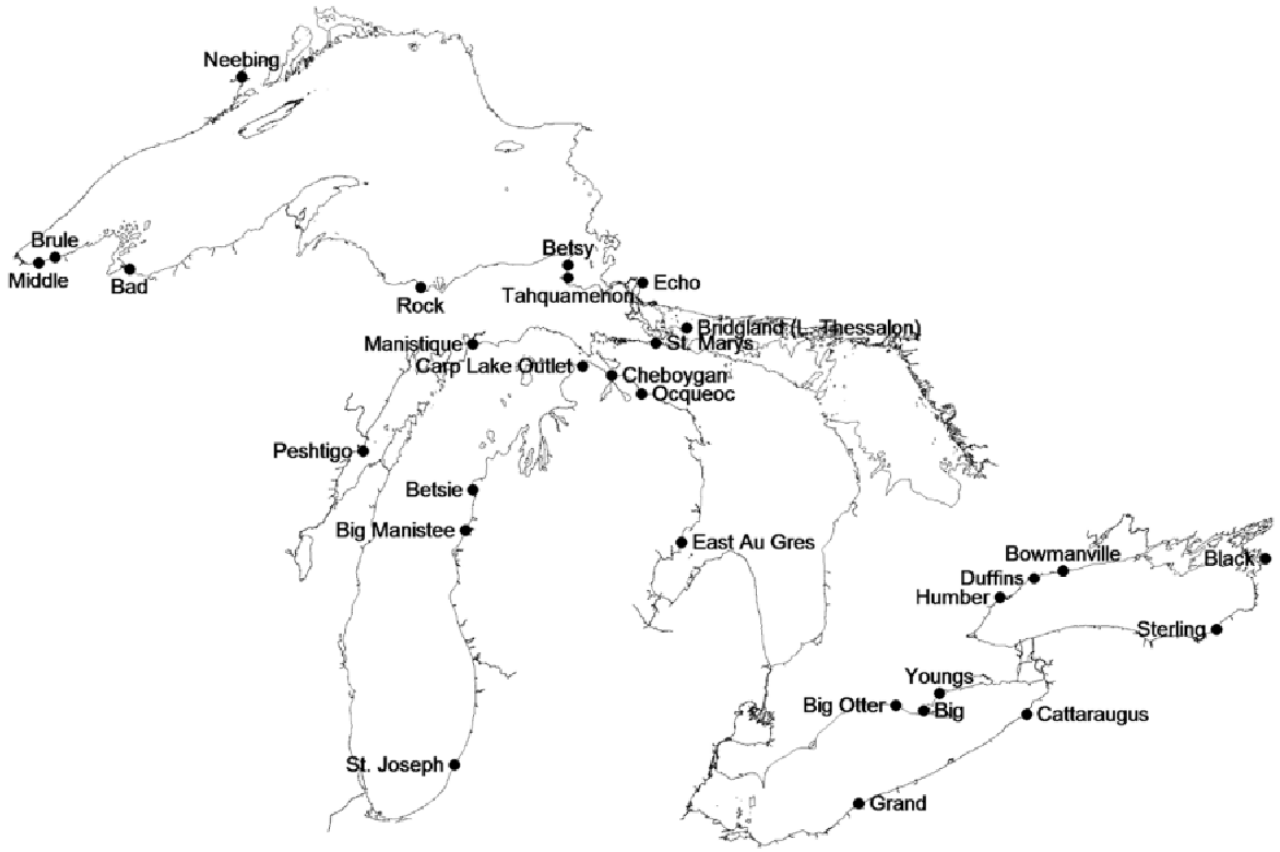
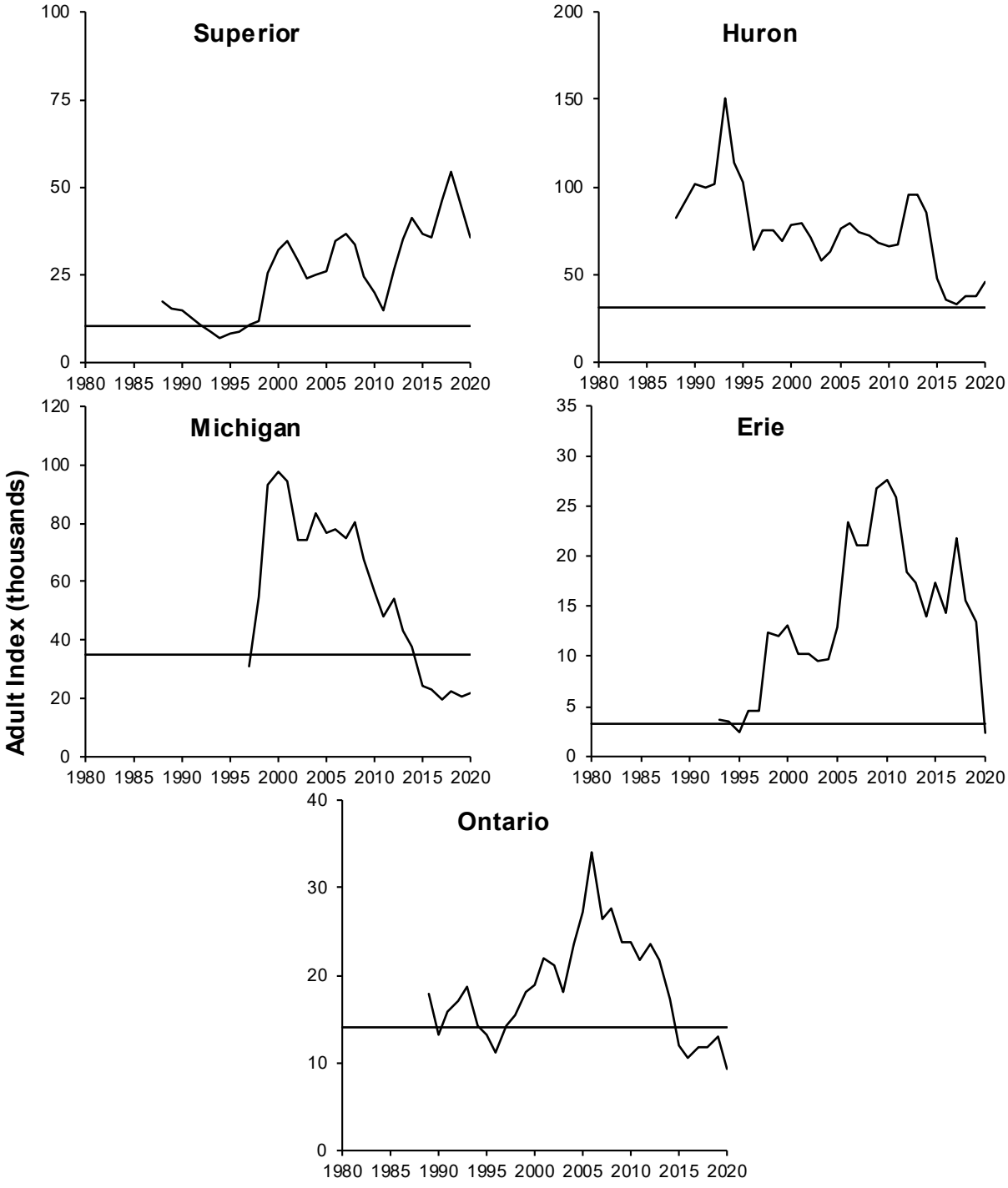


Figure 1. Streams selected for inclusion in the index of adult Sea Lamprey abundance. Source: Great Lakes Fishery Commission.



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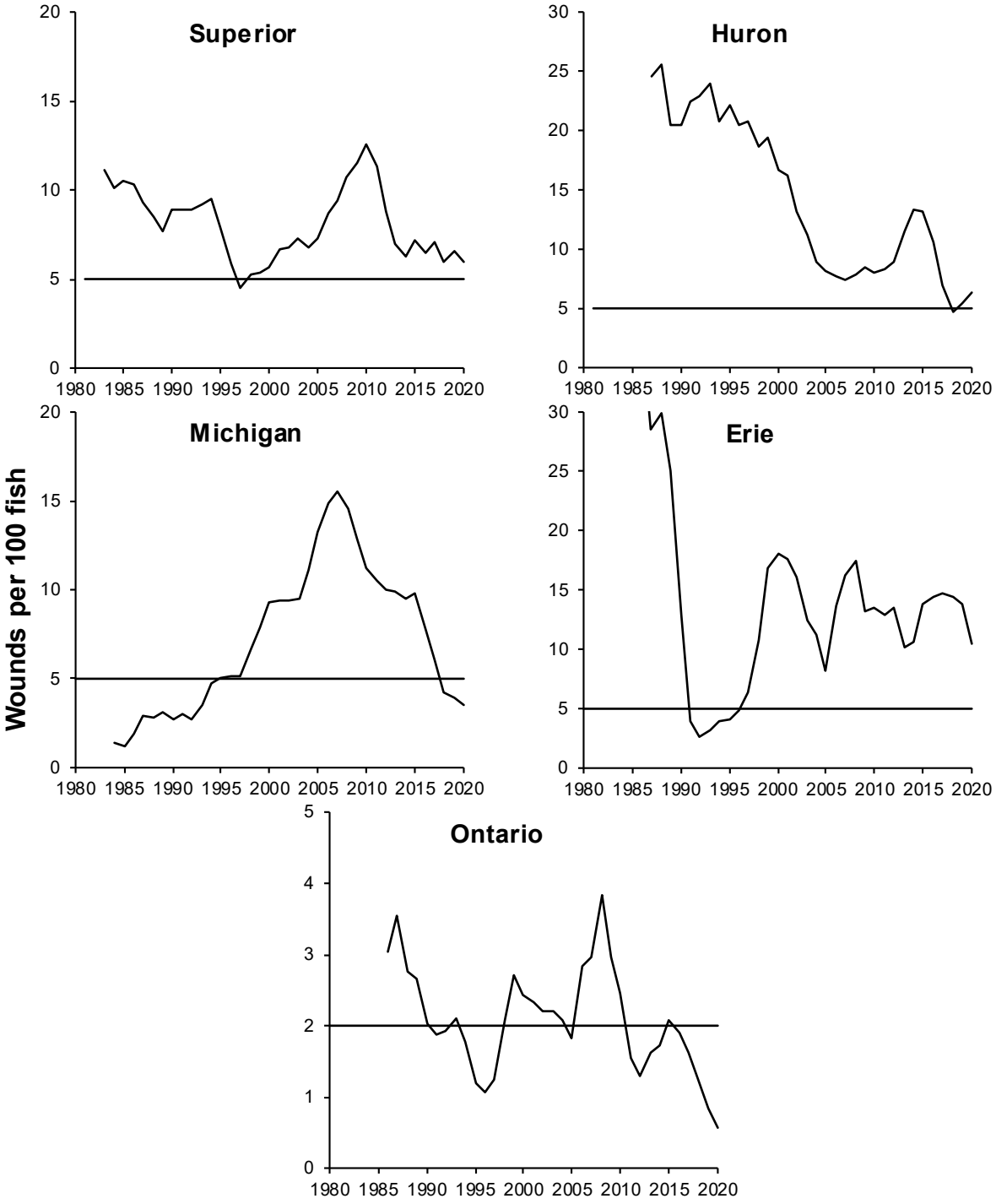

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