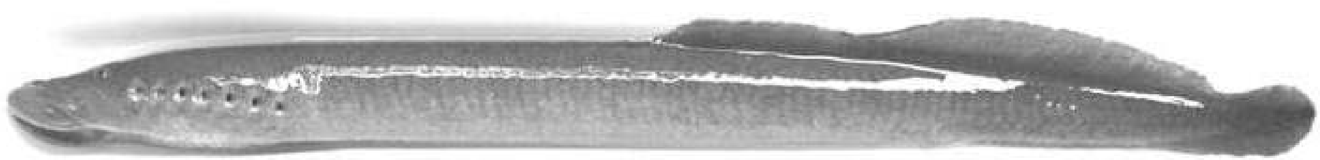
COSEWIC
Assessment and Status Report

on the

Silver Lamprey
Ichthyomyzon unicuspis

Great Lakes - Upper St. Lawrence populations
Saskatchewan - Nelson Rivers populations

in Canada



Great Lakes - Upper St. Lawrence populations - SPECIAL CONCERN
Saskatchewan - Nelson Rivers populations - DATA DEFICIENT
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC. 2009. COSEWIC assessment and status report on the Silver Lamprey *Ichthyomyzon unicuspis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 42 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC acknowledges Fraser B. Neave, Gale A. Bravener, and Nicholas E. Mandrak for writing the provisional status report on Silver Lamprey, *Ichthyomyzon unicuspis*, prepared under contract with Environment Canada. The contractors' involvement with the writing of the status report ended with the acceptance of the provisional report. Any modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status reports were overseen by Dr. Eric Taylor, COSEWIC Freshwater Fishes Specialist Subcommittee Co-chair.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la lamproie argentée, populations des Grands Lacs et du haut Saint-Laurent et populations des rivières Saskatchewan et Nelson (*Ichthyomyzon unicuspis*) au Canada.

Cover illustration/photo:
Silver Lamprey — Adult Silver Lamprey, *Ichthyomyzon unicuspis* (photo by Fraser Neave, with permission).

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COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Silver Lamprey - Great Lakes - Upper St. Lawrence populations

Scientific name
Ichthyomyzon unicuspis

Status
Special concern

Reason for designation
This small parasitic lamprey is found in the Great Lakes – St. Lawrence River basin. The lamprey is susceptible to lampricide treatments that target invasive Sea Lamprey. There are also several other ongoing threats from small dams, habitat alterations, and pollution from herbicide treatments.

Occurrence
Ontario, Quebec

Status history
Designated Special Concern in May 2011.

Assessment Summary – May 2011

Common name
Silver Lamprey - Saskatchewan - Nelson Rivers populations

Scientific name
Ichthyomyzon unicuspis

Status
Data Deficient

Reason for designation
This small parasitic lamprey is thought to be relatively widespread within the Nelson River and Red River watersheds although its status is unknown. Directed surveys for distribution and abundance have not been conducted and data on trends are unavailable. In addition, many occurrence records may be based on larvae where reliable morphological separation from other lampreys is not possible.

Occurrence
Manitoba, Ontario

Status history
Species considered in May 2011 and placed in the Data Deficient category.

COSEWIC
Executive Summary

Silver Lamprey
Ichthyomyzon unicuspis

Great Lakes - Upper St. Lawrence populations
Saskatchewan - Nelson Rivers populations

Species information

The Silver Lamprey (*Ichthyomyzon unicuspis*) is an eel-shaped fish that possesses a sucking disc mouth. Like all lampreys, it does not have jaws or paired fins, and has seven pairs of gill openings. The dentition pattern of adult lampreys is diagnostic to species, and the single dorsal fin helps distinguish *Ichthyomyzon* species from lamprey in other genera. Adult Silver Lamprey range in size from 9 to 39 cm in length. Before spawning, they have grey pigmentation that darkens toward the dorsal side, and are light yellow-tan on the ventral side. Lateral line organs are dark in larger individuals, but colourless in younger, smaller specimens. Larvae ("ammocoetes") of *Ichthyomyzon* species are all very similar to each other morphologically. They appear almost worm-like, as they have no eyes or teeth. They possess an oral hood, rather than the sucking disc-like mouth of the adult form.

Distribution

The Silver Lamprey occurs in freshwater in parts of eastern North America from Québec and New York in the east and from Manitoba to Tennessee in the west. Within Canada, adults have been documented in Ontario, southern Québec, and Manitoba. Their distribution includes the Great Lakes, Lake Nipissing, Nelson River, Ottawa River, and St. Lawrence River watersheds. The Silver Lamprey contains two designatable units (DUs): one in the Great Lakes – St Lawrence River Freshwater Biogeographic Zone (DU1) and one in the Saskatchewan – Nelson Rivers Freshwater Biogeographic Zone (DU2).

Habitat

Silver Lamprey ammocoetes live in burrows in soft stream substrate, usually composed of silt and sand. After metamorphosis, juveniles live within the stream or migrate to larger waterbodies such as larger tributary streams or lakes where transformed individuals feed and grow to maturity. Spawners usually construct nests in shallow riffle areas within streams.

Biology

Silver Lamprey spawn in riffle sections of rivers and streams in the spring, and die shortly thereafter usually at 6-8 years of age. Eggs hatch in approximately two weeks, depending on water temperature. Larvae then drift downstream to calmer waters, and construct shallow burrows from which they filter-feed on microscopic food. After four to seven years, in late summer or fall, the larvae begin a metamorphosis during which they develop eyes and teeth. They emerge from their burrows and may migrate downstream to a lake, and begin their parasitic life stage. Length of newly metamorphosed individuals ranges from 91 to 155 mm.

During the parasitic phase, Silver Lamprey parasitize many different host fish species, attaching themselves with their sucking disc mouth, and feed on flesh and body fluids. They live for between 12 and 20 months as a parasite. Their gonads then begin to mature, they cease feeding, and they undergo a decrease in length and weight and become sexually mature in the spring.

Population sizes and trends

No population estimates have been made, as little effort has been directed at sampling this species. Incidental catch of Silver Lamprey in Sea Lamprey traps suggests some trends, as does the incidental capture of parasitic adults attached to game fishes. Indirect evidence indicates recent abundant populations in areas of Lake St. Clair, and the St. Lawrence River (DU1) and the Nelson Rivers River (DU2). Recent data (from 1989 to 2006, or approximately three generations) indicate low, but relatively stable populations elsewhere. Data collected before this period (i.e., from 1955 to 1975) indicate there were substantially higher catch rates in some parts of the range of DU1 within the Great Lakes, but variation in trapping locations and techniques may have contributed to this apparent decline.

Limiting factors and threats

Key threats to this species include lampricide applications in Great Lakes tributaries (DU1), construction of barriers that limit migration to spawning areas, and pollution (DU1 and DU2). Habitat alteration, siltation, water level fluctuation (DU 1 and DU2), and competition with introduced species (DU1) are other potential threats.

Special significance of the species

Lampreys belong to the most ancestral lineage of vertebrates, and may provide insight into evolutionary pathways (e.g., the transition from jawless to jawed vertebrates). Further research into the Silver Lamprey and the closely related non-parasitic Northern Brook Lamprey may show how different lamprey feeding types have developed. Larval lampreys have been used as biomonitors of contaminant levels and may perform important ecosystem services as filter feeders.

Existing protection

The habitat of the Silver Lamprey is protected to some extent by the federal *Fisheries Act*.

TECHNICAL SUMMARY - Great Lakes - Upper St. Lawrence River populations

Ichthyomyzon unicuspis

Silver Lamprey	Lamproie argentée
Great Lakes – Upper St. Lawrence populations	Populations des Grands Lacs et du haut Saint-Laurent

Range of occurrence in Canada (province/territory/ocean) : Ontario, Québec

Demographic Information

Generation time (average age of parents in the population)	6 yr
Is there an observed, inferred, or projected continuing decline in number of mature individuals?	Unknown, possible in some streams undergoing lampricide treatments
Projected or suspected percent reduction or increase in total number of mature individuals over the next 10 years.	Unknown
Estimated percent of continuing decline in total number of mature individuals within 9 years or three generations.	Unknown
Observed, estimated, inferred, or suspected percent reduction or increase in total number of mature individuals over the last 10 years.	Unknown
Observed, estimated, inferred or suspected percent reduction or increase in total number of mature individuals over any 10 year period including the past and the future. Unknown, but some populations extirpated by lampricide (to treat streams for invasive Sea Lamprey) and herbicide applications.	Unknown
Are the causes of the decline clearly reversible?	Yes, for those streams undergoing lampricide treatments
Are there extreme fluctuations in number of mature individuals?	No. Catch per effort data indicate no clear trend in populations over the past 18 years in the Great Lakes.

Extent and Occupancy Information

Estimated Extent of Occurrence (EO)	511,000 km²
Index of Area of Occupancy (IAO) 2 X 2 km overlaid grid Area of Occupancy (AO) (including lakes) = 1,750 km²	32,962 km² (including lakes)
Is the total population severely fragmented?	No
Number of locations	41 streams and 7 lakes
Is there an observed, inferred, or projected trend in extent of occurrence?	No
Is there an observed, inferred, or projected trend in area of occupancy?	No
Is there an observed, inferred, or projected continuing decline in number of populations? Modest increase from 38 streams to 41 owing to greater detection efforts.	No, appears stable
Is there an observed, inferred, or projected continuing decline in number of locations?	No
Is there an observed, inferred, or projected continuing decline in area, extent and/or quality of habitat?	No
Are there extreme fluctuations in number of populations? Modest increase from 38 streams to 41 owing to greater detection efforts.	No
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No

Are there extreme fluctuations in index of area of occupancy?	No

Number of mature individuals in each population

Population	N Mature Individuals
	Unknown
Total	Unknown

Quantitative Analysis

	Not Applicable

Threats (actual or imminent threats to populations or habitats)

Immediate (known)

- Lampricide treatments of populations co-existing with Sea Lamprey larvae.
- Other sea lamprey control measures (e.g., barriers), stream barriers impeding migration

Immediate (suspected)

- Sedimentation and pollution from land use activities, disruption of water flow from dam operations, competition with invasive Sea Lamprey

Possible

Rescue Effect (immigration from an outside source)

Immigration from US populations in Great Lakes and St. Lawrence River is possible, but seems unlikely as Silver Lamprey are less abundant on the Canadian side of Lake Superior suggesting that streams may be less suitable in Canadian waters.

USA:. In the United States, the Silver Lamprey is currently ranked as critically imperilled (S1) in Nebraska; imperilled (S2) in Kentucky and Tennessee; between imperilled and vulnerable (S2S3) in West Virginia; vulnerable (S3) in Illinois, Iowa and New York; apparently secure (S4) in Indiana, Michigan, Wisconsin and Ohio; and unranked (SNR or S?) in Minnesota, Missouri, North Dakota, Pennsylvania and Vermont.

Is immigration known or possible?	Undocumented, but likely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Yes, likely extensive movement of adults among streams; possibly from streams in US portions of Great Lakes.

Current Status

COSEWIC: Special Concern (May 2011)
NatureServe (NatureServe 2010)

Nature Conservancy Ranks (NatureServe 2010)
Global – G5 (last assessed Globally in 1996)

National
US – N5
Canada N4
Regional
US – Illinois (S3), Indiana (S4), Iowa (S3), Kentucky (S2), Michigan (S4), Minnesota (SNR), Mississippi (S1), Missouri (SNR), Nebraska (S1), New York (S3), North Dakota (SNR), Ohio (S4), Pennsylvania (S1), Tennessee (S2), Vermont (S2?), West Virginia (S2S3), Wisconsin (S4)
Canada – Manitoba (S3), Ontario (S3), Quebec (S3S4)

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** N/A
Reasons for Designation: This small parasitic lamprey is found in the Great Lakes – St. Lawrence River basin. The lamprey is susceptible to lampricide treatments that target invasive Sea Lamprey. There are also several other ongoing threats from small dams, habitat alterations, and pollution from herbicide treatments.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): N/A. No evidence of declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): N/A. Exceeds thresholds
Criterion C (Small and Declining Number of Mature Individuals): N/A. Probably well above thresholds and no evidence of declines.
Criterion D (Very Small Population or Restricted Distribution): N/A. Above thresholds
Criterion E (Quantitative Analysis): Not available.

TECHNICAL SUMMARY - Saskatchewan- Nelson Rivers Populations

Ichthyomyzon unicuspis
Silver Lamprey — Lamproie argentée
Saskatchewan - Nelson Rivers populations — Populations des rivières Saskatchewan et Nelson
Range of occurrence in Canada (province/territory/ocean) : Manitoba, northwestern Ontario

Demographic Information

Generation time (average age of parents in the population)	6 yr
Is there an observed, inferred, or projected continuing decline in number of mature individuals?	Unknown
Projected or suspected percent reduction or increase in total number of mature individuals over the next 10 years.	Unknown
Estimated percent of continuing decline in total number of mature individuals within 9 years or three generations.	Unknown
Observed, estimated, inferred, or suspected percent reduction or increase in total number of mature individuals over the last 10 years.	Unknown
Projected or suspected percent reduction or increase in total number of mature individual's over the next 10 years.	Unknown
Observed, estimated, inferred or suspected percent reduction or increase in total number of mature individuals over any 10 year period including the past and the future.	Unknown
Are the causes of the decline clearly reversible?	Not Applicable
Are there extreme fluctuations in number of mature individuals?	Unknown, but more adults documented since 2001 than all previous years combined

Extent and Occupancy Information

Estimated Extent of Occurrence (EO)	256,000 km²
Area of Occupancy (AO) (including lakes, based on measurements of areas where animals were sampled) Index of Area of Occupancy 2 X 2 km overlaid grid (unable to be mapped owing to logistical issues with GIS-based stream locality data)	2,076 km² Unknown
Is the total population severely fragmented?	No
Number of locations	12 streams and 3 lakes
Is there an observed, inferred, or projected trend in extent of occurrence?	No
Is there an observed, inferred, or projected trend in area of occupancy?	No
Is there an observed, inferred, or projected continuing decline in number of populations?	No, appears stable
Is there an observed, inferred, or projected continuing decline in number of locations?	No
Is there an observed, inferred, or projected continuing decline in area, extent and/or quality of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of mature individuals in each population

Population	N Mature Individuals
	Unknown
Total	Unknown

Quantitative Analysis

	Not Applicable

Threats (actual or imminent threats to populations or habitats)

Variable depending on population; habitat deterioration due to human land use is the major threat, and by inference from reports on other species in the same ecosystem the following are possible threats:

Immediate(known)

- None identified

Potential

- Sedimentation from land use activities, stream barriers preventing migration

Rescue Effect (immigration from an outside source)	Possible
Unknown to what extent animals are distributed or move from US portions of Red River. **Status of outside population(s)?** USA: In the United States, the Silver Lamprey is currently ranked as critically imperilled (S1) in Nebraska; imperilled (S2) in Kentucky and Tennessee; between imperilled and vulnerable (S2S3) in West Virginia; vulnerable (S3) in Illinois, Iowa and New York; apparently secure (S4) in Indiana, Michigan, Wisconsin and Ohio; and unranked (SNR or S?) in Minnesota, Missouri, North Dakota, Pennsylvania and Vermont	
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Possible

Current Status

COSEWIC: Data Deficient (May 2011)

Nature Conservancy Ranks (NatureServe 2010)

Global – G5 (last assessed Globally in 1996)

National

US – N5

Canada N4

Regional

US – Illinois (S3), Indiana (S4), Iowa (S3), Kentucky (S2), Michigan (S4), Minnesota (SNR), Mississippi (S1), Missouri (SNR), Nebraska (S1), New York (S3), North Dakota (SNR), Ohio (S4), Pennsylvania (S1), Tennessee (S2), Vermont (S2?), West Virginia (S2S3), Wisconsin (S4)

Canada – Manitoba (S3), Ontario (S3)

Status and Reasons for Designation

Status: Data Deficient	**Alpha-numeric code:** N/A
Reasons for Designation: This small parasitic lamprey is thought to be relatively widespread within the Nelson River and Red River watersheds although its status is unknown. Directed surveys for distribution and abundance have not been conducted and data on trends are unavailable. In addition, many occurrence records may be based on larvae where reliable morphological separation from other lampreys is not possible.	

Applicability of Criteria:

Criterion A (Decline in Total Number of Mature Individuals): N/A, no estimates available
Criterion B (Small Distribution Range and Decline or Fluctuation): N/A. Exceeds thresholds
Criterion C (Small and Declining Number of Mature Individuals): N/A. Probably well above thresholds and data to evaluate possible declines.
Criterion D (Very Small Population or Restricted Distribution): N/A. Unknown largely, but probably above thresholds
Criterion E (Quantitative Analysis): Not available.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2011)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Silver Lamprey
Ichthyomyzon unicuspis

Great Lakes - Upper St. Lawrence populations
Saskatchewan - Nelson Rivers populations

in Canada

2011

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SPECIES INFORMATION

Name and classification

Kingdom: Animalia
Phylum: Chordata
Superclass: Petromyzontomorphi (Nelson 2006)
Class: Petromyzontida (Nelson 2006)
Order: Petromyzontiformes
Family: Petromyzontidae
Scientific name: *Ichthyomyzon unicuspis* Hubbs and Trautman 1937
English common name: Silver Lamprey
French common name: lamproie argentée (Nelson et al. 2004)

The Silver Lamprey is one of six recognized species in the genus *Ichthyomyzon*. The six species are composed of three pairs of closely related parasitic ("stem") and non-parasitic ("satellite") species (Vladykov and Kott 1979a). This relationship was originally deemed "paired species" by Zanandrea (1959) before it was expanded to include multiple non-parasitic derivatives. The non-parasitic Northern Brook Lamprey, *I. fossor*, is considered a smaller-sized ("dwarfed"), recently derived relative of the larger, parasitic Silver Lamprey (Hubbs and Trautman 1937; Potter 1980a) from which its genetic distinction, as expected, is slight (see below). Silver (*Ichthyomyzon unicuspis*) and Northern Brook (*I. fossor*) lampreys are considered distinct species in all lamprey taxonomic accounts (from Hubbs and Trautman 1937 to Nelson *et al*. 2004) using traits (tooth counts and morphology, myomere counts, body size) that are the foundation of lamprey taxonomy and systematics (reviewed in Renaud et al. 2009). For instance, paired lamprey species in general have traditionally been given species status because size differences between the parasitic and non-parasitic types are thought to promote some degree of reproductive isolation (Hardisty and Potter 1971; Beamish and Neville 1992). Recent molecular data (e.g.,Mandrak et al. 2004; Docker et al. 2005; Filcek et al. 2005; McFarlane 2009) have shown that Silver and Northern Brook lampreys are not reciprocally monophyletic, lack fixed species-specific differences in their mitochondrial genome, and show little to no genetic differentiation at microsatellite loci when they occur sympatrically. While these data suggest that Silver and Northern Brook lampreys may not be recognized as distinct *phylogenetic* species (i.e., that different Northern Brook Lamprey populations may have evolved independently), the lack of genetic differentiation observed to date at neutral loci suggests *either* ongoing gene flow (i.e., lack of reproductive isolation) *and/or* very recent divergence and incomplete lineage sorting (McFarlane 2009).

The situation described above is not, however, uncommon for other closely related parasitic and non-parasitic lamprey taxa. For example, no differences in mitochondrial DNA sequence were detected between the River Lamprey (*Lampetra ayresii*) and the Western Brook Lamprey (*L. richardsoni*) (Docker et al. 1999; Meeuwig et al. 2002), and Schreiber and Engelhorn (1998) concluded that there must be some degree of gene flow between the European Brook Lamprey (*L. planeri*) and the European River

Lamprey (*L. fluviatilis*) due to a lack of allozyme differentiation between the two species. Espanhol et al. (2007) conducted an extensive study on mitochondrial DNA of these same paired species, and concluded that the European Brook Lamprey has had multiple origins; they further suggested that these two taxa could either be alternate life-history forms of the same species, or have very recently (and repeatedly) diverged from each other. Salewski (2003) reviewed speciation in lampreys and argued that satellite lamprey species are an example of speciation in progress. Consequently, large genetic differences at neutral loci (e.g., microsatellites and mitochondrial DNA) may not be expected.

These studies demonstrate the genetic similarity of many paired species, and suggest that some paired species have either separated very recently, are capable of hybridizing, or that feeding type is not genetically determined (Docker 2009). Plasticity of feeding type has been suggested in some lampreys, where feeding has been observed or inferred in some normally non-parasitic species (e.g., Beamish 1987; Cochran 2008) or some individuals of normally parasitic species appear to mature without feeding after metamorphosis (e.g., Kucheryavyi et al. 2007). An investigation is currently underway where both Northern Brook Lamprey and Silver Lamprey will be artificially spawned and reared through metamorphosis in varying environmental conditions to determine if variation from the parental feeding type is possible in these species (Neave and Docker, unpublished). Successful hybridization experiments have been performed between both Northern Brook Lamprey and Silver Lamprey (Piavis et al. 1970), but the offspring were not raised beyond stage 17 (burrowing prolarvae) that occurs a few weeks after fertilization, and the reproductive capacity of the offspring of these crosses is unknown.

By contrast, Silver et al. (2004) reported that gonadotropin-releasing hormone III cDNA differed by 11.2% between the Silver and Northern Brook lampreys, indicating genetic distinctiveness at a functional locus perhaps linked to size and trophic differences between the species. Both species differed from the Sea Lamprey (*Petromyzon marinus*) by from 4.6-11.0% at this same locus (Silver et al. 2004). Interestingly, a phylogenetic analysis at this locus indicated that the Silver and Northern Brook lamprey were not each other’s closest relative; the Northern Brook Lamprey was most closely-related to another non-parasitic lamprey – the Western Brook Lamprey (*Lampetra richardsoni*) – from the eastern Pacific basin, while the Silver Lamprey was most closely-related to a group of three other parasitic lampreys (Silver et al. 2004).

In summary, critical data are needed on the heritability of feeding type in Silver and Northern Brook lampreys (e.g., common garden and reciprocal transplant studies and investigation of other genes involved in feeding and development) to conclusively assess their status as distinct biological species. The most recent review of paired species taxonomy and systematics in lampreys by Renaud et al. (2009) concluded that "until strong evidence rejects the hypothesis that parasitic and nonparasitic members of a paired species represent distinct species, however, we continue to follow conventional taxonomy recognizing them as distinct."

Prior to the publication of Hubbs and Trautman (1937) in which the name *I. unicuspis* was designated, most authors were using Kirtland's name *Ammocoetes concolor* (Scott and Crossman 1998).

Morphological description

The Silver Lamprey is a jawless, eel-shaped fish, characterized by its sucking disc type of mouth and lack of paired fins (Figure 1). Adults are moderately large lamprey, somewhat more laterally compressed than other species (Scott and Crossman 1998). They can reach up to 392 mm in length as adults, as seen in Wisconsin (Cochran and Marks 1995), but are typically smaller in Canadian waters. Vladykov and Roy (1948) found maximum length to be 318 mm in specimens captured from the St. Lawrence River system. Average length of spawning Silver Lamprey has been reported as 248 mm (range 157-308 mm) in Michigan (Morman 1979), 224 mm across various U.S. states (Hubbs and Trautman 1937), and 255 mm in Québec (Vladykov 1951). Trunk myomere counts range between 47 and 55 (Hubbs and Trautman 1937). They have small eyes and seven pairs of gill openings. The three *Ichthyomyzon* lamprey species found in Canada can be distinguished from Sea Lamprey by the presence of a single dorsal fin. The adult Silver Lamprey can be distinguished from other *Ichthyomyzon* by characteristic tooth patterns: usually two supraoral cusps, 5-11 infraoral cusps, four unicuspid teeth in each of the lateral circumoral rows (if present, less than three bicuspid teeth in total (Renaud pers. comm. 2006)), two to four anterior teeth, and five to eight lateral teeth rows (Hubbs and Trautman 1937; Vladykov and Kott 1980).

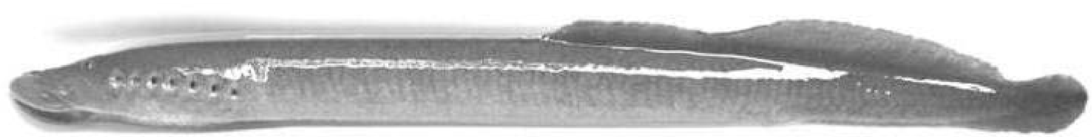

Figure 1. Adult Silver Lamprey, *Ichthyomyzon unicuspis* (photo by Fraser Neave, with permission).

Maturing males have a mid-dorsal ridge that is always present, but not always prominent, and the urogenital papilla occasionally extends beyond the ventral margin of body. Maturing females have a prominent post-anal fold, and their body is greatly distended from behind the gill region to the cloaca (Becker 1983).

Before spawning, the adult is usually a light yellow-tan colour on the ventral side, with grey pigmentation, that gradually darkens toward the dorsal side (Hubbs and Trautman 1937). Large, sexually mature individuals exhibit general darkening to blue or blue-grey on the sides and back, and pronounced greyish or bluish pigmentation on the lower surfaces. The lateral line organs are colourless in young metamorphosed individuals but become darker in specimens greater than 170 mm (Vladykov 1949). Vladykov (1949) also noted that no silvery colouration was observed based on hundreds of adult Silver Lamprey specimens collected in Québec.

The larvae, known as ammocoetes, vary little morphologically within *Ichthyomyzon*. They lack eyes and teeth, and possess an oral hood, in contrast to the sucking disc mouth of the adult (Scott and Crossman 1998). Ammocoetes within the genus are generally indistinguishable from one another (Hubbs and Trautman 1937; Thomas 1963; Morman 1979); however, large ammocoetes (>105 mm) of the Chestnut Lamprey (*I. castaneus*) begin to develop pigmentation in their lateral line organs that appear as dark spots, but this pigmentation character is not diagnostic. The presence of dark spots along the sides indicates that the ammocoete is a Chestnut Lamprey, but its absence (particularly in small individuals) does not reliably indicate that it is a Silver or Northern Brook lamprey (Neave 2004). All other features of larval Chestnut Lamprey are very similar to Silver Lamprey ammocoetes (Neave et al. 2007).

Northern Brook Lamprey and Silver Lamprey ammocoetes have been differentiated from each other by using differences in pigmentation patterns in the branchial region (Lanteigne 1981, Lanteigne 1988; Stewart and Watkinson 2004) and tail (Vladykov and Kott 1980; Fuiman 1982). Some of these keys, however, are contradictory (e.g. Vladykov and Kott 1980; Lanteigne 1988), and other authors have found differences between pigmentation and other external features of ammocoetes of these paired species unreliable or non-existent (Purvis 1970; Morman 1979; Becker 1983; Neave et al. 2007).

Silver Lamprey adults differ from Northern Brook Lamprey adults in that they are usually over twice the length, and although their tooth patterns (number and arrangement of rows) are similar, the Silver Lamprey has more prominent teeth. Silver Lamprey are larger (usually 85-392 mm in total length versus 86 – 166 mm total length in the Northern Brook Lamprey), much more fecund, and tend to be found in larger streams than Northern Brook Lamprey. Furthermore, Northern Brook Lamprey usually remain within streams and are non-parasitic, whereas Silver Lamprey migrate to lakes to parasitize fishes (Scott and Crossman 1998). Appendix 1 outlines further differences between Silver Lamprey and Northern Brook Lamprey.

Spatial population structure and variability

In terms of genetic structure among Silver Lamprey populations, there is likely some degree of gene flow among populations inhabiting different streams because Silver Lamprey are migratory and potentially non-homing (see **Dispersal/Migration** section). Dispersal and gene flow, within some streams, however, may be limited by physical impediments such as natural and artificial barriers (Schreiber and Engelhorn 1998), and geographic variation in the distribution of mitochondrial haplotypes was observed in Silver Lamprey (Mandrak et al. 2004; Docker et al. 2005). Mandrak et al. (2004) found an east-to-west gradient with respect to the distribution of the five most common haplotypes, four belonging to the most common A lineage and one belonging to the rarer B lineage, two lineages found with > 99% boostrap support. This geographic pattern was confirmed by Docker et al. (2005), with an additional 101 Silver Lamprey and 279 additional Northern Brook Lamprey. In particular, the proportion of Silver Lamprey belonging to lineage B declined in an east-to-west fashion (representing 50, 10, 2, and 0% in lakes Ontario, Huron, Michigan, and Superior, respectively; Docker et al. 2005). It may be that the two observed mitochondrial lineages represent different postglacial recolonization routes (see **Designatable Units** section). Assuming an overall rate of mitochondrial DNA sequence divergence of 2% per million years calculated for several mammalian species (Brown et al., 1979) and used to estimate divergence times in a variety of fish taxa (see Billington and Hebert, 1991), a 0.12% divergence between lineages A and B suggests that they diverged approximately 60,000 years ago (Docker pers. comm. 2008) broadly consistent with isolation during the most recent glacial advance.

The RFLP assays described above (which recognize the five most common haplotypes of Silver Lamprey in the Great Lakes Basin) have been applied to 15 Silver Lamprey from the atchewan-Nelson Rivers watershed (Docker, unpublished data). All 15 were designated haplotype A1, i.e. belonging to the common A lineage and corresponding to the same haplotype as was found in 22% of all Great Lakes Silver Lamprey (and 49% of all Great Lakes Northern Brook Lamprey).

Designatable units

The Silver Lamprey likely survived the most recent Wisconsinan glaciation in the Mississippi Refugium and re-colonized its Canadian range from either or both of the Brule-Portage or Chicago postglacial dispersal routes (Mandrak and Crossman 1992). This has resulted in Canadian populations being present in two national freshwater biogeographic zones (NFBZ) used, in part, by COSEWIC for designatable unit (DU) recognition: Great Lakes-Upper St. Lawrence River, and Saskatchewan-Nelson Rivers. The occupancy within two NFBZ reflects isolation within distinct geographic regions with distinct fish faunal communities assemblages. Further, allthough sample sizes obtained for DU2 are small (N = 15), the two areas differ significantly (P = 0.0001, contingency test) in the frequency of four mtDNA haplotypes; DU1 (N = 155) exhibits four haplotypes (“A1”, “A2”, “A4” and “B1”) while DU2 is fixed for a single haplotype (“A1”, Docker et al. 2005). In addition, there is a large distribution gap between the most northwesterly occurrence record in DU1 and the easternmost locality in DU2 (Figures 5,6) and the ecological and environmental conditions experienced by Silver Lampreys in these two NFBZ that stretch from the lower Nelson River near Hudson Bay to the upper St. Lawrence River estuary are undoubtedly quite distinct. Loss of Silver Lamprey in either of these DUs, therefore, would result in a significant gap in the range of the species in Canada and its loss in distinctive ecological areas. For these reasons, the Silver Lamprey satisfies the discrete and significance criteria fro the recognition of two DUs: Great Lakes-Upper St. Lawrence (DU1), and Saskatchewan-Nelson Rivers (DU2).

SPECIAL SIGNIFICANCE

Living lampreys are descended from the most ancestral line of vertebrates and provide insight into the origins and evolution of vertebrates, as they have existed for over 360 million years (Gess et al. 2006). Lampreys have been used extensively in laboratory studies on numerous subjects, such as developmental biology and neurobiology (Moyle and Cech 2004). Due to their sedentary nature, larval lampreys have been used as biomonitors of organochlorine contaminants in fresh water (Renaud et al. 1995; Renaud et al. 1999) and, more generally, probably provide important ecosystem services in aquatic habitats (e.g., Holmlund and Hammer 1999). Silver Lampreys have been reported from Great Lakes' fish markets historically and are important components of predator-prey relationships for native fishes (Scott and Crossman 1998). Further study of the Silver Lamprey and its non-parasitic sister species, the Northern Brook Lamprey, may provide insight into the evolution of alternate feeding strategies, speciation, and could lead to new ways of controlling the invasive Sea Lamprey.

DISTRIBUTION

Global range

The distribution of Silver Lamprey is restricted to eastern North America (Figure 2). In the United States, the Silver Lamprey has been reported from Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Nebraska, New York, North Dakota, Ohio, Pennsylvania, Tennessee, Vermont, West Virginia, and Wisconsin (NatureServe Explorer 2006). The distribution of the Silver Lamprey may well be more widespread than indicated by existing records because of the difficulty in collecting and identifying ammocoetes, and in collecting adults (Becker 1983). The specialized equipment and techniques required to efficiently collect lampreys from streams have not often been used outside of the Great Lakes basin. The widely used electrofishing surveys that target multiple species of fishes rarely collect larval lampreys, as the ammocoetes tend to become immobilized within their burrows. Pulsed DC electrical current is used in lamprey-specific electrofishing surveys because it is much more successful at influencing emergence of burrowed larvae (Weisser and Klar 1990; Bowen et al. 2003). Adult spawning phase Silver Lamprey are occasionally collected in Sea Lamprey traps, and adult feeding phase individuals are taken as incidental catch by commercial and occasionally recreational fishing gear in the Great Lakes. Because, however, they are a non-target catch in both trapping and commercial fishing, the potential for both capturing and reporting them is markedly lower than that of the targeted species. The non-parasitic Northern Brook Lamprey and one other species in this genus, the parasitic Chestnut Lamprey have overlapping ranges with Silver Lamprey (Vladykov and Kott 1979b). The American Brook Lamprey (*Lampetra appendix*) and the invasive Sea Lamprey also overlap with the Canadian distribution of the Silver Lamprey (Scott and Crossman 1998).

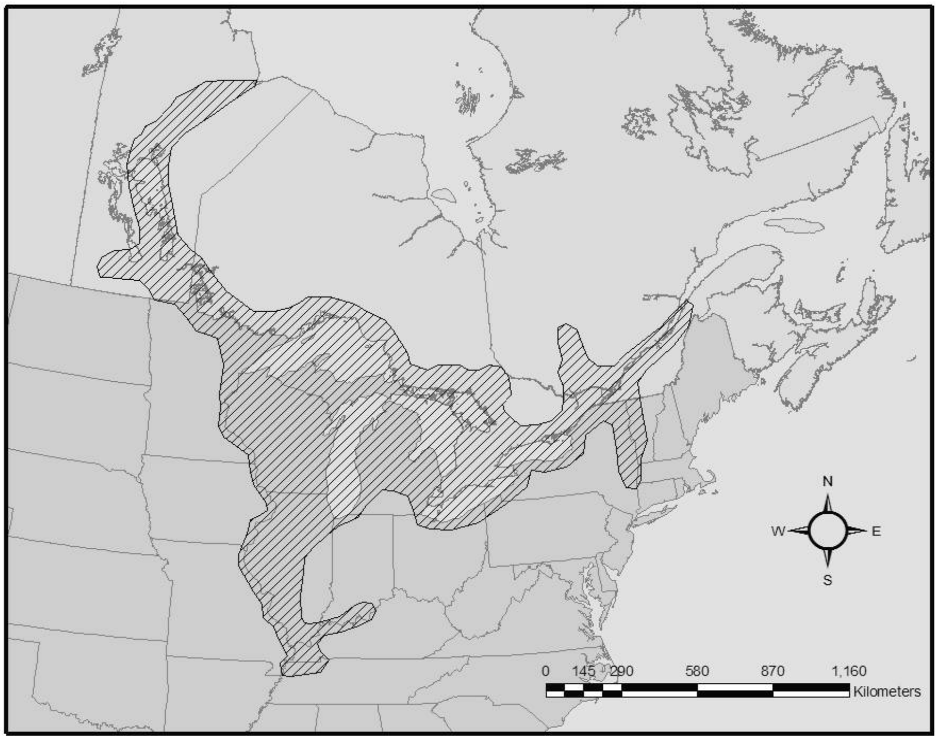

Figure 2. Distribution of the Silver Lamprey in North America.

To obtain a better understanding of Silver Lamprey distribution, surveys that specifically target lamprey species are required on a much broader scale than they are currently performed. Streams within the Great Lakes basin have been sampled more intensively by the Department of Fisheries and Oceans, Sea Lamprey Control Centre (SLCC) due to regular and specialized assessment for invasive Sea Lamprey ammocoetes and adults. Even within the Great Lakes basin, however, survey activities are normally restricted to assessment within streams (and not within lakes), and those streams that support Sea Lamprey receive the overwhelming majority of the sampling effort (Cuddy pers. comm. 2006). In Canada, adults have been found in streams in Ontario, southern Québec and Manitoba. Increased sampling efforts have revealed more streams over the past several years in Ontario (SLCC unpub. data). The widespread occurrence of *Ichthyomyzon* larvae may indicate a much wider distribution of Silver Lamprey, but collection of adults or transformed juveniles is required to confirm identification, as some of these larvae are very likely Northern Brook Lamprey. Between 1989 and 2007 (approximately three generations), adults or juveniles of this species have been found in 58 stream systems in Canada (Table 1).

Table 1. Occupied area of inland lakes and tributaries in Canada with adult or metamorphosed Silver Lamprey detected between 1989 and 2007.

Watershed Name	Stream Name	Occupied Area (km^2)
Great Lakes – Upper St. Lawrence River DU		
Lake St. Clair*	St. Clair R.	101.00
Lake Erie*	Big Cr.	1.14
Lake Erie	Young's Cr.	0.03
Lake Huron*	St. Mary's R.	11.13
Lake Huron	Garden R.	0.14
Lake Huron	Echo R.	0.18
Lake Huron	Koshkawong R.	0.01
Lake Huron	Thessalon R.	0.25
Lake Huron	Spanish R.	10.32
Lake Huron	French R.	2.50
Lake Huron	Musquash R.	0.35
Lake Huron	Coldwater Cr.	0.11
Lake Huron	Sturgeon R.	0.02
Lake Huron	Hogg Cr.	0.02
Lake Huron	Nottawasaga R.	2.75
Lake Huron	Beaver R.	0.02
Lake Huron	Bighead R.	0.37
Lake Huron	Saugeen R.	0.48
Lake Nipissing*	South R.	0.52
Lake Nipissing	Chippewa Cr.	0.02
Lake Ontario	Humber R.	0.10
Lake Ontario	Bowmanville R.	0.06
Lake Ontario	Cobourg Br.	0.01
Lake Ontario	Shelter Valley Cr.	0.01
Lake Ontario	Salmon R.	0.13
Lake Superior*	Big Carp R.	0.01
Lake Superior	Carp R.	0.07
Lake Superior	Pancake R.	0.07
Lake Superior	Neebing-McIntyre R.	0.44
St. Lawrence River	Gatineau R.	1.28
St. Lawrence River	Ottawa R.	190.00
St. Lawrence River	Rivière Blanche	0.50
St. Lawrence River	Rivière du Lièvre	1.22
St. Lawrence River	Rivière Petite Nation	1.00
St. Lawrence River	Lac Saint-Pierre*	365.00
St. Lawrence River	Lac St-Louis*	154.00
St. Lawrence River	Rivière L'Assomption	2.50
St. Lawrence River	Rivière Richelieu	5.00
St. Lawrence River	Ruisseau Hinchinbrook	8.00
St. Lawrence River	Saint-François R.	1.50
St. Lawrence River	St. Lawrence R.	890.00
St. Lawrence River	Rivière Petite Nation	1.00
Lake Champlain	Pike R.	0.35
Saskatchewan-Nelson Rivers DU		
Nelson River	12-Mile Cr.	0.05
Nelson River	Seal Cr.	-----
Nelson River	Assiniboine R.	-----
Nelson River	Berry Cr.	3.00
Nelson River	Burntwood R.	15.00
Nelson River	Gull Lake	52.00
Nelson River	Limestone R.	9.00

Watershed Name	Stream Name	Occupied Area (km^2)
Nelson River	MacMillan Cr.	0.10
Nelson River	Nelson R.	811.00
Nelson River	Pinawa Channel	99.00
Nelson River	Rainy R.	150.00
Nelson River	Split Lake	372.00
Nelson River	Stephens Lake	374.70
Nelson River	Winnipeg R.	190.00
Red River	Rat River	------

*Also found in the lake proper

Great Lakes- Upper St. Lawrence River DU

Silver Lamprey were documented in 41 streams and 7 lakes in the Great Lakes-Upper St. Lawrence DU (Lake Ontario, Lake Huron, Lake Superior, Lake Erie, Lake St. Clair, Lake Nipissing, Lac St. Pierre and Lac St. Louis) from 1989-2007 (Table 1). These numbers are slight increases compared to the previous 18 year period because increased efforts have resulted in additional populations being documented recently.

Between 1989 and 2007 SLCC has documented 68 streams throughout the Canadian side of the Great Lakes with *Ichthyomyzon* ammocoetes (Appendix 3); however, these individuals were not identified to species because of the previously mentioned identification problems. It is strongly suspected that due to their upstream location within many stream systems (as reasoned in Schuldt and Goold 1980); many of these populations of *Ichthyomyzon* ammocoetes are Northern Brook Lamprey. As Silver Lamprey are migratory in nature and usually swim downstream to large rivers or lakes for the parasitic phase of their life cycle (Scott and Crossman 1998), it is unlikely that larvae found above barriers are migratory (Silver) lamprey (Schuldt and Goold 1980). Some Silver Lamprey populations, however, have been documented above barriers where sufficient conditions exist (see **Adaptability** section). Adult Silver Lamprey have been identified in 18 of these 68 Great Lakes streams since 1989. Sampling efforts targeting metamorphosed or adult lampreys are required to unequivocally determine whether Silver Lamprey are present in the remaining 50 streams.

The five Great Lakes have a total area of 244,160 km^2. The Canadian portion is approximately 87,500 km^2 (Fuller et al. 1995). Based on information provided by commercial fishermen, adult Silver Lamprey have been collected in at least 10 of 29 Canadian fishery statistical districts in the Great Lakes since 1989 (SLCC unpub. data), providing evidence that Silver Lamprey inhabit the Great Lakes proper. The combined area of these 10 statistical districts is about 30,500 km^2.

The extent of occurrence was calculated using a polygon composed of concave angles and containing all collection locations within each DU. In-stream areas of occupancy (Table 1) were determined using average stream width, and stream length (using the distance from the furthest upstream collection down to the stream mouth) which have been suggested as reasonable for linear aquatic habitats (Mace et al. 2008). Data such as stream length, width and area had not previously been quantified for all waterbodies that contain Silver Lamprey, so these missing measurements were calculated using GIS software (ESRI ArcGIS 9.1) based on available geographic information. The extent of occurrence and area of occupancy (2 x 2 km grid) for the Great Lakes-Upper St. Lawrence DU are 511,000 km^2 and 1,750 km^2, respectively. If all inhabited lakes and the ten districts of the Great Lakes are included, the area of occupancy is 32,962 km^2.

Saskatchewan-Nelson Rivers DU

Silver Lamprey have been detected and 12 streams and three lakes (Gull Lake, Stephens Lake, and Split Lake) in the Saskatchewan-Nelson Rivers DU in Manitoba and northwestern Ontario, again representing a slight increase in occurrence records from the previous 18 year period. The index of area of occupancy was not able to be mapped owing to logistical issues with the stream location data (A. Filion, COSEWIC Secretariat, Ottawa, pers. comm. 2008). The extent of occurrence and biological area of occupancy for the Saskatchewan-Nelson Rivers DU are 256,000 km^2 and 2,076 km^2, respectively.

HABITAT

Habitat requirements

The Silver Lamprey requires clear water to allow the parasitic phase to locate fish hosts, relatively clean stream substrate composed of sand and organic debris for ammocoete habitat, and unrestricted migration routes for spawners (Trautman 1981). They have several requirements for spawning, including gravel and sand to build their nests (Trautman 1981; Scott and Crossman 1998). They prefer habitats with swift-flowing, unidirectional water current over intermediate-sized gravel and sand substrate (Carpenter et al. 1987; Manion and Hanson 1980). They require water velocities of 0.5-1.5 m/s and a small amount of silt-free sand or some other fine material to which the eggs can adhere (Manion and Hanson 1980).

The Silver Lamprey requires water temperatures of about 18°C for eggs to develop, hatch and reach the burrowing stage of development (Smith et al. 1968). After ammocoetes leave the nest and drift downstream they require sediment consisting of sand, silt, and organic debris (Becker, 1983; Trautman 1981). It has also been noted that clay is usually absent from ammocoete habitat (Becker 1983).

After metamorphosis, the newly parasitic individuals drift downstream, where they require larger waterbodies containing a greater supply of suitable host fishes on which to feed (Trautman 1981; Scott and Crossman 1998). These waterbodies are usually large rivers and lakes (Vladykov 1949).

Schuldt and Goold (1980) reported Silver Lamprey residing in Lake Superior streams with average summer discharges from 0.03 m^3/s to 28 m^3/s and in rivers associated with bays. Morman (1979) reported Silver Lamprey collections in Michigan from streams with discharges from 0.06 m^3/s to 34 m^3/s. More recent data for Canadian Great Lakes tributaries with Silver Lamprey exhibit a wide range in mean summer discharges, ranging from 0.10 m^3/s to 72.27 m^3/s, with an average value of 8.07 m^3/s (SLCC, unpub. data). These data exclude the St. Mary's River and St. Clair River (where Silver Lamprey have been collected) that have average annual discharges of about 2100 m^3/s and 5097 m^3/s, respectively (Edsall and Charlton 1997).

Other studies have examined habitat requirements of other species that may apply to Silver Lamprey. Potter et al. (1986) indicated that organic matter, chlorophyll *a*, macrophyte roots and low-angle shading are important habitat characteristics for Australian Lamprey (*Geotria australis*) larvae. Beamish and Jebbink (1994) found that small larvae of the Southern Brook Lamprey (*I. gagei*) preferred a higher percentage of fine sand in their habitat than did larger larvae. Beamish and Lowartz (1996) determined that larval American Brook Lamprey densities were correlated to the amount of sand and organic matter in the stream substrate.

Habitat trends

In Canada, the Silver Lamprey in both DUs occurs in many areas that have undergone extensive deforestation due to logging and agriculture. No studies exist, however, that specifically examine changes in lamprey habitat over time. The construction of dams has probably prevented Silver Lamprey access to spawning and larval habitat in some river systems (see **Threats and Limiting Factors** section).

Habitat protection/ownership

In Canada, all freshwaters and associated fish habitat within these waters are covered by the federal *Fisheries Act* that provides some protection. Provincial laws also protect the habitat of this species (e.g. in Québec freshwaters are protected on public lands by the *Loi sur la conservation et la mise en valeur de la faune* (Act respecting the conservation and development of wildlife)).

BIOLOGY

Schuldt and Goold (1980) and Schuldt et al. (1987) reported on the biology of the Silver Lamprey from lakes Superior and Michigan, respectively; Hubbs and Trautman (1937) studied Silver Lamprey in Michigan; Vladykov (1949, 1951, 1952) and Renaud (2002) studied the species in Québec; Wilson (1955) conducted work on Lake Champlain; and Roy (1973) studied behaviour and biology in the laboratory. Scott and Crossman (1998) also provide a review of the biology of this species. What follows is a general description of the species' biology based on studies of Silver Lamprey within DU1 or in adjacent areas of the US; there have been no targeted biological studies of the species in DU2.

Life cycle and reproduction

Silver Lamprey are semelparous (i.e., they spawn only once during their lifetime). Upon reaching sexual maturity at, on average, six years of age, and depending on water temperatures and other factors, Silver Lamprey begin their spawning migration. They ascend large rivers in the spring when water temperatures reach 10°C or higher (May to June), where they spawn in shallow nests and subsequently die (Vladykov 1949; Trautman 1981; Scott and Crossman 1998). Manion and Hanson (1980) reported preferred water temperatures for spawning ranging from 10.0 to 26.1°C. Spawning in Michigan was observed at a mean water temperature of 18.3°C (Morman 1979). A temperature of 18.4°C was considered optimal for rearing eggs to the prolarvae stage (Smith et al. 1968).

Mature Silver Lamprey are attracted to bile acids released by larval lamprey of their own species, as well as other species such as the Sea Lamprey (Fine et al. 2004). All lampreys, including Silver Lamprey, may use these bile acids as pheromones, and may choose streams in which to spawn using this cue (Fine et al. 2004).

To construct their nest, Silver Lamprey transport stones by moving them with their mouth, and they remove sand and silt by vigorous tail movements (Scott and Crossman 1998). The male attaches to the head of the female and the mating pair then releases sperm and eggs simultaneously during a rapid vibration of their bodies (Scott and Crossman 1998). Nests have an average cavity depth of 8 cm, and vary in diameter from 33 to 122 cm (Morman 1979). Silver Lamprey have been observed spawning at depths ranging from 13 cm (Manion and Hanson 1980) to 5 m (Lamsa and Westman 1972), averaging 38 cm (Morman 1979). Nests have been found to contain up to 10 adult Silver Lamprey each, indicating communal spawning. This mating system is common in other species such as the Northern Brook Lamprey (Morman 1979; Cochran and Pettinelli 1987) and the American Brook Lamprey (Becker 1983).

Measurements of fecundity and egg diameter of Silver Lamprey have been documented by several authors, and are variable by geographic location. Average estimated number of eggs per female has been documented in Québec as 19,012, with a range from 12,006 to 29,412 (Vladykov 1951). Egg diameters ranged from 0.45 to 0.85 mm with an average of 0.73 mm (Vladykov 1951). Schuldt et al. (1987) found that body length and fecundity were not strongly correlated. Average fecundities from Menominee, Peshtigo, and Oconto rivers (Lake Michigan tributaries) were 13,403, 21,259 and 22,820, respectively. Their gonadosomatic index (the ratio of gonad weight to total body weight) values were 14.3, 18.8 and 15.9, with variable egg diameters of 0.99, 0.91 and 0.94 mm (Schuldt et al. 1987).

After fertilization, Silver Lamprey eggs hatch in 2 to 3 weeks, similar to that of the other four lamprey species in the upper Great Lakes (Smith et al. 1968). Shortly after the eggs hatch, the prolarvae drift downstream and burrow into sand, silt and detritus where they build U-shaped burrows and remain for 4 to 7 years (Scott and Crossman 1998). Their diet consists of microscopic food such as algae, pollen, diatoms and protozoans (Becker 1983). The Northern Brook Lamprey, which has similar larval life history and habitat requirements to the Silver Lamprey, consumes a ‘sestonic biofilm’, which is composed of diatoms, desmids, protozoans, green algae, detritus and pollen (Scott and Crossman 1998; Yap and Bowen 2003). Sutton and Bowen (1994) found almost 98% of the diet of larval Sea Lamprey and Northern Brook Lamprey to be organic detritus, the remainder being algae (2%) and bacteria (0.1%).

In late summer or fall, after several years in their burrows, the ammocoetes undergo a metamorphosis. This begins while they are still in their burrows and involves development of eyes, teeth and a functional intestine (Vladykov 1949; Scott and Crossman 1998). Metamorphosis is completed by early spring, after which they emerge from their burrows and may migrate downstream to a lake (Scott and Crossman 1998). Lengths of recently metamorphosed individuals have been reported as 89-110 mm (Scott and Crossman 1998), but appear to vary geographically. Other reported lengths include 91-155 mm in Michigan (Morman 1979), 103-139 mm in Wisconsin (Becker 1983), and an average of 107.9 mm for males and 113.0 mm for females in Québec (Vladykov and Roy 1948). Their weight at this stage ranges from 1 to 6 grams (Vladykov and Roy 1948; Becker 1983; Scott and Crossman 1998).

After migrating downstream, parasitic-phase Silver Lamprey feed on fishes. They attach themselves with their “suction cup-like” mouth and rasp a hole through the scales and skin of host fishes with their sharp teeth and tongue, and feed on flesh and body fluids (Becker 1983; Vladykov 1949). The life span of the adult has been documented as 12 to 13 months (Vladykov and Roy 1948), and as 12 to 20 months depending on growth and maturation of eggs (Scott and Crossman 1998). During this phase, greatest growth and highest feeding activity occurs between June and September (Becker 1983). Cochran et al. (2003) reported that, in Wisconsin, mean Silver Lamprey body mass continued to increase over the period of October to March, and concluded that at least some parasitic phase individuals continue to feed over the winter months.

Host fish species for the Silver Lamprey are numerous, and include at least 23 species (Appendix 4). Renaud (2002) described Silver Lamprey parasitism on Muskellunge (*Esox masquinongy*) in the Ottawa River, stating that the lamprey preferred larger fish, and often fed on blood rather than flesh. No deep wounds were found. Eighty percent of the host fish had multiple marks, and 26.7% of the host fish had healed injuries, indicating non-lethal past events of parasitism.

Between May 31 and August 10, 2006, the Michigan Department of Natural Resources (MDNR) collected 217 Silver Lamprey on Lake Sturgeon (*Acipenser fulvescens*) in Lake St. Clair. Average total length was 150.8 mm (range 85-237 mm, N=217), and average disc diameter was 15.7 mm (range 7-25 mm, N=217). Characteristics of Silver Lamprey marks on these fish were also measured and documented, with an average diameter of marks of 15.3 mm (range 7-34 mm, N=141 marks) (Thomas pers. comm. 2006). Vladykov (1985) reported 61 Silver Lamprey on a single lake sturgeon caught in the St. Lawrence River. Average length of these specimens was 104 mm (range 89-139 mm) and the average weight was 2.0 g (range 1.2 – 3.9 g).

Near the end of the parasitic phase, and usually over the winter, Silver Lamprey begin to mature; they experience gonadal development, a decrease in length and weight, and the intestine becomes progressively less functional (Scott and Crossman 1998). Total generation time is roughly six years, when using a mean of five years spent in the larval phase (Scott and Crossman (1998) documented a range of four to seven years) and one year as an adult (Vladykov and Roy 1948).

Roy (1973) studied feeding behaviour and growth of feeding phase Silver Lamprey held in a laboratory setting. Female lamprey grew faster than males and attained a larger maximum length. Lamprey grew more rapidly and reached maturity earlier in captivity than in their natural habitat. Of 50 specimens used in the study, 24 attached themselves to fishes, for an average attachment period equivalent to a third of their stay in the aquarium. Lamprey fed on seven of the 23 fish species presented to them. Feeding activity diminished as lamprey approached sexual maturation. The average weight of the hosts selected was directly proportional to the average length of the lamprey. There was no relationship between the percentage of hosts killed and the duration of attachment. One third of wounds resulted in the death of the host, the most critical factors being the stage of maturity of lamprey (growing lamprey were more detrimental than those that had finished growing) and the location of wounds in most vulnerable regions, such as the head and abdomen (Roy 1973). Becker (1983) stated that, based on observations in the laboratory, the majority of Silver Lamprey attacks (81.5%) occurred at night.

Predation

As eggs and freshly hatched larvae, lamprey species are fed on by larger fishes (Potter 1980b). Predation on ammocoetes is probably minimal due to their sedentary existence in burrows for extended periods. Given the opportunity, however, piscivorous fishes likely consume ammocoetes, considering the historic use of ammocoetes as bait by anglers (Vladykov 1973; Scott and Crossman 1998). Predation on adult lamprey by other fishes, small mammals and birds likely occurs most often during the spawning event, because lamprey lay their eggs in shallow water (Manion and Hanson 1980; Cochran et al. 1992) when they are vulnerable.

Physiology

As the large extent of occurrence suggests, Silver Lamprey inhabit a variety of lake and stream habitats, and survive in a variety of hydrological, water chemistry and temperature conditions, but there are few data concerning Silver Lamprey specifically. Parasitic-phase Silver Lamprey were collected as by-catch by commercial fisheries in Canadian waters of the Great Lakes from 1983-2006 and the mean water depth where the Silver Lamprey were collected was 21.5 m (range 2.6-133.3 m) (SLCC unpub. data). It has also been found that 18.4°C is conducive to rearing Silver Lamprey eggs (Smith et al. 1968). Although little is known about the physiology of the Silver Lamprey, knowledge of other lamprey species is likely comparable. Sea Lamprey eggs are very sensitive to temperature, as eggs hatch only between 15.5 and 21.1°C (Piavis 1961). Sea Lamprey larvae mortality increases markedly at 22°C (Piavis 1961). Water depth and velocity were important factors in determining location of larval European Brook Lamprey (Malmqvist 1980).

Dispersal/migration

Silver Lamprey migrate up streams and rivers in the spring to spawn (Scott and Crossman 1998). The distance travelled during migration can be substantial. Silver Lamprey have been observed 73 km (Morman 1979) and 112 km (SLCC, unpub. data) upstream from a river mouth, although these distances may not necessarily represent migration distances, as some Silver Lamprey may reside as parasites permanently within large rivers that have a suitable forage base (Vladykov 1949; Scott and Crossman 1998; Cochran and Lyons 2004).

The nature of the Silver Lamprey attachment behaviour results in dispersal of the lamprey by their host fish. Silver Lamprey have been observed on Lake Sturgeon during the sturgeon's migration and spawning season, and it is possible that lamprey that remain attached to hosts in the early spring could be transported upstream toward their spawning grounds (Cochran et al. 2003).

While no studies of Silver Lamprey homing have been published, Bergstedt and Seelye (1995) found that Sea Lamprey do not seem to return to their natal stream to spawn. As discussed in the life cycle section, pheromones produced by larvae resident in streams may play an important role in determining which streams Silver Lamprey ascend and ultimately use to spawn (Fine et al. 2004).

Interspecific interactions

Invasive Sea Lamprey co-exist with Silver Lamprey within the Great Lakes – Upper St. Lawrence River DU. Vladykov (1951) suggested that the high fecundity of the invasive Sea Lamprey may lead to competition with lampreys native to the Great Lakes. Scott and Crossman (1998) hypothesized that the relatively low abundance of Silver Lamprey in Lake Ontario, and higher abundance in the upper Great Lakes, may be the result of the long-term presence of Sea Lamprey in Lake Ontario. Silver Lamprey also co-exist in stream systems with Northern Brook Lamprey and, occasionally, American Brook Lamprey (SLCC, unpub. data). Where ranges overlap, generally only one species is common (Becker 1983). Silver Lamprey generally do not prefer to use smaller streams, which are more suitable for brook lampreys (Scott and Crossman 1998). In areas where Silver Lamprey and Chestnut Lamprey occur sympatrically, the Silver Lamprey often migrate furthest upstream (Scott and Crossman 1998). Morman (1979) found that Silver Lamprey and Chestnut Lamprey were typically more common in the lower sections of main streams and comparatively large tributaries, and diminished progressively upstream, where they were displaced by Northern Brook Lamprey, American Brook Lamprey and Sea Lamprey.

During the parasitic phase, Sea Lamprey are more associated with cool water than Silver Lamprey, and display a pattern of more pronounced growth later into the fall that presumably reflects a tendency to feed more actively at lower temperatures. By comparison, the Silver Lamprey achieves much of its growth during the summer months. According to Cochran and Marks (1995), Silver Lamprey prefer habitats such as that found in Green Bay, Lake Michigan, that provide a combination of suitable warmer water temperatures and sufficient host population densities. The differences in bioenergetics and habitat preferences of different lamprey species may promote coexistence (Cochran and Marks 1995).

Larval bile acids may attract migrating lamprey of three different lamprey species, including Silver Lamprey (Fine et al. 2004). This suggests that interactions may occur between different life stages of different species, and that all lampreys may use a similar, relatively unspecialized pheromone (Fine et al. 2004; see **Dispersal/migration** section).

Interspecific interactions also occur during spawning. Morman (1979) found that, of the 31 observed nests occupied by Silver Lamprey, 25 (81%) also contained other lamprey species. Of the shared nests reported by Morman (1979), there were no incidences of antagonistic or territorial behaviour between species. Interspecific mating was not observed, but the possibility of cross fertilization exists. The shared nests displayed physical characteristics typical of Sea Lamprey nests (Morman 1979).

Scott and Crossman (1998) speculated that where Silver and Chestnut lamprey occur together, they probably compete for spawning grounds and food, but suggested that stream size and temperature selection, and the absence of chestnut lamprey from most Canadian waters reduce this possibility of competition.

Adaptability

The variety of habitats and conditions in which this species has been collected, from the St. Lawrence River through the Great Lakes and Lake of the Woods to the Nelson River, suggests a considerable level of adaptability. Limiting factors would be availability of fish hosts in rivers or lakes, and suitable spawning and larval habitat in streams.

Given that an ecologically similar lamprey, the American Brook Lamprey, has accidentally been introduced into other streams with high survival rates (Cuddy pers. comm. 2006), it is likely that there is some degree of adaptability to new areas on relatively short times scales.

Morman (1979) found that some populations of Silver Lamprey can persist upstream of barriers, if conditions are favourable, especially in terms of the presence of a suitable forage fish base. He reported that “remnant” populations were present in reaches upstream from long established (early 1900s) permanent dams on three large rivers in Michigan. Each of these reaches was associated with inland lakes or impoundments capable of providing host fishes (Morman 1979). SLCC data (unpublished) provide another example of metamorphosed Silver Lamprey upstream of dams in the Fox River, Wisconsin. This system also is associated with a series of large inland lakes.

POPULATION SIZES AND TRENDS

Search effort

Given the difficulty in identifying *Ichthyomyzon* ammocoetes to the species level, collection of identifiable Silver Lamprey is usually limited to metamorphosed individuals in the fall or spring, or adults in the spring before post-spawning mortality occurs. Most of the information in this report is based on incidental catch data for DU1 obtained through assessment of Sea Lamprey by Sea Lamprey control agents, the Department of Fisheries and Oceans Sea Lamprey Control Centre (SLCC) and United States Fish and Wildlife Service (USFWS). Silver Lamprey data were also provided by museums and other provincial, federal and private organizations. These collections were typically from routine fish community assessments using a variety of sampling methods, which typically do not target lampreys, and do not standardize or record effort. Data for which search effort is quantifiable were limited to that of the SLCC.

Ammocoetes

Great Lakes-Upper St. Lawrence River DU

In Great Lakes tributaries, *Ichthyomyzon* ammocoete data were collected largely as incidental catch during surveys targeting larval Sea Lamprey. These surveys are biased toward streams with known Sea Lamprey populations. The majority of these Silver Lamprey data are derived from backpack electrofishing surveys, as well as surveys conducted by boat in deeper water using the granular formulation of the lampricide "Bayluscide". A small number of collections were made during TFM stream treatments.

Saskatchewan-Nelson Rivers DU

Little to no targeted effort has been directed at ammocoete collection in this DU.

Adults

Great Lakes-Upper St. Lawrence River DU

Trapping for spawning phase Sea Lamprey provides the majority of the data for adult Silver Lamprey in this DU. Commercial fisheries occasionally provide the SLCC with Silver Lamprey specimens. These specimens are found in the much larger Sea Lamprey collections that are provided to SLCC on an annual basis.

In the spring of 2000 and 2001, assessment staff at the SLCC conducted electrofishing surveys explicitly to identify undocumented streams inhabited by adult and/or metamorphosed Silver Lamprey and Northern Brook Lamprey. These efforts identified one previously unknown stream in the Lake Nipissing drainage (South River) and confirmed other existing populations in the Great Lakes region. Further directed efforts in the fall of 2007 confirmed the presence of metamorphosed Silver Lamprey in South River, Coldwater Creek, Saugeen River and Hog River, and found a previously undocumented population in Chippewa Creek, a tributary of Lake Nipissing.

Saskatchewan-Nelson Rivers DU

Very little effort has been directed at collection of adults in this DU.

Abundance

NatureServe (2006) estimates global abundance between 10,000 and 1,000,000 individuals, and estimated the number of “element occurrences” (areas with communities present) at 81 to fewer than 300. Abundance estimates specific to each DU are not available, but are probably much larger in DU1 owing to the greater number of reported localities (48 vs. 15).

Ammocoetes

Great Lakes-Upper St. Lawrence River DU

Population estimates have generally not been calculated for *Ichthyomyzon* ammocoetes. One exception is the Black Sturgeon River, on the north shore of Lake Superior (DU1), where a population estimate was calculated for *Ichthyomyzon* ammocoetes in 2006 by SLCC. Based on electrofishing and habitat surveys, the population was estimated at 14,583,327 ammocoetes. Because, however, of the location in the watershed, the presence of metamorphosed Northern Brook Lamprey, and the lack of Silver Lamprey records in the system, it is suspected that this population is composed of Northern Brook Lamprey. Nevertheless, these data do suggest that when present, *Ichthyomyzon* ammocoetes can be extremely abundant within even single systems.

Between 2001 and 2006, 8,129 *Ichthyomyzon* ammocoetes were incidentally caught while electrofishing during larval Sea Lamprey assessment in Canadian tributaries to the Great Lakes. In the previous six year period (1995-2000), 7,917 *Ichthyomyzon* ammocoetes were collected with a slightly lower collecting effort (SLCC, unpub. data). Although these ammocoetes cannot be identified to species, it can be assumed that some of them are Silver Lamprey, and these comparisons suggest that catch rates have remained relatively constant (e.g., Figure 3).

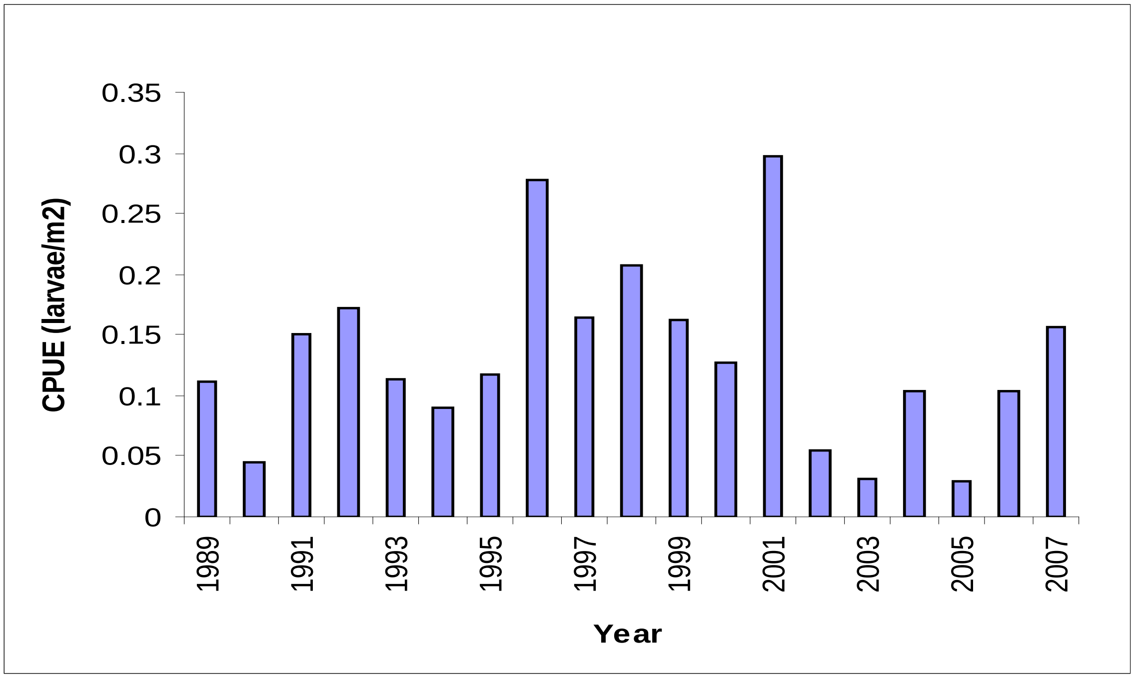

Figure 3. DFO electrofishing bycatch rates of *Ichthyomyzon* ammocoetes in Canadian Great Lakes tributaries (DU1), 1989-2007.

Saskatchewan – Nelson Rivers DU

No abundance estimates for ammocoetes are available.

Adults

Although population estimates have not been made, recent indirect evidence indicates abundant populations of Silver Lamprey in areas of Lake St. Claird and the St. Lawrence River (SLCC, unpub. data).

Great Lakes-Upper St. Lawrence River DU

Reports of fish wounding in Lake St. Clair from Silver Lamprey (species determined by size of wounds and presence of attached lamprey) have been received by the SLCC, where anecdotal reports from anglers suggest a 20-40% wounding rate on Muskellunge. This abundance is supported by reports by professional divers of large congregations of spawning Silver Lamprey in 2006 (Johnson and Lashbrook pers. comm. 2006) and by high wounding rates of Lake Sturgeon in Lake St. Clair. The Lake St. Clair Fisheries Research Station (MDNR) collected 217 Silver Lamprey from Lake Sturgeon in 2006, and observed an average of almost six scars per sturgeon in 2005 (Thomas, pers. comm. 2006). Renaud (2002) described host-parasite interactions between Silver Lamprey and Muskellunge in the Ottawa River. The number of wounds per fish ranged from 1-31 and, in two cases, two Silver Lamprey were attached to a single Muskellunge. Wounding rates were dependant on Muskellunge size, with those of total length less than 91 cm having no wounds, individuals between 91 and 122 cm showing a 2 to 5% wounding rate, and those >122 cm showing a 21.4% wounding rate (Renaud 2002). Scott and Crossman (1998) stated that the abundance of this species in Lake Ontario is low, possibly as a result of the long presence of Sea Lamprey in the lake.

Saskatchewan-Nelson Rivers DU

Although efforts were not targeted at lampreys, surveys on the Nelson River, Manitoba, near (and within) Limestone River indicate that the species is abundant and widespread (Nelson pers. comm. 2006). No other abundance information was available for this DU.

Fluctuations and trends

It is difficult to examine trends in the distribution and abundance of Silver Lamprey because of the difficulties associated with collecting adults, identifying ammocoetes, and limited targeted sampling of native lampreys.

Ammocoetes

Great Lakes-Upper St. Lawrence River DU

Schuldt and Goold (1980) compared the occurrence of *Ichthyomyzon* ammocoete data (likely both Northern Brook Lamprey and Silver Lamprey) for Lake Superior between two time periods (1953-1972 and 1973-1977). They found Silver Lamprey in a total of 47 tributaries of Lake Superior in Canada. Of these 47 tributaries, 32 were treated with lampricide and of these 32 streams, 16 had no Silver Lamprey when they were re-sampled between 1973-1977 (Schuldt and Goold 1980). They found that their presence in Canadian streams had dropped from 47 (1953-1972) to 17 streams (1973-1977). They hypothesized that the reduction was due to the effects of lampricide treatments targeting invasive Sea Lamprey. *Ichthyomyzon* ammocoetes have been recently (1989-2007) documented in 20 Canadian tributaries to Lake Superior, including 13 of the 16 tributaries reported by Schuldt and Goold. While some Silver Lamprey appear to have returned to streams from which they were eliminated by lampricide treatments, they have not yet recovered to include all affected streams (Appendix 3).

In recent years, Canadian Lake Superior collections of Silver Lamprey remain low in comparison to American Lake Superior collections. These findings suggest that the Canadian tributaries of Lake Superior may possess less preferred Silver Lamprey habitat than American streams. Furthermore, lampricide treatments are an ongoing, persistent threat to Silver Lamprey; 49 Lake Superior tributaries (up to 17 in Canada and 32 in the United States) are treated for Sea Lamprey on a regular 3-5 year cycle (Young and Klar 2006; see also http://www.glfc.org/sealamp/where.php).

Based on SLCC search effort for *Ichthyomyzon* ammocoetes, regression analysis of catch-per-effort data for *Ichthyomyzon* ammocoetes collected during Sea Lamprey electrofishing surveys shows no significant trend over the past three generations (Figure 3). For time periods 1989-1994, 1995-2000 and 2001-2006, the CPUE values were 0.114 larvae/m^2, 0.175 larvae/m^2 and 0.103 larvae/m^2, respectively.

Saskatchewan-Nelson Rivers DU

No data were available regarding trends in *Ichthyomyzon* ammocoetes in this DU.

Adults

Because effort data were not always available, standardizing adult catch results was not possible. Another potential problem in evaluating trends is mis-identification of adult Silver Lamprey, particularly in distinguishing them from Chestnut Lamprey (Stewart and Watkinson 2004).

Great Lakes-Upper St. Lawrence River DU

In the Great Lakes, Canadian and American Sea Lamprey Control agents often hire contractors to monitor Sea Lamprey traps. Contractors usually have some fish identification experience, which allows them to release incidental native fishes (including Silver Lamprey) from the trap back to the river, or over the associated barrier. In the United States, however, not all contractors are able to distinguish Silver Lamprey from Sea Lamprey and, therefore, no lampreys are passed over barriers (Doemel pers. comm. 2006).

Despite these difficulties, there are some trends that can be derived from the literature and available data. Trautman (1981) discussed how habitat alteration and construction of dams as long ago as 1875 coincided with the beginning of a decline in Silver Lamprey populations in Ohio waters. Fishermen in Ohio before 1900 used to catch and sell hundreds of Silver Lamprey, caught in Sandusky Bay and Lake Erie, to biological supply houses, but by 1945 (before Sea Lamprey control began) they were so uncommon that only the occasional one was captured (Trautman 1981).

Silver Lamprey have been recorded in many new waterbodies in recent years (29 streams and lakes in five watersheds in the past 10 years). These include seven from the Lake Huron watershed, five from the St. Lawrence River watershed, four from Lake Ontario, and two from Lake Nipissing. These are, however, very likely due to previous lack of detection rather than an actual increase in range (Figure 4).

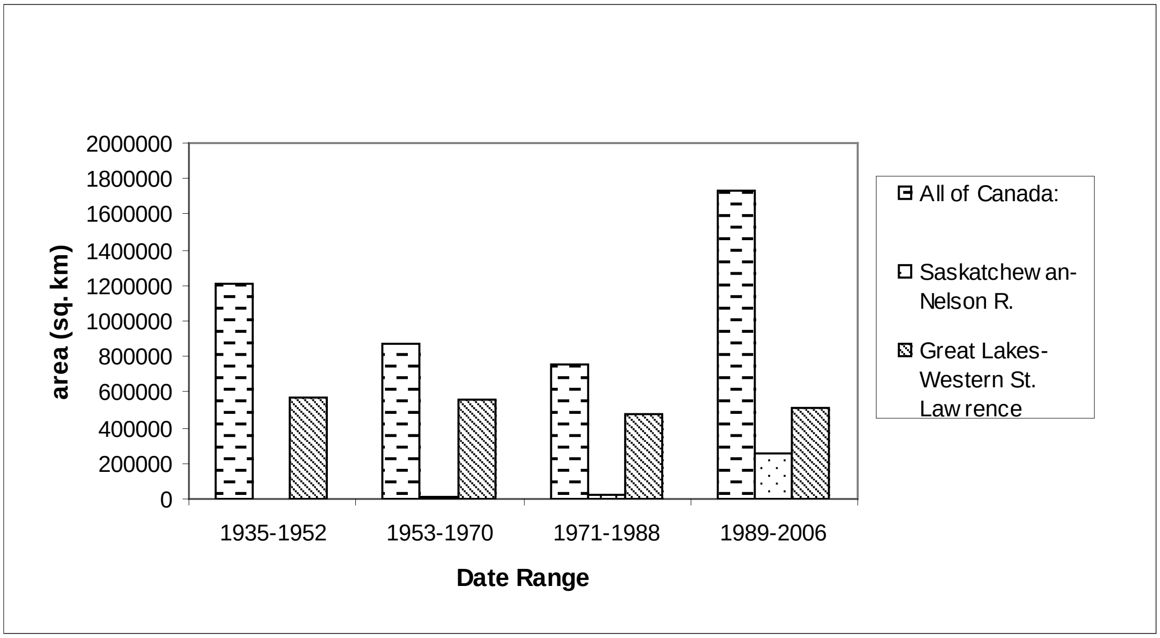

Figure 4. Patterns in estimates of Silver Lamprey extent of occurrence in Canada as a whole and separated by its two designatable units.

Commercial fisheries from the Great Lakes have provided the SLCC with a significant portion of the Silver Lamprey collections over the past 40 years. Silver Lamprey are often included with Sea Lamprey, for which the fishermen are paid. The number of fishermen taking part in this program has decreased markedly over the past 18 years, from 32 fishermen during 1989-1994; ten during 1995-2000; and eight during 2001-2006. The number of Silver Lamprey provided has also decreased (136, 22 and 3, respectively) (SLCC, unpub. data).

The SLCC operates approximately 30 Sea Lamprey traps in Canadian Great Lakes tributaries, with the primary purpose being assessment of Sea Lamprey spawner abundance. An important consideration for these data are that the same rivers have not been trapped over the time series (more rivers were trapped earlier in the time series), and trapping techniques and trap efficiencies have not been consistent (traps often used to be employed in association with weirs). Catch-per-effort data for Silver Lamprey captured in Sea Lamprey traps in Canadian Great Lakes streams (pooled by lake) show no statistically significant trend over the past three generations (SLCC, unpub. data). When all available data prior to 2006 are pooled by lake, however, Lake Huron and Lake Superior show a downward trend (Figure 7). The other lakes show no significant trend, but Lake Ontario shows signs of increasing abundance since trapping started in 1981. Silver Lamprey were captured in only one year prior to 1999, but this was followed by collection of Silver Lamprey in seven of the past eight years. When the data set are limited to more recent information, regression analysis of catch-per-effort data for Silver Lamprey captured in Sea Lamprey traps in Canadian Great Lakes streams (pooled by six year time-periods), shows no statistically significant trend over the past three generations (Figure 8). For time periods 1989-1994, 1995-2000, and 2001-2006, basin-wide (Lake Huron, Lake Superior, Lake Erie and Lake Ontario pooled together) average CPUE values were 0.0074 lamprey/trap-day, 0.0089 lamprey/trap-day and 0.0094 lamprey/trap-day, respectively.

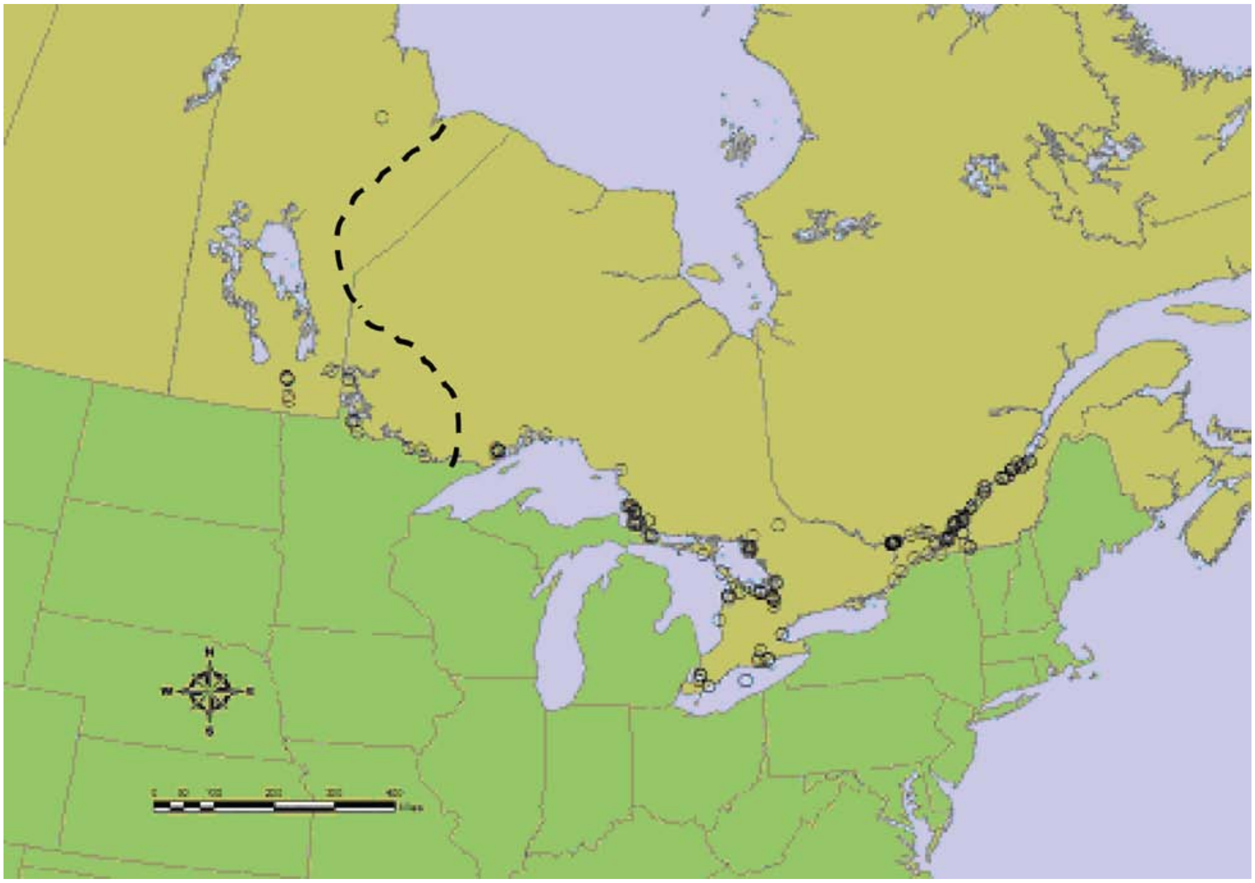

Figure 5. Historical (pre-1989) collections of Silver Lamprey in Canada. The dashed line shows the approximate border between DU1 and DU2.

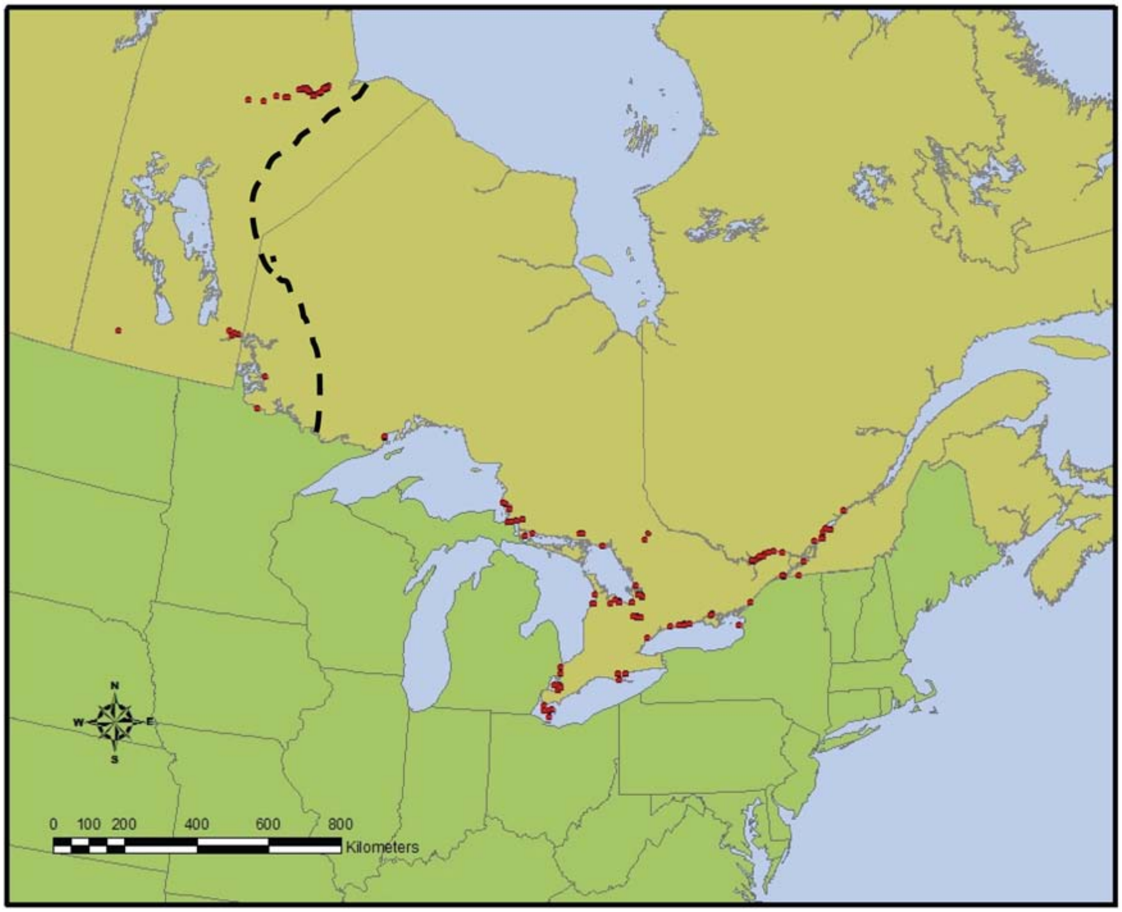

Figure 6. Recent (post-1988) collections of Silver Lamprey in Canada. The dashed line shows the approximate border between DU1 and DU2.

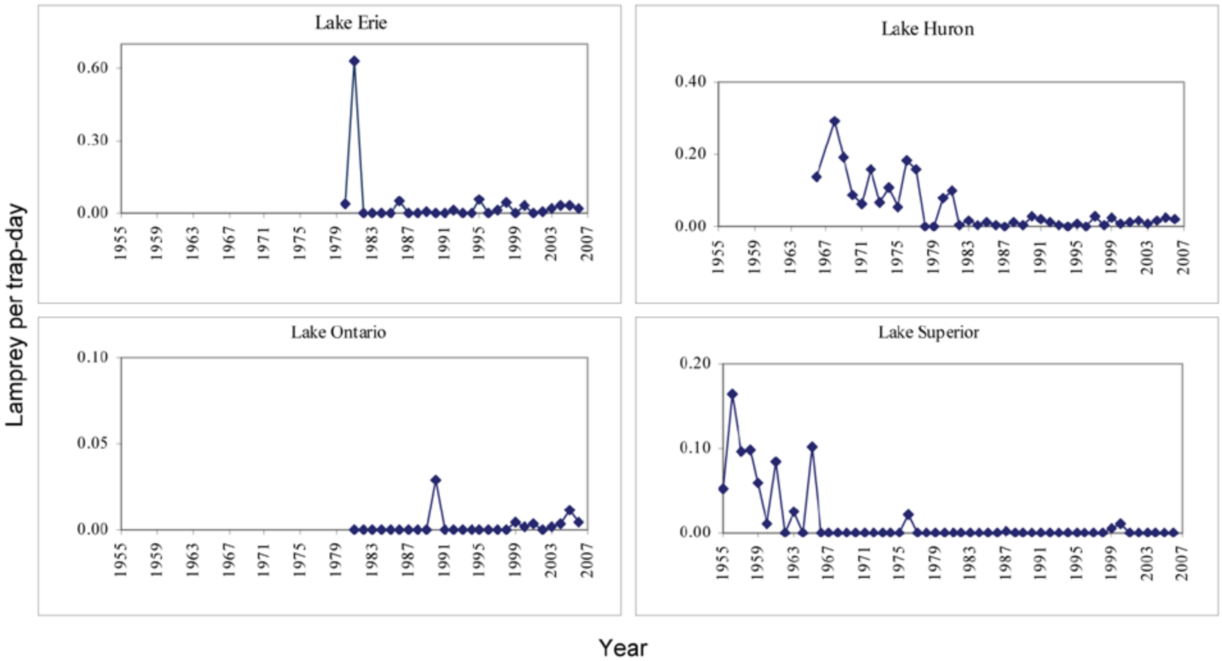

Figure 7. Long term catch per effort data for Silver Lamprey from DU 1 collected in Canadian Sea Lamprey traps in the Great Lakes. Note differences in y-axis scales.

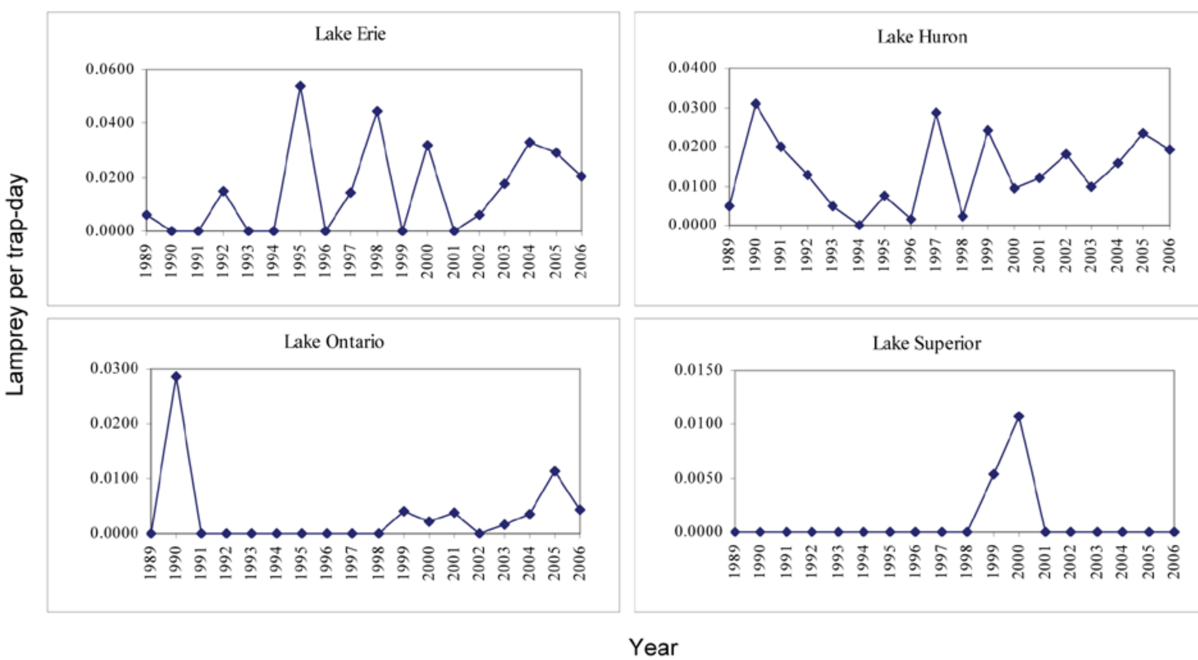

Figure 8. Recent catch per unit effort data for Silver Lamprey collected in Canadian Sea Lamprey traps in the Great Lakes (DU1), 1989-2006. Note differences in y-axis.

Between 1989 and 2006, Silver Lamprey were collected in 29 Canadian Great Lakes streams (41 streams if St. Lawrence River tributaries are included). Of these streams, Sea Lamprey have been found in 26 of them, and 19 of them have been treated with lampricide since 1989. Of the 19 lampricide-treated streams containing Silver Lamprey, 15 have had Sea Lamprey traps operated since 1989. Trapping in these streams have shown sporadic Silver Lamprey catches over the past 18 years, ranging from zero to 13 individuals in a year, with no apparent trends (Appendix 5), but trapping effort has not been consistent. Adult Silver Lamprey have also been found in lentic habitats in Canadian waters within all the Great Lakes, as well as Lake St. Clair, and in 25 waterbodies in Canada outside of the Great Lakes since 1989 (see Table 1 for occupied tributaries). In the previous 18-year period (1971-1988), Silver Lamprey were found in 23 Great Lakes Canadian streams, as well as lentic habitats of the Canadian Great Lakes, Lake St. Clair and 16 waterbodies in Canada outside of the Great Lakes.

In the past 10 years, biologists and anglers on Lake St. Clair have witnessed a high number of Silver Lamprey attachments to Lake Sturgeon (Thomas pers. comm. 2006; Cooper pers. comm. 2006) and Muskellunge (Thomas pers. comm. 2006). Average number of lamprey scars per Lake Sturgeon (assumed to be inflicted by Silver Lamprey based on mark characteristics) in Lake St. Clair since 1996 have shown an increasing trend (from 0.29 in 1996 to 5.95 in 2005, with an average of 2.32 over the 10 year period). Maximum number of scars per sturgeon has also shown a general upward trend (ranging from 3 in 1996 to 73 in 2005, N=1649 sturgeon) (Thomas pers. comm. 2006) (Figure 9). No population estimates have been conducted. It is possible that this resurgence of Silver Lamprey is due to rehabilitation of stream habitat in the Huron-Erie corridor, as has been hypothesized as the cause for re-establishment of other fish species in this area (e.g. Caswell et al. 2004; Roseman et al. 2007).

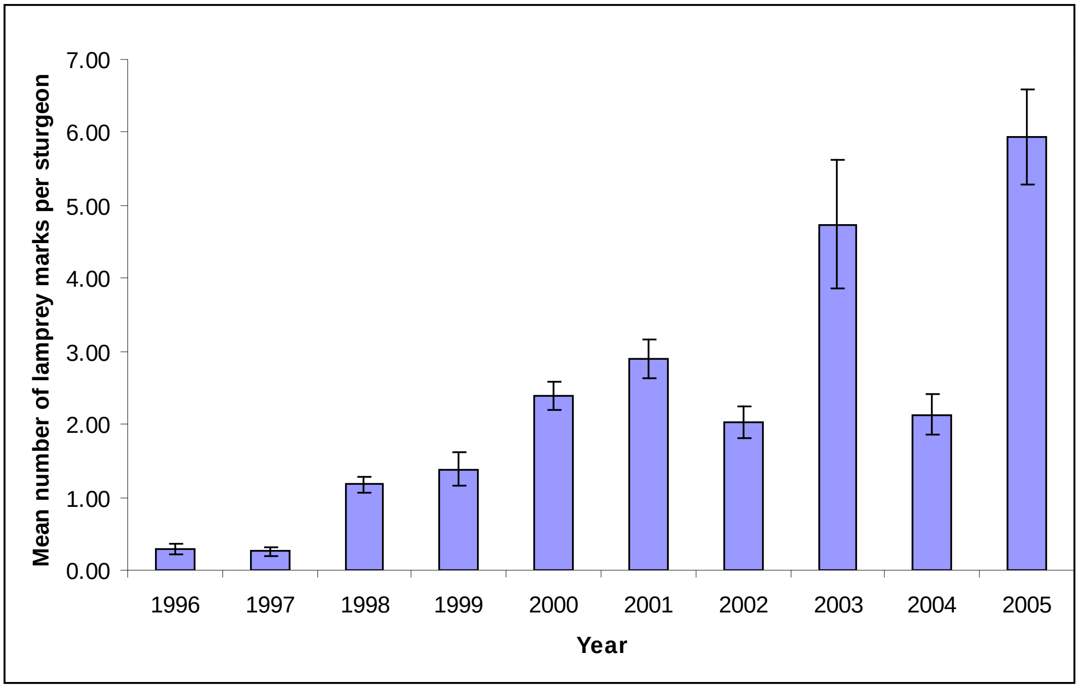

Figure 9. Mean number of lamprey marks per St. Clair River sturgeon captured by Michigan DNR, +/- one standard error (Thomas, unpublished). Any Silver Lampreys within the St. Clair River are within DU1.

In Québec, the Silver Lamprey was first documented in the St. Lawrence River watershed in 1906 when a specimen was taken from Rivière Richelieu (Royal Ontario Museum, unpub. data). The amount and type of data collected do not permit identification of trends, but there are enough recent records to be reasonably sure that several areas are able to maintain populations. Since 1989, 287 verified Silver Lamprey have been collected in Québec from 13 waterbodies, including one tributary to Lake Champlain, five tributaries to the Ottawa River and seven tributaries to the St. Lawrence River (Environment Canada, Québec Ministère des Ressources naturelles et de la Faune, Royal Ontario Museum, Canadian Museum of Nature, unpub. data). Prior to 1989, 1315 Silver Lamprey had been collected from about 23 waterbodies including two tributaries to Lake Champlain, two tributaries to the Ottawa River and 19 tributaries to the St. Lawrence River (Environment Canada, Québec Ministère des Resources naturelles et de la Faune, Royal Ontario Museum, Canadian Museum of Nature, unpub. data). Data from a trap at St. Nicolas (on the St. Lawrence River) illustrate a substantial decrease in Silver Lamprey between 1975 and 2004 (Figure 10). An average of 68.2 lamprey per year was caught in the first ten year period the trap was run (1975 to 1984), which contrasts sharply with the mean of 8.6 lamprey caught annually over the most recent ten year period (1995 to 2004).

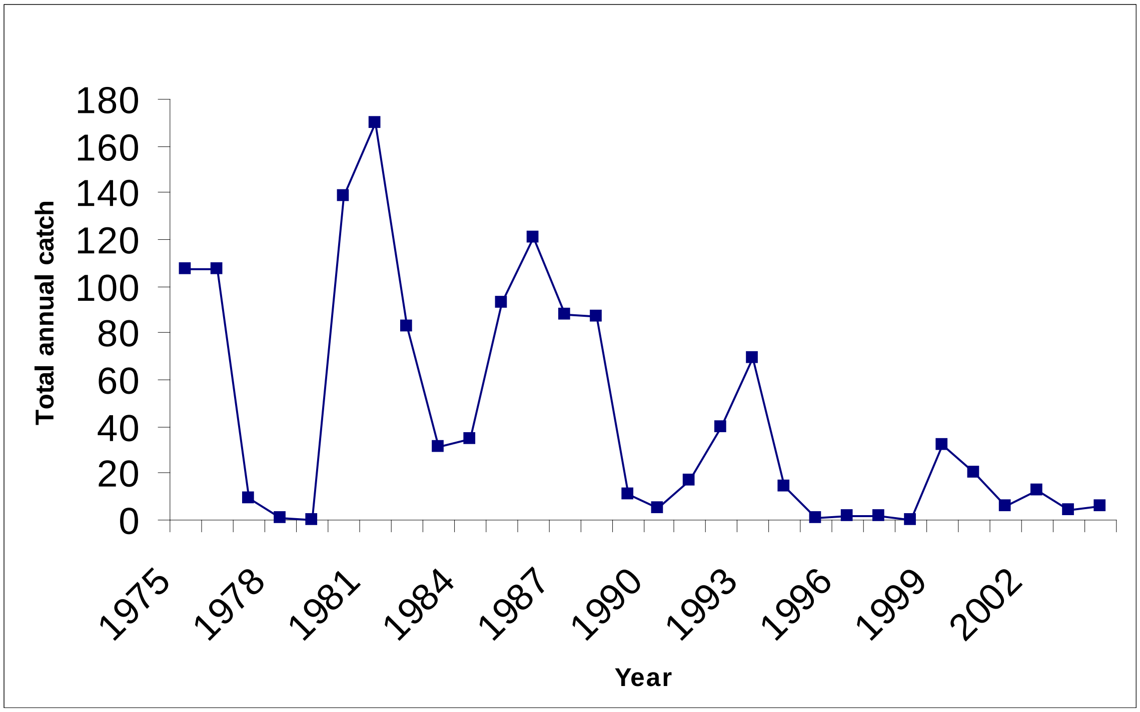

Figure 10. Adult Silver Lamprey trap catches in St. Nicolas, Québec (DU1), 1975-2004.

Saskatchewan-Nelson Rivers DU

In Manitoba, the Silver Lamprey was originally documented in the Nelson River watershed in 1908 when a specimen was taken from Lake of the Woods (Royal Ontario Museum, unpub. data). Again, too few specimens have been caught to infer trends, but the most recent records in 2006 indicate that this population is still extant (Nelson pers. comm. 2006). Stewart and Watkinson (2004) believed that this species may be more widespread in Manitoba than records indicate. Since 1989, 88 Silver Lamprey have been collected in the Nelson River watershed, including Winnipeg River, Assiniboine River, Lake of the Woods, Rainy River, several lakes and smaller tributaries to the Nelson River (Watkinson pers. comm. 2006; Nelson pers. comm. 2006). Prior to 1989, only 41 Silver Lamprey had been collected from about 12 waterbodies in Manitoba (Royal Ontario Museum, Canadian Museum of Nature, unpub. data).

Several new occurrences have been documented in the past ten years. These include 11 waterbodies from the Nelson River watershed, but as in the Great Lakes-Upper St. Lawrence River DU, these are likely due to previous lack of detection from limited sampling effort.

The long-term trend in number of Silver Lamprey collected in both of Canada's DU's, over four 18-year time periods (Appendix 6) is based on data that are not standardized by effort and, therefore, conclusions cannot be drawn regarding trends in actual populations. Of the four time periods, the 1971-1988 time period shows the highest total number of lamprey in the Great Lakes-Upper St. Lawrence River DU, as well as in Canada as a whole, followed by the 1989-2006 time period. In the Saskatchewan-Nelson Rivers DU, the total number of Silver Lamprey is highest in the 1989-2006 time period.

Rescue effect

Several aspects of the Silver Lamprey life history suggest that there is potential for rescue effect from one stream to another. When Silver Lamprey move downstream they often leave their natal stream to feed on host fishes (Scott and Crossman 1998). During the parasitic phase, Silver Lamprey may disperse a considerable distance from their natal stream, depending on the movement patterns of their host. If Silver Lamprey are non-homing, as is the case with the Sea Lamprey (Bergstedt and Seelye 1995), it is conceivable that mature individuals seeking spawning habitat could be attracted to the pheromone cue from tributaries with populations of other lamprey species. In this way, there is potential for rescue effect from one stream or one region of a lake to another. This includes the potential natural immigration of Silver Lamprey from waterbodies in the United States.

The rescue effect from the United States could be significant for the Great Lakes populations (DU1). The number of adult Silver Lamprey caught in Sea Lamprey traps over the past 50 years in the United States (over 28,000 individuals, most from southern Lake Superior and western Lake Michigan (USFWS unpub. data) is much higher than the total number of Silver Lamprey collected in Canadian traps over the same time period (around 1,800 individuals) (SLCC unpub. data).

LIMITING FACTORS AND THREATS

Silver Lamprey, like other native lamprey species, are vulnerable to habitat alterations, dam construction, competition from invasive species (see **Interspecific Interactions** section above), pollution from anthropogenic sources, and in the Great Lakes-Upper St. Lawrence River DU, Sea Lamprey management practices.

Great Lakes-Upper St. Lawrence River DU

Locations within the DU1 are affected by ongoing lampricide applications conducted by Canadian and American agents of the Sea Lamprey management program. These applications reduce populations of Sea Lamprey; however, other lamprey species are similarly vulnerable to the chemical (King and Gabel 1985). Streams with *Ichthyomyzon* larvae that have been infested by Sea Lamprey, and subsequently treated with lampricide, have undergone significant reductions or extirpations of native lamprey populations (Schuldt and Goold 1980). Larval *Ichthyomyzon* lamprey are less susceptible to the lampricide than Sea Lamprey larvae (King and Gabel 1985), but this difference is insufficient to allow for selective control of Sea Lamprey without impacting native lampreys including the Silver Lamprey.

Permanent barriers to Sea Lamprey migration could offer some refuge to those populations of Silver Lamprey in DU1 that are able to complete their life cycle above a lamprey barrier (Morman 1979; Cochran et al. 2003; McLaughlin et al. 2006), as these portions of the stream are not exposed to the chemical applications. Silver Lamprey have been observed feeding in lakes above barriers (Morman 1979), implying that they are able to mature in upstream reaches.

Barriers, however, can also serve as a threat to this lamprey by denying access to upper portions of streams (Trautman 1981). There are hundreds of dams owned by federal, provincial and municipal governments throughout the Silver Lamprey's range in Canada. The Ontario Ministry of Natural Resources owns and operates over 300 dams in Ontario alone and some of these may directly affect the ability of the Silver Lamprey to access previously available habitat. Dams may also potentially limit dispersal and natural patterns of gene flow among populations within the species (Schreiber and Engelhorn 1998).

Fluctuating water levels associated with operation of some dams are suspected to cause ammocoete mortality, due to exposing of larval burrows during low water levels (Bailey 1959). Flooding conditions may pose a risk due to excessive water flow forcing ammocoetes from the substrate (Potter 1980b).

Renaud et al. (1995) has also listed pollution (specifically, the herbicide atrazine) as a possible contributor to ammocoete mortality. The Yamaska River in Québec, which once had a high density of Northern Brook Lamprey (Vladykov 1952), was found, 40 years later, to not have ammocoetes of any species (Renaud et al. 1995). Renaud et al. (1995) speculated that phytoplankton levels were reduced by this chemical; thereby, limiting food availability for the ammocoetes. In samples taken in 2003-2004, 13 different pesticides were detected at the mouth of the Yamaska River. Atrazine concentrations in the Yamaska River exceeded the quality criteria for the protection of aquatic life in 7% of samples (Environment Canada 2006). Atrazine is a systemic herbicide that is used to control weeds in cornfields and other crops. At varying concentrations, it can be toxic to fishes, freshwater invertebrates and aquatic plants (Environment Canada 2006). Despite some heavy pesticide use in smaller St. Lawrence

River tributaries, the Great Lakes were found to be the greatest source (90%) of contamination by herbicides (atrazine, simazine and cyanazine) in the St. Lawrence River through the 1990's (Pham et al. 2000).

The removal of riparian vegetation is thought to threaten lamprey populations in some areas (Fortin et al. 2004). Removal of riparian vergetation, which often accompanies agricultural and suburban development, increases sediment load in a stream and decreases shade and natural filtering of fertilizers and pesticides. Siltation itself has also been suggested as a threat to spawning success (Starrett et al. 1960). A threats assessment using the International Union for the Conservation of Nature calculator returned an overall threats impact of "Very High" (see Appendix 7).

Saskatchewan – Nelson Rivers DU

Specific threats to Silver Lamprey within DU2 have not been identified. There are some man-made barriers to fish movements within some rivers within DU2, but the degree to which these limit movement above that which might have occurred naturally is unknown (several of the man-made barriers were constructed at points were natural potential barriers existed).

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Like that of all fish species, the habitat of the Silver Lamprey is afforded some protection under the federal *Fisheries Act*. In Québec, it is protected on public lands by the Loi sur la conservation et la mise en valeur de la faune (Act respecting the conservation and development of wildlife).

The Silver Lamprey was assessed by COSEWIC in May 2011 and designated Special Concern for the Great Lakes - Upper St. Lawrence populations and Data Deficient for the Saskatchewan - Nelson River populations It is not listed in the most recent (2010) Species at Risk in Ontario List (http://www.mnr.gov.on.ca/en/Business/Species/). Wildspecies 2005 (http://www.wildspecies.ca/wildspecies2005) lists the Silver Lamprey as 'Sensitive' in Canada. The Ontario Natural Heritage Information Centre website (http://nhic.mnr.gov.on.ca/nhic_.cfm) reports NatureServe's (2006) ranking for Canadian species: it is designated a Global Rank of G5 (Secure), a National Rank of N4 (Apparently Secure) in Canada, and N5 (Secure) in the United States (NatureServe 2006). The species is ranked as S3 (Vulnerable) in both Manitoba and Ontario, and S3S4 (range between Vulnerable and Apparently Secure) in Québec. In the United States, the Silver Lamprey is currently ranked as critically imperilled (S1) in Nebraska; imperilled (S2) in Kentucky and Tennessee; between imperilled and vulnerable (S2S3) in West Virginia; vulnerable (S3) in Illinois, Iowa and New York; apparently secure (S4) in Indiana, Michigan, Wisconsin and Ohio; and unranked (SNR or S?) in Minnesota, Missouri, North Dakota, Pennsylvania and Vermont (NatureServe 2006).

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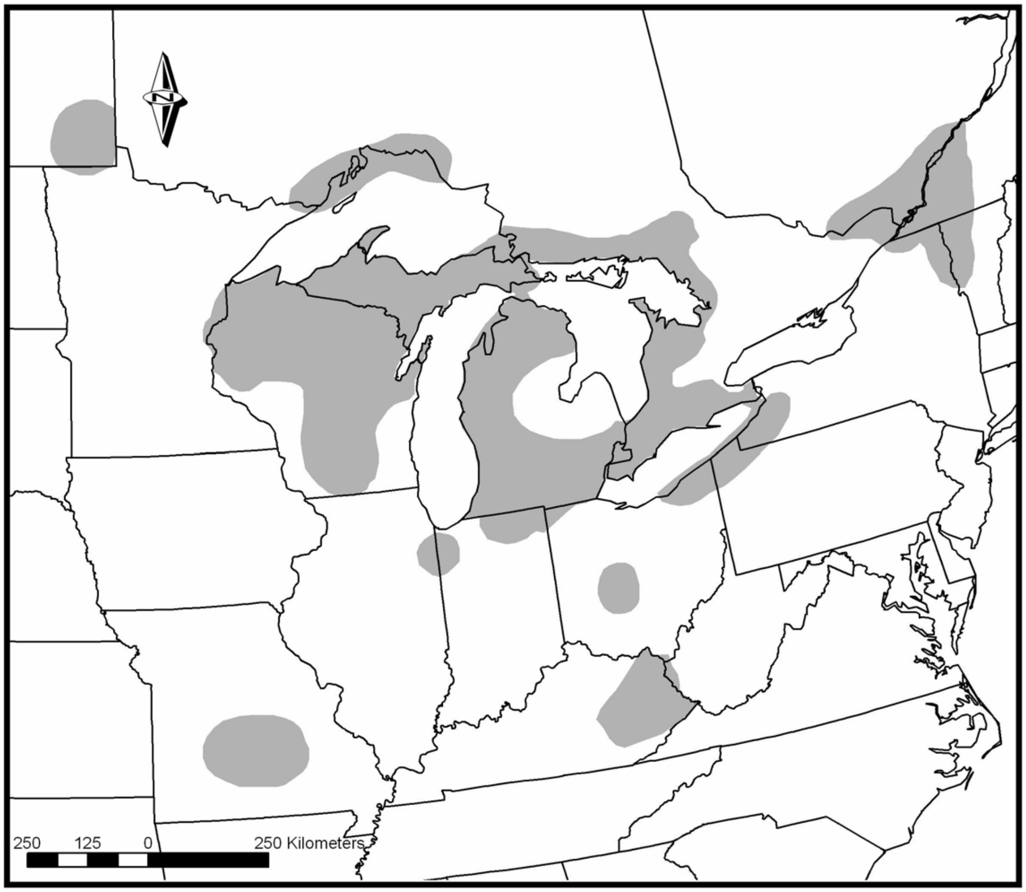
Appendix 1. Comparison of Silver Lamprey and Northern Brook Lamprey, from Scott and Crossman (1998).

	Northern Brook Lamprey	Silver Lamprey
Average adult size	15 cm	33 cm
Adult teeth	Small, blunt and peglike	Long, curved and sharp
Eye size	Small	Moderately large
Number trunk myomeres	51-58	47-55
Diameter of sucking disc	Less than branchial region	Greater than branchial region
Lifespan as adult	3-4 months	12-20 months
Larval duration	5-7 years	4-7 years
Average fecundity	1,200	10,800
Migratory	No	Yes
Parasitic	No	Yes
Semelparous	Yes	Yes

Appendix 2. Global distribution of Northern Brook Lamprey (COSEWIC 2007).



Appendix 3. Tributaries sampled within DU1 in Canada with *Ichthyomyzon* ammocoetes found between 1989 and 2007, but not identified to species (Northern Brook Lamprey or Silver Lamprey). Streams with an asterisk (*) have had adult or metamorphosed Silver Lampreys documented during the same time period.

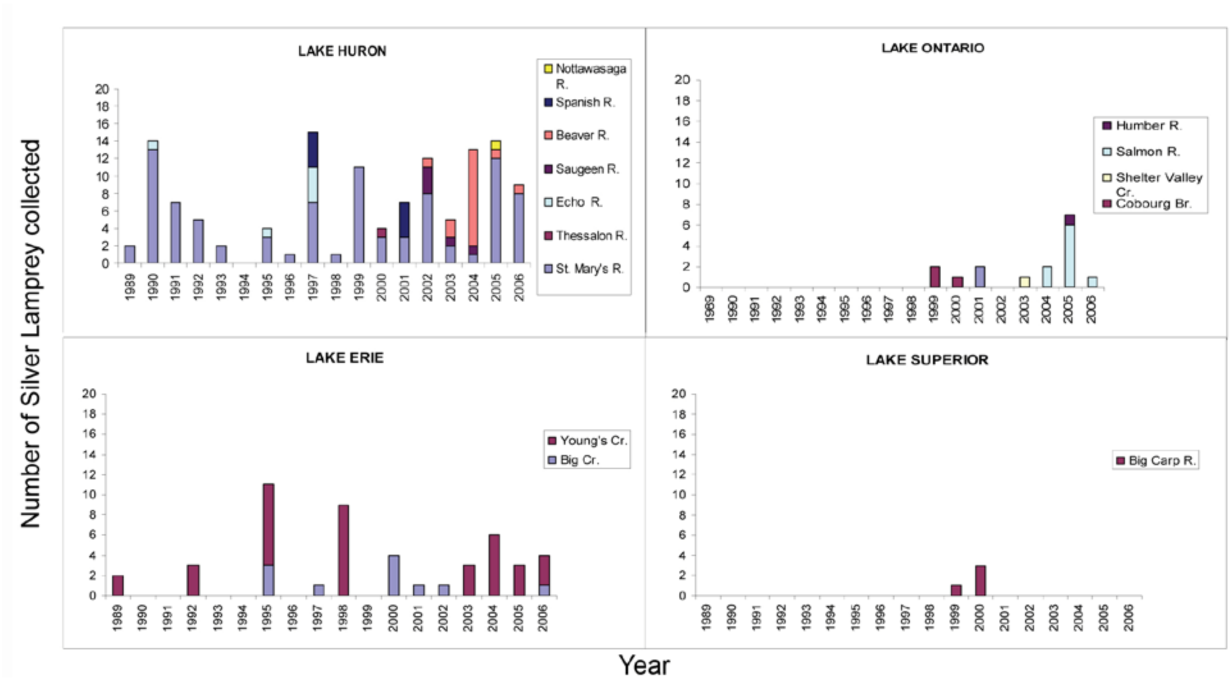
Lake	Stream Name	Lake	Stream Name
Lake St. Clair	St. Clair R.*	Lake Nipissing	Bear Cr.
	Thames R.		South Cr.*
Lake Erie	Silver Cr.		Wolsely R.
	Big Otter Cr.		Chippewa Cr.*
	Big Cr.*	Lake Superior	West Davignon Cr.
	Grand R.		Little Carp R.
	Detroit R.		Cranberry C.
Lake Huron	St. Mary's R.*		Goulais R.
	Root R.		Stokely C.
	Garden R.*		Jones Landing Cr.
	Echo R.*		Chippewa R.
	Bar R.		Pic R.
	Thessalon R.*		L. Munro Cr.
	Mississagi R.		Little Pic R.
	Blind R.		Prairie R.
	Serpent R.		Pays Plat R.
	Spanish R.*		Gravel R.
	Kagawong R.		Jackfish R.
	Manitou R.		Nipigon R.
	Blue Jay Cr.		Black Sturgeon R.
	Chikanishing R.		Pearl R.
	French R. System*		Sibley Cr.
	Key R.		Mackenzie R.
	Still R.		Neebing-McIntyre R.*
	Magnetawan R.	Lake Champlain	Pike R.*
	Naiscoot R.		
	Shawanaga Landing Cr.		
	Shebeshekong R.		
	Blackstone Cr.		
	Musquash R.*		
	Simcoe/Severn System		
	Coldwater R.		
	Sturgeon R.		
	Hogg Cr.*		
	Wye R.		
	Nottawasaga R.*		
	Silver Cr.		
	Beaver R.*		
	Bighead R.*		

Lake	Stream Name	Lake	Stream Name
	Sydenham R.		
	Sauble R.		
	Saugeen R.*		
	Nine Mile R.		
	Bayfield R.		

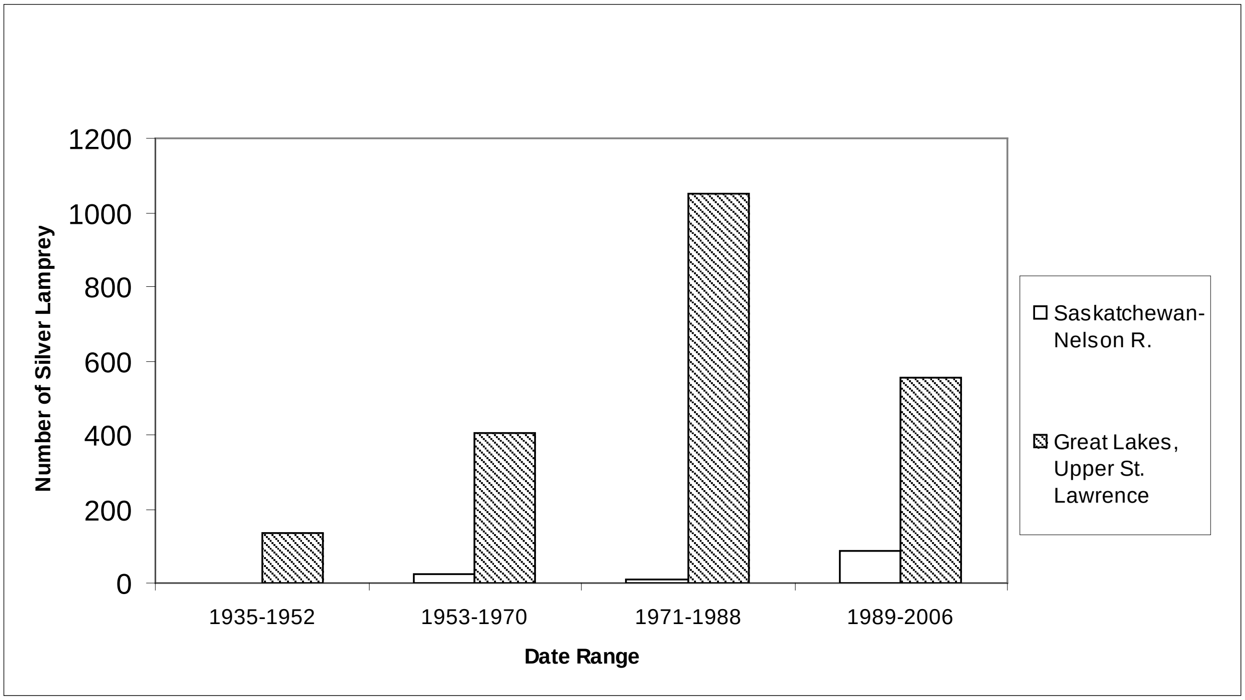
Appendix 4. Host fish species for the Silver Lamprey (adapted from Renaud 2002).

Common Name	Source
Atlantic Sturgeon (*Acipenser oxyrinchus*)	Renaud (2002)
Black Buffalo (*Ictiobus niger*)	Renaud (2002)
Brook Trout (*Salvelinus fontinalis*)	Renaud (2002)
Brown Bullhead (*Ameiurus nebulosus*)	Vladykov and Roy (1948), Renaud (2002)
Burbot (*Lota lota*)	Cochran and Marks (1995), SLCC unpub. data
Common Carp (*Cyprinus carpio*)	Renaud (2002)
Goldfish (*Carassius auratus*)	Renaud (2002)
Cisco (*Coregonus artedi*)	SLCC unpub. data
Lake Sturgeon	Vladykov (1985), Renaud (2002), Cochran et al. (2003)
Lake Trout (*Salvelinus namaycush*)	Renaud (2002), SLCC unpub. data
Lake Whitefish (*Coregonus clupeaformis*)	Renaud (2002), SLCC unpub. data
Longnose Gar (*Lepisosteus osseus*)	Renaud (2002)
Longnose Sucker (*Catostomus catostomus*)	Renaud (2002)
Muskellunge	Renaud (2002)
Northern Pike (*Esox lucius*)	Renaud (2002)
Paddlefish (*Polyodon spathula*)	Renaud (2002)
Rock Bass (*Ambloplites rupestris*)	Renaud (2002)
Smallmouth Bass (*Micropterus dolomieu*)	Renaud (2002)
Striped Bass (*Morone saxatilis)*	Renaud (2002)
Walleye (*Sander vitreus vitreus*)	Renaud (2002), SLCC unpub. data
White Bass (*Morone chrysops*)	Renaud (2002)
White Sucker (*Catostomus commersonii*)	Renaud (2002), SLCC unpub. data
Yellow Perch (*Perca flavescens*)	Cochran and Marks (1995), SLCC unpub. data

Appendix 5. Cumulative Silver Lamprey collections in SLCC Sea Lamprey traps by stream (not standardized by effort) from 1989 to 2006. All figures represent Silver Lamprey from DU1.



Appendix 6. Trend in number of Silver Lamprey collected in two DUs over four 18 year time periods (note: data are not standardized by effort). DU1 = Great Lakes St, Lawrence River, DU 2 = Saskatchewan-Nelson Rivers.



THREATS ASSESSMENT WORKSHEET

See instructions in 'Instructions' worksheet. Scroll down in top pane to view the entire table.

Species or Ecosystem Scientific Name	Silver Lamprey DU1 (Great Lakes upper St. Lawrence River NFBZ)		
Element ID		**Elcode**	

Suggested Number of Locations
48

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	low range
A	Very High	0	0
B	High	3	3
C	Medium	1	1
D	Low	2	2
	Calculated Overall Threat Impact:	Very High	Very High

Assigned Overall Threat Impact: **A = Very High**

Impact Adjustment Reasons: The silver lamprey is estimated to be found at 48 locations because each of the threats below is considered to act independently within each tributary stream or lake where the fish occurs.

Overall Threat Comments Completed by L. Bouvier and N.E. Mandrak, January 2011

Threat		Impact (calculated)		Scope	Severity	Timing	Comments	Number of Locations: Lowest	Most Likely	Highest
1	Residential & commercial development	C	Medium	Restricted	Serious		See below.			
1.1	Housing & urban areas	C	Medium	Restricted	Serious		1 - "The removal of riparian vegetation is thought to threaten lamprey populations in some areas (Fortin et al. 2004). This trend, which often accompanies agricultural and suburban development, increases sediment load in a stream and decreases shade and natural filtering of fertilizers and pesticides. Siltation itself has also been suggested as a threat to spawning success (Starrett et al. 1960)."			
1.2	Commercial & industrial areas						NA			
1.3	Tourism & recreation areas						NA			
2	Agriculture & aquaculture									

Threat		Impact (calculated)		Scope	Severity	Timing	Comments	Number of Locations		
								Lowest	Most Likely	Highest
2.1	Annual & perennial non-timber crops						NA			
2.2	Wood & pulp plantations						NA			
2.3	Livestock farming & ranching						NA			
2.4	Marine & freshwater aquaculture						NA			
3	Energy production & mining									
3.1	Oil & gas drilling						NA			
3.2	Mining & quarrying						NA			
3.3	Renewable energy						NA			
4	Transportation & service corridors									
4.1	Roads & railroads						NA			
4.2	Utility & service lines						NA			
4.3	Shipping lanes						NA			
4.4	Flight paths						NA			
5	Biological resource use	D	Low	Large	Slight		See below.			
5.1	Hunting & collecting terrestrial animals						NA			
5.2	Gathering terrestrial plants						NA			
5.3	Logging & wood harvesting	D	Low	Large	Slight		1 - " In Canada, the silver lamprey occurs in many areas that have undergone extensive deforestation due to logging and agriculture"			
5.4	Fishing & harvesting aquatic resources									
6	Human intrusions & disturbance									
6.1	Recreational activities						NA			
6.2	War, civil unrest & military exercises						NA			
6.3	Work & other activities						NA			
7	Natural system modifications	B	High	Large	Serious		See below.			
7.1	Fire & fire suppression						NA			

Threat		Impact (calculated)		Scope	Severity	Timing	Comments	Number of Locations		
								Lowest	Most Likely	Highest
7.2	Dams & water management/use	B	High	Large	Serious		1 - "The construction of dams has probably prevented silver lamprey access to spawning and larval habitat in some river systems." 2 - "Mormon (1979) found that some populations of silver lamprey can persist upstream of barriers, if conditions are favourable. He reported that “remnant” populations were present in reaches upstream from long established (early 1900s) permanent dams on three large rivers in Michigan. Each of these reaches was associated with inland lakes or impoundments capable of providing host fishes (Morman 1979)", 3 - "However, barriers can also serve as a threat to this lamprey by denying it access to upper portions of streams (Trautman 1981). There are hundreds of dams owned by federal, provincial and municipal governments throughout the silver lamprey’s range in Canada. The Ontario Ministry of Natural Resources owns and operates over 300 dams in Ontario alone and some of these may directly affect the ability of the silver lamprey to access previously available habitat. Dams may also potentially limit gene flow within the species (Schreiber and Engelhorn 1998). "			
7.3	Other ecosystem modifications	D	Low	Restricted	Moderate		1 - "The removal of riparian vegetation is thought to threaten lamprey populations in some areas (Fortin et al. 2004). This trend, which often accompanies agricultural and suburban development, increases sediment load in a stream and decreases shade and natural filtering of fertilizers and pesticides. Siltation itself has also been suggested as a threat to spawning success (Starrett et al. 1960)."			
8	Invasive & other problematic species & genes	B	High	Large	Serious					
8.1	Invasive non-native/alien species	B	High	Large	Serious		1 - lampricide applications continue in all Great lakes (Superior, Huron, Erie, Ontario) where Silver Lamprey are found in Canada, 2 - "the high fecundity of the invasive sea lamprey may lead to competition with lampreys native to the Great Lakes", 3 - "In the Great Lakes, Canadian and American Sea Lamprey Control agents often hire contractors to monitor sea lamprey traps. Contractors usually have some fish identification experience, which allows them to release incidental native fishes (including silver lamprey) from the trap back to the river, or over the associated barrier"			
8.2	Problematic native species	D	Low	Large	Slight		1 - "Predation on ammocoetes is probably minimal due to their sedentary existence in burrows for extended periods. However, given the opportunity, piscivorous fishes likely consume ammocoetes, considering the historic use of ammocoetes as bait by anglers", 2 - "Predation on adult lamprey likely occurs most often during the spawning event, as egg laying usually takes place in shallow water (Manion and Hanson 1980) where they are vulnerable. One documented case of predation was on the Fox River, Wisconsin, where a gull was observed feeding on a silver lamprey (Cochran et al. 1992)."			

Threat		Impact (calculated)		Scope	Severity	Timing	Comments	Number of Locations		
								Lowest	Most Likely	Highest
8.3	Introduced genetic material						NA			
9	Pollution	B	High	Large	Serious		1 - "The Silver Lamprey Technical Summary is reported at a stream level, due to the fact that stream-specific events can influence populations (e.g. chemical spill or lampricide treatment).", 2 - "Silver lamprey are vulnerable to ...pollution from anthropogenic sources...", 3 - "Streams with Ichthyomyzon larvae that have been infested by sea lamprey, and subsequently treated with lampricide, have undergone significant reductions or extirpations of native lamprey populations", 4 - "Larval Ichthyomyzon lamprey are less susceptible to the lampricide than sea lamprey larvae (King and Gabel 1985), but this difference is insufficient to allow for selective control of sea lamprey without impacting native lampreys", 5 - "Renaud et al. (1995) has also listed pollution (specifically, the herbicide atrazine) as a possible contributor to ammocoete mortality."			
9.1	Household sewage & urban waste water						NA			
9.2	Industrial & military effluents						NA			
9.3	Agricultural & forestry effluents						NA			
9.4	Garbage & solid waste						NA			
9.5	Air-borne pollutants						NA			
9.6	Excess energy						NA			
10	Geological events									
10.1	Volcanoes						NA			
10.2	Earthquakes/tsunamis						NA			
10.3	Avalanches/landslides						NA			
11	Climate change & severe weather	D	Low	Pervasive	Slight					
11.1	Habitat shifting & alteration						NA			
11.2	Droughts	D	Low	Pervasive	Slight		1 - "Fluctuating water levels are suspected to cause ammocoete mortality, due to exposing of larval burrows during low water levels (Bailey 1959)."			
11.3	Temperature extremes						NA			
11.4	Storms & flooding	D	Low	Pervasive	Slight		1 - "Flooding conditions may pose a risk due to excessive water flow forcing ammocoetes from the substrate (Potter 1980b)."			
Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008).										