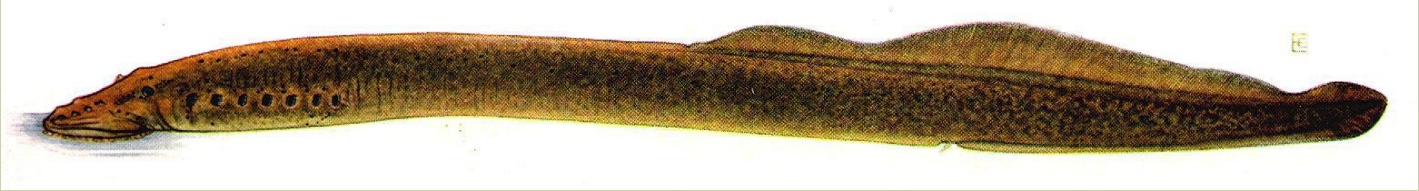
Species at Risk Act
Management Plan Series

Management Plan for the Silver Lamprey (*Ichthyomyzon unicuspis*), Great Lakes-Upper St. Lawrence populations, in Canada

Silver Lamprey



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Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for the protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of a management plan for species listed as special concern and are required to report on progress 5 years after the publication of the final document on the Species at Risk Public Registry and in every subsequent 5-year period, until its objectives have been achieved.

The Minister of Fisheries and Oceans and the Minister responsible for Parks Canada are the competent ministers under SARA for the Silver Lamprey and have prepared this management plan, as per section 65 of SARA. In preparing this management plan, the competent ministers have considered, as per section 38 of SARA, the commitment of the Government of Canada to conserving biological diversity and to the principle that, if there are threats of serious or irreversible damage to the listed wildlife species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty. To the extent possible, this management plan has been prepared in cooperation with many individuals, organizations and government agencies, including the provinces of Ontario and Quebec as per subsection 66(1) of SARA (appendix A).

As stated in the preamble to SARA, success in the conservation of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions and measures for the conservation of the species set out in this plan and will not be achieved by Fisheries and Oceans Canada (DFO) and the Minister responsible for Parks Canada, or any other jurisdiction alone. The cost of conserving species at risk is shared amongst different constituencies. All Canadians are invited to join in supporting and implementing this plan for the benefit of the Silver Lamprey and Canadian society as a whole.

A SARA management plan includes measures for the conservation of the species to manage the species of special concern to prevent it from becoming threatened or endangered. The competent ministers must prepare a management plan that includes measures for conservation of the species that the ministers consider appropriate. These measures set out to achieve the management objectives identified in the management plan. Implementation of this management plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Acknowledgments

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Quebec; Margaret Docker (University of Manitoba); Claude Renaud (Canadian Museum of Nature); Scott Reid (Ontario Ministry of Natural Resources); Nicholas Mandrak (University of Toronto); Clint Jacobs (Walpole Island Heritage Centre); Julien April and Isabelle Gauthier (MELCCFP). Mapping for this management plan was developed by Andrew Geraghty and revised by Michael Goldring and Adriana Rivas Ruiz (DFO).

Executive summary

The Silver Lamprey (*Ichthyomyzon unicuspis*) Great Lakes-Upper St. Lawrence populations was listed as special concern under the *Species at Risk Act* (SARA) in 2019. This management plan is part of a series of documents for this species that are linked and should be taken into consideration together, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessment and status reports (COSEWIC 2011, 2020), and a conservation status report (Neave et al. 2007a).

The Silver Lamprey is a freshwater fish in the family Petromyzontidae. It belongs to 1 of the 2 surviving groups of the jawless (agnathan) stage in vertebrate evolution. The parasitic Silver Lamprey is considered a larger-sized relative of the non-parasitic Northern Brook Lamprey (*Ichthyomyzon fossor*). There is a growing body of evidence, based principally on recent genetic studies, that these species lack genetic divergence and might represent ecotypes of a single species with divergent feeding types. Presently, Great Lakes-Upper St. Lawrence populations of the Silver Lamprey and the Northern Brook Lamprey are both listed in Schedule 1 of SARA and have been assessed as distinct but related species by COSEWIC (2020).

Across Canada, the Silver Lamprey lives in rivers and lakes sharing a largely overlapping range with the Northern Brook Lamprey in the Great Lakes and Upper St. Lawrence system. These Silver Lamprey have been located in the watersheds of lakes Ontario, Huron, Superior, Erie, St. Clair, Nipissing, St. Lawrence fluvial lakes Saint-Pierre and Saint-Louis, and the Nelson, Ottawa river watersheds.

The 4 main threats facing Silver Lamprey, Great Lakes-Upper St. Lawrence populations are described in section 5. Lampricide use to manage the invasive Sea Lamprey (*Petromyzon marinus*) is the main threat to Silver Lamprey in the Great Lakes basin. Secondary threats include habitat loss and degradation often resulting from the presence of dams and water management. As the Sea Lamprey is indigenous to Quebec and is not known to cause significant decline in freshwater game fishes, it is not under control measures (that is, no lampricide applications) in Quebec. Thus, in Quebec, habitat loss and degradation are the principal threats. Consequently, management actions are expected to differ in Ontario and Quebec. Invasive and other problematic species/genes, as well as effects of climate change, represent threats across the Great Lakes-Upper St. Lawrence distribution.

The management objectives for Silver Lamprey as described in section 6 are to:

i. refine understanding of population and habitat trends
ii. identify, mitigate, and monitor threats impacting the species' survival and conservation
iii. maintain, enhance, and, where feasible, restore habitat to support Silver Lamprey
iv. expand knowledge of the species' biology and ecology to enable and enhance management activities
v. improve the efficiency of conservation efforts through coordinated actions with other aquatic ecosystem recovery teams and other complementary conservation groups and/or initiatives
vi. increase public awareness about the importance of biodiversity and healthy aquatic ecosystems, particularly among various partners, Indigenous groups, interest groups, organizations, and landowners interested in supporting the conservation efforts for Silver Lamprey

A description of the broad strategies and measures for conservation of the Silver Lamprey, Great Lakes-Upper St. Lawrence populations, that provide the best chance of achieving the management objectives are included in section 7.

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1 Introduction

The Silver Lamprey (*Ichthyomyzon unicuspis*), Great Lakes-Upper St. Lawrence populations was listed as special concern under the *Species at Risk Act* (SARA) in 2019.

This management plan is part of a series of documents regarding Silver Lamprey that should be taken into consideration together, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessment and status reports (COSEWIC 2011, 2020) and the "Conservation Status Report for Silver Lamprey (*Ichthyomyzon unicuspis*) in Canada" (Neave et al. 2007a). A management plan includes measures for conservation of the species to ensure that a species of special concern does not become threatened or endangered. It sets objectives and identifies measures for conservation of the species to support achieving the management objective(s).

2 COSEWIC species assessment information

Date of assessment: November 2020

Species common name (population): Silver Lamprey (Great Lakes-Upper St. Lawrence populations)

Scientific name: *Ichthyomyzon unicuspis*

Status: Special concern

Reason for designation: This small parasitic lamprey is distributed in streams and lakes throughout the Laurentian Great Lakes basin and in southern Quebec. In the Great Lakes basin, a major part of its range, about half of the streams that it inhabits have barriers, or are subjected to ongoing chemical treatment for Sea Lamprey control. These control methods prevent migration to spawning areas or cause significant mortality to larval individuals, respectively. Throughout its range, it may be exposed to additional threats such as pollution from agricultural effluents, effects of water control structures, and increased temperatures and decreased water flows related to climate change. If these threats are not managed effectively, this species may become at greater risk of extinction.

Canadian occurrence: Ontario, Quebec

Status history: This species was designated special concern in May 2011. Status was re-examined and confirmed in November 2020.

3 Species status information

The Silver Lamprey has a global status rank of secure (G5) (NatureServe 2022)[1]. Nationally the species is ranked vulnerable (N3) within Canada and nationally secure (N5) in the United States (U.S.). The species is ranked vulnerable in Ontario (S3) and vulnerable to apparently secure (S3S4) in Quebec, while it is unranked in Manitoba (SU) (NatureServe 2022). Within the U.S., depending on the state, Silver Lamprey ranks between unranked to critically imperiled and apparently secure (SNR/SU to S4) (NatureServe 2022) (table 1).

Table 1. Summary of existing protection or other status designations assigned to Silver Lamprey.

Jurisdiction	Authority/ organization	Status/description
Global (G)	NatureServe	Secure (G5)
National (N) Canada	NatureServe	Vulnerable (N3)
National (N) United States	NatureServe	Secure (N5)
Sub-national (S) Canada	NatureServe	Manitoba (SU), Ontario (S3), Quebec (S3S4)
Sub-national (S) United States	NatureServe	Illinois (S1S2), Indiana (S4), Iowa (S3), Kentucky (S2), Michigan (S4), Minnesota (SNR), Mississippi (S1), Missouri (SNR), New York (S3), North Dakota (SNR), Ohio (S4), Pennsylvania (SU), Tennessee (S2), Vermont (S2), West Virginia (S2S3), Wisconsin (S4)
Provincial Ontario	*Endangered Species Act*	Special concern

4 Species information

4.1 Species description

The Silver Lamprey (figure 1) is 1 of 6 species in the genus *Ichthyomyzon*. The parasitic Silver Lamprey is considered a larger ancestor of the dwarfed, non-parasitic Northern Brook Lamprey (*I. fossor*; Potter et al. 2015). There is lack of clarity regarding their standing as separate species; recent genetic analyses have led scientists to question whether the Silver Lamprey and Northern Brook Lamprey are truly distinct species (Hubert et al. 2008; Lang et al. 2009; April et al. 2011; Docker et al. 2012). As they are currently classified as separate species (see Renaud

[1] G5/N5 (secure): common; widespread and abundant; S4 (apparently secure): uncommon but not rare; some cause for long-term concern due to other factors; N3/S3 (vulnerable): vulnerable in the nation/state or province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation; S2 (imperiled): imperiled in the state or province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state or province; S1 (critically imperiled): critically imperiled in the state or province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state or province; SNR/SU (unranked): national or provincial/state status not yet assessed. For more information on ranking see NatureServe.

et al. 2009; Page et al. 2013), the Silver Lamprey will be regarded as such for the purpose of this management plan.

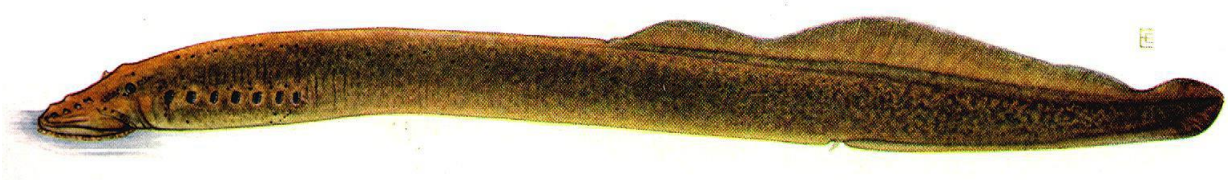

Figure 1. Adult Silver Lamprey (*Ichthyomyzon unicuspis*) (© E. Edmondson, New York State Department of Environmental Conservation [NYSDEC]).

The Silver Lamprey can reach in excess of 300 mm in length as an adult, while the Northern Brook Lamprey is typically less than half this length (Docker 2009). The Silver Lamprey has the characteristic features of lampreys, namely, an eel-like appearance with a round mouth and teeth arranged in a circle. Adult Silver Lamprey can be distinguished from other adult lampreys by its single dorsal fin, dentition pattern, and larger size. The teeth are relatively sharp and long in contrast to the small, dull and knob-like teeth of non-parasitic lamprey forms. In Canada, the Silver Lamprey overlaps with the distribution of 4 other lamprey species (Page and Burr 2011). The American Brook Lamprey (*Lethenteron appendix*) and Sea Lamprey (*Petromyzon marinus*) are distinguished by the presence of 2 dorsal fins and a consistently greater number of myomeres, while the adult and juvenile Northern Brook Lamprey can be distinguished by its size, less prominent teeth and its oral disc size. The Chestnut Lamprey (*Ichthyomyzon castaneus*) is most similar to the Silver Lamprey, but can be distinguished by the presence of at least 2 bicuspid endolateral teeth, which are unicuspid in the Silver Lamprey (Renaud 2011).

The Silver Lamprey stages of development include egg, larva, transformer, juvenile, and adult (Potter et al. 2015). Known as ammocoetes, larvae appear wormlike, lacking eyes and teeth. At this stage, they cannot be differentiated morphologically from other species within the *Ichthyomyzon* genus (Neave et al. 2007b). Although Silver Lamprey and Northern Brook Lamprey cannot be distinguished by any known genetic methods, researchers in a recent study were able to design genetic markers to differentiate other lamprey species and genera (that is, American Brook Lamprey and Chestnut Lamprey) (Docker 2009; Docker et al. 2012; Gingera et al. 2016). *Ichthyomyzon* larvae are distinguishable from other lampreys by the presence of a single dorsal fin; this single dorsal fin may be notched but the notch never reaches the dorsal surface of the body (Scott and Crossman 1998). They are filter feeders and, instead of a sucker mouth, they have an oral hood. They live for up to 7 years burrowed in the sediment, eventually metamorphosing into juveniles that emerge, attach to the stream bottom using their oral disc, and swim periodically (Dawson et al. 2015). During metamorphosis (transformation) to the juvenile stage, the oral hood develops into a sucker mouth lined with teeth. Newly transformed juveniles migrate downstream into lakes or rivers to locate fish hosts on which to feed for approximately 1 year before returning to spawn in the spring. The adult stage corresponds with sexual maturation (at the conclusion of the parasitic feeding stage). The Silver Lamprey dies shortly after spawning, typically at 6 to 8 years of age.

4.2 Population abundance and distribution

Global range: Silver Lamprey is restricted to eastern North America, including the St. Lawrence-Great Lakes basin, south through the upper Mississippi and Ohio river basins to central Tennessee; Hudson Bay basin, Manitoba; and Missouri River, Nebraska (Page and Burr 2011; figure 2). In the U.S., it has been found in Illinois, Indiana, Iowa, Kentucky, Michigan,

Minnesota, Mississippi, Missouri, Nebraska, New York, North Dakota, Ohio, Pennsylvania, Tennessee, Vermont, West Virginia, Wisconsin and, recently, in Arkansas (Robison et al. 2011). In Canada, Silver Lamprey occur in Manitoba, Quebec and Ontario.

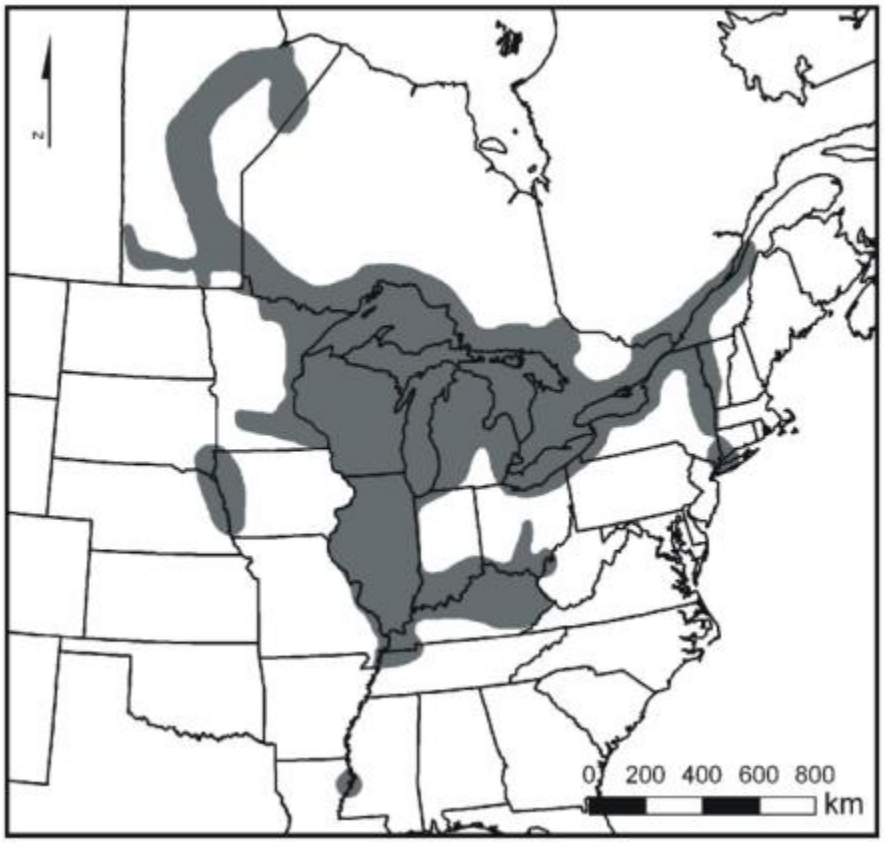

Figure 2. Global distribution of Silver Lamprey (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2020; adapted from Renaud et al. 2009). The shaded area indicates the distribution.

Canadian range: The Canadian range of the Silver Lamprey is the Great Lakes, Lake Nipissing, Nelson and Winnipeg River watersheds, Ottawa River, and St. Lawrence River watersheds. The Silver Lamprey in Canada has been subdivided into 3 designatable units (DUs): the Saskatchewan-Nelson River populations, the Southern Hudson Bay-James Bay populations, and the Great Lakes-Upper St. Lawrence populations. The separation into 3 DUs is based on the species' distribution within 3 different biogeographic zones (COSEWIC 2020), in addition to genetic distinctions (McFarlane 2009). The status of the Saskatchewan-Nelson River populations is special concern and the status of the Hudson Bay-James Bay populations is unknown (COSEWIC designation: data deficient) (COSEWIC 2020). The content of the current management plan is restricted to the Great Lakes-Upper St. Lawrence populations (COSEWIC designation: special concern), which encompasses streams and lakes throughout the Great Lakes and St. Lawrence River basins (figure 3).

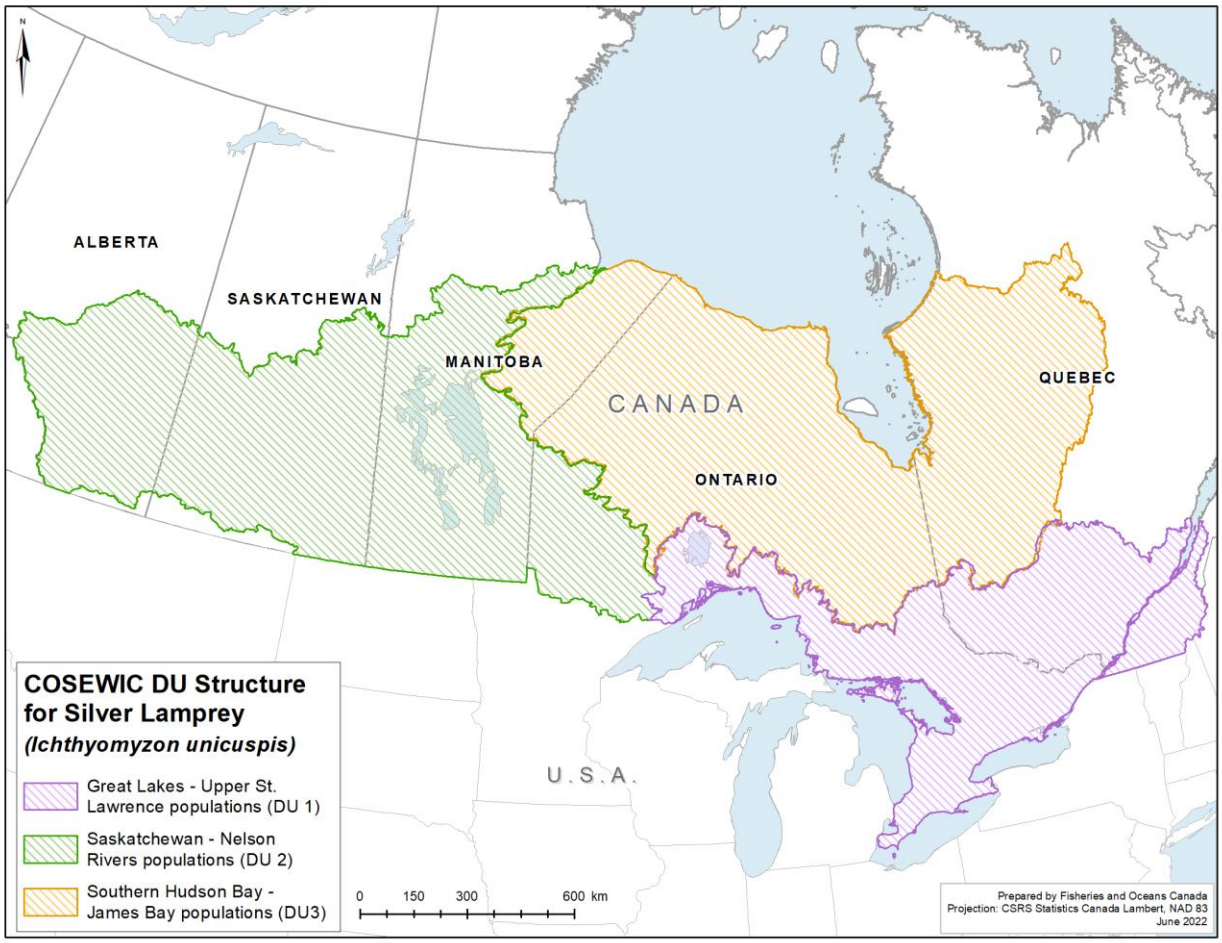

Figure 3. Silver Lamprey Designatable Units (DUs) in Canada (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2020).

Ontario range: The Silver Lamprey has been documented in 91 waterbodies in Ontario, including stream systems and tributaries to lakes St. Clair, Nipissing, Superior, Huron, Ontario, and Erie from 1882 until 2018 (figure 4a and 4b). Populations in southern and northwestern Ontario are shown in figures 4a and 4b, respectively; appendix B lists historical and current records by watershed. Furthermore, between 1989 and 2007, the Sea Lamprey Control Program (SLCP) documented 68 streams throughout the Canadian Great Lakes drainage with *Ichthyomyzon* ammocoetes (COSEWIC 2011); data from 2008 to 2018 show that there were 52 rivers with unidentified *Ichthyomyzon* larvae (COSEWIC 2020). Although no species identification was possible, some of these individuals are suspected to be Silver Lamprey (based on location of capture, as Silver Lamprey are more likely to be found in larger streams and absent upstream of barriers relative to Northern Brook Lamprey).

Many of the Silver Lamprey observations in the Great Lakes are a result of Sea Lamprey control activities, including trapping of adult Sea Lampreys, stream surveys to determine the presence and extent of infestation of larval Sea Lampreys, and during lampricide applications. Gaps in years of observation (appendix B) may indicate differential sampling effort, such as ceasing to operate traps, or only encountering larval *Ichthyomyzon* species during sampling or lampricide application that could not be identified to species, and do not necessarily reflect Silver Lamprey population declines in an area. Further, overlap in years of observation of Silver Lampreys and

years of lampricide application indicate that Silver Lampreys continue to use lampricide-treated rivers for spawning and nursery requirements.

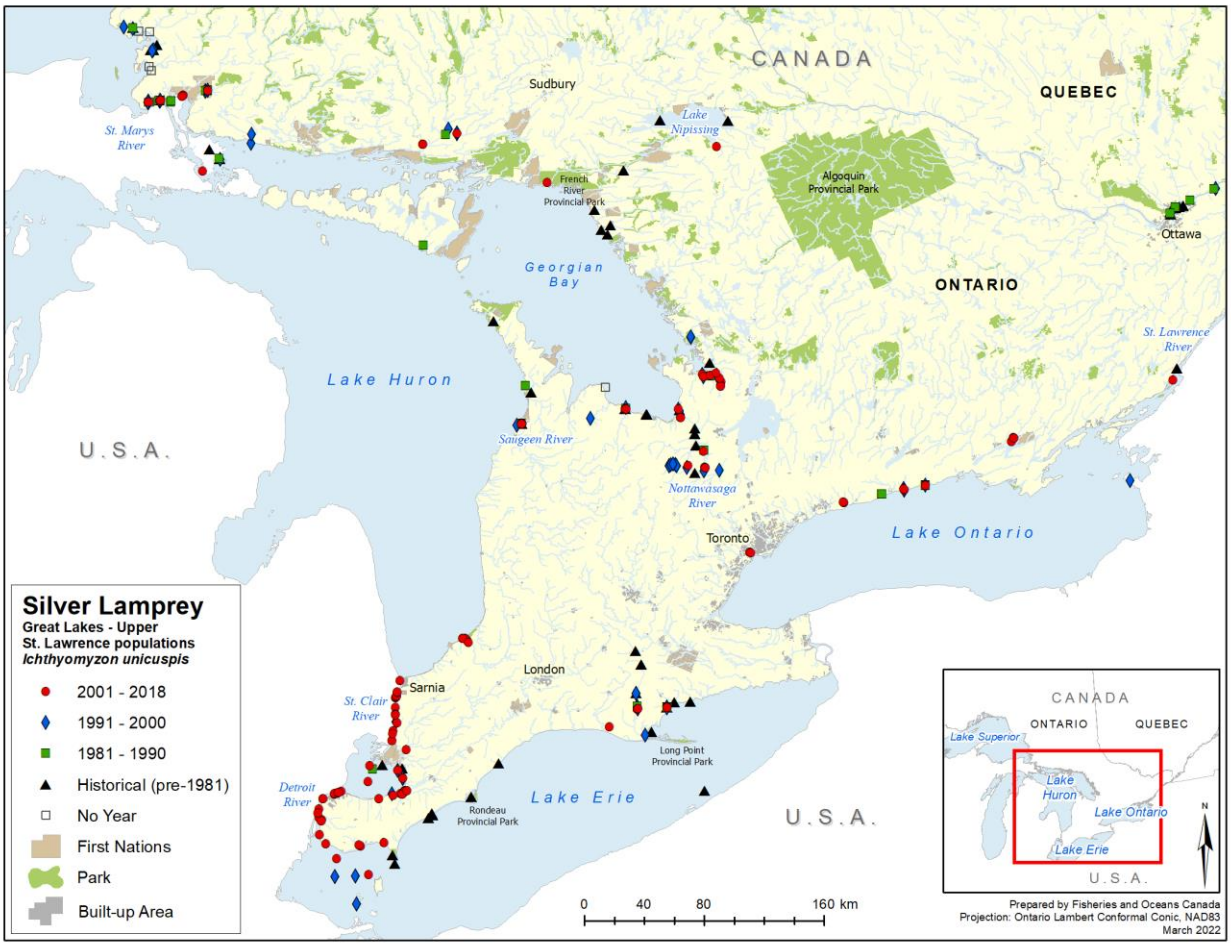

Figure 4a. Silver Lamprey, Great Lakes-Upper St. Lawrence populations in southern Ontario based on sampling from 1882 to 2018.

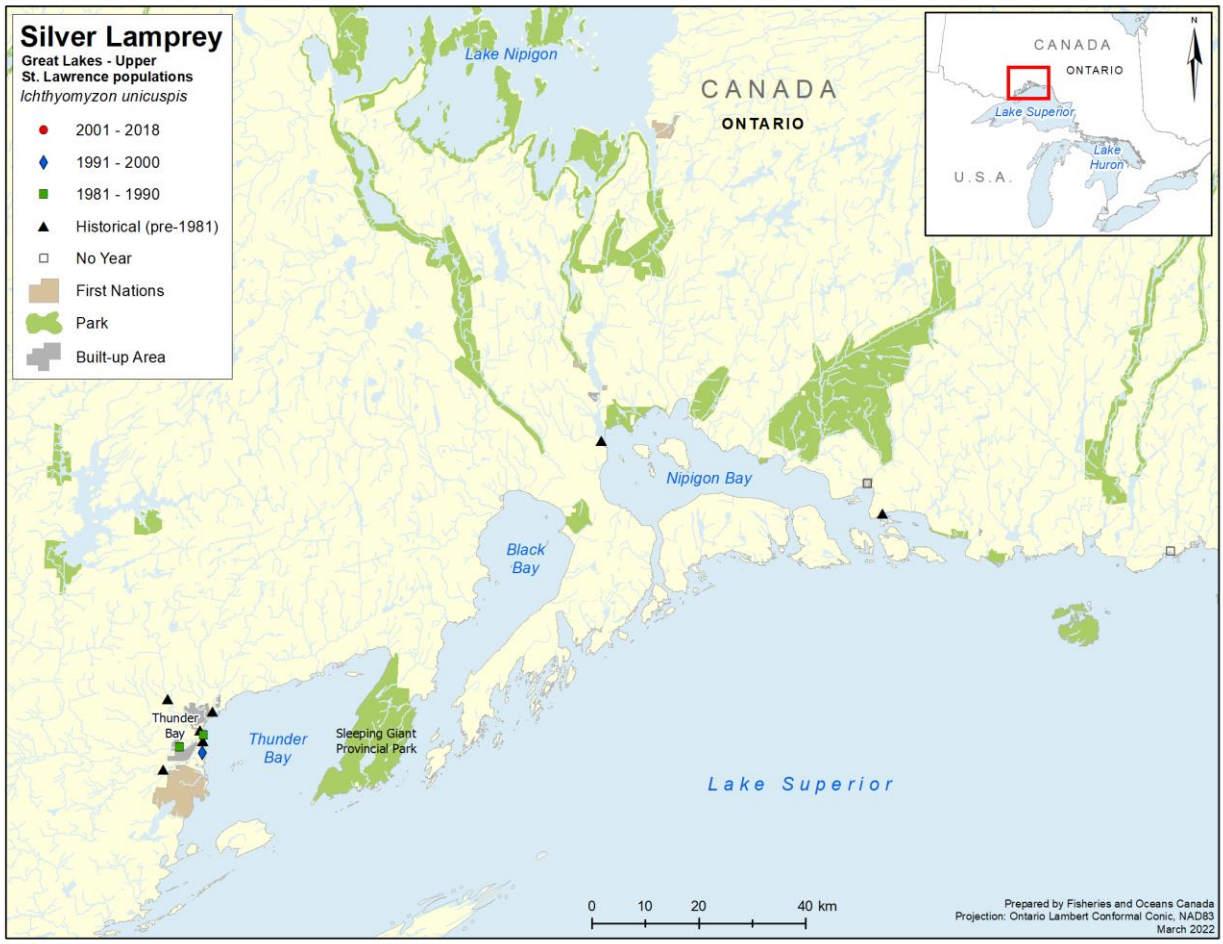

Figure 4b. Silver Lamprey, Great Lakes-Upper St. Lawrence populations in northwestern Ontario based on sampling from 1882 to 2018.

Quebec range: In Quebec, the Silver Lamprey was first identified in the early 1900s. Since then, the species has been found in the St. Lawrence River and its fluvial lakes (St. Francis, St. Louis and Saint-Pierre) to Berthier-sur-Mer eastward, and in other watercourses and lakes in the St. Lawrence lowlands, the Ottawa River and the St. Maurice River watersheds (figure 5, appendix C).

Sampling generally does not target Silver Lamprey specifically and the fishing gear used are relatively ineffective at capturing lamprey, with the exception of fixed eel traps at Saint-Nicolas and Cap-Santé in the St. Lawrence River. In some sites, ammocoetes were caught but, unless adults are observed in the same stream, it was not possible to identify ammocoetes to the species level. In general, not enough data have been collected to estimate population size of Silver Lamprey in Quebec.

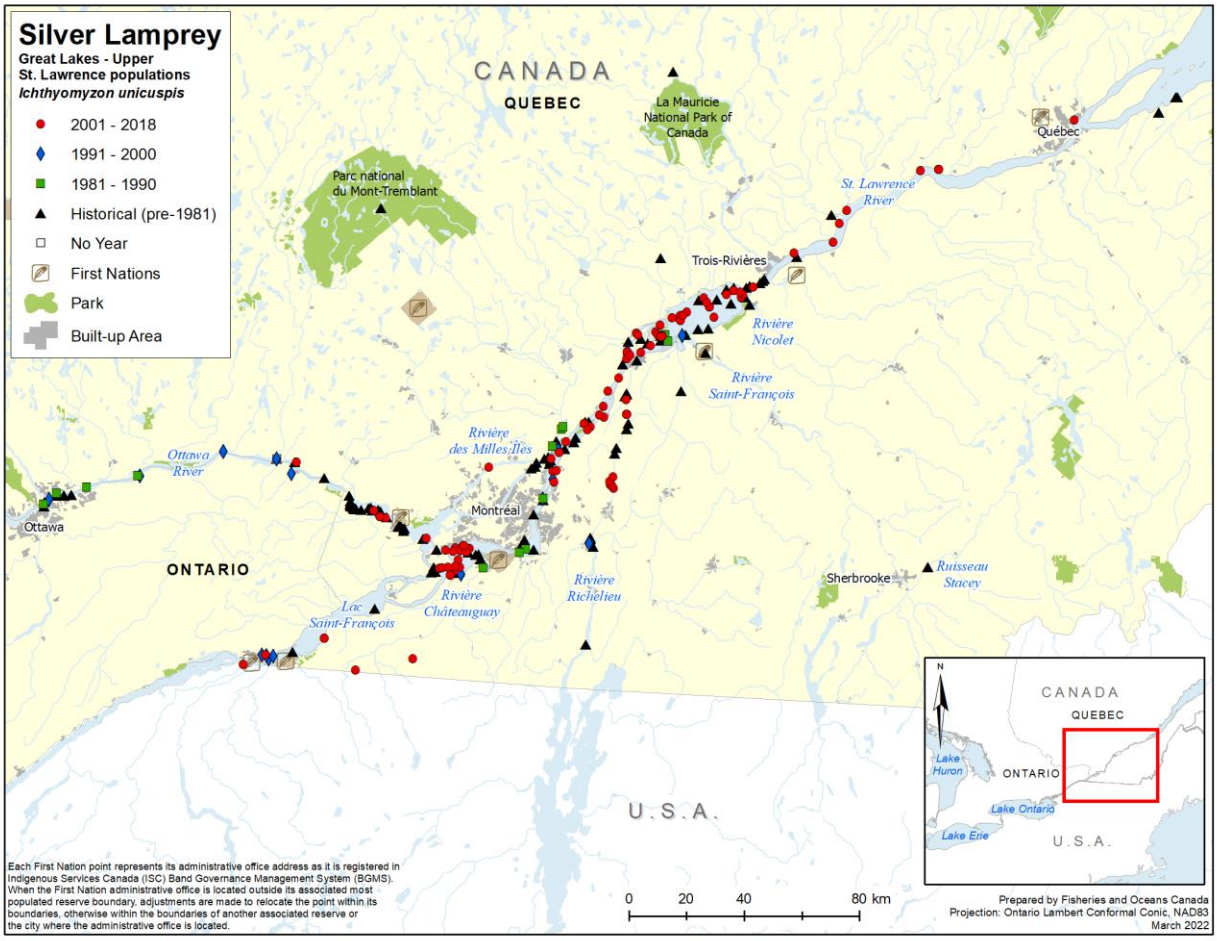

Figure 5. Silver Lamprey, Great Lakes-Upper St. Lawrence populations in Quebec based on sampling from 1901 to 2018.

Most observations of the Silver Lamprey are from the St. Lawrence River where the species was observed during sampling campaigns by the Ministère des Forêts, de la Faune et des Parcs (Quebec Ministry of Forestry, Wildlife and Parks) and Université du Québec à Trois-Rivières from 2007 to 2009, from the Réseau de suivi ichtyologique (Fish Monitoring Network [RSI]; 2004 to 2012), from the Réseau d'inventaire des poissons de l'estuaire (Estuary Fish Inventory Network) campaigns from 2009 to 2011, as well as in one-time sampling efforts (for example, for other species such as Lake Sturgeon, *Acipenser fulvescens*; Copper Redhorse, *Moxostoma hubbsi*; Channel Darter, *Percina copelandi*). Most recently, the species has been observed in the St. Lawrence River and its impoundments, Lakes St. Pierre, St. Louis and des Deux Montagnes and in Des Prairies River. The species was also reported in the Richelieu River between 2006 and 2009. Other occurrences predate 2006.

Global population size, status and trends: Globally, the Silver Lamprey is considered secure with a G5 status (table 1) (NatureServe 2022). Silver Lamprey population sizes and trends are poorly known throughout its range. There has been limited targeted sampling for adults. In addition, it is difficult to identify the species at the ammocoete stage and to observe adults and newly metamorphosed individuals in lakes and large rivers. Trautman (1981) catalogued a decline in adult Silver Lamprey populations in Ohio waters. Silver Lamprey appears more abundant on the U.S. side of Lake Superior compared to the Canadian side (Schuldt and Gould 1980; COSEWIC 2020). No significant trend in Silver Lamprey abundance was observed in U.S. portions of the Great Lakes over the 1989 to 2006 time period (Neave et al. 2007a).

Canadian population size, status and trends: Population estimates for Silver Lamprey in Canada are not available. The main data source used for understanding trends in Silver Lamprey population dynamics is incidental catch data from Sea Lamprey assessments performed by the SLCP during its 65-year history. While most sampling targets the larval life stage of Sea Lampreys and any *Ichthyomyzon* larvae captured cannot be identified to species, sampling also includes incidental catch of adults at Sea Lamprey traps providing an opportunity to confirm species identity.

The Silver Lamprey, Great Lakes-Upper St. Lawrence populations, was designated as a species of special concern by COSEWIC (2011). The status was re-examined and confirmed in November 2020 (COSEWIC 2020). Silver Lamprey, Great Lakes-Upper St. Lawrence populations, was listed as a species of special concern on Schedule 1 of SARA in 2019. A comprehensive list of sampling efforts is catalogued in the joint Northern Brook Lamprey and Silver Lamprey COSEWIC report, which details the waterbodies with both adult Silver Lamprey presence and *Ichthyomyzon* ammocoetes from 1882 to 2018 (COSEWIC 2020). The Silver Lamprey was documented in 41 streams and 7 lakes within the range of the Great Lakes-Upper St. Lawrence DU from 1989 to 2007 (COSEWIC 2011) and in 29 waterbodies from 2008 to 2018, including the Erie, Huron, Ontario, Superior, Lake St. Clair, and Lake Nipissing watersheds, and the Ottawa and St. Lawrence River watersheds (COSEWIC 2020). Ten of these recent occurrences are in locations where Silver Lamprey adults had not been observed previously.

There has been an increase in the number of documented locations over the past 4 successive 3-generation (18-year) time periods (2001 to 2018, 1983 to 2000, 1965 to 1982, and 1947 to 1964) and prior to 1947, but this has been attributed to an increase in sampling effort rather than a range expansion of the species (COSEWIC 2020). Based on analysis of 2008 to 2018 distribution records and comparison to the last status report (1989 to 2007 time period) and historical data (pre-1989), the range of occurrence within this DU is declining (COSEWIC 2020).

Indirect evidence, such as the incidental capture of parasitic juveniles attached to game fishes, indicates that there may be abundant populations in areas of Lake St. Clair and the St. Lawrence River, while low but relatively stable populations exist elsewhere (COSEWIC 2011). More recently (2011 to 2018, for about 3 generations), Silver Lamprey populations were not very abundant but were relatively stable in the Great Lakes region (COSEWIC 2020) and were consistently low (less than 1 per trap-year) in lakes Ontario and Superior between 1989 and 2018. Data suggests that they were more abundant previously (1955 to 1975), but this variation may be due to differences in fishing techniques and in the catch sites visited. There are no population abundance assessments for the Silver Lamprey in Quebec; however, during the 2008 to 2018 time period, there were observations of 110 parasitic feeding-phase Silver Lamprey in the St. Lawrence River (COSEWIC 2020). Recent records suggest that several areas are able to maintain populations, while other populations may be in decline (COSEWIC

2011). In particular, data obtained from a trap at Saint-Nicolas (St. Lawrence River) showed a decline in lamprey abundances, that may reflect a decline in Silver Lamprey. The average annual number of lamprey caught decreased from 68 (1975 to 1984) to 9 (1995 to 2004) in less than 30 years. Trap records from 2005 to 2019 indicate that the numbers of Silver Lamprey in this location continue to be low but stable (COSEWIC 2020).

4.3 Needs of the Silver Lamprey

4.3.1 Habitat and biological needs

The Silver Lamprey is found in a wide variety of habitats, suggesting considerable adaptability to a wide variety of lake and stream habitats. The species appears to preferentially use the lower sections of large streams relative to the Northern Brook Lamprey (Schuldt and Goold 1980). As Silver Lamprey migrates upstream to spawn (Scott and Crossman 1998), unobstructed river reaches are required, although, in many systems structures impede access to upper reaches. Riffle areas that feature unidirectional, swift-flowing current, and are composed of sand and gravel are required at spawning sites (Carpenter et al. 1987; Manion and Hanson 1980), although the species may also spawn in swifter and deeper water than other *Ichthyomyzon* species in the connecting channels of the Great Lakes (Cochran and Lyons 2004). In spring, when temperatures begin to exceed 10°C, the Silver Lamprey ascends large rivers to spawn in shallow nests (Vladykov 1949; Trautman 1981; Scott and Crossman 1998). To construct its nest, the Silver Lamprey transports stones by moving them with its mouth, and it removes sand and silt by vigorous tail movements (Scott and Crossman 1998). Ammocoetes require soft substrates of sand, silt and organic debris in which to burrow. Parasitic juveniles may require clear water to allow the capture of fish hosts (Trautman 1981). While Silver Lamprey appears capable of parasitizing numerous fish species (see Renaud 2002), it has been strongly associated with relatively large native host species with small scales or naked skin (Cochran and Lyons 2004).

4.3.2 Ecological role

All stages of Silver Lamprey from egg to adult are preyed upon by a variety of fish species; additional predators include snakes, birds, and mammals (see Churchill 1945; Cochran et al. 1992; Cochran 2009; Scott and Crossman 1998). As the ammocoetes are filter feeders and detritivores, Vladykov (1973) highlighted the species' role in the food chain, recycling organic matter and providing a food source to many fish species. Ammocoetes may have a substantial impact on physical and geochemical conditions in the streambed, largely through the effects of biological perturbation (Shirakawa et al. 2013). Shirakawa et al. (2013) recorded changes in streambed oxygen, hardness, organic matter levels, and distribution in relation to the presence of ammocoetes. The nest-building activities of adult lampreys are also thought to increase streambed complexity in ways that benefit other organisms (Sousa et al. 2012; Hogg et al. 2014). Although the Silver Lamprey is known to have a predatory juvenile phase on a variety of fish species, the effects of Silver Lamprey predation on host fishes is not well quantified. In a laboratory setting, host fish mortality has been observed (Roy 1973), but the effects on host fish fitness in nature warrants further investigation.

4.3.3 Limiting factors

Silver Lamprey may be limited by predation, although ammocoetes may be less vulnerable as they spend most of their time in burrows (Potter 1980). Cochran (2009) highlighted the possibility that the stocking of non-native predators (for example, Brown Trout [*Salmo trutta*] and

Rainbow Trout [*Oncorhynchus mykiss*]) has led to the decline in native lampreys. Schuldt and Goold (1980) observed far greater numbers of Sea Lamprey and Northern Brook Lamprey relative to Silver Lamprey along the southeastern shoreline of Lake Superior. The authors suggest that this observation indicates that Silver Lamprey may require more specialized conditions than Sea Lamprey for successful spawning and the larvae may be less competitive than American Brook Lamprey ammocoetes. A clearer understanding of Silver Lamprey and Northern Brook Lamprey habitat requirements for spawning and/or larval rearing is required to determine whether Silver Lamprey is limited in early life history requirements, compared to Northern Brook Lamprey. Substrate requirements appear to be quite specific for successful spawning and ammocoete survival. Silver and Sea lampreys have been observed spawning in the same nests in Cobourg Brook (P. Sullivan, SLCP, pers. comm. 2015) and the St. Clair River (J. Boase, U.S. Fish and Wildlife Service, pers. comm. 2015), indicating overlap in the substrate requirements for the 2 species. The availability of fish hosts for parasitic juveniles and suitable spawning and larval habitat may be the most significant limiting factors for the Silver Lamprey.

5 Threats

5.1 Threat assessment

A threat assessment for Silver Lamprey is provided in COSEWIC (2020) based on the International Union for Conservation of Nature - Conservation Measures Partnership (IUCN-CMP) threats classification system. Threats are defined as nearby activities or processes that have caused, are causing, or may cause destruction, degradation, and/or impairment of Silver Lamprey populations. For purposes of this threat assessment, only present and anticipated threats to Silver Lamprey are listed in table 2. Historical threats, indirect or cumulative effects of the threats, or other relevant information that would help to explain the nature of the threats are presented in section 5.2. Threat assessment, particularly where evidence is limited, is an ongoing process linked to both species assessment and, where applicable, management. Threats ranked as ‘negligible’ impact in COSEWIC (2020) are not described in this section.

Table 2. Threat assessment for Silver Lamprey, Great Lakes-Upper St. Lawrence populations.

Threat	Impact / level of concern[2] (calculated)	Scope / extent[3] (next 10 years)	Severity[4] (10 years / 3 generations)	Timing / occurrence[5]
Pollution (for example, lampricides, household sewage and urban waste water)	High	Large	Extreme	High (continuing)
Natural system modifications (for example, dams and water management/use, other ecosystem modifications)	Medium-low	Large	Moderate-slight	High (continuing)
Invasive and other problematic species and genes	Medium-low	Pervasive	Moderate-slight	High (continuing)
Climate change and severe weather (for example, habitat shifting and alterations, droughts, temperature extremes, storms and flooding)	Medium-low	Pervasive	Moderate-slight	High (continuing)
Biological resource use (for example, loss of riparian vegetation and forest canopy)	Low	Small	Slight	High (continuing)

2 **Impact / level of concern** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines); High (40%); Medium (15%); and Low (3%). Unknown: used when impact cannot be determined (for example, if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (for example, timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

3 **Scope / extent** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive: 71 to 100%; Large: 31 to 70%; Restricted: 11 to 30%; Small: 1 to 10%; Negligible: < 1%).

4 **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or 3-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme: 71 to 100%; Serious:31 to 70%; Moderate: 11 to 30%; Slight: 1 to 10%; Negligible: < 1%; Neutral or Potential Benefit: ≥ 0%).

5 **Timing / occurrence** – High: continuing; Moderate: only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low: only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible: only in the past and unlikely to return, or no direct effect but limiting.

5.2 Description of threats

Information within section 5.2 refers to the IUCN threats calculator headings; see COSEWIC (2020) for more information. Note that not all IUCN threat headings are applicable to Silver Lamprey. The following brief descriptions emphasize the principal threats acting on Silver Lamprey, Great Lakes-Upper St. Lawrence populations. Threats to Silver Lamprey were ranked based on their relative impact, spatial extent, and expected severity. The top 4 threats from greatest to lowest impact are pollution (for example, lampricide treatments), natural system modifications (for example, dams and water management/use), invasive species and other problematic species and genes, and climate change and severe weather; however, there may be some variability in the severity and level of concern for some threats within the Great Lakes-Upper St. Lawrence populations. Based on the threats calculator, the overall threat impact to Silver Lamprey is 'very high'.

5.2.1 Pollution

Lampricide applications

One of the primary threats to Silver Lamprey is Sea Lamprey control practices in the Great Lakes basin due to the considerable overlap in distribution of the 2 species. In addition, Silver Lamprey's lower fecundity makes it a poor competitor relative to the invasive Sea Lamprey.

The current use of lampricides targeting Sea Lamprey ammocoetes is the primary control method used by the SLCP to reduce Sea Lamprey abundance in the Great Lakes basin. The use of lampricides (3-trifluoromethyl-4-nitrophenol [TFM] and 2′,5-dichloro-4′-nitrosalicylanilide [Bayer 73 or Bayluscide]) to control Sea Lamprey in the Great Lakes basin began in 1958 (Applegate et al. 1961). The Great Lakes Fishery Commission also applies lampricides to assess tributaries of each of the above waters to the extent necessary to investigate any fish stock or habitat of common concern, which is confined predominantly to the Convention on Great Lakes area.

The SLCP mandate includes Lake Superior, Lake Michigan, Lake Huron (including Lake St. Clair), Lake Erie, Lake Ontario (including the St. Lawrence River from Lake Ontario downstream to 45ºN), and their connecting waters as defined by the *Great Lakes Fishery Convention Act*. In these areas, Silver Lamprey are susceptible to lampricide treatments because they are restricted to relatively short stretches of watercourses downstream of Sea Lamprey barriers (Schuldt and Goold 1980). In Quebec, where Sea Lamprey is native (see Renaud et al. 2009), control measures are not applied and, as a result, lampricides are not deemed a threat to Silver Lamprey in Quebec.

Lampricide toxicity to native lampreys has been demonstrated (see King and Gabel 1985; Scholefield and Seelye 1992) and lampricide use has inadvertently contributed to decreased distribution of native lampreys throughout the Great Lakes watershed (see Schuldt and Goold 1980; Andrews et al. 2021; Neave et al. 2021). Due to the extended larval stage of lampreys, a single lampricide treatment has the potential to eradicate multiple year-classes. Approximately 50% of Great Lakes streams with current or historical records of *Ichthyomyzon* lampreys have been treated with lampricides. Half of these are exposed every 2 to 5 years, killing multiple larval age classes (COSEWIC 2020).

Of the 76 *Ichthyomyzon*-containing streams that receive lampricide treatments, Silver Lamprey presence was confirmed in 46 streams, although over the last 3 generations only 18 of these

included reports of adult Silver Lamprey (COSEWIC 2020). *Ichthyomyzon* ammocoetes (thought to be both Silver Lamprey and Northern Brook Lamprey) were recorded in 47 Canadian tributaries to Lake Superior during the time period of 1953 to 1972, compared with only 17 during 1973 to 1977 (Schuldt and Goold 1980). More recent sampling by the SLCP (1989 to 2013) detected *Ichthyomyzon* ammocoetes in 23 Canadian tributaries to Lake Superior where they had not been observed in some time, suggesting the ability of native lampreys to re-establish after exposure to lampricide applications. A variety of sampling methods were used, however, which could account for some of the observed differences. Those lampreys living upstream of treated areas may serve as a source for re-establishing treated portions of the watershed through downstream drift (P. Sullivan, SLCP, pers. comm. 2017).

Contaminant inputs

In general, the level of historically monitored contaminants in the St. Lawrence and Great Lakes, including levels measured in fishes and sediments, have declined since their peak in the 1970s (Environment Canada 2008a, b; Environment Canada and United States Environmental Protection Agency 2009), although great temporal and spatial variability in contaminant exposure exists within these vast systems.

The relative vulnerability of native lampreys to contaminants in water is largely unknown beyond the threat associated with lampricides, discussed above. Based on the relative sensitivity of other lamprey species to chemical contaminants, Andersen et al. (2010) found that ammocoetes (likely Pacific Lamprey [*Entosphenus tridentatus*] and Western Brook Lamprey [*Lampetra richardsoni*]) were relatively sensitive to pesticides such as pentachlorophenol, were of average sensitivity to copper, and were relatively insensitive to diazinon, aniline, naphthalene, and lindane compared to other tested aquatic species. Renaud et al. (1998) found that, even though ammocoetes are filter feeders, they accumulated significantly lower concentrations of a variety of metals in their tissue relative to mussels (with the exception of mercury, which was higher in the lampreys); impacts on vital function were not tested.

In some parts of the distribution of Silver Lamprey, including southwestern Ontario and the St. Lawrence River, industrial effluents may also be having a negative effect on the species, particularly where lampreys are exposed to pollutants and other contaminants in the sediments, and when feeding on contaminated large-bodied fishes (for example, MacEachen et al. 2000; Maitland et al. 2015).

Lampreys inhabiting the upper St. Lawrence and Great Lakes watersheds continue to be exposed to a variety of pesticides. In the St. Lawrence River, those pesticides are mainly transported from the Great Lakes, with an additional source of run-off from surrounding agricultural land (Pham et al. 2000). In Lake Ontario, the concentration of the herbicide atrazine (implicated in the loss of Northern Brook Lamprey from the Yamaska River in Quebec [Renaud et al. 1995]) increased by 57% between 1998 and 2006 (Environment Canada and United States Environmental Protection Agency 2009). This information is not provided for Quebec, but a 49% increase in area of pesticides application in Quebec has occurred between 1996 and 2006 (Environment Canada 2009) and a relative increase in runoff can be presumed. The toxic effects of herbicides from agricultural land run-off and their impact on phytoplankton, a key food source for ammocoetes, remains a concern despite dilution effects in larger rivers. The toxicity of historical contaminants and emerging ones (for example, flame retardants, plasticizers, hormone disrupting pharmaceuticals, and personal care products) on native lampreys is largely unknown.

Larval lampreys appear tolerant of sewage outflow and eutrophication, although anoxic sediment or urban wastewater may be harmful during embryonic development. Other water-quality issues, such as elevated nutrient levels, are not currently suspected to adversely affect these lamprey species, but further understanding, particularly of potential impacts on life history, would support a more confident threat assessment.

5.2.2 Natural system modifications

Dams and water management / water use

Dams and barriers that prevent Silver Lamprey from accessing upstream spawning and larval rearing habitat have historically restricted the distribution of native lampreys within this DU (Neave et al. 2007a). There are hundreds of dams throughout the range of the Silver Lamprey, some that have been intentionally constructed to deny Sea Lamprey access to spawning habitat in tributaries. At barriers that contain Sea Lamprey traps, Canadian and American Sea Lamprey Control programs often contract external personnel to monitor the traps. Some contractors have fish identification experience that allows them to release native fishes caught incidentally in the traps (including Silver Lamprey) back into the river or over the barrier. However, in the United States, contractors are not always qualified to distinguish Silver Lamprey from Sea Lamprey, consequently, no lampreys are passed over barriers (COSEWIC 2011). Based on the non-homing tendencies of Silver Lamprey, these mortalities may impact the Canadian Great Lakes populations as well. As lampreys have relatively poor swimming ability, those dams and barriers that are impassable to Silver Lamprey result in habitat and population fragmentation, including the loss of spawning areas and habitat for all life stages. As available habitat is reduced, dispersal and natural patterns of gene flow can be limited among populations within the species (Schreiber and Engelhorn 1998). Lucas et al. (2001) raised the additional concern that barriers may delay lamprey migration, which could make them more vulnerable to predation. The ability of these species to persist upstream of impassable barriers has been observed and, in the case of Silver Lamprey, the availability of inland lakes, possibly as a source of host fish, appears to be necessary for this to occur (Morman 1979). Morman (1979) catalogued the distribution and ecology of lampreys in the lower peninsula of Michigan and noted remnant Silver Lamprey populations were present in reaches upstream from long-established (that is, early 1900s) dams in 3 streams. Each of these locations was associated with impoundments or inland lakes, presumably important for providing habitat and suitable hosts. Silver Lamprey was sampled as far inland as 240 km upstream, above a series of 7 dams.

Dams also disrupt hydrologic regimes affecting native lampreys, particularly at the ammocoete stage (see Maitland et al. 2015). For example, ammocoete mortality can result from low water levels (Bailey 1959), while flood conditions may force ammocoetes from their substrate, potentially resulting in mortality (Potter 1980; Potter et al. 1986). Mormon (1979) considered low and unstable flows to be 2 of the major limiting factors for the absence or scarcity of lamprey larvae in many streams in the Great Lakes basin. Furthermore, altered hydrological characteristics may influence dispersal and movement of Silver Lamprey. Dams that outlet cooler water from the bottom (hypolimnion) of the headpond may also affect the thermal profile downstream. The most severe effect of dam operating regimes and water use is dewatering downstream areas that puts several larval year classes at risk, although risk of mortality may be lower if Silver Lamprey spawn and rear in deeper waters. A decline in adult Silver Lamprey in Ohio waters was attributed to habitat alteration and construction of dams (Trautman 1981).

Other system modifications

Physical work (such as construction) or activities in and near water may also negatively impact Silver Lamprey habitat. Direct impacts (for example, physical habitat removal from dredging sediment containing multiple generations of burrowed lamprey or removal of riparian vegetation) and indirect impacts (for example, deposition of sediment mobilized during construction) to habitat are likely to reduce the number of Silver Lamprey. The riparian zone also filters and stabilizes river banks and protects the watercourse against fertilizer and pesticide inputs (Ministère des Forêts, de la Faune et des Parcs du Québec 2003). These zones also provide shade, an important habitat component for ammocoetes (see Dawson et al. 2015). It has been suggested that the loss of riparian vegetation and other alterations (for example, deforestation) that result in increased siltation levels may threaten native lampreys (Starrett et al. 1960; Fortin et al. 2007). The removal or loss of riparian vegetation can lead to soil erosion and, hence, increased sedimentation along the river bed, which can alter spawning grounds (Moyle and Cech 2004). While excessive sediment inputs likely negatively impact spawning habitat, moderate amounts of sedimentation may be beneficial for larval lampreys in high-gradient streams or other sediment-poor areas (Beamish 1998).

5.2.3 Invasive and other problematic species and genes

Invasive Sea Lamprey compete with Silver Lamprey for larval/spawning habitat. Schuldt and Goold (1980) found that, even before adult numbers were affected by lampricide treatments, Sea Lamprey outnumbered Silver Lamprey 9:1. This competitive advantage of Sea Lamprey over native lampreys has been postulated as a cause for the reduction of native lampreys in some watercourses (Hubbs and Trautman 1937; Schuldt and Goold 1980). Vladykov (1951) suggested that the relatively high fecundity of Sea Lamprey may result in a competitive advantage of this invasive species relative to native lampreys. The potential for competition for resources, spread of parasites and disease, and increased predation rates on native lampreys resulting from invasive species, remains to be explored for Canadian populations. Cochran (2009) reported that many streams in Minnesota are stocked with non-native Brown Trout that may prey on several species of lampreys. Although most fish species have a large enough gape to consume larval lamprey, Brown Trout are large enough to feed on large ammocoetes and adult lampreys. Non-native fish species such as Round Goby (*Neogobius melanostomus*) may prey on Silver Lamprey eggs, while Common Carp (*Cyprinus carpio*) may act as hosts for Silver Lamprey during the parasitic feeding phase, actually providing benefit to the species (COSEWIC 2020). Warming trends resulting from climate change may favour the establishment and propagation of potentially harmful invasive species that may currently be limited by cooler water temperatures.

5.2.4 Climate change and severe weather

Climate change is expected to have significant effects on aquatic communities of the Great Lakes and St. Lawrence basins through several mechanisms including increasing water and air temperatures, lower water levels, shorter periods of ice cover, increased frequency of extreme weather events, emergence of diseases, and shifts in predator-prey dynamics (Lemmen and Warren 2004). Climate change may specifically affect native lampreys by altering the timing of a variety of processes; for example, temperature appears to determine the timing of spawning (Cochran et al. 2012) and larval drift.

As Silver Lamprey is at the northern limit of its range and tends to prefer cooler waters, warming water temperatures could allow the Silver Lamprey to expand its distribution into new river

systems (Cline et al. 2014). In areas where barriers limit upstream expansion to cooler waters, however, warming temperatures may prevent Silver Lamprey from expanding its distribution, possibly resulting in range contraction. The overlap in the distributions of Silver Lamprey and Sea Lamprey is unlikely to change as a result of warming water temperatures, but increased growth, fecundity, and distribution of Sea Lampreys could be expected (Lennox et al. 2020). While climate change-mediated shifts in the distribution of marine fishes have been observed (see Perry et al. 2005), long-term analysis is lacking for freshwater systems (Cline et al. 2014). Current and anticipated implications relating to climate change on Silver Lamprey requires further assessment.

Drought

Generally, temperatures in northern areas are changing more rapidly but the severity of change is currently unknown. Impacts of drought may be somewhat buffered in larger river systems and migratory Silver Lamprey presumably would be able to colonize new river systems with more suitable thermal regimes, provided barriers to migration do not limit movement.

Temperature extremes

Within the St. Lawrence basin, climate change has altered hydrological regimes and sediment dynamics (Boyer et al. 2010) and has likely impacted fish recruitment (Hudon et al. 2010). Temperatures in excess of 22°C in late spring and early summer, when embryonic development is occurring, could result in increased Silver Lamprey mortality (Maitland et al. 2015).

Storms and flooding

Extreme flooding and high flow events could scour larval silt beds and dislodge ammocoetes, although this effect may be less severe than drought (COSEWIC 2020).

5.2.5 Biological resource use

Logging and wood harvesting

Silver Lamprey occurs in areas that have undergone deforestation associated with logging and agriculture (that is, destruction of riparian vegetation and tree cover). The loss of riparian vegetation and other alterations that increase erosive surface runoff and siltation are addressed in section 5.2.2.

6 Management objectives

The management objectives establish, to the extent possible, the number of individuals and/or populations, and their geographic distribution, necessary to conserve and protect extant populations of Silver Lamprey in the Great Lakes-Upper St. Lawrence DU and prevent them from becoming threatened or endangered.

Although understanding of the taxonomic distinction between Silver Lamprey and Northern Brook Lamprey has improved, further insight into the genetic and environmental components that drive feeding types is required. Conservation activities are difficult to plan due to the lack of information on basic population characteristics of the Silver Lamprey, including a habitat distribution map and population demographic data, which would allow for a greater

understanding of abundance trends. Furthermore, some of the basic biological and habitat needs are poorly characterized. In particular, further understanding of the species' life history, with an emphasis on factors that may be limiting its distribution, is needed (for example, determining what constitutes habitat fragmentation for this species), along with a further understanding of population dynamics of the species (for example, mortality rates), so that minimum viable population sizes may be estimated. Further targeted surveys are required to determine the population status in its entire range. Locating the various habitats used during different stages in the life cycle, particularly habitats vital for spawning and larval development, is desirable. Presently, the quantity and quality of habitat required to ensure long-term conservation of Silver Lamprey is unknown. Filling the knowledge gaps relating to the distribution and biology of Silver Lamprey will help to inform management objectives and actions.

Management should be directed towards ensuring the conservation and restoration of habitat for known populations. However, some differentiation in management actions is expected between the Great Lakes basin (where lampricide is applied), and the St. Lawrence watershed. Silver Lamprey records are primarily generated through the monitoring program that exists to support Sea Lamprey control. The monitoring program will be a key management tool to allow the control of Sea Lamprey without compromising the conservation of Silver Lamprey. Monitoring generates records for 4 lamprey species (including Northern Brook Lamprey and American Brook Lamprey) and co-management approaches can be implemented and enabled through the information gathered during monitoring. More quantifiable objectives relating to individual populations will be developed once necessary sampling and analysis have been completed.

The management objectives for the Silver Lamprey, Great Lakes-Upper St. Lawrence populations are to:

i. refine understanding of population and habitat trends
ii. identify, mitigate, and monitor threats impacting the species' survival and conservation
iii. maintain, enhance, and, where feasible, restore habitat to support Silver Lamprey
iv. expand knowledge of the species' biology and ecology to enable and enhance management efforts
v. improve the efficiency of conservation efforts through coordinated actions with other aquatic ecosystem recovery teams and other complementary conservation groups and/or initiatives
vi. increase public awareness about the importance of biodiversity and healthy aquatic ecosystems, particularly among various partners, Indigenous groups, interest groups, organizations, and landowners interested in supporting the conservation efforts for Silver Lamprey

7 Broad strategies and conservation measures

This management plan includes 5 broad strategies and related measures for the conservation of the species to prevent the Silver Lamprey, Great Lakes-Upper St. Lawrence populations, from becoming threatened or endangered.

Section 7.1 provides an overview of the actions related to conserving the species already completed and underway. Section 7.2 identifies the broad strategies for conservation of Silver

Lamprey. The measures to be implemented for conservation of the species are summarized in an implementation schedule (tables 3, 4, and 5) in section 7.3, which prioritizes actions and identifies leads, partners and timelines, to the extent possible at this time. Section 7.4 provides additional information on conservation measures identified in the implementation schedule.

7.1 Actions already completed or currently underway

Recovery strategies and management plans exist (or are being developed) for co-occurring species and the resulting recovery and conservation measures could benefit the Silver Lamprey (for example, Redhorse spp. [*Moxostoma spp*.]; Eastern Sand Darter [*Ammocrypta pellucida*]; and Channel Darter [*Percina copelandi*]). In Ontario, Fisheries and Oceans Canada's (DFO) regional Species at Risk Program has proactively partnered with the DFO Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) and the Sea Lamprey Control Centre to develop additional guidance and Best Management Practices (BMPs), as needed, for SLCP activities, to mitigate potential impacts to aquatic species at risk; this work has been ongoing since 2012. To address some knowledge gaps, a peer review science advisory meeting was held in February 2019 to evaluate the potential lethal and sub-lethal impacts of Sea Lamprey assessment and treatment activities to fish and mussel species at risk in the Great Lakes basin, including Silver Lamprey (Andrews et al. 2021). Results indicated that for fishes, relative risk of Sea Lamprey assessment and control measures using granular Bayluscide was greatest for native lampreys (Silver Lamprey [*Ichthyomyzon unicuspis*] and Northern Brook Lamprey [*Ichthyomyzon fossor*]). Potential means of mitigating these impacts include modifying the frequency and timing of treatments and decreasing the size of application sites; however, additional testing is necessary to ensure that desired outcomes of potential mitigation measures for species of conservation concern are realized while avoiding unintended consequences including increased survival and production of Sea Lamprey, and subsequent impact of predation on Great Lakes fishes. An investigation of the potential for feeding plasticity in Silver Lamprey and Northern Brook Lamprey was completed in 2019 (Neave, et al. 2019). This study determined that Silver Lamprey and Northern Brook Lamprey are closely related and may experience some gene flow, but it is unlikely that they represent 1 panmictic species. Therefore, they should be regarded as independent evolutionary units and managed as 2 species.

7.2 Broad strategies

The following broad strategies support the management objectives outlined in section 6. Broad strategies and conservation measures are summarized and prioritized in tables 3, 4, and 5. The following 5 broad strategies have been identified:

1. surveys and monitoring
2. management and coordination
3. research
4. habitat protection, restoration, and enhancement
5. outreach and communication

Many of the conservation measures listed in the tables below can, and should, be performed in conjunction with other recovery and management teams dealing with individual species and ecosystem-based approaches. There are a number of species at risk with ranges overlapping that of the Silver Lamprey in Ontario and Quebec (for example, Eastern Sand Darter, Channel Darter, Copper Redhorse, River Redhorse) that have single-species or multispecies recovery strategies/management plans in development or completed. Additionally, there are numerous watershed-based management plans and initiatives that could benefit native lampreys, including

Great Lakes lakewide management plans, Great Lakes areas of concern remedial action plans, the St. Lawrence action plan, fish and fish habitat management plans, and source water protection plans. In Quebec, several integrated resource and sustainable development management initiatives are currently underway within the range of the Silver Lamprey, most notably the Watershed Committee, Priority Intervention Zone committees, and Lake Protection Association.

7.3 Conservation measures

Success in the conservation of this species is dependent on the actions of many different jurisdictions; it requires the commitment and cooperation of the constituencies that will be involved in implementing the measures set out in this management plan.

The measures set out in this management plan provide the best chance of achieving the management objectives for Silver Lamprey and guide not only activities to be undertaken by DFO, but those for which other jurisdictions, organizations and individuals may have a role to play. As new information becomes available, these measures and the priority of these measures may change. DFO strongly encourages all Canadians to participate in the conservation of the Silver Lamprey by undertaking conservation measures outlined in this management plan.

Table 3 identifies the measures to be undertaken by DFO to support the management and conservation of Silver Lamprey.

Table 4 identifies measures to be undertaken collaboratively between DFO and its partners, other agencies, organizations or individuals. Implementation of these measures will be dependent on a collaborative approach, in which DFO is a partner in conservation efforts but cannot implement the measures alone. As all Canadians are invited to join in supporting and implementing this management plan, table 5 identifies remaining measures that represent opportunities for other jurisdictions, organizations, or individuals to lead for the management of this species. If your organization is interested in participating in one of these measures, please contact the Species at Risk office within Ontario and Prairie Region or within Quebec Region.

Federal funding programs for species at risk that may provide opportunities to obtain funding to carry out some of the outlined activities include the Habitat Stewardship Program for Species at Risk, the Aboriginal Fund for Species at Risk Program and the Canada Nature Fund of Aquatic Species at Risk. Other levels of government may also provide funding opportunities for those interested in undertaking activities to conserve Silver Lamprey populations.

While DFO has already commenced efforts to implement the plan, the conservation measures for Silver Lamprey included in this management plan that have not yet been implemented by the department will be subject to the availability of funding and other required resources. Where appropriate, partnerships with specific organizations and sectors will provide the necessary expertise and capacity to carry out the listed measures. However, this implementation schedule is intended to be advice to other jurisdictions and organizations, and carrying out these actions will be subject to each group’s priorities and budgetary constraints (note: the list of partner agencies in the following tables are not meant to be exhaustive).

Table 3. Measures to be undertaken by Fisheries and Oceans Canada (DFO) for the Silver Lamprey, Great Lakes-Upper St. Lawrence populations.

#	Conservation measures	Broad strategy	Priority[6]	Objective(s) addressed	Timeline
1	Develop standardized protocols for surveying and monitoring Silver Lamprey populations and a robust monitoring plan to provide a clear indication of the progress toward the management objectives. Monitoring efforts may include: a. long-term abundance monitoring at index sites throughout the species' range b. presence/absence sampling to confirm species occurrence at historical or potential locations	Surveys and monitoring	Medium	i, iv	2024 to 2029
2	Collaborate with the Sea Lamprey Control Program (SLCP) and Great Lakes Laboratory for Fisheries and Aquatic Sciences to continue exploring ways to minimize the negative effects of Sea Lamprey control measures on Silver Lamprey.	Management and coordination	High	i, ii, iv, v	2024 to 2029
3	Work with dam/water control structure operators to ensure appropriate flow regimes and water depths during periods when the Silver Lamprey is vulnerable.	Management and coordination	Medium	i, ii, iii, vi	2024 to 2029
4	Resolve taxonomic uncertainties related to Silver Lamprey and Northern Brook Lamprey.	Research	High	iv	2024 to 2029
5	Determine the quantity and quality of habitat required to ensure long-term conservation of Silver Lamprey and to support the long-term management goal.	Research	Medium	i, iv	2024 to 2029
6	Continue to evaluate threats (for example, lampricide treatments, invasive species, and barriers); update threat assessments as new information becomes available.	Research	High	ii, v	2024 to 2029

[6] "Priority" reflects the degree to which the measure contributes directly to the conservation of the species or is an essential precursor to a measure that contributes to the conservation of the species:

- "High" priority measures are considered likely to have an immediate and/or direct influence on the conservation of the species
- "Medium" priority measures are important but considered to have an indirect or less immediate influence on the conservation of the species
- "Low" priority measures are considered important contributions to the knowledge base about the species and mitigation of threats

#	Conservation measures	Broad strategy	Priority[6]	Objective(s) addressed	Timeline
7	Develop Silver Lamprey educational materials to be included in communication and outreach programs for recovery and conservation of ecosystems and other species at risk, to promote an awareness about the need to protect freshwater fishes and ensure healthy aquatic ecosystems (for example, Hinterland Who's Who program, lamprey identification field guide).	Outreach and communication	Medium	v, vi	2024 to 2029

Table 4. Measures to be undertaken collaboratively between Fisheries and Oceans Canada (DFO) and its partners for the Silver Lamprey, Great Lakes-Upper St. Lawrence populations.

#	Conservation measures	Broad strategy	Priority[7]	Objective(s)addressed	Timeline	Partner(s)
8	Conduct background surveys to confirm current status/abundance of Silver Lamprey at sites of known occurrence.	Surveys and monitoring	High	i, iv	2024 to 2029	Researchers (for example, academic institutions, consultants), Provincial government, industry, other federal departments (for example, Parks Canada [PC]), and Indigenous groups
9	Conduct surveys in areas with historical records and in areas of high probability of occurrence.	Surveys and monitoring	Medium	i, iv	2024 to 2029	Researchers (for example, academic institutions, consultants), Provincial government, industry, other federal departments, and Indigenous groups

[7] "Priority" reflects the degree to which the measure contributes directly to the conservation of the species or is an essential precursor to a measure that contributes to the conservation of the species:

- "High" priority measures are considered likely to have an immediate and/or direct influence on the conservation of the species
- "Medium" priority measures are important but considered to have an indirect or less immediate influence on the conservation of the species
- "Low" priority measures are considered important contributions to the knowledge base about the species and mitigation of threats

#	Conservation measures	Broad strategy	Priority[7]	Objective(s)addressed	Timeline	Partner(s)
10	Monitor the occurrence, abundance and potential arrival of invasive species in Silver Lamprey habitat; where possible, this should be coordinated with relevant ecosystem-based programs.	Surveys and monitoring	Low	ii, iv, v, vi	2024 to 2029	Researchers (for example, academic institutions, consultants), Provincial government, industry, other federal departments (for example PC), and Indigenous groups
11	Collaborate and share information between relevant stakeholders, Indigenous groups, and recovery/management teams (for example, ecosystem-based recovery teams, watershed organizations and lake protection associations) and governmental authorities (federal, provincial, international and municipal) to address management actions of benefit to Silver Lamprey.	Management and coordination	Medium	ii, v, vi	2024 to 2029	Potentially stewardship groups, industry, local, provincial, and other federal governments and Indigenous groups

#	Conservation measures	Broad strategy	Priority[7]	Objective(s)addressed	Timeline	Partner(s)
12	Collaborate with United States (U.S.) organizations involved in management actions benefiting Silver Lamprey in the Great Lakes; take into account ecosystems and species when planning large-scale water-level management (for example, International Joint Commission Plan 2007 on the regulation of water levels in Lake Ontario and the St. Lawrence River).	Management and coordination	Medium	All	2024 to 2029	U.S. Geological Survey, Great Lakes Fishery Commission and U.S. state departments
13	Consolidate Silver Lamprey data into existing federal and provincial centralized databases, including habitat parameters, and report on studies and survey results.	Management and coordination	Medium	All	2024 to 2029	Provincial and other federal governments
14	Increase knowledge of Silver Lamprey life-history, particularly in knowledge areas currently limiting conservation planning (for example, habitat mapping for spawning and larval rearing).	Research	High	i, iv	2024 to 2029	Provincial and other federal departments, Academic institutions
15	Develop and test mitigation measures associated with identified threats.	Research	Medium	ii, iv	2024 to 2029	Provincial and other federal departments, academic institutions, conservation groups and Indigenous groups

#	Conservation measures	Broad strategy	Priority[7]	Objective(s)addressed	Timeline	Partner(s)
16	Implement best management practices, relating, for example, to agricultural practices, the establishment of riparian buffers, nutrient management (organic and mineral fertilizers), and tile drainage at locations where the primary threats are related to water quality.	Habitat protection, restoration, and enhancement	Medium	ii, iii, v, vi	2024 to 2029	Provincial and other federal departments, conservation partners, agricultural organizations, landowners and Indigenous groups
17	Promote awareness with municipal planning offices and planning officials to develop and adopt land management practices that minimize impacts on the Silver Lamprey and its habitat.	Outreach and communication	Medium	vi	2024 to 2029	Local municipal and provincial governments, conservation groups and organizations and Indigenous groups

Table 5. Measures that represent opportunities for other jurisdictions, organizations or individuals to lead for the Silver Lamprey, Great Lakes-Upper St. Lawrence populations.

#	Conservation measures	Broad strategy	Priority[8]	Objective(s) addressed	Suggested other jurisdictions or organizations
18	Gather information on population dynamics of Silver Lamprey, integrating the long-term monitoring requirements with existing fish community survey efforts, where possible.	Surveys and monitoring	Medium	i	Provincial and other federal departments, academic institutions, conservation groups/organizations and Indigenous groups
19	Promote and prioritize stewardship initiatives (for example, through federal/provincial funding programs) related to Silver Lamprey conservation.	Habitat protection, restoration, and enhancements	Medium	v, vi	Local municipal, provincial and other federal governments, conservation groups/organizations and Indigenous groups

[8] "Priority" reflects the degree to which the measure contributes directly to the conservation of the species or is an essential precursor to a measure that contributes to the conservation of the species:

- "High" priority measures are considered likely to have an immediate and/or direct influence on the conservation of the species
- "Medium" priority measures are important but considered to have an indirect or less immediate influence on the conservation of the species
- "Low" priority measures are considered important contributions to the knowledge base about the species and mitigation of threats

7.4 Narrative to support implementation schedule

7.4.1 Surveys and monitoring

The development of standardized protocols for Silver Lamprey sampling is required to allow for confident comparisons of population demographics in space and time. Current lamprey sampling methods include a method for sampling ammocoetes in regions where backpack electrofishing is impractical due to water depth (see Bergstedt and Genovese 1994) and non-electrofishing (for example, chemical) methods for ammocoete surveys in small rivers (Lasne et al. 2010). The detection of larval and metamorphosing lampreys in deep water of large river systems via electrofishing is increasing (see Jolley et al. 2012; Taverny et al. 2012), however, 2′,5-dichloro-4′-nitrosalicylanilide [Bayer 73 or Bayluscide]) remains the primary method in deepwater habitats, at this time. Further understanding of basic life history is needed to ensure optimal sampling design is developed. Moser et al. (2007) studied collection and capture techniques for lampreys. Briefly, it would be easier to design an effective sampling program if better information was available regarding the extent and distribution of preferred ammocoete habitat and the extent of their movement. When sampling adults, knowledge of the timing of migration is required. Therefore, certain studies are dependent on the findings of other studies, and the implementation schedule should reflect this.

To obtain a better understanding of Silver Lamprey distribution and population demographics, surveys targeting this species are required on a much wider scale than are currently undertaken. Surveys should include the use of standardized sampling techniques (see below). Added to existing distribution data, survey data will support efforts to plan other management actions. Sampling efforts that target post-metamorphic stages are desirable and necessary to understand species-specific distributions and abundances. If the sampling protocol targets the ammocoete stage, then it will be necessary to treat Silver Lamprey and Northern Brook Lamprey as a single unit due to the practical difficulty of species identification at this stage. Classification of habitat types, or habitat mapping, is also required. A standardized index population and habitat monitoring program should be coordinated with existing monitoring programs (for example, SLCP) where possible. A long-term monitoring program will enable assessments of changes in range, population distribution and abundance trends, key demographic characters, and changes/trends in habitat parameters (for example, temperature and dissolved oxygen levels).

7.4.2 Management and coordination

To facilitate implementation, management efforts targeting Silver Lamprey should be coordinated with other groups, such as local Indigenous groups, interested lake protection associations, and relevant recovery teams. Management efforts benefiting Silver Lamprey should also be included in integrated management plans where possible (for example, Lake Superior Lakewide Management Plan).

In Ontario, the chemical control of Sea Lamprey is a key factor in the current status of Silver Lamprey. The ongoing inclusion and consideration of native lampreys within Standard Operating Procedures (SOPs)[9] for chemical control of Sea Lampreys is vital. Alternative non-chemical Sea Lamprey control measures will be encouraged and supported. In addition to application of lampricides, the SLCP relies on low-head barriers specifically constructed or modified to block Sea Lamprey spawning migrations in 37 locations across Ontario. Working

[9] Great Lakes Fishery Commission standard operating procedures for chemical control of Sea Lampreys.

with managers of dams and water-control structures will help to ensure that the design of flow and water-level management plans consider native lampreys, particularly their spawning requirements and ammocoete habitat, while maintaining the important Sea Lamprey control function. When invasive species are known downstream of impassible barriers, any mitigation or barrier removal projects should carefully consider the potential impact removal/mitigation may have on upstream native lamprey populations.

As Silver Lamprey is present in waterbodies shared by Canada and the U.S., general conservation efforts underway in the U.S. may directly affect the health of populations assessed in Canada. Continued coordination with officials in the U.S. on survey efforts and aquatic ecosystem protection is imperative.

To prioritize future research, integrate habitat information, and coordinate conservation efforts, all available information on Silver Lamprey should be entered into existing federal and provincial geo-referenced databases. Such information should be made easily accessible to organizations such as the Ministère de l'Environnement, de la Lutte aux Changements Climatique, de la Faune et des Parcs du Québec, the Natural Heritage Information Centre of the Ontario Ministry of Natural Resources and Forestry, and other stakeholders concerned with species and fisheries management.

7.4.3 Research

Current knowledge regarding some general biology and threats facing this species is limited. Protection of existing populations and their habitat is the principal foundation of this management plan. To implement adequate and targeted safeguards, continued threat assessments will be required. Where there are regional differences, it is important to ensure that threats are differentiated by geographic area (region) when applicable. An assessment of in-stream barriers should be conducted for all watersheds where the Silver Lamprey is known to exist. Barriers should be mapped and their effects on local habitat conditions (for example, flow, temperature, substrate stability and composition) should be assessed to determine if these barriers are impacting native lamprey habitat. Mitigation should be developed and applied where appropriate to improve conservation of Silver Lamprey.

Uncertainty exists as to whether Silver Lamprey and Northern Brook Lamprey should be regarded as independent species (Docker et al. 2012) and, therefore, whether the 2 species should be combined in a single DU and managed accordingly. To answer this question, further insight into the genetic and environmental components that drive feeding types (that is, parasitic versus non-parasitic) is required.

7.4.4 Habitat protection, restoration, and enhancement

Active promotion of stewardship activities will raise community support and awareness of conservation issues regarding Silver Lamprey and will increase awareness of opportunities to improve aquatic habitats and land management practices that affect aquatic ecosystems. Habitat improvement activities should be coordinated with existing groups and initiatives (for example, ecosystem-based recovery programs), to which direction, technical expertise/contacts and information on financial incentives and funding programs (for example, existing funding opportunities for private landowners) should be provided. Important activities for habitat improvement include: BMPs for agriculture, establishment of riparian buffers, and nutrient management (organic and mineral fertilizers) as a means of reducing contaminant and nutrient inputs into tributaries and lakes where Silver Lamprey is resident.

7.4.5 Outreach and communication

Silver Lamprey is not widely known. Education efforts that emphasize the ecological, historical, cultural and scientific value of native lampreys is necessary to counteract the negative general perception of lampreys that the public may have, especially in Ontario where the invasive SLCP operates. Silver Lamprey should be included in existing communication and outreach programs for both ecosystem-based recovery as well other special concern, endangered, and threatened aquatic species' conservation and recovery efforts. This will facilitate the efficient use of resources, and instill awareness about the need to protect freshwater fishes and ensure the health of freshwater ecosystems. Ensuring that Silver Lamprey is considered where feasible in surveys, outreach, and educational efforts targeted at species at risk will result in more efficient and cost-effective conservation efforts.

8 Measuring progress

Reporting on implementation of the management plan under section 72 of SARA will be done by assessing progress toward implementing the broad strategies and conservation measures. The implementation of this management plan will be assessed within 5 years after the plan has been included as final on the Species at Risk Public Registry (section 72) with the intent to revisit it at similar intervals until the objectives have been achieved. The performance indicators below in table 6 identify the broad strategies and how progress towards achieving them will be evaluated in the future.

Table 6. Performance indicators for achieving broad strategies for the Silver Lamprey, Great Lakes-Upper St. Lawrence populations.

Broad strategy	Performance indicator
Surveys and monitoring	Appropriate monitoring program has been developed. Existing populations and historical sites and potential habitats have been sampled.
Management and coordination	Collaborative working relationships established.
Research	Research has determined whether Silver Lamprey and Northern Brook Lamprey are 1 or 2 species. Gained knowledge of currently occupied and potential of historical habitats.
Habitat protection, restoration, and enhancement	Stewardship action taken to reduce threats to the species and its habitat. Partners engaged.
Outreach and communication	Outreach materials developed and distributed.

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Appendix A: Record of cooperation and consultation

Management plans are to be prepared in cooperation and consultation with other jurisdictions, organizations, affected parties, and others as outlined in the *Species at Risk Act* (SARA) section 66. Fisheries and Oceans Canada (DFO) has utilized a process of consultation with species experts and the Canadian public to seek input for the development of this management plan. Information on participation is included below.

Table A1. Subject matter expert reviewers.

Name	Organization
Staton, Shawn	Ontario Freshwater Fish Recovery Team
April, Julien	Ministère de l'Environnement, de la Lutte aux Changements Climatique, de la Faune et des Parcs du Québec (formerly, Ministère des Forêts, de la Faune et des Parcs du Québec)
Balint, David	DFO, Species at Risk Branch, Central and Arctic Region
Bérubé, Marthe	DFO, Species at Risk Branch, Quebec Region
Bourgeois, Myriam	DFO, Species at Risk Branch, Quebec Region
Couillard, Marc-Antoine	Biologist, Ministère de l'Environnement, de la Lutte aux Changements Climatique, de la Faune et des Parcs du Québec (formerly, Ministère des Forêts, de la Faune et des Parcs du Québec)
Docker, Margaret	University of Manitoba
Dunn, Shelly	DFO, Species at Risk Branch, Central and Arctic Region
Gauthier, Isabelle	Ministère de l'Environnement, de la Lutte aux Changements Climatique, de la Faune et des Parcs du Québec (formerly, Ministère des Forêts, de la Faune et des Parcs du Québec)
Geraghty, Andrew	DFO, Species at Risk Branch, Central and Arctic Region
Jacobs, Clint	Walpole Island Heritage Centre, Walpole Island First Nation
Mandrak, Nicholas E	Department of Biological Sciences, University of Toronto Scarborough
Massé, Huguette	Ministère de l'Environnement, de la Lutte aux Changements Climatique, de la Faune et des Parcs du Québec (formerly, Ministère des Forêts, de la Faune et des Parcs du Québec)
Neave, Fraser	DFO, Sea Lamprey Control Centre
Pratt, Thomas	DFO, Great Lakes Laboratory for Fisheries and Aquatic Sciences
Reid, Scott	Ontario Ministry of Natural Resources and Forestry
Renaud, Claude	Canadian Museum of Nature
Steeves, Mike	DFO, Sea Lamprey Control Centre
Sullivan, W. Paul	DFO, Sea Lamprey Control Centre

Consultation on the draft management plan occurred through letters and online consultation with potentially affected Indigenous groups, key stakeholders and the Canadian public. For the proposed management plan for Silver Lamprey (*Ichthyomyzon unicuspis*), Great Lakes-Upper St. Lawrence populations in Canada, additional stakeholder, Indigenous, and public input was sought through publication of the proposed document on the Species at Risk Public Registry for a 60-day public comment period. Comments received were used to inform the final document.

Appendix B: Adult Silver Lamprey observations in Ontario and years when lampricide was applied (1882 to 2018)

Table B1. Adult Silver Lamprey observations in Lake Ontario watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.
[a] records provided through personal communication (SLCP)
[c] records reported in COSEWIC 2020 only

Waterbody	Years of observation	Years of lampricide application
Lake Ontario	1999	n/a
Bowmanville Creek	1992[a], 1995[a], 2001	1971, 1974, 1978, 1980, 1983, 1986, 1989, 1992, 1995, 1998, 2001, 2004, 2008, 2011, 2014, 2017
Cobourg Brook	1995a, 1998 to 2001	1971, 1974, 1978, 1983, 1986, 1989, 1992, 1996
Humber River	2006, 2007[a]	unknown
Port Britain Creek	1985[a], 1990	1971, 1976, 1979, 1982, 1985, 1988, 1991, 1996, 2000, 2002, 2007, 2012, 2016
Royal Botanical Gardens Fishway	2006[c], 2008[c], 2010[c]	n/a
Salmon River	1986[a], 1988[a], 2004 to 2006	1971, 1975, 1978, 1991, 1994, 1997, 2000, 2016
Shelter Valley Creek	1987, 1989[a], 1990, 1991[a], 1998, 2003	1971, 1974, 1977, 1980, 1982, 1984, 1986, 1996, 2003, 2016

Table B2. Adult Silver Lamprey observations in Lake Erie watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.
[a] records provided through personal communication (SLCP)
[b] records reported in Neave et al. 2021
[c] records reported in COSEWIC 2020 only

Waterbody	Years of observation	Years of lampricide application
Lake Erie	1913, 1919 to 1921, 1928, 1930, 1935 to 1937, 1952, 1996, 1997, 2001, 2004, 2005, 2010, 2015[c], 2016	n/a
Big Creek	1964[bc], 1973, 1980, 1981[a], 1986, 1989[a], 1992[a], 1995, 1997, 1998, 2000 to 2002, 2006, 2007, 2013, 2014, 2016, 2017	1987, 1989, 1992, 1996, 1999, 2003, 2006, 2008, 2009, 2013, 2014, 2017
Black Creek / Lynn River	1950	n/a
Canard River	2016, 2017	n/a
Cedar Creek	2017, 2018	n/a
Detroit River	2004, 2012, 2014, 2015	n/a
Horner Creek	1964	n/a
McCormick Meadow Drain	1973	n/a

Waterbody	Years of observation	Years of lampricide application
Rondeau Harbour	1919, 1921	n/a
South Otter Creek	1992[a], 2009	1986, 2009, 2010
Young's Creek	1980, 1981, 1986, 1987[a], 1988[a], 1989, 1990[a], 1992, 1995, 1996[a], 1997[a], 1998, 1999 to 2002[a], 2003 to 2008, 2009 to 2018[bc]	1987, 1991, 2001, 2006, 2008, 2009, 2013

Table B3. Adult Silver Lamprey observations in Lake Huron watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.

[a] records provided through personal communication (SLCP)

[b] records reported in Neave et al. 2021

[c] records reported in COSEWIC 2020 only**Waterbody**	Years of observation	Years of lampricide application
Lake Huron	1940, 1989	n/a
Ausable River	2015 to 2018	Unknown
Bayfield River[b]	1966 to 1975[b]	Unknown
Beaver River	1980, 1981, 1986[a], 1995[a], 1997[a], 1998, 2000[a], 2001[a], 2002 to 2009, 2013[a], 2014[a], 2016[a]	n/a
Bighead River	1998[c], 1999[a], 2000	2000, 2003, 2006, 2007, 2010, 2012, 2015, 2018
Blue Jay Creek[b]	1967 to 1969[b], 1972[b]	Unknown
Boyne River	1971	1961, 1997, 2002, 2013, 2016, 2018
Coldwater River	1998, 1999, 2001, 2003[a], 2006, 2007, 2009, 2011[c] 2015	n/a
Echo River	1966[b], 1968 to 1970[b], 1988, 1990, 1995, 1997, 1999, 2003[a], 2004[a], 2014	Upper: 1968, 1971, 1973, 1977, 1978, 1980, 1983, 1987, 1990, 1998, 1999, 2004, 2008, 2011, 2012, 2013, 2015; Lower: 1967, 1971, 1994, 2010, 2011
French River	2006	Wanapitei River: 1969, 1973, 1978, 1984, 1989, 1994, 2000, 2005, 2011; Old Voyageur Channel: 1976, 1992, 2006, 2012
Garden River	1965[b], 1966[b], 2001	1966, 1970, 1974, 1977, 1979, 1981, 1984, 1987, 1990, 1994, 1997, 2001, 2002, 2006, 2009, 2010, 2011, 2014
Georgian Bay	1975	n/a
Harris River / Naiscoot River	1965, 1966, 1978	1960, 1968, 1972, 1980, 1984, 1988, 1993, 1999, 2004, 2008, 2012, 2013, 2016, 2018
Hog Creek	1998, 2001, 2005[a], 2006[a], 2007	1978

[c] records reported in COSEWIC 2020 only **Waterbody**	**Years of observation**	**Years of lampricide application**
Koshkawong River	1968 to 1970[b], 1972 to 1977[b],1978, 1980, 1982, 1990[a], 1998, 2007[a], 2008[a]	1966, 1970, 1974, 1978, 1982, 1985, 1989, 1993, 1997, 2000, 2006, 2010, 2012, 2015, 2018
Lake 22	1971	Unknown
Manitou River	1968[c], 1969[b], 1984, 1990[a]	1969, 1973, 1977, 1982, 1986, 1990, 1994, 1999, 2007, 2012, 2013, 2018
Musquash River	1990[a], 1996	1970, 1988, 1996, 2005, 2013
Nottawasaga River	1937, 1958[c],1961, 1966 to 1968[b], 1971[b], 1983[a], 1985, 1988[a] to1990[a], 1993, 1995[a], 1996, 1998, 2002, 2005, 2013	Main: 1961, 1968, 1993, 1997, 2002, 2013, 2017; Pine: 1961, 1968, 1991, 1993, 1996, 1998, 2002, 2005, 2012, 2013, 2016, 2018; Mad: 1961, 1968, 1972, 1976
Rankin River/ Sauble River	1974	n/a
Root River[b]	1965[b], 1966[b]	Unknown
Saugeen River	1960[c], 1971[b], 1972[a], 1975[a], 1976[a], 1978 to 1981[a],1980, 1986[b], 1987, 1998, 2002 to 2004, 2007	1971
Silver Creek	1974, 1979[a], 1980, 1991[a]	1960, 1968, 1972, 1976, 1979, 1982
Spanish River	1989, 1993[a], 1994[a], 1995, 1997, 1998, 1999[a], 2001	Main: 1967, 1972, 1989, 1994, 1998, 2002, 2010, 2011, 2015; Aux Sable only: 1978, 1988, 2008
St. Marys River[1]	1977 to 1982[b], 1983, 1984[a], 1985, 1986, 1988 to 2013, 2015, 2016, 2017[b], 2018	1972 to 1985, 1995, 1996, 1998, 1999, 2001, 2003 to 2018
Still River	1965 to 1972[b],1974[b], 1975[b], 1978	1960, 1968, 1972, 1976, 1983, 1988, 1996, 2017
Sturgeon River	1979[a], 1980[a], 1981, 2003	1960, 1968, 1972, 1976, 1979, 1985, 1989, 1995, 1999, 2003, 2007, 2011, 2012
Sydenham River	1979[a], 2015	1968, 1972
Thessalon River	1980[a], 2000	Lower: 1967, 1971, 1975, 1979, 1984, 1988, 1992, 1998, 2001, 2005, 2009, 2010, 2014; Upper: 1967, 1971, 1998, 2002, 2007, 2010, 2011
Willow Creek	1958	n/a

[1] Discrete areas treated with Bayluscide (2′,5-dichloro-4′-nitrosalicylanilide [Bayer 73 or Bayluscide]), not the lampricide (3-trifluoromethyl-4-nitrophenol [TFM]) treatment applied to flowing waters.
n/a = not applicable (that is, no lampricide treatment).

Table B4. Adult Silver Lamprey observations in Lake Superior watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.
[a] records provided through personal communication (SLCP)
[b] records reported in Neave et al. 2021
[c] records reported in COSEWIC 2020 only

Waterbody	Years of observation	Years of lampricide application
Lake Superior	1945, 1953, 1957[c]	n/a
Agawa River [b]	1958[b]	Unknown
Big Carp River	1981[a], 1956[b], 1958[b], 1960[b], 1961[b], 1965[b], 1998 to 2000, 2001[c], 2012	1959, 1962, 1966, 1972, 1977, 1981, 1985, 1989, 1993, 2001, 2007
Batchawana River	1956 to 1965[b], 1967[b]	Unknown
Carp River	1954, 1956[b], 1960[b], 1965[b], 1988, 1995[a], 1998	1959, 1961 to 1968, 1970, 1974, 1976, 1978, 1982, 1986, 1990, 1994, 2000, 2006, 2009, 2016
Chippewa River	1956 to 1963[b], 1965 to 1967[b],	Unknown
Cloud River	1960[b], 1975	Unknown
Cranberry Creek	1956 to 1958[b]	Unknown
Cypress River[b]	1959[b]	Unknown
Goulais River[b]	1956 to 1958[b]	Unknown
Harmony River	1954, 1957[b], 1965[b]	1959, 1963, 1967, 1972, 1976, 1990, 2009, 2014
Havilland Creek	1955	2013
Kaministiquia River	1950	1960, 1962, 1964, 1969, 1973, 1977, 1979, 1983, 1987, 1992, 1997, 2002, 2006, 2010, 2013, 2016
Little Carp River	1956[b], 1958[b]	Unknown
Little Gravel River[b]	1957[b]	Unknown
McIntyre River	1950, 1987[c], 1998[c]	1960, 1964
McKellar River	1998	Unknown
Michipicoten Rivera	1958[b], 1960[b], 1963[c]	Unknown
Neebing River	, 1987	1972
Neebing-McIntyre Floodway	1955, 1957 to 1959[b], 1971[b], 1987[b], 1990[a]	1985, 1990, 1994, 1997, 2007, 2008, 2013, 2017
Pancake River	1994[a], 1956 to 1962[b], 1998	1958, 1961, 1965, 1969, 1973, 1977, 1981, 1985, 1989, 1993, 1998, 2004, 2008, 2012, 2016
Pays Plat River	1956[b], 1965[b]	Unknown
Pearl River	1980's and 1990's[c] (observed in at least one year)	n/a
Prairie River	1953 to 1972[c] (observed in at least one year)	n/a
Sable River	1953 to 1972[c] (observed in at least one year)	n/a
Sibley Creek	1953 to 1972[c], 1980's and 1990's[c] (observed in at least one year)	n/a
Stokely Creek	1954, 1956[b], 1980[a], 1981[a], 1995, 1998	1959, 1960, 1964, 1970, 1974, 1977, 1980, 2000, 2008

Thunder Bay	1950, 1953, 1957, 1987	n/a
White River	1953 to 1972[c] (observed in at least one year)	n/a
Wolf River	1980's and 1990's[c] (observed in at least one year)	n/a

Table B5. Adult Silver Lamprey observations in Lake St. Clair watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.

[a] records provided through personal communication (SLCP)

[b] records reported in Neave et al. 2021

[c] records reported in COSEWIC 2020 only

Waterbody	Years of observation	Years of lampricide application
Lake St. Clair	1882, 1938[a], 1978[c], 1979, 1980[c], 1985[c], 1986[c], 1989, 1991, 1992, 1996 to 1998, 1999[c], 2000, 2005, 2006, 2007 to 2009[c], 2011[c], 2014[c], 2016[c], 2018	n/a
Clay Creek	2016	n/a
Jeanette's Creek	2015, 2016	n/a
Mitchell Bay	1979	n/a
Ruscom River	2016	n/a
St. Clair River	1980[b], 1992, 1999[a], 2000[a], 2003, 2004, 2007, 2012, 2013[b], 2014, 2017	n/a
Thames River	1980[a], 2013 to 2016, 2018	Komoka Creek: 2015
Tremblay Creek [a]	1992[a], 2006[a]	n/a

Table B6. Adult Silver Lamprey observations in Lake Nipissing watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.

[a] records provided through personal communication (SLCP)
[b] records reported in Neave et al. 2021
[c] records reported in COSEWIC 2020 only

Waterbody	Years of observation	Years of lampricide application
Lake Nipissing	1932, 1953[a], 1960, 2009[c]	n/a
Chippewa Creek	1995[a], 2007	
South Creek	2003, 2007[bc]	n/a
Squaw Lake	1977	n/a

Table B7. Adult Silver Lamprey observations in St. Lawrence River watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.

Waterbody	Years of observation	Years of lampricide application
St. Lawrence	1939, 1994, 1995, 2004, 2005	No treatment; outside Convention on Great Lakes Fishery (CGLF) area
Lake St. Francis	1938	No treatment; outside CGLF area

Table B8. Adult Silver Lamprey observations in Ottawa River watershed relative to years in which lampricide was applied to assess or control invasive Sea Lamprey populations.

Waterbody	Years of observation	Years of lampricide application
Ottawa River	1927, 1936, 1977, 1979, 1983, 1987, 1988, 1990, 1999, 2000	No treatment; outside CGLF area
Brewery Creek	1976	No treatment; outside CGLF area Fishery area

Appendix C: Silver Lamprey observations in Quebec (1901 to 2018)

Table C1. Silver Lamprey observations in Quebec from 1901 to 2018.[1]

Watershed	Waterbody	Year of observation
Saint-Maurice River	Boitel Lake	1979
St. Lawrence River	St. Lawrence River (Montréal-Sorel)	2015, 2009, 2001, 1999, 1992, 1991, 1983, 1982, 1977, 1975, 1973, 1965, 1943, 1942, 1941
	St. Lawrence River (Nicolet-Batiscan)	2012, 2008, 2007, 2001, 1975, 1972
	St. Lawrence River (Grondines-Saint-Nicolas)	2011, 2010, 2009, 2006, 1947, 1945, 1944, 1928
	Des Deux Montagnes Lake	2010, 2009, 1979, 1978, 1969, 1968, 1966, 1965, 1964
	St. Francis Lake	2004, 1968
	St. Louis Lake	2013, 2011, 2009, 1992, 1974, 1971, 1969, 1968, 1967, 1942, 1941, 1911
	St. Pierre Lake	2011, 2009, 2007, 2005, 1972, 1946, 1944
	St. Pierre Lake Archipelago	2010, 2001, 1984, 1972, 1971
	Des Mille Îles River	2005
	Des Prairies River	1976, 1971
Beauport River	Beauport River	2010
Batiscan River	Batiscan River	1987, 1967
Châteauguay River	Châteauguay River	1987, 1963, 1906
	Mitchel Creek	2006
	Oak Creek	2006
	Hinchinbrooke River	2005, 1986
L'Assomption River	L'Assomption River	1990, 1989, 1986, 1969, 1944
	Du Bois-Franc Lake	1942, 1939
	Ouareau River	2004
Nicolet River	Nicolet River	1969, 1944
Richelieu River	Richelieu River	2011, 2010, 2009, 2008, 2007, 2006, 2005, 1995, 1993, 1990, 1977, 1970, 1969, 1965, 1906
Rivière-du-Loup River	Petite Rivière-du-Loup River	1972
Saint-François River	Saint-François River	1991, 1990, 1947
	Stacey Creek	1980
Yamaska River	Yamaska River	1967, 1908
Lake Champlain	Missisquoi Bay	1985
Ottawa River	Simard Lake (Témiscamingue)	1976
	Ottawa River	2000, 1999, 1990, 1988, 1987, 1971, 1965, 1964
	Gatineau River	2000, 1999, 1998
	Kingham River	2004
	Blanche River	2000

Watershed	Waterbody	Year of observation
	Petite Nation River	2000
	Du Lièvre River	2002, 2000
	Rouge River	2000, 1901

[1]Data compilation was obtained from ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec [Quebec Ministry of Sustainable Development, Environment, Wildlife and Parks] in October 2013 and updated by DFO (Ontario and Prairie Region database including Quebec Region records) for years prior to 2019. Consulted databases: Centre de données sur le patrimoine naturel du Québec [Centre for Natural Heritage of Québec]; Réseau de suivi ichtyologique [Fish Monitoring Network]; Inventaire de faune aquatique [Inventory of Aquatic Wildlife]; Réseau de suivi des poissons de l'estuaire [Estuary Fish Monitoring Network]; Fiches de pêche [Fishing logbooks]; Royal Ontario Museum; Canadian Museum of Nature; International Union for the Conservation of Nature (IUCN).

Appendix D: Effects on the environment and other species

In accordance with the Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals (2010), the *Species at Risk Act* (SARA) recovery and management planning documents incorporate strategic environmental assessment (SEA) considerations throughout the document. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery or management planning document could affect any component of the environment or achievement of any of the Federal Sustainable Development Strategy's goals and targets.

Management planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that plans may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the plan itself, but are also summarized below in this statement.

This management plan will benefit the environment by promoting the conservation of the Silver Lamprey, Great Lakes-Upper St. Lawrence populations. The potential for the plan to inadvertently lead to adverse effects on other species was considered. The SEA concluded that this plan will benefit the environment and will not entail any significant adverse effects.

Even if Silver Lamprey numbers would increase, it is unlikely that other co-occurring species would be detrimentally affected. The proposed management actions will benefit the environment in general and are expected to have a net positive effect on other native species within the same areas. Some of the stewardship and habitat improvement activities will be implemented through ecosystem-based recovery programs that have already taken into account the needs of other species at risk.