



Sea Lamprey

Formerly Indicator # 18

Overall Assessment

Status: Fair

Trend: Unchanging

Rationale: Lake-wide spawning-phase sea lamprey abundances are above targets in all lakes except Superior and Ontario. Lake-wide sea lamprey wounding rates on lake trout are above targets in all lakes except Ontario. Lake trout relative abundances are variable.

Lake-by-Lake Assessment

Lake Superior

Status: Fair

Trend: Improving

Rationale: Sea lamprey abundance has declined since 2005, reaching the target range and holding there since 2009. The lake trout wounding rate is above target and has been increasing since 1999. Lake trout relative abundance has been increasing since 2003.

Lake Michigan

Status: Poor

Trend: Unchanging

Rationale: Sea lamprey abundance is above the target range after 2 years of decline to within the target range. The lake trout wounding rate is above target and has been increasing since 1995. Lake trout relative abundance has been variable, but unchanging.

Lake Huron

Status: Poor

Trend: Unchanging

Rationale: Sea lamprey abundance is above the target range and has not been within the target range since 1980. The lake trout wounding rate is above target and has been unchanging since 2002. Lake trout relative abundance has been increasing since 1995.

Lake Erie

Status: Poor

Trend: Deteriorating

Rationale: Sea lamprey abundance is nearly five times above the target range and remains at a pre-sea lamprey control level. The lake trout wounding rate is above the target and has been variable since 1997. Lake trout relative abundance has been variable.

Lake Ontario

Status: Good

Trend: Unchanging

Rationale: Sea lamprey abundance is within the target range and has been near or at the target for more than 25 years. The lake trout wounding rate is below the target and has been for 2 years. Lake trout relative abundance has been decreasing since 1995.

Purpose

- To estimate lake-wide spawning-phase sea lamprey abundances
- To estimate the damage caused by the sea lamprey to the Great Lakes fish communities and ecosystem through the calculation of lake-wide sea lamprey wounding rates on lake trout
- To measure the success of sea lamprey control
- The sea lamprey indicator is used in the Great Lakes indicators suite as a pressure indicator in the invasive species top level reporting category

Ecosystem Objective

Sea lamprey control supports the fish community objectives that were established by the Great Lakes Fishery Commission (commission) and fishery management agencies under *A Joint Strategic Plan for the Management of Great Lakes Fisheries*. 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 (Horns *et al.* 2003, Eshenroder *et al.* 1995, DesJardin *et al.* 1995, Ryan *et al.* 2003., Stewart *et al.* 1999). During 2004, the commission and fishery management agencies agreed upon target ranges for lake-wide spawning-phase sea lamprey abundances (Table 1) that will facilitate progress towards achieving fish community objectives in each lake. Suppressing sea lamprey abundances to the target ranges and minimizing sea lamprey damage to lake trout to five wounds or less per 100 fish in each lake (two wounds in Lake Ontario) should result in acceptable mortality on lake trout and other fish species. In addition, sea lamprey control and the sea lamprey indicator support Annex 2 of the Great Lakes Water Quality Agreement.

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 their impact on the Great Lakes fish communities (Smith and Tibbles 1980) and ecosystem. The first complete round of stream treatments with the lampricide TFM (as early as 1960 in Lake Superior) successfully suppressed sea lamprey populations to less than 10% of pre-control abundances in all of the Great Lakes, 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 the need for sea lamprey control continues to preserve, restore, and maintain the Great Lakes fish communities and ecosystem.

Lake-wide spawning-phase sea lamprey abundances relative to lake-specific target ranges are the primary performance indicators of the sea lamprey control program. Sea lamprey abundances are calculated by summing the population estimates generated using mark/recapture, trap catch data extrapolation, and the spawner-discharge model (Mullett *et al.* 2003) methods from sea lamprey-producing streams in a given lake. On all lakes except Huron, target ranges are the average sea lamprey abundance (+/- the 95% confidence interval) 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, the target range is set at 25% of the average sea lamprey abundance during the late 1980s. Sea lamprey abundances and target ranges for each lake are updated during the fall of each year as the newest data are incorporated into the population model.

In addition to setting sea lamprey abundance targets, lake trout wounding rates are used as another measure of sea lamprey abundance in relation to their prey and provide an indicator of damage caused to the fish community in each lake. Care must be taken, however, when interpreting lake trout wounding rates because they are also

influenced by lake trout abundance (e.g. the lake trout wounding rate can increase while sea lamprey abundance remains static, if lake trout abundance is declining). Therefore, lake-wide relative abundance of lake trout is also estimated and reported with sea lamprey abundance and the lake trout wounding rate. Abundance and wounding data are collected during lake trout population assessment surveys conducted during spring (lakes Superior and Michigan), late summer (Lake Erie), and fall (lakes Michigan and Ontario). For all lakes except Ontario, abundance data and sea lamprey wounds in stages 1-3 (of 4) of healing from lake trout greater than 533 mm are used to estimate the lake trout relative abundance and wounding rate. Fishery managers on Lake Ontario decided that abundance data and sea lamprey wounds in stage 1 of healing only from lake trout greater than 433 mm was more appropriate for estimating the lake trout relative abundance and wounding rate for Lake Ontario.

Status of Sea Lamprey

Annual lake-wide spawning-phase sea lamprey abundances with 95% confidence intervals and the lake-specific target ranges are presented in Figure 1. Annual lake-wide sea lamprey wounding rates on lake trout and lake-specific targets are presented in Figure 2. Annual lake-wide relative abundance estimates of lake trout are presented in Figure 3.

Lake Superior

During the past 20+ years, sea lamprey abundance has fluctuated, but remained at a level less than 10% of peak abundance (Heinrich et al. 2003). Sea lamprey abundance was within the target range during the late 1980s and mid-1990s and reached the lowest level of the time series in 1994. Sea lamprey abundance trended upward from 1994 to 2001, but has since been trending downward and has been within the target range since 2008.

The lake trout wounding rate has been increasing since 1997 and has not shown a corresponding decrease as seen recently in sea lamprey abundance, even with increasing lake trout relative abundance. The lake trout wounding rate is above target and increasing with the most dramatic changes in the western portion of the lake, though there have been recent declines in Minnesota waters. Lake trout mortality estimates in Michigan waters indicate that sea lamprey-induced mortality exceeds fishery-induced mortality (commercial and recreational combined), but fishery-induced mortality is low in Michigan waters. Fishery objectives for lake trout continue to be met, but lake trout populations are still threatened by the sea lamprey as indicated by the above target lake trout wounding rate.

In response to above target sea lamprey abundance and the lake trout wounding rate, the number of lampricide treatments were increased beginning in 2001. In addition, large lentic populations along the north shore, which had been treated on a consistent basis until the late 1980's, but discontinued during the 1990's as a result of programmatic cuts, were once again treated at regular intervals beginning in 2005. Additionally, lampricide treatment crews adopted basin-wide tactics during 2006 that were tailored to increase treatment effectiveness by reducing the number of sea lamprey larvae that survive treatment. These tactics included increasing lampricide concentrations and the duration of treatment; applying lampricides to backwaters, springs, rivulets, and seepage areas that were not affected by the primary treatment that otherwise provided areas of escapement or refuge; and timing treatments to take advantage of seasonal susceptibility of larvae (Scholefield et al. 2008) and optimal flow regimes. Furthermore, greater effort was expended on assessing treatment efficacy basin-wide, such that significant residual populations could be addressed in a timely manner. The effects of increased treatment effort and the implementation of basin-wide tactics to increase treatment effectiveness likely have contributed to the downward trend in sea lamprey abundance to within the target range. Increased treatment efforts will continue and their impacts on sea lamprey abundance and the lake trout wounding rate will be observed in the future.

Lake Michigan

Sea lamprey abundance is at about 10% of peak levels, but has not been consistently within the target range since the mid-1990s and has been widely variable since 2003. After trending upward since 1980 (Lavis et al. 2003), sea lamprey abundance fell to within the target range during 2009, but was again above the target range during 2010.

The lake trout wounding rate has also shown an upward trend and has been above target since 1995. This upward trend is likely attributable in part to the declining abundance of larger lake trout in the northern part of the lake (lake trout relative abundance across the whole lake has been variable, but holding steady) as well as recent increases in sea lamprey abundance. Increased sea lamprey-induced mortality on lake trout in the northern waters has set lake trout restoration efforts back by a decade or more by removing a large portion of the spawning population. Furthermore, elevated sea lamprey-induced mortality is affecting the quota allocation of lake trout (caught as bycatch in the whitefish fishery) in that components of the lake trout management regimen in the consent decree between the tribes, the state, and the federal government are currently suspended. Achievement of lake trout rehabilitation and other fishery objectives will continue to be challenged if sea lamprey abundance and the lake trout wounding rate remain above targets.

Increases in sea lamprey abundance and the lake trout wounding rate during the 1990s were attributed to sea lamprey production from the St. Marys River, the large connecting channel between lakes Superior and Huron. In response, an integrated control approach using lampricides, sterile male release, and spawning-phase traps was initiated in the St. Marys River (Schleen et al. 2003) and has reduced the reproductive potential of sea lampreys in the river by about 90%. The continuing upward trend in sea lamprey abundance and the lake trout wounding rate during the late 1990s and early 2000s indicated there were other significant sources of sea lampreys. The number of lampricide treatments increased on Lake Michigan during 2001 and included the treatment of newly discovered populations in nearshore lentic areas and the Manistique River, a large system where the deterioration of a dam near the river mouth allowed sea lampreys access to hundreds of kilometers of habitat. During 2003, sea lamprey abundance and the lake trout wounding rate did not show decreases as a result of the increased treatments during 2001, however, the sharp decrease in sea lamprey abundance observed during 2005 was most likely associated with the 2003 treatment of the Manistique River. Increased lampricide treatment efforts during recent years, including implementation of the basin-wide tactics in 2006 to increase treatment effectiveness (see brief description above under *Lake Superior*) and additional treatments of the Manistique River have not consistently reduced sea lamprey abundance or the lake trout wounding rate. Other potential sources of sea lampreys are being assessed and increased treatment efforts will continue with the effects expected to be observed in future estimates of sea lamprey abundance and the lake trout wounding rate.

Lake Huron

During the past 20+ years, sea lamprey abundance has fluctuated, but remained at a level less than 10% of peak abundance (Morse et al. 2003). During the early 1980s, sea lamprey abundance increased from the target range, particularly in the northern portion of the lake, peaking during 1993 with a gradual decline since then. Despite this decline, sea lamprey abundance is currently above the target range and has been since 1981.

Through the 1990s, there were more sea lampreys in Lake Huron than all the other lakes combined and fishery objectives were not being achieved. Sea lamprey-induced mortality was so severe that during 1995, lake trout restoration efforts were suspended in the northern portion of the lake. There has been a significant reduction in the lake-wide sea lamprey wounding rate on lake trout since the implementation of the integrated control approach on the St. Marys River (see brief description above under *Lake Michigan* and Schleen et al. 2003), although they remain above target. Lake trout restoration efforts have resumed, showing positive signs such as increasing

populations and significant natural reproduction. Nevertheless, achievement of lake trout restoration and other fishery objectives will continue to be challenged if sea lamprey abundance and the lake trout wounding rate remain above targets.

During the 1990s, the St. Marys River was identified as the major source of sea lampreys in Lake Huron, but the size of the river prohibited conventional treatment with the lampricide TFM. As part of the integrated control approach (see brief description above under *Lake Michigan* and Schleen et al. 2003), a new formulation of a bottom-release lampricide (granular Bayluscide) was used to treat roughly 800 ha of St. Marys River larval sea lamprey habitat during 1999. As predicted, the integrated approach significantly reduced the larval sea lamprey population in the river from 5.2 to 1.4 million, which was followed by dramatic declines in lake-wide spawning-phase sea lamprey abundance and the lake trout wounding rate. Nevertheless, sea lamprey abundance has been variable since 2001 (the year in which the effects of the 1999 integrated control approach were first observed). Granular Bayluscide spot treatments on the St. Marys River continued to target areas with high larval sea lamprey densities through 2009, with average annual treatment of around 100 ha. By 2009, however, the larval sea lamprey population had risen to 3.3 million, the highest since integrated control was implemented and not differing significantly from the pre-1999 estimate of 5.2 million. During 2010, 876 ha were treated as part of a large-scale strategy that included the treatment of 40 infested tributaries in the North Channel and northern Lake Huron. This effort will be repeated in 2011 with the effects to be seen beginning in 2012. In addition to the integrated control strategy on the St. Marys River, basin-wide tactics to increase treatment effectiveness were implemented during 2006 (see brief description above under *Lake Superior*), but did not reduce sea lamprey abundance and the lake trout wounding rate to targets.

Lake Erie

Following the completion of the first round of stream treatments in 1987, sea lamprey abundance plummeted (Sullivan et al. 2003) and remained within the target range during 1989 to 1997. Sea lamprey abundance increased briefly during 1998 to 2000, but with increased control effort, returned to within the target range during 2001 to 2004. Unexpectedly, sea lamprey abundance has rebounded, exceeding targets since 2005, and reaching a historic high in 2009.

After the initial stream treatments, and retreatment of most of the major producing tributaries, beginning in 1989, the lake trout wounding rate declined and lake trout survival increased to a level sufficient to meet the rehabilitation objectives in the eastern basin of the lake. During 1997 to 2002, the lake trout wounding rate increased to and remained at a level that threatened lake trout restoration. The lake trout wounding rate fell below the target during 2003, but has been variable since, has trended upward, and is currently above target. Reductions in lake trout stocking that occurred during the late 1990s and early 2000s may have affected lake trout abundance and hence, the lake trout wounding rate. Wounding rates on other fish species have also been increasing. Efforts to rehabilitate lake trout and achieve other fishery objectives will be impossible to achieve, and may be suspended, if high sea lamprey abundance and the lake trout wounding rate are not significantly reduced.

In response to recent increases in sea lamprey abundance, basin-wide tactics to increase treatment effectiveness were implemented during 2006, but failed to reduce sea lamprey abundance and the lake trout wounding rate to targets. Additionally, an aggressive and experimental whole-lake treatment strategy in which all sea lamprey-producing streams were treated at least twice in consecutive years was conducted during 2008 to 2010. Results from the whole-lake treatment strategy will not be fully known until 2011, but high sea lamprey abundance during 2010 and a high lake trout wounding rate during 2009 and 2010 are not promising signs.

Lake Ontario

Sea lamprey abundance was greatly reduced following the completion of important lampricide treatments during the 1980s (including the Black and Oswego river systems) and steadily declined from the mid-1980s to 2003 (Larson et al. 2003). Sea lamprey abundance has been slightly above or within the target range since the mid-1980s and is currently within the target range.

The lake trout wounding rate has also been holding steady at around or below the target since the mid-1980s, although high localized wounding has been noted in the nearshore areas adjacent to the Oswego and Niagara rivers in recent years, and the Ontario Ministry of Natural Resources has reported increased wounding on steelhead at the Ganaraska River fishway. Changing strain composition and reduced abundance of lake trout may be affecting wounding rates and host selection.

Lampricide treatments are continuing, including the basin-wide tactics to increase treatment effectiveness implemented during 2006 (see brief description above under *Lake Superior*), and sea lamprey abundance and the lake trout wounding rate are expected to remain close to targets during the future. Despite the relative success of control efforts in Lake Ontario, achievement of lake trout rehabilitation and other fishery objectives will continue to be challenged by the sea lamprey.

Linkages

Lake Trout; Walleye; Lake Sturgeon; Threatened Species; Top Predator Fish; Other Fish Species: Sea lampreys remain a significant source of mortality 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, steelhead, walleye, whitefish, 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 fishery objectives for many different species, and to preserve functioning ecosystems.

Aquatic Habitat Connectivity; Water Quality: The potential for sea lamprey to colonize new locations is increased with improved aquatic habitat connectivity through the removal of dams and improved water quality. 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. As examples, during the mid 2000's, 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, whitefish, and brindled madtom, it is likely only a matter of time before sea lamprey reproduction is documented in the Detroit River. This could have dire consequences for efforts to control sea lampreys and rehabilitate native coldwater species in Lake Erie.

Climate Change: Rising temperatures in the Great Lakes have recently been associated with increasing size of adult sea lampreys (Jim Kitchell, personal communication). As temperatures rise, sea lampreys may grow larger increasing metabolism and becoming more fecund, which may increase the number of sea lampreys and the damage they cause to host fish.

Management Challenges/Opportunities

Sea lamprey control in the Great Lakes has successfully reduced spawning-phase sea lamprey abundance from peak levels by about 90%. Sea lampreys, however, still remain a significant source of mortality on many Great Lakes fish species and a road block to achieving critical fishery objectives. The commission and its agents have increased the number of stream and lentic lampricide treatments and made changes to improve the efficacy of lampricide applications in response to increasing sea lamprey abundances and lake trout wounding rates during recent years. To best guide lampricide application, computer models driven by empirical data are being used to help allocate lampricide control effort, and research is being conducted to better understand and manage the variability in sea lamprey populations and assess the impact of sea lamprey control. Continuing lampricide treatments, improving methodologies, and searching for new/unidentified sources of sea lampreys are critical to the maintenance and advancement of sea lamprey control.

The commission has a goal of increasing efforts to integrate other control techniques, such as the sterile-male-release technique, spawning-phase trapping, and the installation and maintenance of barriers to stop the upstream migration of spawning-phase sea lampreys. Expansion of the sterile-male-release technique will be challenged by the number of males available for sterilization, but current research on sea lamprey behavior may help to increase trapping efficiency (and thus provide more males to sterilize). Sea lamprey trapping is currently only a viable control technique when associated with sterile-male-releases, but again, recent research on sea lamprey behavior may help to increase trapping efficiency so that enough sea lampreys can be removed to affect recruitment in a stream. Environmental issues related to sea lamprey barriers and fish passage, and the deterioration of dams built for other purposes, but also provide a sea lamprey control function, will continue to challenge the sea lamprey control program in terms of dam rehabilitation costs or increased parasitic-phase sea lamprey production and the associated sea lamprey control costs. The commission also continues to focus on research and development of new control strategies. For instance, pheromones that affect migration and mating have been discovered and offer exciting potential as new controls. Additionally, the sequencing of the sea lamprey genome has rapidly advanced basic sea lamprey research and may uncover new ways to control sea lampreys through avenues yet to be conceived.

As fish communities recover from the effects of sea lamprey predation, there is evidence that sea lamprey populations will benefit from increased prey availability. Facilitated through what are called “compensatory mechanisms”, more sea lampreys may survive to maturity due to the increase in prey availability, thus precipitating an increase in reproductive potential and recruitment (i.e. more sea lampreys may be available to prey on fish). To combat potential compensatory responses, significant additional control efforts, like the integrated control approach on the St. Marys River, the experimental whole-lake treatment strategy on Lake Erie and the large-scale treatment strategy in northern Lake Huron, and the implementation or development of other sea lamprey control strategies will be necessary to further suppress sea lamprey abundances and lake trout wounding rates to targets.

Comments from the author(s)

Increases in lampricide treatments have reduced lake-wide spawning-phase sea lamprey abundances to within target ranges in two of the five Great Lakes. The effects of increased lampricide treatments will be observed in sea lamprey abundances beginning two years after they occur and in lake-wide sea lamprey wounding rates on lake trout beginning within a year after they occur. Discrepancies among sea lamprey abundances and lake trout wounding rates need to be resolved beyond the influence of the number of lake trout in a lake. Efforts to identify new/unidentified sources of sea lampreys also need to continue. In addition, research to better understand sea lamprey/prey interactions, the population dynamics of sea lampreys that survive treatment, and refinement of and research into other control methods are all keys to achieving and maintaining sea lamprey abundances and lake trout wounding rates at targets.

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Assessing Data Quality

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	X					
2. Data are traceable to original sources	X					
3. The source of the data is a known, reliable and respected generator of data	X					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin	X					
5. Data obtained from sources within the U.S. are comparable to those from Canada	X					
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report	X					
Clarifying Notes:						

Acknowledgments

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Table 1. Sea lamprey abundance targets and 95% confidence interval ranges.

Source: Great Lakes Fishery Commission

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Figure 1. Yearly lake-wide adult sea lamprey abundances (blue diamonds) with 95% confidence intervals plotted on sea lamprey spawning year. Green horizontal and dashed lines represent the target abundances and ranges for each lake.

*Note: the smaller scale for Lake Erie.

Source: Great Lakes Fishery Commission

Figure 2. Yearly lake-wide sea lamprey wounding rates on lake trout (red circles) plotted on sea lamprey spawning year. Green horizontal lines represent the wounding rate targets for each lake.

*Note: Lakes Superior, Michigan, and Huron report A1-3 wounds on lake trout greater than 533 mm and have a target of five wounds per 100 fish. Lake Erie reports A1-3 wounds on age 5 or older lake trout from the east basin and uses a target of five wounds per 100 fish. Lake Ontario reports A1 wounds only (notice different scale) on lake trout greater than 433 mm and uses a target of two wound per 100 fish.

Source: Great Lakes Fishery Commission

Figure 3. Yearly lake-wide relative abundance of lake trout (gray squares) with 95% confidence intervals for each lake.

*Note: CPE = fish/km/net night of lean lake trout greater than 533 mm total length for lakes Superior, Michigan, and Huron; CPE = relative abundance of age 5 and older lake trout sampled in gill nets from the east basin; and CPE = arithmetic mean fish/0.1476 km/net night of lean lake trout greater than 433 mm total length.

Source: Great Lakes Fishery Commission

Last Updated

State of the Lakes Ecosystem Conference (SOLEC) 2011

Lake	Abundance Target	95% Confidence Interval
Superior	37,000	19,000
Michigan	57,000	13,000
Huron	73,000	20,000
Erie	3,000	1,000
Ontario	31,000	4,000

Table 1. Sea lamprey abundance targets and 95% confidence interval ranges.

Source: Great Lakes Fishery Commission

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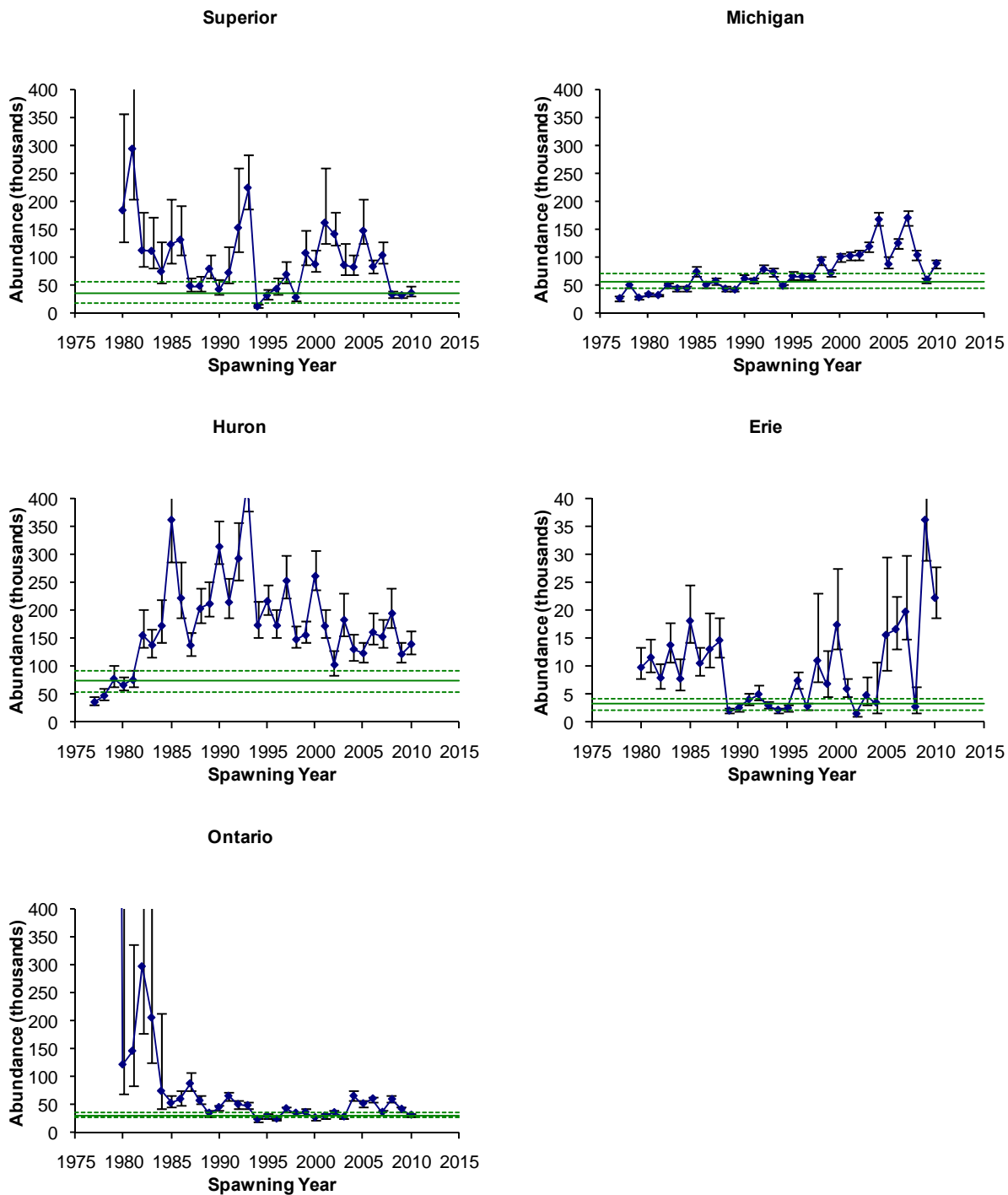


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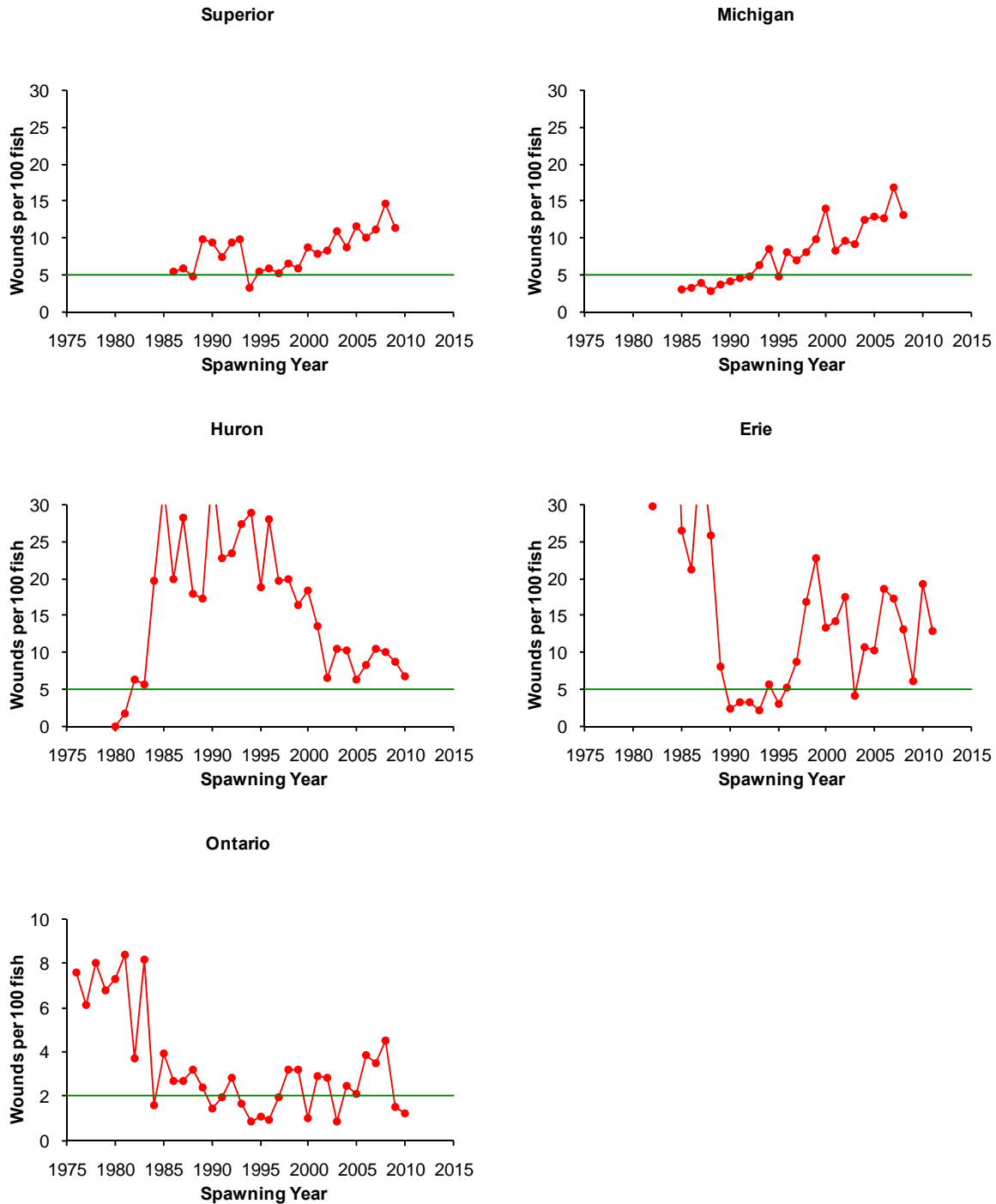


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*Note: Lakes Superior, Michigan, and Huron report A1-3 wounds on lake trout greater than 533 mm and have a target of five wounds per 100 fish. Lake Erie reports A1-3 wounds on age 5 or older lake trout from the east basin and uses a target of five wounds per 100 fish. Lake Ontario reports A1 wounds only (notice different scale) on lake trout greater than 433 mm and uses a target of two wound per 100 fish.

Source: Great Lakes Fishery Commission

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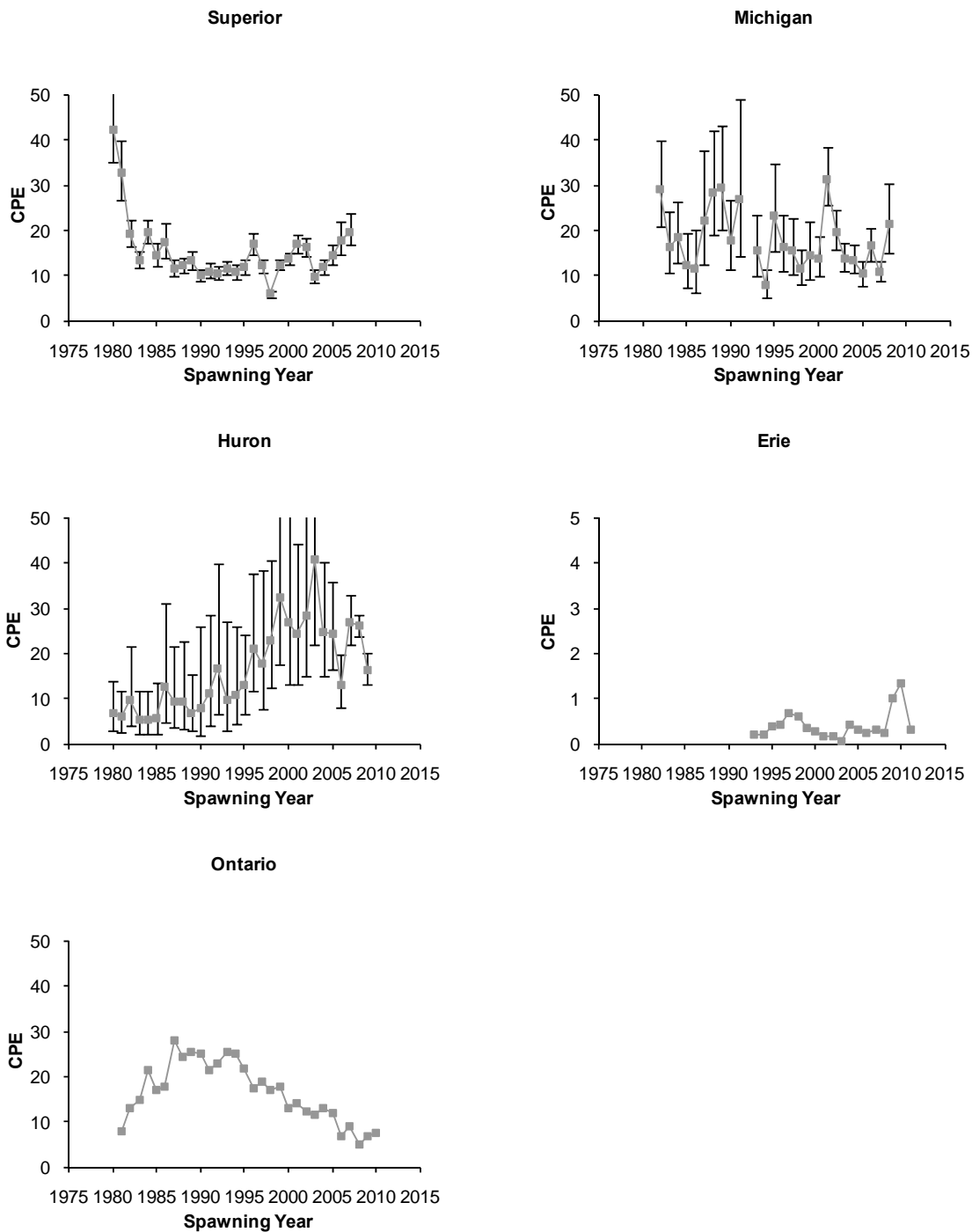


Figure 3. Yearly lake-wide relative abundance of lake trout (gray squares) with 95% confidence intervals for each lake.

*Note: CPE = fish/km/net night of lean lake trout greater than 533 mm total length for lakes Superior, Michigan, and Huron; CPE = relative abundance of age 5 and older lake trout sampled in gill nets from the east basin; and CPE = arithmetic mean fish/0.1476 km/net night of lean lake trout greater than 433 mm total length.

Source: Great Lakes Fishery Commission