PROPOSED

Species at Risk Act
Management Plan Series

Management Plan for the Northern Brook Lamprey (*Ichthyomyzon fossor*) in Canada (Great Lakes – Upper St. Lawrence populations)

Northern Brook Lamprey

2016

Fisheries and Oceans Canada
Pêches et Océans Canada
Canada

About the *Species at Risk Act* Management Plan Series

What is the *Species at Risk Act* (SARA)?

SARA is the Act developed by the federal government as a key contribution to the common national effort to protect and conserve species at risk in Canada. SARA came into force in 2003, and one of its purposes is "*to manage species of Special Concern to prevent them from becoming Endangered or Threatened*."

What is a species of Special Concern?

Under SARA, a species of Special Concern is a wildlife species that could become Threatened or Endangered because of a combination of biological characteristics and identified threats. Species of Special Concern are included in the SARA List of Wildlife Species at Risk.

What is a management plan?

Under SARA, a management plan is an action-oriented planning document that identifies the conservation activities and land use measures needed to ensure, at a minimum, that a species of Special Concern does not become Threatened or Endangered. For many species, the ultimate aim of the management plan will be to alleviate human threats and remove the species from the List of Wildlife Species at Risk. The plan sets goals and objectives, identifies threats, and indicates the main areas of activities to be undertaken to address those threats.

Management plan development is mandated under Sections 65–72 of SARA.

A management plan has to be developed within three years after the species is added to the List of Wildlife Species at Risk. Five years is allowed for those species that were initially listed when SARA came into force.

What's next?

Directions set in the management plan will enable jurisdictions, communities, land users, and conservationists to implement conservation activities that will have preventative or restorative benefits. Cost-effective measures to prevent the species from becoming further at risk should not be postponed for lack of full scientific certainty and may, in fact, result in significant cost savings in the future.

The series

This series presents the management plans prepared or adopted by the federal government under SARA. New documents will be added regularly as species get listed and as plans are updated.

To learn more

To learn more about the *Species at Risk Act* and conservation initiatives, please consult the SAR Public Registry.

Management Plan for the Northern Brook Lamprey (*Ichthyomyzon fossor*) in Canada (Great Lakes – Upper St. Lawrence populations) [Proposed]

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PREFACE

The Northern Brook Lamprey is a freshwater fish under the responsibility of the federal government. The Minister of Fisheries and Oceans is a "competent minister" for aquatic species under the *Species at Risk Act* (SARA). The Northern Brook Lamprey (Great Lakes – Upper St. Lawrence populations) was listed as a species of Special Concern under SARA in March 2009. The Saskatchewan – Nelson populations were assessed as Data Deficient by COSEWIC and have not been listed under SARA or included in this document. SARA (Section 65) requires the competent minister(s) to prepare management plans for species listed as Special Concern. The development of this management plan was led by Fisheries and Oceans Canada, Central and Arctic Region and Quebec Region, in cooperation and consultation with many individuals, organizations and government agencies, including the provinces of Ontario and Quebec. Since Northern Brook Lamprey (Great Lakes - Upper St. Lawrence populations) are also located in the proposed Lake Superior National Marine Conservation Area[1] administered by the Parks Canada Agency, the Minister of the Environment will become a competent minister under SARA when the Lake Superior National Marine Conservation Area is established. The plan meets SARA requirements in terms of content and process (SARA sections 65-68).

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 set out in this plan and will not be achieved by Fisheries and Oceans Canada or any other party alone. This plan provides advice to jurisdictions and organizations that may be involved or wish to become involved in activities to conserve this species. In the spirit of the Accord for the Protection of Species at Risk, the Minister of Fisheries and Oceans invites all responsible jurisdictions and Canadians to join Fisheries and Oceans Canada in supporting and implementing this plan for the benefit of the Northern Brook Lamprey and Canadian society as a whole. The Minister will report on progress within five years.

RESPONSIBLE JURISDICTIONS

Under the *Species at Risk Act,* the responsible jurisdiction for the Northern Brook Lamprey is Fisheries and Oceans Canada. The Northern Brook Lamprey occurs in Ontario and Quebec, and their respective governments also cooperated in the production of this management plan.

ACKNOWLEDGMENTS

Fisheries and Oceans Canada (DFO) would like to thank the following authors: Peter L. Jarvis, Shelly Dunn, Marthe Bérubé and Myriam Bourgeois for their part in developing the first draft of this management plan. Additionally, the following offered their support in the review, development and/or updating of this management plan and greatly improved the document:

[1] In 2007, a federal - provincial agreement was signed respecting the establishment of the Lake Superior National Marine Conservation Area (NMCA). However, formal designation under the *National Marine Conservation Areas Act* has not occurred at the time this management plan was finalized, thus the lands, including submerged lands remain provincial jurisdiction. Until the Lake Superior NMCA is established, the Minister of Fisheries and Oceans remains the sole competent minister under SARA for this species.

Ontario Ministry of Natural Resources and Forestry (OMNRF), ministère des Forêts, de la Faune et des Parcs du Québec (MFFP), Ontario Freshwater Fish Recovery Team, Fraser Neave (DFO) for an update on native lamprey distribution in the Great Lakes basin, Huguette Massé and Marc-Antoine Couillard (MFFP) for an update on native lamprey distribution in Quebec, Margaret Docker (University of Manitoba), Mike Steeves, Paul Sullivan, Yvan Lambert, Kim Mathieu, Simon Trépanier, Michelle Osborne, and Simon Nadeau (DFO), Claude Renaud (Canadian Museum of Nature), Chantal Vis (PCA), Scott Reid, Tim Haxton, Rich Drouin, Bob Bergmann, Melissa Robillard, Jay Fitzsimmons, and Scott Gibson (OMNRF), Clint Jacobs (Walpole Island Heritage Centre), Marc-Antoine Couillard and Isabelle Gauthier (MFFP), Suzie O'Bomsawin (Grand Conseil de la Nation Waban-Aki, territorial consultations), Christine Zachary-Deom (Mohawk Council of Kahnawake). Mapping for this management plan was developed by Andrew Geraghty (DFO).

STRATEGIC ENVIRONMENTAL ASSESSMENT

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. 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.

Recovery 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 on non-target species or habitats. The results of the SEA are incorporated directly into the plan itself, but are also summarized below.

This management plan will benefit the environment by promoting the conservation of the Northern Brook Lamprey. 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. The reader should refer to the following sections of the document in particular: Description of the Species' Habitat and Biological Needs (Section 1.4.1), Ecological Role (Section 1.4.2); Limiting Factors (Section 1.4.3); Description of Threats (Section 1.5.2); Management Actions (Section 2.3); and Effects on Other Species (Section 2.4).

EXECUTIVE SUMMARY

The Northern Brook Lamprey (Great Lakes – Upper St. Lawrence populations) (hereafter 'Northern Brook Lamprey') was designated a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada in 2007. In 2009, the Northern Brook Lamprey was listed on Schedule 1 of the *Species at Risk Act*.

The Northern Brook Lamprey is a freshwater fish from the family Petromyzontidae. It belongs to one of the two surviving groups of the jawless (agnathan) stage in vertebrate evolution. The non-parasitic Northern Brook Lamprey is considered a smaller-sized relative of the parasitic Silver Lamprey. There is a growing body of evidence, based principally on recent genetic studies, that both species lack genetic divergence and might possibly be considered ecotypes of a single species presenting divergent feeding types. Presently, the two species are being considered separately.

Northern Brook Lamprey lives up to seven years as ammocoetes (larval lampreys). Burrowed in soft sediments of streams, ammocoetes are relatively protected before metamorphosis. The adult Northern Brook Lamprey has a non-parasitic adult stage that limits its mobility (compared to the Silver Lamprey) and its fertility is relatively low (i.e., it has a lower reproductive capacity compared to other lamprey species). The Northern Brook Lamprey migrates up streams to spawn near the end of its life. Across Canada, the Northern Brook Lamprey lives in rivers and lakes sharing a largely overlapping range in the Great Lakes and Upper St. Lawrence system with the Silver Lamprey. The Northern Brook Lamprey has been located in the watersheds of lakes Nipissing, Superior, Huron and Erie, and the Winnipeg, Ottawa and St. Lawrence river watersheds.

In addition to the question of species distinction of Northern Brook Lamprey and Silver Lamprey, ammocoetes within the *Ichthyomyzon* genus are generally indistinguishable from one another. Although confirmation is required, other life history characteristics can be an indication of the presence of one species over another. For example, the Northern Brook Lamprey is more likely to be found in smaller streams compared to the Silver Lamprey, and thus, ammocoetes are sometimes distinguished according to their location of capture. Additionally, the presence of adult lampreys with ammocoetes could help to confirm which ammocoete species are present. Nevertheless, these difficulties have resulted in uncertainties about the species for many occurrences in different databases, which implies, in some cases, a low level of confidence for species identification. In the future, taxonomic examination of specimens may help to improve confidence in the historical database records of the Northern Brook Lamprey, and hence better support for management planning and implementation.

Lampricide use to manage invasive Sea Lamprey is the main threat for Northern Brook Lamprey in the Great Lakes. Given that in Quebec the Sea Lamprey is indigenous and is not known to affect game fishes, it is not under control measures. Thus, in Quebec, habitat loss and deterioration, and pollution from agricultural activities are the principal threats. Consequently, management actions should differ in Ontario and Quebec. See recommended approaches and actions later in the management plan (see 2.3. Actions, and subsections within).

The long-term goal of this management plan is to ensure the persistence of Northern Brook Lamprey throughout its current and historical ranges in the Great Lakes – Upper St. Lawrence designatable unit. The following short-term objectives have been identified to assist in meeting this goal over a five-year period:

i. To conserve and protect extant populations;
ii. To refine understanding of population and habitat trends;
iii. To identify, mitigate and monitor threats impacting the species' survival and conservation;
iv. To maintain, enhance, and where feasible, restore habitat to support Northern Brook Lamprey;
v. To address knowledge gaps and broaden knowledge of the species' biology and ecology to enable and enhance management efforts;
vi. To improve the efficiency of conservation efforts through coordinated actions with other aquatic ecosystem recovery teams and other complementary conservation groups and/or initiatives; and,
vii. To increase public awareness about the importance of biodiversity and healthy aquatic ecosystems, particularly amongst various partners, First Nations, interest groups, organizations and landowners interested in supporting the conservation efforts for Northern Brook Lamprey.

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1. SPECIES INFORMATION

1.1. Species Assessment Information from COSEWIC*

Date of Assessment: April 2007
Common Name (population): Northern Brook Lamprey, Great Lakes – Upper St. Lawrence populations
Scientific Name: *Ichthyomyzon fossor*
COSEWIC Status: Special Concern
Reason for Designation: This nonparasitic lamprey is distributed in streams throughout the Great Lakes basin (except Lake Ontario) and in southwestern Quebec. In the Great Lakes basin, which comprises most of its range, about 50% of the streams it is known to inhabit are subjected to ongoing chemical treatment for Sea Lamprey control which causes mortality to its larval stage. However, in untreated streams, the species is still abundant.
Canadian Occurrence: Ontario and Quebec
COSEWIC Status History: The species was considered a single unit and designated Special Concern in April 1991. When the species was split into separate units in April 2007, the "Great Lakes – Upper St. Lawrence populations" unit was designated Special Concern. Last assessment based on an update status report.

*****COSEWIC – Committee on the Status of Endangered Wildlife in Canada

1.2. Description

The Northern Brook Lamprey (*Ichthyomyzon fossor*; Figure 1) is one of six species in the genus *Ichthyomyzon*. The non-parasitic Northern Brook Lamprey is considered a smaller relative of the larger, parasitic Silver Lamprey (*I. unicuspis*; Potter 1980a). There is a lack of clarity regarding their standing as separate species, as recent genetic analyses have led to questions whether the Northern Brook Lamprey and Silver Lamprey are truly distinct (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 et al. 2009), they will be regarded as such for the purpose of this management plan.

The Northern Brook Lamprey reaches up to about 160 mm in length as an adult, while the Silver Lamprey can exceed double this length. The Northern Brook Lamprey has the characteristic features of lampreys, namely, an eel-like appearance with a round mouth and teeth arranged in circular rows. The adult Northern Brook Lamprey can be distinguished from other adult lampreys by its single dorsal fin, teeth patterns, and, potentially, its smaller size. The teeth are small, dull and knob-like in contrast to the sharp, longer teeth of parasitic lamprey forms. In Canada, the Northern Brook Lamprey overlaps with the distribution of four other lamprey species (Page and Burr 2011). The American Brook Lamprey (*Lethenteron appendix*) and Sea Lamprey (*Petromyzon marinus*) are distinguished from the Northern Brook Lamprey by the presence of two dorsal fins. The Chestnut Lamprey (*I. castaneus*) and Silver Lamprey can be separated from the Northern Brook Lamprey by their relatively long and sharp teeth (Scott and Crossman 1998) and darkly pigmented lateral line organs (Renaud 2011).

The Northern Brook Lamprey stages of development includes: egg, larva, a transformational stage, and adult. Known as ammocoetes, larvae appear wormlike, lacking eyes and teeth. Silver and Northern Brook lamprey larvae are indistinguishable; the other Great Lakes lamprey larvae are easily identified based on morphometric characteristics. Northern Brook Lamprey

larvae are filter-feeders and have an oral hood, instead of a sucker mouth like the adult. They live for up to seven years burrowed in the sediment, eventually metamorphosing into juveniles that emerge, attach to the stream bottom and swim periodically. During metamorphosis to the juvenile stage, the oral hood becomes a mouth with teeth. Adults live for only four to six months before spawning and dying. Adults do not have a functional alimentary canal (digestive system) and do not feed during their short adult life.

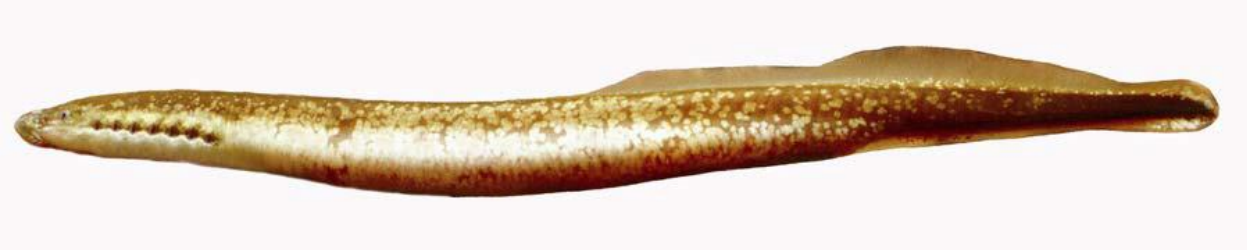

Figure 1. Adult Northern Brook Lamprey (*Ichthyomyzon fossor*) (© Fisheries and Oceans Canada).

1.3. Populations and Distribution

Global Range: Northern Brook Lamprey is restricted to eastern North America (Figure 2). In the United States, it has been found in Illinois, Indiana, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Vermont, West Virginia and Wisconsin, while Canadian residents occur in Manitoba, Quebec, and Ontario.

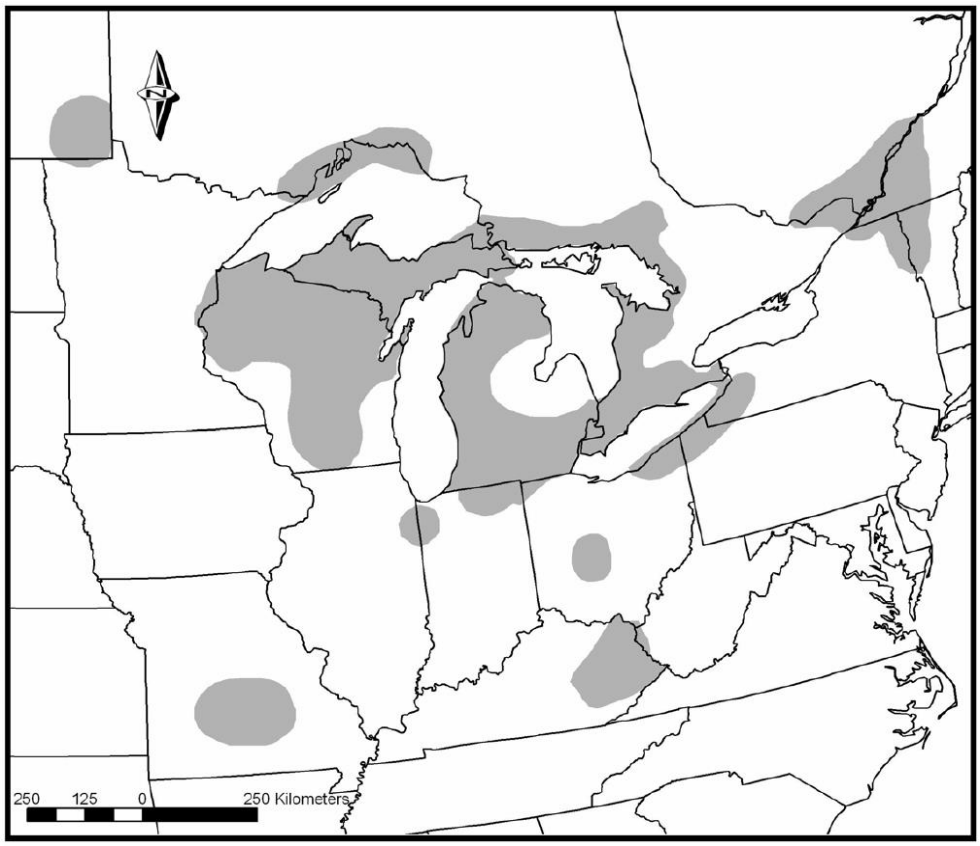

Figure 2. Global distribution of Northern Brook Lamprey (COSEWIC 2007, Adapted from Page and Burr 1991).

Canadian Range: The Canadian range of the Northern Brook Lamprey is within the Great Lakes, St. Lawrence and Winnipeg River watersheds (Figure 2), including stream systems and tributaries to lakes Nipissing, Superior, Huron and Erie, and the Winnipeg, Ottawa and St. Lawrence rivers (COSEWIC 2007). The Northern Brook Lamprey in Canada has been subdivided into two designatable units (DUs), one which encompasses the Saskatchewan – Nelson populations and one which covers the Great Lakes – Upper St. Lawrence populations. The separation into two DUs is based on the species' distribution within two different biogeographic zones (see COSEWIC 2007). The status of the Saskatchewan – Nelson populations is undetermined (COSEWIC designation: Data Deficient). Consequently, the content of the current management plan is restricted to the Great Lakes – Upper St. Lawrence populations (COSEWIC designation: Special Concern), which encompasses streams throughout the Great Lakes basin (except Lake Ontario) and in southwestern Quebec (Figure 2).

Ontario – In Ontario, the Sea Lamprey Control Centre (SLCC) has documented Northern Brook Lamprey in 30 tributaries since 1990 (Figure 3; Table 1). In addition to the locations listed in the COSEWIC report (COSEWIC 2007), the Northern Brook Lamprey has been collected subsequently from South Otter Creek, a tributary of Lake Erie, the Key, Root, and Thessalon rivers, tributaries to Lake Huron, and the Black Sturgeon River, a tributary of Lake Superior (F. Neave, SLCC, pers. comm. 2014). Furthermore, over the same time period, the SLCC has documented 74 streams throughout the Great Lakes drainage with *Ichthyomyzon* ammocoetes. No species identification was possible, but it is suspected that over half of these populations are

Northern Brook Lamprey based on location of capture, as Northern Brook Lamprey is more likely to be found in smaller streams relative to Silver Lamprey.

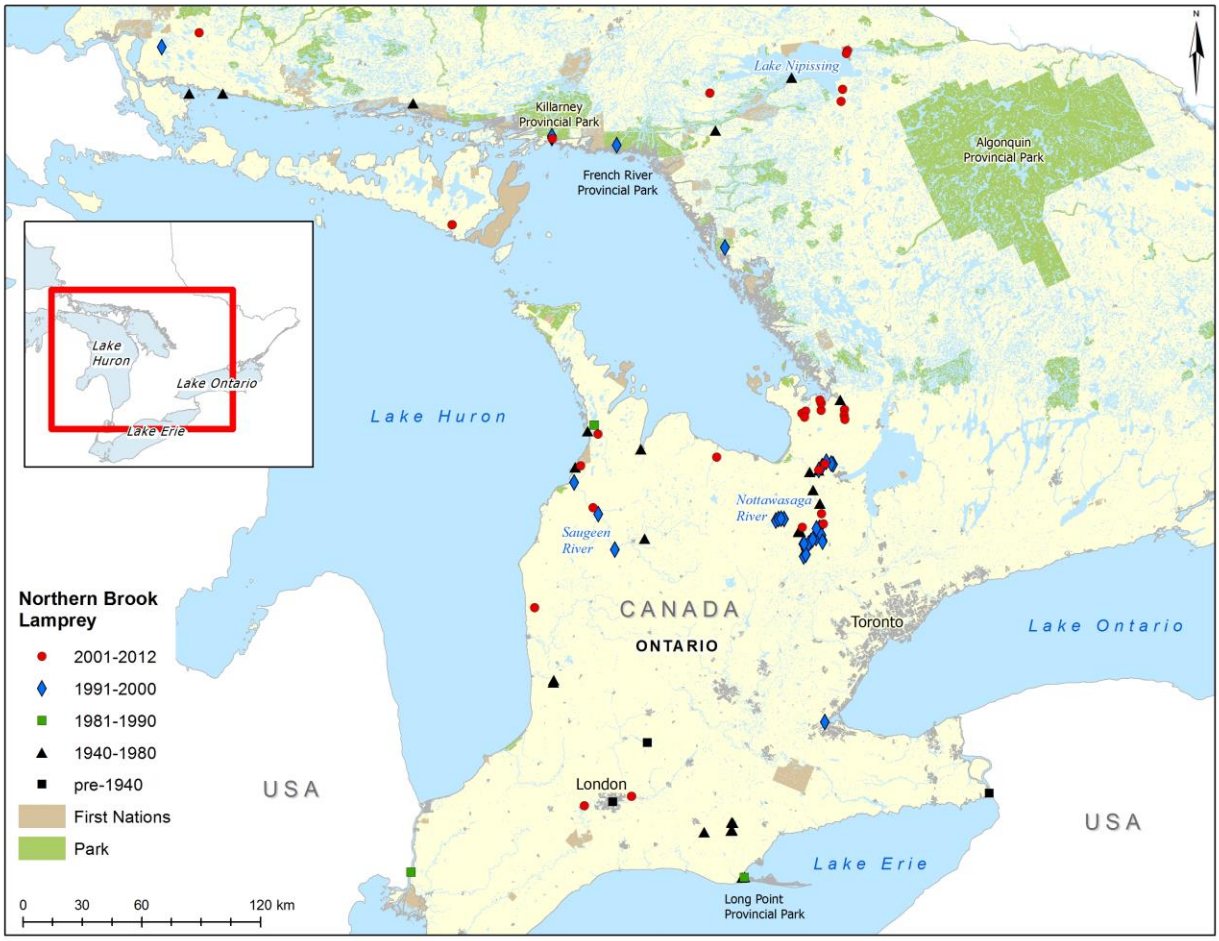

Figure 3 (a). Distribution of Northern Brook Lamprey (Great Lakes – Upper St. Lawrence populations) in southwestern Ontario based on sampling from 1882 to 2012.

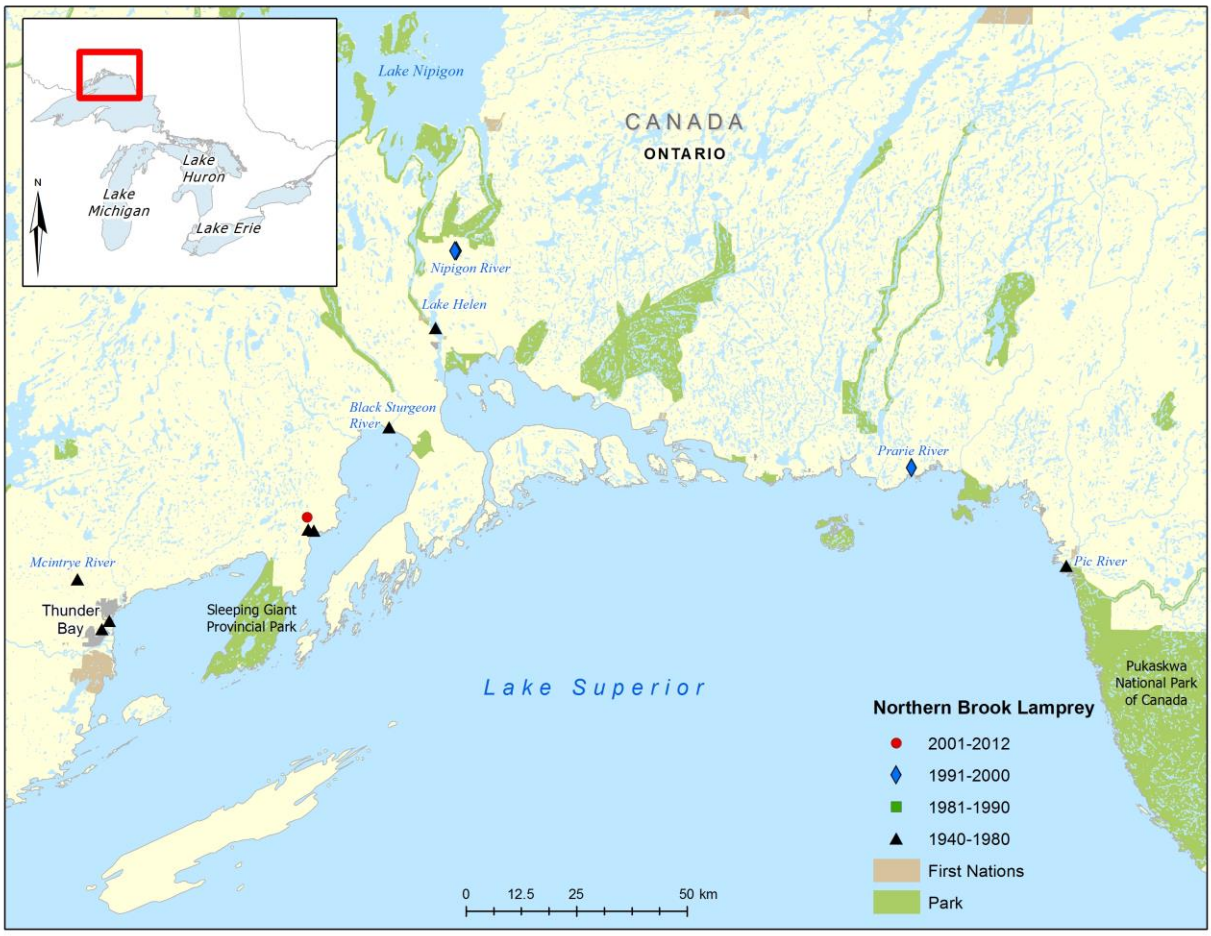

Figure 3 (b). Distribution of Northern Brook Lamprey (Great Lakes – Upper St. Lawrence populations) in northern Ontario based on sampling from 1882 to 2012.

Table 1. Northern Brook Lamprey locations in Ontario.

Watershed	Waterbody	Year of Observation
Lake Erie	Grand River	to be confirmed (tbc)
	South Otter Creek	2009
Lake St. Clair	St. Clair River	1986
	Thames River	1884
Lake Huron	Bar River	1999, 2007
	Beaver River	2004, 2007, 2008
	Browns Creek	tbc
	Chikanishing River	1999, 2000, 2002, 2007
	Coldwater River	1978, 2001, 2007, 2009, 2011
	Echo River	tbc
	French River	1978
	Hog Creek	2001, 2004, 2006, 2007
	Key River	2012
	Manitou River	2001, 2004
	Nine Mile River	2001, 2007
	Nottawasaga River	1958, 1973, 1996, 1997, 2000, 2001, 2002, 2004, 2007, 2008, 2013
	Root River	2010
	Sauble River	1978, 2001, 2008, 2009
	Saugeen River	1951, 1952, 1997, 2001
	Shebeshekong River	1997
	Spanish River	1978, 2007
	Thessalon River	2007, 2008
	Wye River	2002, 2006, 2007
Lake Nipissing	Bear Creek	2003, 2007
	Chippewa Creek	2003, 2007, 2008
	South Creek	2003, 2007
	Wolsely River	2003, 2007
Lake Superior	Black Sturgeon River	2006
	Nipigon River	1998, 1999, 2006, 2007
	Pearl River	1955, 2001, 2006, 2007
	Prairie River	1995
	Sibley Creek	tbc
	Stokely Creek	tbc
	undetermined	1931, 1947

Quebec – The Northern Brook Lamprey has been known in Quebec since 1940, when it was the subject of targeted projects (Vladykov 1952). Since 1990, there has been an increased effort to sample fish communities in the St. Lawrence River watershed; this led to Northern Brook Lamprey being observed in a number of new sites. Populations were located in the Ottawa and St. Lawrence river watersheds, from Lake Saint-Louis to Saint-Nicolas toward the

east, where specimens were observed in the Ottawa and St. Lawrence rivers and 18 other rivers in central Quebec (Figure 4; Table 2).

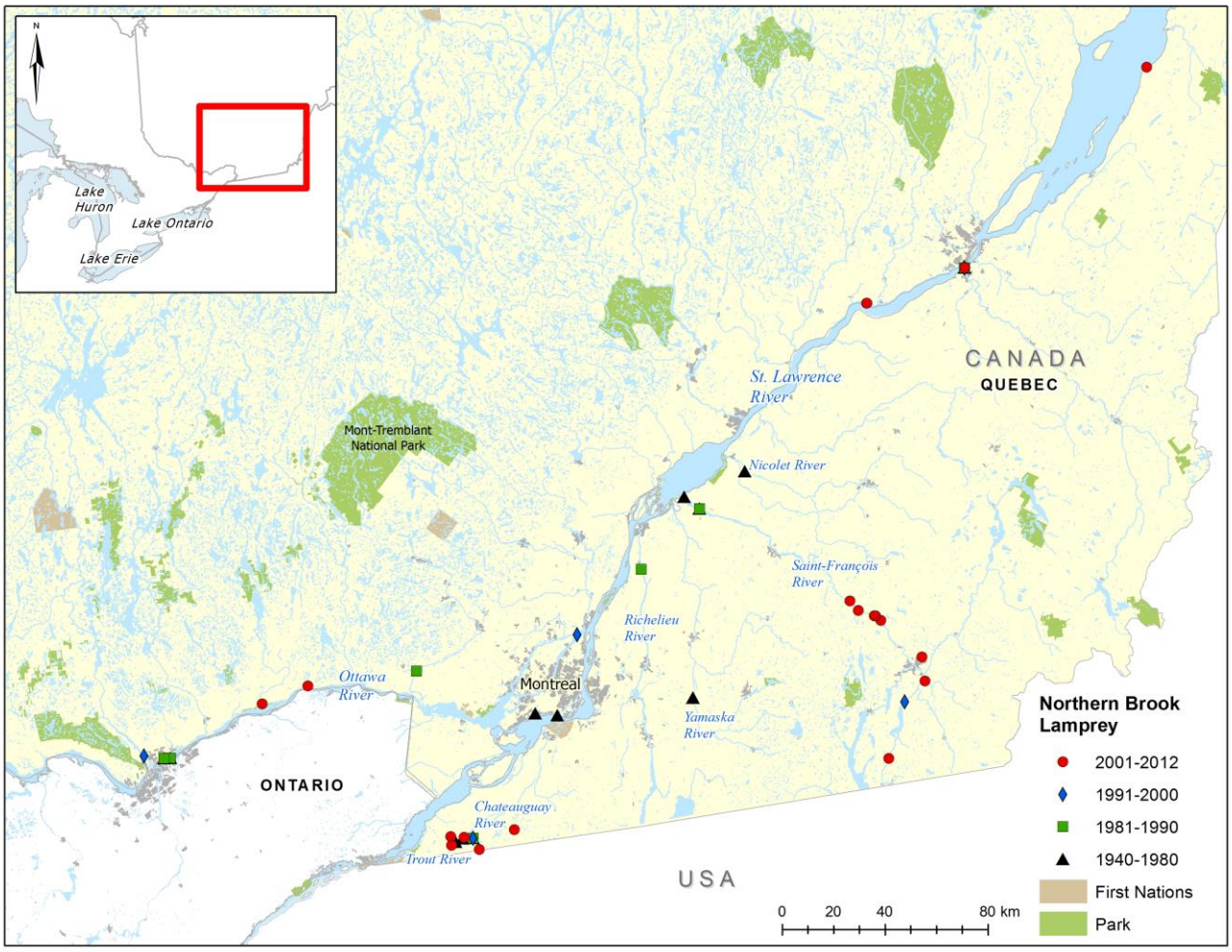

Figure 4. Distribution of Northern Brook Lamprey (Great Lakes – Upper St. Lawrence populations) in Quebec based on sampling from 1940 to 2012.

As the species has not been the object of targeted sampling since the 1940s and 1950s, there may be some Northern Brook Lamprey populations yet to be discovered. In general, multi-species inventories use relatively ineffective fishing gear for detecting the species, except in the case of fixed eel traps in Cap-Santé and Saint-Nicolas in the St. Lawrence River. In some sites, ammocoetes were caught, but unless adults are observed in the same stream, it is not always possible to identify ammocoetes to the species level. In general, not enough data have been collected to estimate population size of Northern Brook Lamprey in Quebec (Fortin et al. 2007).

Historically (since the 1940s), the species has been observed in Lake Saint-Louis and in the St. Lawrence River (the Lachine Rapids) and some of its tributaries, including the Nicolet, Saint-François, and Yamaska rivers (Table 2). In 1976, the species was observed southwest of Montreal, in the Hinchinbrooke (Fortin et al. 2005) and Trout rivers (Centre de données sur le patrimoine naturel du Québec [CDPNQ] in Fortin et al. 2007). In the 1980s, new sites were located in the Ottawa River watershed (Comtois et al. 2004; Fortin et al. 2005) and in the Châteauguay (Renaud et al. 1995, 1998), des Prairies (CDPNQ in Fortin et al. 2007), Richelieu (Renaud et al. 1995), and Massawipi rivers (Desroches et al. 2008).

Since the 2000s, Northern Brook Lamprey has been found at other sites in the Saint-François and Ottawa river watersheds (Fortin et al. 2005; Proulx et al. 2012; CDPNQ 2013). Recently, the species was also observed in the Réseau d'inventaire des poissons de l'estuaire campaigns, in the east, and in Cap-Santé and Saint-Nicolas on the St. Lawrence River (Bourget 2011a,b,c) However, according to expert opinions, most of the observations in Saint-Nicolas could be of Silver Lamprey (CDPNQ data provided, 2013). The species was also recently caught during a few random inventories (Gareau et al. 2011; Proulx et al. 2012; CDPNQ data provided, 2013). This reconfirmed the presence of the species in the Châteauguay, Ottawa and Saint-François river watersheds. The Pierreville islands area in the Saint-François River was historically qualified as ideal for ammocoetes (Vladykov 1952). The species now seems to have disappeared from the Yamaska River, where it was once abundant, likely because of water pollution from agricultural development (Fortin et al. 2007).

Table 2. Northern Brook Lamprey locations in Quebec[1].

Watershed	Waterbody	Year of Observation
St. Lawrence River	St. Lawrence River (Saint-Nicolas)[2]	2012, 2011, 2009, 2008, 2004, 2003, 2001, 1999, 1980-1996, 1971-1977
	St. Lawrence River (Lachine)	1950
	St. Lawrence River (Cap-Santé)	2011, 2010, 2009
	Des Prairies River	1998
	St. Louis Lake	1941
Nicolet River	Nicolet River	1951
Saint-François River	Saint-François River	2009, 2003, 1990, 1947-1951
	Willow Creek	2009
	Massawippi River	1995
	au Saumon River (Melbourne)	2009
	au Saumon River (Huntingville)	2011
	Tomifobia River	2008
Châteauguay River	Châteauguay River	2012, 1992, 1990
	Hinchinbrooke River	1976
	Aux Outardes-Est River	2002
	Trout River	2011, 2001, 1976
Ottawa River	Ottawa River (Gatineau)	1982, 1980
	Gatineau River	1999
	De La Petite Nation River	2011
	William Creek	1985
	Saumon River	2011
Yamaska River	Yamaska River	1946-1950
Richelieu River	Richelieu River	1990

[1]Data compilation was obtained from ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec in October 2013.
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].
[2] May be predominately Silver Lamprey.

Global Population Size, Status and Trends: Globally, the Northern Brook Lamprey is considered apparently secure with a G4 status[2], while imperilled in Manitoba, vulnerable in Ontario and vulnerable or imperilled in Quebec (NatureServe 2014) (Table 3).

Table 3. Global, national and sub-national conservation ranks for the Northern Brook Lamprey (NatureServe 2014).

Scale	Conservation Rank
Global (G)	**G4** (last reviewed 07 February 2012)
National (N)	
Canada	**N3**
United States	**N4**
Sub-national (S)	
Canada	Manitoba (**S2**), Ontario (**S3**), Quebec (**S2S3**)
United States	Illinois (**S1**), Indiana (**S1**), Kentucky (**S2**), Michigan (**S4**), Minnesota (**S3**), Missouri (**S4**), New York (**S1**), Ohio (**S1**), Pennsylvania (**S1**), Vermont (**S1**), West Virginia (**S1**), Wisconsin (**S5**)

Source: NatureServe (2014) (Accessed: October 10, 2014).

Northern Brook Lamprey population sizes and trends are poorly known throughout its range because of the difficulty in identifying the species at the ammocoete stage and collecting ammocoetes because they are burrowed and small, and because of limited targeted sampling for ammocoetes and adults.

Canadian Population Size, Status and Trends: Population estimates for Northern Brook Lamprey in Canada are not available. Although poorly known due to difficulties with identification and sampling, these parameters are probably better known in the Great Lakes basin due to greater sampling efforts targeting invasive Sea Lamprey. The main data source used for understanding trends in Northern Brook Lamprey population dynamics is incidental catch data from Sea Lamprey assessments performed by the SLCC; species identification only occurs for post-ammocoete stages. The Sea Lamprey control program has been in operation for over 50 years. As a part of the operation of the program, the SLCC performs regular surveys to catalogue lamprey populations. These efforts have resulted in the current understanding of Northern Brook Lamprey within the Great Lakes basin.

The Northern Brook Lamprey (Great Lakes – Upper St. Lawrence populations) was designated as a species of Special Concern in 2007 by COSEWIC (2007) and was listed on Schedule 1 of the *Species at Risk Act* (SARA) in 2009. A comprehensive list of sampling efforts is catalogued in the Northern Brook Lamprey COSEWIC report, which details the waterbodies with both adult Northern Brook Lamprey presence and *Ichthyomyzon* ammocoetes since 1990 (COSEWIC 2007). The COSEWIC report recorded adult Northern Brook Lamprey in 36 tributaries to the Great Lakes and St. Lawrence River, while 66 streams within the Great Lakes drainage

[2] The conservation status of a species or community is designated by a number from 1 to 5, preceded by a letter reflecting the appropriate geographic scale of the assessment (G = Global, N = National, and S = Subnational). The numbers have the following meaning: 1 = critically imperilled; 2 = imperilled; 3 = vulnerable to extirpation or extinction; 4 = apparently secure 5 = demonstrably widespread, abundant, and secure. S#S#: Range rank – A doubled numeric range rank (e.g., S2S3) is used to indicate the range of uncertainty in the status of a species or community. A S2S3 rank would indicate that there is a roughly equal chance of S2 or S3 and other ranks are much less likely. http://www.natureserve.org/explorer/ranking.htm.

contained ammocoetes, at least half of which are suspected to be Northern Brook Lamprey. At the time of the COSEWIC report, the range of occurrence within the Great Lakes – Upper St. Lawrence DU was thought to be stable, while the species appeared lost from 11 streams. New locations have been detected but, due to the sampling difficulties associated with this species and the lack of a comprehensive monitoring program, it is difficult to have confidence in these findings (i.e., that the species is occupying novel locations or has been extirpated from former areas of occupancy). Based on collections of *Ichthyomyzon* ammocoetes from 2000-2004, the Northern Brook Lamprey may be more abundant than previously thought. One population estimate was generated for *Ichthyomyzon* ammocoetes in the Black Sturgeon River (north shore Lake Superior) in 2006 by the SLCC. The population was estimated at 14,583,327 ammocoetes, which are thought to be Northern Brook Lamprey, suggesting that the species can be highly abundant at the ammocoete stage. The SLCC have recorded higher abundances and greater stability in Northern Brook Lamprey populations not exposed to lampricide compared to populations in treated streams. Northern Brook Lamprey population abundances and trends in the St. Lawrence River basin are unknown. The Yamaska River population appears to be lost (Fortin et al. 2007), while other populations have been recently discovered (Fortin et al. 2007; Bourget et al. 2011a,b,c; Proulx et al. 2012,) or recently reconfirmed to exist (Desroches et al. 2008; Gareau et al. 2011).

1.4. Needs of the Northern Brook Lamprey

1.4.1. Habitat and Biological Needs

Adults appear to inhabit a wide range of streams that vary considerably in their size and flow rates, and whose substrates range from sand to gravel (Trautman 1981). An extensive cataloging of this species in Michigan found it less common in small stream systems, while most frequent in small isolated segments of moderate to large streams (Morman 1979). The habitat requirement for spawning areas may be more specific, requiring rocky or gravel substrate with swift-flowing water (COSEWIC 2007). Water temperature appears to be an important trigger for spawning. According to studies conducted in Quebec, spawning has been observed to occur in May at water temperatures ranging from 13 to 16ºC (Vladykov 1949) and in June at 19ºC (Comtois et al. 2004). To construct its nest, Northern Brook Lamprey transports pebbles by moving them with its mouth to create a slight depression, and it remove sand by vigorous tail movements (Hardisty and Potter 1971). Nests have been recorded in the interstices beneath large stones (18 to 36 cm in diameter; Lanteigne 1991) and in gravel shallows just above riffles (Hankinson 1932). Ammocoetes reside in burrows that are typically associated with depositional areas of silt to sand substrates and are predominantly detritivores that feed mainly on organic detritus (Sutton and Bowen 1994). Ammocoetes have also been associated with warmwater tributaries and warm headwaters (Morman 1979). Movement of ammocoetes in the form of downward drift has been recorded in lamprey species (Potter 1980b) and ammocoetes have been observed in lentic habitats (e.g., Morman 1979).

1.4.2. Ecological Role

The Northern Brook Lamprey contributes to the biodiversity of rivers and streams (Fortin et al. 2007). All stages from egg to adult are preyed upon by a variety of fish species; additional predators include snakes, birds, and mammals (e.g., Churchill 1945; Cochran et al. 1992; 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. Lamprey 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 lamprey ammocoetes. Unlike the Sea Lamprey and Silver Lamprey, the Northern Brook Lamprey does not have a parasitic phase, and hence, it does not present a danger of injuring or killing other fish species (Fortin et al. 2007).

1.4.3. Limiting Factors

The life history of the species requires further research; without knowing definitively whether Silver Lamprey and Northern Brook Lamprey are the same or separate species makes it difficult to know with certainty the significant limiting factors to conservation potential. A few intrinsic factors may limit recovery following a decline, including a low reproductive rate (Hardisty 1971; Fortin et al. 2007) or a lower fecundity relative to other lamprey species (Manion and Hanson 1980; Schuldt et al. 1987). Due to its low fecundity and dispersal abilities, Fortin et al. (2007) postulated that the Northern Brook Lamprey has a low capacity to adapt to changes in its environment. Northern Brook Lamprey may be limited by predation, although ammocoetes may be less vulnerable as they spend most of their time in burrows (Potter 1980b). Cochran (2009) highlighted the possibility that the stocking of nonnative predators (e.g., Brown [*Salmo trutta*] and Rainbow Trout [*Oncorhynchus mykiss*]) has led to the decline in native lampreys. Habitat requirements appear to be quite specific for the success of spawning and ammocoete survival. Furthermore, the species' mobility is limited to passive larval drift (Potter 1980b) and short movement to spawning grounds by adults (Leach 1940). This is not the case for Silver Lamprey, which has a parasitic phase. Mobility constraints may limit the capacity of the Northern Brook Lamprey to recolonize watercourses once extirpated (Fortin et al. 2005) and may limit its capacity for dispersal and range expansion (Morman 1979).

1.5. Threats

1.5.1. Threat Evaluation

Current and anticipated threats to Northern Brook Lamprey conservation are listed in Table 4. Threats were ranked based on their relative impact, spatial extent and expected severity. The threats have been prioritized starting with the greatest perceived threat to the survival of the species based on the strongest evidence. There may be some variability in the severity and level of concern for some threats for individual populations. Most significantly, the use of lampricide appears the main threat in the Great Lakes basin (although some populations do not overlap with the Sea Lamprey and, hence, are exempt from this threat), while habitat degradation and water pollution appear most significant to lamprey in the St. Lawrence system. Threat assessment, particularly where evidence is limited, is an ongoing process linked to both species assessment and, where applicable, management. The threat classification parameters are defined as follows:

Extent – spatial extent of the threat in the species range/waterbody (widespread/localized);
Occurrence – current status of the threat (e.g., current, imminent, anticipated);
Frequency – frequency with which the threat occurs in the species range/waterbody (seasonal/continuous);
Causal Certainty – level of certainty that it is a threat to the species (high/medium/low);
Severity – severity of the threat in the species range/waterbody (high/medium/low); and,
Overall Level of Concern – composite level of concern regarding the threat to the species, taking into account the five parameters listed above (high/medium/low).

Table 4. Threat classification table for Northern Brook Lamprey.

Threat	Extent (widespread/localized)	Occurrence (current, imminent, anticipated)	Frequency (seasonal/continuous)	Causal Certainty (high, medium, low)	Severity (high, medium, low)	Overall Level of Concern (high, medium, low)
Lampricide Applications[1]	Widespread	Current	Seasonal	High	High	High
Habitat Loss or Degradation						
Barriers	Localized	Current	Continuous	High	High	High
Damage/Destruction of Riparian Vegetation	Localized	Current/ Anticipated	Continuous	High	Medium	High
Sediment Loading	Localized	Current/ Anticipated	Continuous	High	Medium	Medium
Contaminant Inputs	Localized/ Widespread	Current	Continuous	Low	Low	Low
Invasive Species	Widespread	Current/ Anticipated	Continuous	Low	Unknown	Low
Climate Change	Widespread	Current/ Anticipated	Continuous	Low	Unknown	Low

[1] Lampricide Applications: Applies only to Northern Brook Lamprey in Ontario.

1.5.2. Threat Description

The primary threats affecting the Northern Brook Lamprey appear to be Sea Lamprey management practices and habitat modification with lesser threats including water quality, invasive species, and climate change. In Quebec, given that the Sea Lamprey is indigenous and is not known to affect game fishes, it is not under control measures. Thus, in Quebec, lampricide application does not represent a threat to Northern Brook Lamprey.

Lampricide Applications: The use of lampricides (3-trifluoromethyl-4-nitrophenol [TFM] and 2′,5-dichloro-4′-nitrosalicylanilide [Bayer 73 or Bayluscide]) targeting Sea Lamprey ammocoetes, is the primary control method used by the SLCC to reduce Sea Lamprey abundance in the Great Lakes basin. Within the Great Lakes – Upper St. Lawrence DU of the Northern Brook Lamprey, the mandate of the SLCC includes the following geographic area as defined by the *Great Lakes Fishery Convention Act*: Lake Ontario (including the St. Lawrence River from Lake Ontario to the forty-fifth parallel of latitude), Lake Erie, Lake Huron (including Lake St. Clair), Lake Michigan, Lake Superior, and their connecting waters. Additionally, tributaries of each of the above waters to the extent necessary to investigate any stock of fish of common concern, the taking or habitat of which is confined predominantly to the Convention Area, and to eradicate or minimize populations of the Sea Lamprey in the Convention Area. The use of lampricide to control Sea Lamprey in the Great Lakes began in 1958 (Applegate et al. 1961).

Lampricide toxicity to native lampreys has been demonstrated (e.g., King and Gabel 1985; Scholefield and Seelye 1992) and lampricide use has inadvertently resulted in a decrease in the distribution of native lampreys throughout the Great Lakes watershed (e.g., Schuldt and Goold 1980). *Ichthyomyzon* ammocoetes (thought to be both Northern Brook Lamprey and Silver Lamprey) were recorded in 47 Canadian tributaries to Lake Superior during the time period of 1953-1972, compared with only 17 during 1973-1977 (Schuldt and Goold 1980). More recent sampling (1989-2013) by the SLCC 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 reestablish after the suspension of lampricide applications. Sampling methodologies have changed over time and may account for some of the observed differences.

Vulnerability of Northern Brook Lamprey to lampricide applications is dependent upon its distribution in relation to Sea Lamprey, particularly, the native lamprey ammocoetes' location relative to the upstream distribution of Sea Lamprey ammocoetes in the system (Schuldt and Goold 1980). In some cases, Northern Brook Lamprey may be less vulnerable to lampricide applications as it is more likely to inhabit headwater areas frequently free of Sea Lamprey, but due to its relative lack of mobility compared to the Silver Lamprey, may be less likely to recolonize from elsewhere following lampricide application. In Lake Superior, native lamprey ammocoetes appeared to be more vulnerable to the effects of lampricide in streams where they were confined to short stretches and where few sources of recruitment were available, and less vulnerable when inhabiting areas above barriers, lentic habitats, difficult to reach locations (e.g., springs, oxbows) and areas that lacked spawning Sea Lamprey (Schuldt and Goold 1980). Due to the extended larval stage of Northern Brook Lamprey, a single lampricide treatment has the potential to eradicate multiple year-classes. Unless there is a dramatic change in Sea Lamprey distribution, it is unlikely that the Sea Lamprey control program effects will impact Northern Brook Lamprey populations beyond current levels (M. Steeves, SLCC, pers. comm. 2014).

Habitat Loss or Degradation: *Barriers* – There are hundreds of dams throughout the range of the Northern Brook Lamprey. Some of these barriers may affect the ability of native lampreys to access previously available habitat (Neave et al. 2007). Barriers have also been constructed to deny Sea Lamprey access to its spawning habitat in tributaries. As lampreys have relatively poor swimming ability, many dams are impassable to the Northern Brook Lamprey, resulting in habitat and population fragmentation, including the loss of spawning areas and habitat used at all life stages. Consequently, available habitat may be reduced, potentially limiting dispersal and natural patterns of gene flow among populations within the species (Schreiber and Engelhorn 1998). Yamazaki et al. (2011) found a reduction in movement and, hence, concern that a reduction in gene flow will occur in subpopulations of a fluvial lamprey inhabiting a paddy water system following the installation of sluice gates. Lucas et al. (2001) raised the additional concern that barriers can delay lamprey movement, possibly making the species more susceptible to predation.

In addition to acting as physical barriers, the impact of dams on hydrologic regimes may disrupt native lampreys, particularly at the ammocoete stage. 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 1980b). Furthermore, altered hydrological characteristics may influence dispersal and movement of Northern Brook Lamprey, particularly ammocoetes.

Under specific conditions, barrier removal has the potential to negatively affect native lamprey populations in the long-term, as dams can protect native lampreys from Sea Lamprey and, more

importantly, from lampricide applications. Smyth (2011) postulated that the removal of the Camp 43 Dam on the Black Sturgeon River (north shore of Lake Superior), could facilitate a decrease in Northern Brook Lamprey abundance. This population of Northern Brook Lamprey resides above the dam but the dam has excluded Sea Lamprey. Hence, removal of the dam would allow Sea Lamprey upstream and subsequent Sea Lamprey control measures, if they were to be applied, would expose the native lampreys to lampricide treatment. The Ontario government has initiated an environmental assessment (2012), which considers the effects of removing the Camp 43 Dam and the possibility of installing a new barrier 50 km upstream that would prevent the Sea Lamprey's full access to the Black Sturgeon River. Based on Sea Lamprey control history, in the long-term, Sea Lamprey can be expected to infest the additional area of the river, irrespective of dam removal and barrier construction, which would expose the entire population of native lampreys to lampricide (M. Steeves, SLCC, pers. comm. 2014).

Damage/Destruction of Riparian Vegetation – River channel modifications through excavation and other techniques could have negative effects on Northern Brook Lamprey, particularly by disrupting spawning grounds and disturbing or destroying ammocoetes. The riparian zone filters and stabilizes river banks and protects the watercourse against fertilizer and pesticide inputs (Société de la faune et des parcs du Québec 2003). These zones also provide shade, an important habitat component for ammocoetes (Potter et al. 1986). The removal or loss of riparian vegetation can lead to soil erosion and hence, increased sedimentation to the river bed, which can alter spawning grounds. These impacts are a major threat to lamprey species (Moyle and Cech 2004).

Sediment Loading – Prevailing water quality concerns related to fish communities include turbidity, nutrients, and toxic compounds. It has been suggested that the loss of riparian vegetation and other alterations that result in increased siltation levels (e.g., deforestation) may threaten native lampreys (Starrett et al. 1960; Fortin et al. 2007). Moderate amounts of sedimentation (e.g., associated with logging) may be beneficial for larval lampreys (particularly in high gradient streams or other sediment-poor areas; Beamish 1998), while excessive sediment inputs likely negatively impact spawning habitat.

Contaminant Inputs – The relative vulnerability of native lampreys to contaminants in water is largely unknown aside from the clear threat associated with lampricide mentioned separately. The sensitivity of the Northern Brook Lamprey to other forms of chemical contamination is unknown. Based on the relative sensitivity of other lamprey species to chemical contaminants, Andersen et al. (2010) found ammocoetes (likely Pacific Lamprey [*Entosphenus tridentatus*] and Western Brook Lamprey [*Lampetra richardsoni*]) were relatively sensitive to pentachlorophenol, of average sensitivity to copper, and relatively insensitive to diazinon, aniline, naphthalene, and lindane compared to other tested aquatic species. Renaud et al. (1998) found that even though lamprey ammocoetes are filter feeders (including the Northern Brook Lamprey collected from tributaries of the St. Lawrence River), 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); no impact on vital function was tested.

The apparent loss of Northern Brook Lamprey from the Yamaska River in Quebec may be related to the use of the herbicide atrazine in surrounding farmland (Renaud et al. 1995). The authors speculated that atrazine run-off was resulting in a reduction in the phytoplankton community, hence reducing the food source for ammocoetes. Lampreys inhabiting the upper St. Lawrence and Great Lakes watersheds continue to be exposed to a variety of pesticides. In the St. Lawrence, those are mainly brought 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 atrazine increased by 57% between 1998 and 2006 (Environment and Climate Change 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 and Climate Change Canada 2013).

Generally, 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 (e.g., Environment and Climate Change Canada 2008a,b and 2009), though a great temporal and spatial variability in contaminant exposure exists within these vast systems. The toxicity of historical contaminants and that of emerging ones that bring new concerns (e.g., flame retardants, plasticizers, hormone disrupting pharmaceuticals and personal care products) on native lampreys is largely unknown. Other water quality issues, such as elevated nutrient levels, are not currently suspected to adversely affect these lamprey species but further understanding, particularly of life history, is required to allow a more confident threat assessment.

Invasive Species: A 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 lead to competition with native lampreys. However, Purvis (1970) suggests that differences in ammocoete growth are mainly caused by a major decrease in lamprey population density following lampricide treatments. The result of this is a decrease in competition for food and space and an increase in growth in the residual population. The COSEWIC report (2007) also states that introduction of the American Brook Lamprey in streams along the north shore of Lake Superior could also pose a threat to the Northern Brook Lamprey in this region because these species rarely coexist (Becker 1983). This introduction and the subsequent expansion of the species' range may cause competition to the detriment of the Northern Brook Lamprey, which is less common. However, there are no data on the disappearance of the Northern Brook Lamprey connected to the introduction of other lamprey species. 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; these trout are much larger than most native fish species, few of which are large enough to feed on large ammocoetes or adult lampreys, and may be a significant predator on several species of lampreys.

Climate Change: While climate change-mediated shifts in the distribution of marine fishes have been observed (e.g., Perry et al. 2005), long-term analysis is lacking for freshwater systems. Climate change is expected to have significant effects on aquatic communities of the Great Lakes and St. Lawrence basins through several mechanisms, including increases in water and air temperatures, lowering of water levels, shortening of the duration of ice cover, increases in the frequency of extreme weather events, emergence of diseases, and shifts in predator-prey dynamics (Lemmen and Warren 2004). Within the St. Lawrence basin, climatic change has altered hydrological regimes and sedimentary dynamics (Boyer et al. 2010) and likely impacted fish recruitment (Hudon et al. 2010). In addition to physical changes to their environment, warming trends, as a result of climate change, may favour the establishment and propagation of potentially harmful invasive species that may currently be limited by cooler water temperatures. As it is at the northern limit of its range, a warming of the water temperature may perhaps allow the Northern Brook Lamprey to expand its distribution. 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 (e.g., Cochran et al. 2012) and of larval drift.

Current and anticipated implications relating to climatic change on Northern Brook Lamprey requires further assessment.

1.6. Actions Already Completed or Underway

Recovery strategies and management plans exist (or are being developed) for co-occurring species and the resulting recovery measures could benefit the Northern Brook Lamprey (e.g., redhorse spp. [*Moxostoma* spp.]; Eastern Sand Darter [*Ammocrypta pellucida*]; Channel Darter [*Percina copelandi*]). Control of the Sea Lamprey is ongoing and control measures have been modified over time in an attempt to lessen negative impacts on native lampreys (e.g., finding alternatives to lampricide). In Ontario, Fisheries and Oceans Canada (DFO) regional Species at Risk Branch has proactively partnered with the DFO Great Lakes Laboratory for Fisheries and Aquatic Sciences, and Sea Lamprey control programs, to develop additional guidance and best management practices (as needed) for Sea Lamprey control program activities, to mitigate any potential impacts to aquatic species at risk. This work has been on-going since 2012-2013 and continued throughout 2013-2014 (D. Balint, DFO, pers. comm. 2013). An investigation of the potential for feeding plasticity in Northern Brook Lamprey and Silver Lamprey is ongoing, with an expected completion date of 2017 (F. Neave, SLCC, pers. comm. 2013). This study will help determine whether Northern Brook Lamprey and Silver Lamprey should be regarded as independent evolutionary units and, therefore, whether the two species should be managed as a single unit, which will influence management actions.

1.7. Knowledge Gaps

Although understanding of the taxonomic distinction between the Northern Brook Lamprey and Silver 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 Northern Brook Lamprey, including a robust distribution map and basic population demographic data, which would allow confident statements on abundance trends. Furthermore, some of the basic biological and habitat needs are poorly characterized. In particular, further understanding of the species' life history, with a particular emphasis on factors that may be limiting its distribution, is needed (e.g., habitat requirements for spawning and larval rearing, and what constitutes habitat fragmentation for this species). Along with a further understanding of population dynamics of the species (e.g., mortality rates), 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 the 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 Northern Brook Lamprey is unknown. Once there is a better understanding of the distribution and biology of Northern Brook Lamprey, a more precise assessment of threats will be possible and additional information may reveal further threats to the survival of the species.

1.8. Federal and Provincial Legislation for Management of Fish Habitat and Fisheries

Canada – In addition to SARA, there are other federal statutes and related regulations that may have direct or indirect application to the management of Northern Brook Lamprey and its habitat within Canadian waters. These include, but may not be limited to, the following:

- *Fisheries Act,* administered by DFO and Environment and Climate Change Canada.
- *Navigable Waters Protection Act*, administered by Transport Canada.
- *Canadian Environmental Assessment Act* (CEAA) 2012, administered by the Canadian Environmental Assessment Agency. In Canada, SARA and CEAA 2012 directly and indirectly address Northern Brook Lamprey management. Section 79 of SARA states that environmental assessments must identify the effects of a project on all species listed at risk in the area. When the CEAA 2012 applies and a species at risk has been identified as a valued ecosystem component within the scope of the review pursuant to that Act, the environmental assessment will take into account any change that might be caused to aquatic species as defined in s.2(1) of SARA. Furthermore, under s.79 of SARA, during an environmental assessment of a project under CEAA 2012, the competent minister must be notified if the project will affect a listed wildlife species.
- *Canada National Marine Conservation Areas Act* (CNMCA), administered by Parks Canada Agency. The establishment of the Lake Superior NMCA is currently under consideration. In 2007, a federal/provincial agreement was signed respecting the establishment of the Lake Superior NMCA. Formal designation under the Act has not yet occurred and the lands, including submerged lands, remain provincial jurisdiction. Once designated, Northern Brook Lamprey habitat located in the Lake Superior NMCA will be subject to the CNMCA and the Minister of the Environment will become a "competent minister" under SARA. According to the CNMCA, marine conservation areas shall be managed and used in a sustainable manner that meets the needs of present and future generations without compromising the structure and function of the ecosystems, including the submerged lands and water column, with which they are associated.

Ontario – In Ontario, several provincial statutes and related regulations may have a direct or indirect application to the management of the Northern Brook Lamprey and its habitat within the province of Ontario. These include, but may not be limited to, the following:

- *Endangered Species Act* (ESA) *2007* (the Northern Brook Lamprey is listed as a Special Concern species under Ontario's ESA, 2007), *Fish and Wildlife Conservation Act*, *Lakes and Rivers Improvement Act*, *Public Lands Act*, *Aggregate Resources Act*, *Crown Forest Sustainability Act*, administered by the Ontario Ministry of Natural Resources and Forestry (OMNRF). Furthermore, subsection 3(5) of the *Planning Act* requires that decisions taken by various bodies "be consistent with" provincial policy statement issued under subsection 3(1) of that Act. Paragraph 2.1.7 of the Provincial Policy Statement, 2014*,* prohibits development and site alteration in the "habitat of endangered species and threatened species except in accordance with provincial and federal requirements". The terms "development" and "site alteration" have a precise definition in the Policy Statement. This will indirectly benefit species of Special Concern that co-habit with Endangered or Threatened species. Subsection 2.1.6 of the Provincial Policy Statement, 2014 prohibits development and site alteration in fish habitat except in accordance with provincial and federal requirements, which may provide some protection to Northern Brook Lamprey habitat.

- *Environmental Assessment Act*, *Environmental Protection Act*, and the *Water Resources Act*, administered by the Ontario Ministry of the Environment.
- *Conservation Authorities Act*, administered by the conservation authorities.

Quebec – Northern Brook Lamprey is indirectly and directly protected by several pieces of provincial legislation and regulations. Specifically, the Northern Brook Lamprey, has had threatened species status since October 2009, under *An Act Respecting Threatened or Vulnerable Species* (CQLR, chapter E-877 12.01), in force in Quebec.

Under the *Quebec Fishery Regulations, 1990,* which results from the *Fisheries Act*, it is forbidden to use any lamprey species as fish bait. Chapter IV.1 (Wildlife Habitats) of *An Act Respecting the Conservation and Development of Wildlife* (RSQ, c C-61.1) also ensures some habitat protection. Section 128.6 of this Act stipulates that "No person may, in a wildlife habitat, carry on an activity that may alter any biological, physical or chemical component peculiar to the habitat of the animal or fish concerned." This Act applies to lands in the domain of the State and includes certain exceptions.

General protection of fish habitat is addressed in the *Environment Quality Act* (EQA), which prohibits the release or emission of contaminants into the environment that may harm wildlife on public and private lands. The EQA also regulates the development and implementation of the Politique de protection des rives, du littoral et des plaines inondables (Protection policy for lakeshores, riverbanks, littoral zones and floodplains) that aims to protect lakes and streams. Under *An Act Respecting Land Use Planning and Development*, minimum standards for development of municipal lands are set. The Agricultural Operations Regulation section of the EQA may also indirectly protect Northern Brook Lamprey habitat as it prohibits free access of livestock to waterbodies and shorelines.

2. MANAGEMENT

The following management goals and objectives, and the actions required to achieve them, were developed based on information provided by the COSEWIC assessment and status report on the Northern Brook Lamprey (COSEWIC 2007) and recent Northern Brook Lamprey survey and research efforts.

2.1. Goal

The long-term goal of this management plan is to ensure the long-term persistence of Northern Brook Lamprey throughout its current and historical ranges in the Great Lakes – Upper St. Lawrence DU. Management should be directed towards ensuring the conservation and restoration of habitat for known populations. However, some separation in management actions is expected for Northern Brook Lamprey in the Great Lakes basin, (where lampricide is applied), compared with the St. Lawrence watershed. Northern Brook Lamprey records are primarily generated through the monitoring program that exists to support Sea Lamprey control. The Sea Lamprey control monitoring program (and lampricide application) is conducted on a rotational basis within the Great Lakes basin. The monitoring program will be a key management tool to allow the control of Sea Lamprey without compromising the conservation of Northern Brook Lamprey. Monitoring generates records for four species (including Silver Lamprey) and co-management approaches can be implemented and enabled through the information that is gathered during monitoring. More quantifiable objectives relating to individual populations will be developed once necessary sampling and analysis have been completed.

2.2. Objectives

The following short-term objectives have been identified to assist in meeting this goal over a five-year period:

i. To conserve and protect extant populations;
ii. To refine understanding of population and habitat trends;
iii. To identify, mitigate and monitor threats impacting the species' survival and conservation;
iv. To maintain, enhance, and where feasible, restore habitat to support Northern Brook Lamprey;
v. To address knowledge gaps and broaden knowledge of the species' biology and ecology to enable and enhance management efforts;
vi. To improve the efficiency of conservation efforts through coordinated actions with other aquatic ecosystem recovery teams and other complementary conservation groups and/or initiatives; and,
vii. To increase public awareness about the importance of biodiversity and healthy aquatic ecosystems, particularly amongst various partners, First Nations, interest groups, organizations and landowners interested in supporting the conservation efforts for Northern Brook Lamprey.

2.3. Actions

In an effort to meet the goals and objectives of the management plan, five strategies will be used, to which recommended actions of Table 5 are linked:

1. Surveys and Monitoring
2. Management and Coordination
3. Research
4. Habitat Protection, Restoration, and Enhancement
5. Outreach and Communication

Many of these actions can and should be performed in conjunction with other recovery and management teams dealing with individual species and ecosystem-based approaches. Ensuring that Northern Brook 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.

2.3.1. Surveys and Monitoring

To obtain a better understanding of Northern Brook Lamprey distribution and population demographics, surveys targeting this species are required on a much wider scale than are currently performed. Surveys should include the use of standardized sampling techniques (see 2.3.3. Research). Added to existing distribution data, survey data will support efforts to plan other management actions. Classification of habitat types is also required. If the sampling protocol targets the ammocoete stage, then it will be necessary to treat the Northern Brook Lamprey and Silver Lamprey as a single unit due to the practical difficulty of species identification at this stage. A standardized index population and habitat monitoring program should be coordinated with existing monitoring programs (e.g., SLCC) where possible. A long-term monitoring program will enable assessments of changes/trends in range, population

distribution and abundance; key demographic characters; and changes/trends in habitat parameters (e.g., temperature and dissolved oxygen levels).

Actions:

1. Conduct background surveys to confirm current status/abundance at sites of known occurrence.
2. Conduct surveys in areas with historical records and in high probability settings.
3. Gather information on population dynamics of Northern Brook Lamprey, integrating the long-term monitoring requirements with existing fish community survey efforts, where possible.
4. Monitor the occurrence, abundance and potential arrival of invasive species in Northern Brook Lamprey habitat. Where possible, this should be coordinated with relevant ecosystem-based programs.

2.3.2. Management and Coordination

Management efforts targeting Northern Brook Lamprey should be coordinated with existing relevant management (e.g., Lake Protection Associations [LPA] and Watershed Committees [WC] in Quebec) First Nations and recovery teams (e.g., Équipe de rétablisssement des cyprinidés et petits percidés [Cyprinidae and Small Percidae Recovery Team] and Équipe de rétablisssement du chevalier cuivré [Copper Redhorse[3] Recovery Team]). Management efforts benefiting Northern Brook Lamprey should be included in integrated management plans where possible (e.g., Lake Superior Lakewide Management Plan).

In Ontario, the chemical control of Sea Lamprey is a key factor in the current condition of Northern Brook Lamprey. In coordination with the SLCC, lampricide treatments will be implemented judiciously, especially in areas of vulnerable native lamprey populations. The inclusion and consideration of native lampreys will be considered within the lampricide treatment Standard Operation Procedures (SOPs)[4]. Alternative, non-chemical Sea Lamprey control measures will be encouraged and supported. In addition, work 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.

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

To prioritize future research, to integrate habitat information, and to coordinate conservation efforts, all available information on Northern Brook 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 des Forêts, de la Faune et des Parcs du Québec (MFFP), the Natural Heritage Information Centre (NHIC) of the OMNRF, Centre de données sur le patrimoine naturel du Québec, and other stakeholders concerned with species and fisheries management.

[3] *Moxostoma hubbsi*
[4] http://www.glfc.org/sealamp/sop.php

Actions:

1. Collaborate and share information between relevant stakeholders, Aboriginal groups, and recovery/management teams (e.g., ecosystem-based recovery teams, watershed organizations and lake protection associations) and governmental authorities (federal, provincial, international, municipal) to address management actions of benefit to Northern Brook Lamprey.
2. Cooperate with the SLCC to continue exploring ways to minimize the negative effects of Sea Lamprey control measures on the Northern Brook Lamprey (e.g., research non-chemical alternatives to lampricide, accelerate efforts designed to minimize deleterious impacts of current lampricide treatment SOPs).
3. Work with dam/water control structure operators to ensure appropriate flow regimes and water depths during periods when the Northern Brook Lamprey is vulnerable.
4. Collaborate with American organizations involved in management actions benefiting the Great Lakes. Favour taking into account ecosystems and species when planning large-scale water level management (e.g., the International Joint Commission's Plan 2007 on the regulation of water levels in Lake Ontario and the St. Lawrence River).
5. Consolidate Northern Brook Lamprey data into existing federal and provincial centralized databases, including habitat parameters, and report on studies and survey results.

2.3.3. Research

The development of standardized protocols for Northern Brook Lamprey sampling (see 2.3.1.Surveys and Monitoring) is required to allow for confident comparisons of population demographics in space and time. Current lamprey sampling methodologies include a method for sampling ammocoetes in regions where backpack electrofishing is impractical due to water depth (see Bergstedt and Genovese 1994) and non-electric fishing methods for ammocoete surveys in small rivers (Lasne et al. 2010). Further understanding of basic life history information is needed to ensure optimal sampling design is developed. Moser et al. (2007) have studied collection and capture techniques for lampreys. Briefly, better information on preferred ammocoete habitat and on the importance of their movement would facilitate the development of an effective sampling program. When sampling is targeting adults, knowledge on the timing of migration and environmental effects on movement is required.

Current knowledge regarding 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 enact adequate and targeted measures, an accurate assessment of the threats and their impacts will be required. It is important to ensure that threats are differentiated by geographic area where necessary. An assessment of instream barriers should be conducted for all watersheds where the Northern Brook Lamprey is known to exist. Barriers should be mapped and their effects on local habitat conditions (e.g., 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 Northern Brook Lamprey.

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

Actions:

1. Develop standardized protocols for surveying and monitoring Northern Brook Lamprey populations.
2. Increase knowledge of Northern Brook Lamprey biology, particularly in knowledge areas currently limiting conservation planning (e.g., habitat requirements for spawning and larval rearing).
3. Determine the quantity and quality of habitat required to ensure long-term conservation of Northern Brook Lamprey and to support the long-term management goal.
4. Conduct threat assessments, to evaluate causes and consequences on the Northern Brook Lamprey (e.g., lampricide treatments, invasive species, barriers); assessments will be updated as new information becomes available.
5. Develop and test mitigation measures associated with identified threats.
6. Resolve taxonomic uncertainties related to Northern Brook Lamprey and Silver Lamprey.

2.3.4. Habitat Protection, Restoration, and Enhancement

Active promotion of stewardship activities will raise community support and awareness of conservation issues regarding Northern Brook 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 (e.g., ecosystem-based recovery programs), to which direction, technical expertise/contacts, and information on financial incentives and funding programs (e.g., existing funding opportunities for private landowners) should be provided. Important activities for habitat improvement includes, Best Management Practices (BMPs) for agriculture, the 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 Northern Brook Lamprey is resident.

Actions:

1. Encourage the implementation of BMPs 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.
2. Promote and prioritize stewardship initiatives (e.g., federal/provincial funding programs) related to Northern Brook Lamprey conservation.

2.3.5. Outreach and Communication

Northern Brook Lamprey is not widely known, especially compared with Sea Lamprey. Northern Brook 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 instil awareness about the need to protect freshwater fishes and ensure the health of freshwater ecosystems.

Actions:

1. Develop Northern Brook Lamprey educational materials, to be included in communication and outreach programs for recovery and conservation of ecosystems and of other species at risk, to promote an awareness about the need to protect

freshwater fishes and ensure healthy aquatic ecosystems (e.g., Hinterland Who's Who program, lamprey identification field guide).
2. Promote awareness with municipal planning offices and planning officials to develop and adopt land management practices that minimize impacts on Northern Brook Lamprey and its habitat.

2.4. Effect on Other Species

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.

2.5. Conservation Actions and Proposed Implementation Schedule

DFO encourages other agencies and organizations to participate in the conservation of Northern Brook Lamprey through the implementation of this management plan. Table 5 summarizes those actions that are recommended to support the management goals and objectives. The activities implemented by DFO 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 action. However, this implementation schedule is intended to be advice to other agencies, and carrying out these actions will be subject to each agency's priorities and budgetary constraints. (Note that the list of participating agencies is not meant to be exhaustive.) The implementation of this plan will be assessed within five years after this plan has been included on the Species at Risk Public Registry (SARA s.72) with the intent to revisit it at similar intervals until the objectives have been achieved.

Table 5. Implementation schedule.

Action	Objectives	Priority	Threats addressed†	Participating agencies††		Approximate timeframe†††
				Ontario	Quebec	
2.3.1. Surveys and Monitoring (populations and habitat)						
1&2. Baseline surveys	ii	Necessary	All	DFO, OMNRF	DFO, MFFP	2015-2020
3. Long-term monitoring	ii	Necessary	All	DFO, OMNRF	DFO, MFFP	2015-2020
4. Invasives monitoring	iii	Beneficial	Exotics	DFO, OMNRF	DFO, MFFP	2015-2020
2.3.2. Management and Coordination						
1, 2, 3&4. Collaboration	vi, vii	Necessary	All	DFO, OMNRF, GLFC, USGS	DFO, MFFP	2016-2021
5. Data management	vi	Beneficial	All	DFO, OMNRF	DFO, MFFP	2016-2021
2.3.3. Research						
1. Protocol development	ii	Necessary	All	DFO, OMNRF	DFO, MFFP	2015-2020
2&6. Species' biology	v	Necessary	All	DFO, OMNRF, AI	DFO, MFFP, AI	2015-2020
3. Habitat quantity and quality determination	iv	Necessary	All	DFO, OMNRF, AI	DFO, MFFP, AI	2015-2020
4&5. Threat evaluation	iii	Necessary	All	DFO, OMNRF, AI	DFO, MFFP, AI	2015-2020
2.3.4. Habitat Protection, Restoration, and Enhancement						

1. Fostering of BMPs	i, iv, vi, vii	Necessary	All	DFO, OMNRF	DFO, MFFP, WC	2015-2020
2. Promotion and coordination of funding opportunities and stewardship activities	i, iv, vii	Necessary	All	DFO, OMNRF	DFO, MFFP, WC	2015-2020
2.3.5. Outreach and Communication						
1. Development and implementation of communication and outreach programs	vii	Necessary	All	DFO, OMNRF	DFO, MFFP, WC	2015-2020
2. Promotion of planning office awareness	iv, vii	Beneficial	All	DFO, OMNRF	DFO, MFFP, WC	2015-2020

† See Section 1.5.2. Threat Description
†† See Section 6. for acronyms
††† Timeframes are subject to change in response to demands for resources.

3. ASSOCIATED PLANS

There are a number of species at risk with ranges overlapping that of Northern Brook Lamprey in Quebec and Ontario (e.g., Eastern Sand Darter; Channel Darter; Copper Redhorse) that have single- or multi-species recovery strategies/management plans in development or completed. Recovery initiatives within these strategies/plans may also provide some benefit for Northern Brook Lamprey. 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, St. Lawrence Action Plan, Fish and Fish Habitat Management Plans, and Source Water Protection Planning. In Quebec, several integrated resource and sustainable development management initiatives are currently underway within the range of the Northern Brook Lamprey, most notably WC, Priority Intervention Zone committees, and LPA.

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6. ACRONYMS

AI	Academic Institutions
BMP	Best Management Practices
CDPNQ	Centre de données sur le patrimoine naturel du Québec. 2013
CEAA	*Canadian Environmental Assessment Act*
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Fisheries and Oceans Canada
DU	Designatable Unit
GLFC	Great Lakes Fishery Commission
LPA	Lake Protection Association
MFFP	Ministère des Forêts, de la Faune et des Parcs du Québec
OMNRF	Ontario Ministry of Natural Resources and Forestry
SARA	*Species at Risk Act*
SEA	Strategic Environmental Assessment
SLCC	Sea Lamprey Control Centre
USGS	United States Geological Survey
WC	Watershed Committee