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# Conservation Status Report for Silver Lamprey (*Ichthyomyzon unicuspis*) in Canada

# Rapport sur l'état de conservation de la lamproie argentée (*Ichthyomyzon unicuspis*) au Canada

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## ABSTRACT

The silver lamprey (*Ichthyomyzon unicuspis*) is an eel-like parasitic fish native to parts of central and eastern Canada. It has not yet undergone a COSEWIC evaluation, and this report acts as a pre-COSEWIC assessment to facilitate any potential required conservation efforts. The silver lamprey has two designatable units, the Great Lakes-Upper St. Lawrence area, and the Saskatchewan-Nelson River area. This report analyzes the current and historical distributions, discusses habitat requirements and trends, provides general biological information about adults and ammocoetes, examines population sizes and trends, and lists threats to the species. General trends for this species are: stable extent of occurrence, stable area of occupancy and populations, and stable to increasing total population over the last three generations. However, due to a lack of directed survey effort, very little is known about the Saskatchewan-Nelson River population. Complicating assessment of this species is the inability to distinguish the larvae of silver lamprey from northern brook lamprey larvae, along with an inability to differentiate these two species using genetic analyses.

## RÉSUMÉ

La lamproie argentée (*Ichthyomyzon unicuspis*), une espèce indigène des régions du centre et de l'est du Canada, est un poisson parasite qui ressemble à une anguille. Comme le COSEPAC ne l'a pas encore évaluée, le présent rapport se veut une évaluation préalable à celle du COSEPAC dont le but est de favoriser, au besoin, d'éventuels efforts de conservation. La lamproie argentée compte deux unités désignables, à savoir celle du cours supérieur du fleuve Saint-Laurent et des Grands Lacs ainsi que celle de la région de la rivière Saskatchewan et du fleuve Nelson. Le présent rapport analyse les aires de répartition actuelles et historiques de l'espèce, traite de ses exigences et des tendances en matière d'habitat, contient des renseignements généraux sur la biologie des adultes et des ammocètes, examine la taille des populations et les tendances connexes et dresse la liste des menaces pesant sur l'espèce. Parmi les tendances générales concernant cette espèce, mentionnons la stabilité de son occurrence, de son aire d'occupation et des populations ainsi que la stabilité ou l'augmentation de ses populations totales au cours des trois dernières générations. Cependant, comme aucun relevé spécifique à l'espèce n'est effectué, on sait très peu de choses au sujet de la population de la rivière Saskatchewan et du fleuve Nelson. Qui plus est, notre incapacité de distinguer les larves de lamproie argentée des larves de lamproie du Nord, en plus de notre incapacité de différencier ces deux espèces en utilisant des analyses génétiques, viennent compliquer l'évaluation de l'espèce.

# 1. SPECIES INFORMATION

## 1.1 Description of Species

### 1.1.1 Name and Classification

Kingdom: Animalia
Phylum: Craniata
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 du nord (Roy 1973) or lamproie argentée (Scott and Crossman 1998)

The silver lamprey is one of six species in the genus *Ichthyomyzon*. The six species are composed of three pairs of closely related parasitic (stem) and non-parasitic (satellite) species (Hubbs and Potter 1971). The northern brook lamprey (*Ichthyomyzon fossor*) is considered a dwarfed relative of the larger, parasitic silver lamprey (Hubbs and Trautman 1937; Potter 1980a). Two other species in this genus, the parasitic chestnut lamprey (*I.castaneus*) and the non-parasitic species northern brook lamprey (*I. fossor*) have overlapping ranges with silver lamprey (Vladykov and Kott 1979).

The nomenclature, according to Scott and Crossman (1998) includes:

| | |
|---|---|
| *Ichthyomyzon unicuspis* | Hubbs and Trautman 1937: 53 |
| *Petromyzon argenteus* | Kirtland 1841b: 343 |
| *Ammocoetes concolor* | Kirtland 1841b: 473 |
| *Ammocoetes borealis* | Agassiz 1850: 252 |
| *Petromyzon* | Fortin 1864: 71 |
| *Petromyzon hirundo* | Jordan and Copeland 1876: 161 |
| *Ichthyomyzon castaneus* | Provancher 1876 |
| *Ammocoetes hirundo* | Jordan 1878a: 120 |
| *Ammocoetes argenteus* | Jordan 1878a: 120 |
| *Lampetra fluriatitis* | Ward 1878: 222 |
| *Petromyzon nigricans* | Ward 1878: 222 |
| *Ichthyomyzon Argenteus* | Small 1883: 47 |
| *Petromyzon concolor* | Jordan and Fordice 1886: 282 |
| *Ichthyomyzon concolor* | Cox 1897: 9 |
| *Ichthyomyzon bdellium* | Huntsman 1917: 24 |

Prior to the publication of, “*A Revision to the Lamprey Genus Ichthyomyzon*” (Hubbs and Trautman 1937) where the name *unicuspis* was designated, most authors were using Kirtland’s name *concolor*. This name was based on unidentifiable ammocoetes (Scott and Crossman 1998).

### 1.1.2 Morphological Description

The silver lamprey is a jawless, eel-like fish characterized by its sucking disc type of mouth, lack of lateral line and lack of paired fins. Adults are moderately large lamprey, somewhat more laterally compressed than other species (Scott and Crossman 1998). They have small eyes and seven pairs of gill openings. The Canadian distribution of silver lamprey overlaps the distributions of four other lamprey species (Scott and Crossman 1998). Adult silver lamprey can be distinguished from other lampreys by a single dorsal fin and characteristic teeth patterns: usually 2 supraoral cusps, 5-11 infraoral cusps, 4 unicuspid teeth in circumoral row (if present, less than 3 bicuspid teeth, C. Renaud, personal communication), 2 to 4 teeth in anterior row, and 5 to 8 teeth in lateral row (Hubbs and Trautman 1937). They can reach up to 392 mm in length as adults, as seen in Green Bay, Wisconsin (Cochran and Marks 1995), but are typically smaller in Canadian waters. Vladykov and Roy (1948) found maximum length to be 318 mm. Average length of spawning silver lamprey has been reported as 248 mm (range 157-308 mm) in Michigan (Mormon 1979), 224 mm (Hubbs and Trautman 1937) and 255 mm (Vladykov 1951). Trunk myomere counts have been found to range between 47 and 55 (Hubbs and Trautman 1937).

The sense organs along the lateral line and on the underside of the branchial region are usually slightly darkened but contain far less black pigment than in the chestnut lamprey. Maturing males have a mid-dorsal ridge always present but not always prominent, and the urogenital papilla occasionally extend beyond the ventral margin of body (Becker 1983). 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, gradually darkening 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 transformed individuals, but become dark, or almost black 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 Quebec.

The larvae, known as ammocoetes, vary little within the *Ichthyomyzon* genus. They lack eyes and teeth, and possess an oral hood, in contrast to the sucker 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, larval silver and northern brook lampreys have been differentiated 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). Other authors have found no reliable differences between ammocoetes of these two species (Purvis 1970, Morman 1979, Becker 1983, Neave *et al.* 2007). Large ammocoetes (>105 mm) of the chestnut lamprey develop pigmented lateral line organs that appear as spots; however, before reaching this size this pigmentation character is not reliable (Neave 2004). All other features of larval chestnut lamprey are very similar to silver lamprey ammocoetes (Neave *et al.* 2007).

### 1.1.3 Genetic Description

There have been several studies investigating the genetics of the silver lamprey (Mandrak *et al.* 2004; Docker *et al.* 2005; Filcek *et al.* 2005) and its relationship to the northern brook lamprey.

No consistent differences between the paired northern brook lamprey and silver lamprey were detected in a study by Mandrak *et al.* (2004). They analyzed seven adult northern brook lamprey and five adult silver lamprey from different regions around the Great Lakes. Although they found intraspecific differences likely due to geographic variation, they found no species-specific differences between the two species in the 10,255 base pairs of the mitochondrial genome and the 523 base pairs from the nuclear genome that have been sequenced. Subsequent genetic analysis showed that individuals from the two species could be distinguished using microsatellite analysis (Filcek *et al.* 2005). Using one microsatellite locus, Filcek *et al.* (2005) had high success rates in differentiating between silver and northern brook lampreys from tributaries to Lake Michigan and Lake Superior, respectively. However, follow-up studies using the same microsatellite markers and individuals from a greater geographic range and from areas where they occur sympatrically found substantially different results (Docker *et al.* 2005). Interspecific variation was found to be less than intraspecific variation, which indicated the two species may not be distinct (Docker *et al.* 2005; Docker *et al.* submitted). This was supported by low $F_{ST}$ values, which suggests contemporary gene flow between northern brook and silver lampreys (Docker *et al.* 2005).

Several studies have examined the genetic relationship between other paired lamprey species and found no clear genetic differences, such as the river lamprey (*Lampetra ayresii*) and the western brook lamprey (*L. richardsoni*) (Docker *et al.* 1999, Meeuwig *et al.* 2002). Schreiber and Engelhorn (1998) concluded that there must be some degree of gene flow between the European brook lamprey (*Lampetra planeri*) and the European river lamprey (*Lampetra fluviatilis*) due to a lack of allozyme differentiation between the two species. These studies demonstrated the genetic similarity of many of these paired species, and indicated that some paired species have either separated very recently, or are capable of hybridizing.

Successful hybridization experiments have been performed between both northern brook and silver lampreys (Piavis *et al.* 1970); however, 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.

Being migratory and potentially non-homing (see Dispersal/Migration section), populations of silver lamprey are likely to have some degree of gene flow between streams. However, gene flow within streams may be limited by physical impediments such as barriers (Schreiber and Engelhorn 1998).

### 1.1.4 Designatable Units

Mandrak and Crossman (1992) hypothesized that the silver lamprey may have survived glaciation in a Mississippian refugium. Data collected by Docker *et al.* (2005) suggested that the silver and northern brook lampreys may have survived glaciation in two distinct refugia: an Atlantic coastal refugium, and a Mississippian refugium. In Canada, the silver lamprey is present in Manitoba, Ontario and Quebec waters. The species is present in two National Freshwater Ecological Areas in Canada, the Great Lakes-Upper St. Lawrence, and the Saskatchewan-Nelson River areas.

## 1.2 Distribution

### 1.2.1 Global Range

The distribution of this species is restricted to eastern North America (Figure 1). In the United States, the silver lamprey has been reported in 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 is likely 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 collect lampreys in 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 fishing gear in the Great Lakes. However, since they are a non-target catch in both trapping and commercial fishing, the potential to capture and report them is markedly lower than that of the targeted species.

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 sea lamprey ammocoetes. However, even within the Great Lakes basin, survey activities are normally restricted to stream assessment, and those streams that support sea lamprey receive the overwhelming majority of the sampling effort (SLCC, unpublished data).

### 1.2.2 Canadian Range

In Canada, adults have been found in streams in Ontario, southern Quebec, and Manitoba. Increased sampling efforts have revealed more locations over the past several years in Ontario (SLCC, unpublished data). The widespread occurrence of *Ichthyomyzon* larvae may indicate a much wider distribution, but collection of adults is required to confirm identification, as some of these larvae are very likely northern brook lamprey.

Since 1989 (approximately three generations), adults or transformers of this species have been found in 48 streams systems in Canada, including tributaries to the Nelson River (including Red, Assiniboine, and Winnipeg River/Lake of the Woods watersheds), Lake Superior, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Lake Nipissing, Ottawa River, and St. Lawrence River. Adult lamprey have also been found in most of these larger rivers and lakes parasitizing fishes.

During the same time period (1989-2006), SLCC has documented 68 streams throughout the Canadian side of the Great Lakes with *Ichthyomyzon* ammocoetes (Table 1); however, these individuals were not identified to species because of the previously mentioned identification problems. It is strongly suspected that due to their location within the stream system (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 silver lamprey. Adult silver lamprey have been identified in 28 of these 68 Great Lakes streams since 1989, suggesting that many of the remaining 40 streams may harbour primarily northern brook lamprey. Sampling efforts targeting transformed or adult lampreys are required to unequivocally determine the identity of these populations.

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 fishery statistical districts in the Great Lakes since 1989 (SLCC unpublished data), providing evidence that silver lamprey inhabit the Great Lakes proper. The combined area of these 10 statistical districts is about 30,500 km$^2$.

Data such as length, width and area were not available for all waterbodies that contain silver lamprey. Stream and lake area measurements that were not quantified in the field were calculated using GIS software (ESRI ArcGIS 9.1) based on available geographic information. The in-stream area of occupancy is approximately 3,830 km$^2$ (Table 2). The total Canadian area of occupancy (including lentic areas of Canadian lakes where silver lamprey have been collected) is approximately 35,000 km$^2$.

The extent of occurrence (using data from 1989-2006) in Canada encompasses a large range, at 1,728,000 km$^2$. This extent of occurrence is the highest of those calculated for the three previous 18 year periods (1935-1951, 1952-1971, and 1972 to 1988)(Figure 2).

### 1.3 Habitat Considerations

#### 1.3.1 Habitat Requirements

Lamprey species, whether parasitic or non-parasitic, share common spawning habitat requirements. Adult lampreys deposit their eggs in nests constructed in riffle areas of streams. After completing the embryonic phase and hatching in the nest, ammocoetes move downstream to backwaters with softer sediments in which they burrow (Beamish and Jebbink 1994; Hardisty and Potter 1971).

According to Trautman (1981), the silver lamprey has a number of requirements, including: clear water for the parasitic phase (to allow the capture of fish hosts); relatively clean stream substrate, composed of sand and organic debris for ammocoete habitat; and unrestricted migration routes for spawners (the adverse effects of man-made barriers is discussed in the Threats section).

Silver lamprey ascend large rivers in the spring when water temperatures reach approximately 10°C. They construct shallow nests in gravel and sand in riffle areas of streams (Trautman 1981; Scott and Crossman 1998). To construct the nest, spawning phase silver lamprey transport stones in their mouths and remove sand and silt using their tails (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 0.5-1.5m/s, and depths ranging from 13 to 170 cm (Manion and Hanson 1980). Spawning silver lamprey were observed on nests constructed at the upper end of a shallow riffle (45-50 cm water depth) with moderate to rapid water velocity (Mormon 1979). Nests had an average depth of 38 cm, average cavity depth of 8 cm, and varied in diameter from 33 to 122 cm (Mormon 1979). In June 1971, silver lamprey were observed spawning in Lake Huron near the inflow to the St. Clair River on nests in water with a depth of 3 to 5 m, on gravelled and sandy substrate (Lamsa and Westman 1972). They require a small amount of silt-free sand or some other fine material to which the eggs can adhere (Manion and Hanson 1980).

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. Mormon (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, unpublished 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 1997).

Silver lamprey require water temperatures of about 18°C for eggs to develop, hatch and reach the burrowing stage of development in about 2 to 3 weeks (Smith *et al.* 1968). After ammocoetes leave the nest and drift downstream they require sediment consisting of sand, silt, and organic debris (Becker, 1983; Trauman 1981). It has also been noted that clay is usually absent from ammocoete habitat (Becker 1983).

After transformation, 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).

Cochran and Marks (1995) reported that the majority of parasitic silver lamprey in Lake Michigan seem to be largely confined to Green Bay proper. In Green Bay, silver lamprey feed on fishes such as yellow perch, white sucker and burbot at depths between 6 and 12 metres. Silver lamprey were collected in higher numbers than sea lamprey in this shallow warm water habitat (Cochran and Marks 1995).

No literature has dealt with silver lamprey preferences with respect to pH, salinity or hardness. In studies of other lamprey species, Potter *et al.* (1986) found 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 (*Ichthyomyzon gagei*) preferred a higher percentage of fine sand in their habitat than did larger larvae. Beamish and Lowartz (1996) found that larval American brook lamprey densities were correlated to the amount of sand and organic matter in the stream substrate.

### 1.3.2 Habitat Trends

In Canada, the silver lamprey occurs in many areas that have undergone extensive deforestation due to logging and agriculture. However, no studies exist 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. The effects of dams are discussed in more detail in the Threats section of this report.

### 1.3.3 Habitat Protection/ Ownership

In Canada, all publicly owned waters and associated fish habitat within these waters is protected by the federal Fisheries Act. Provincial laws also protect the habitat of this species.

### 1.3.4 Identification of Critical Habitat

The silver lamprey life cycle involves three distinct phases, all of which rely on specific habitat requirements.

Spawning silver lamprey require rivers with water temperatures that reach approximately 10°C (Scott and Crossman 1998). They have been found in rivers with average summer discharges from 0.03 $m^3$/s to 72 $m^3$/s (Schuldt and Goold 1980; Mormon 1979, SLCC unpublished data). They have also been observed spawning in the St. Clair River (Lamsa and Westman 1972), which has an average discharge of over 5000 $m^3$/s (Edsall 1997). In these rivers, they spawn in shallow nests which they construct in riffle areas of streams (as described in the Residence section of this report).

Once the eggs hatch and reach stage 17, the burrowing prolarvae drift downstream and burrow into sand, silt and detritus, avoiding clayey soil, where they build U shaped burrows, and remain in the larval phase for 4 to 7 years (Scott and Crossman 1998; Vladykov 1949). During this phase, their diet consists of microscopic food such as algae, pollen, diatoms and protozoans (Becker 1983).

After migrating downstream, parasitic phase silver lamprey feed on fishes (Becker 1983; Vladykov 1949). Documented host fish species for the silver lamprey are numerous (Table 3). Cochran and Marks (1995) reported that areas such as Green Bay provide a suitable combination of water temperatures and host population densities.

### 1.3.5 Studies Required to Identify Critical Habitat

None identified.

### 1.3.6 Identification of Residence

Based on the concept of a residence as outlined by the Species At Risk Act (SARA), silver lamprey are known to have one residence – the nest site.

Silver lamprey nests are usually constructed in streams at the upstream end of a shallow riffle with water velocities of 0.5-1.5 m/s (Manion and Hanson 1980; Mormon 1979). Water depth at the nest can vary from 13 cm to 500 cm (Mormon 1979; Lamsa and Westman 1972). The substrate is moved by the lamprey to form a somewhat circular nest, with a depression in the middle, with a crescent shaped downstream lip (Scott and Crossman 1998). The average cavity depth of the nest is approximately 8 cm, and diameter of the nest can vary from 33 cm to 122 cm (Mormon 1979). Silver lamprey nests can be very similar to nests of other lamprey species, such as the sea lamprey. To construct the nest, spawning phase silver lamprey transport stones in the mouth, and remove sand and silt by vigorous tail movements (Scott and Crossman 1998). The nest site is essential to successful reproduction.

### 1.4 Biology

Several authors have studied the biology of the silver lamprey. 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 (1948, 1949, 1951) and Renaud (2002) studied the species in Quebec; 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.

#### 1.4.1 Life Cycle and Reproduction

Silver lamprey are semelparous. Upon reaching sexual maturity, 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 of silver lamprey in Michigan was observed at a mean water temperature of 18.3°C (Mormon 1979). A temperature of 18.4°C was considered optimal for rearing both sea lamprey and native lamprey (including silver and northern brook lamprey) eggs to the prolavae 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 (*Petromyzon marinus*) (Fine *et al.* 2004). Lampreys of the family Petromyzontidae, 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 mating pair then releases sperm and eggs simultaneously during a rapid vibration of their bodies while the male is attached to the head of the female (Scott and Crossman 1998).

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 silver lamprey from Quebec as 19,012, with a range from 12,006 to 29,412. Egg diameters ranged from 0.45 to 0.85 mm with an average of 0.73 mm (Vladykov 1951). In his work on silver lamprey in Quebec, Vladykov (1949) reported that an average of 10,800 eggs per female was laid during spawning. Schuldt *et al.* (1987) found that in silver lamprey collected in two major rivers on the western shore of Lake Michigan, body length and fecundity were not strongly correlated. Average fecundities from Menominee, Peshtigo, and Oconto rivers 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, probably due to 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). Once the eggs hatch and reach stage 17, 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, has a diet consisting of 'sestonic biofilm', composed of diatoms, desmids, protozoans, green algae, detritus and pollen (Scott and Crossman 1973, Yap and Bowen 2003). Sutton and Bowen (1994) found almost 98% of the diet of larval sea and northern brook lampreys 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 transformation. This usually begins while they are still in their burrows. Transformation involves development of eyes, teeth and a functional intestine (Vladykov 1949; Scott and Crossman 1998). Transformation is completed by early spring, after which they emerge from their burrows and may migrate downstream to a lake (Scott and Crossman 1998). Length of recently transformed individuals has been reported as 89-110 mm (Scott and Crossman 1998), but appears to vary geographically. Other reported lengths include 91-155 mm in Michigan (Mormon 1979), 103-139 mm in Wisconsin (Becker 1983), and an average of 107.9 mm for males and 113.0 mm for females in Quebec (Vladykov and Roy 1948). Their weight at this stage ranges from 1 to 6 grams (Becker 1983; Scott and Crossman 1998; Vladykov and Roy 1948).

After migrating downstream, parasitic phase silver lamprey feed on fishes. They attach themselves with their suction cup 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 increased over the period of October to March, and concluded that at least some parasitic phase silver lamprey continue to feed over the winter months.

Natural host fish species for the silver lamprey are numerous, and include at least 23 species (Table 3). Renaud (2002) described silver lamprey parasitism on muskellunge in the Ottawa River, stating that the lamprey preferred larger fish, and often fed on blood rather than flesh. No deep wounds were found in this study. Eighty per cent 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 in Lake St. Clair. Average length of the silver lamprey was 150.8 mm (range 85-237 mm, N=217). Average disc diameter of the silver lamprey was 15.7 (range 7-25 mm, N=217). Characteristics of silver lamprey marks on these fish were also measured and documented. Average diameter of silver lamprey marks on lake sturgeon was 15.3 mm (range 7-34 mm, N=141 marks) (Mike Thomas, MDNR, personal communication).

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).

Roy (1973) gained valuable information on feeding behaviour and growth of silver lamprey held in a laboratory setting. Female lamprey grew faster than males and attained larger maximum length. The reduction in length that occurred as lamprey approached maturity was slower but more pronounced in females. Lamprey that fed did not shrink as much as those that did not eat. Lamprey grew more rapidly and reached maturity earlier in captivity than in their natural habitat. The younger the individual when placed into an aquarium, the faster it reached maturity. Out of 50 specimens used in the experiment, 24 attached themselves to fishes, for an average attachment period equivalent to a third of their stay in the aquarium. Lamprey chose to feed on seven of the 23 fish species presented to them. The percentage of attachments for feeding was larger in females. Feeding activity diminished as lampreys approached the adult stage. 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 adverse factors being the stage of maturity of lampreys and the location of wounds in most vulnerable regions, such as the head and abdomen. Bowfin proved the most resistant to lamprey parasitism (Roy 1973). Becker (1983) stated that based on observations in the laboratory, the majority of silver lamprey attacks (81.5%) occurred at night.

### 1.4.2 Predation

As eggs and freshly hatched larvae, lamprey species are fed on by larger fishes (Potter 1980b). Predation on ammocoetes is 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 (Vladykov 1973; Scott and Crossman 1998). 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 the fish 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).

### 1.4.3 Physiology

As the large extent of occurrence suggests, the silver lamprey inhabits a variety of lake and stream habitats, surviving in a variety of hydrological, water chemistry and temperature conditions. Parasitic phase silver lamprey were collected by commercial fisheries in Canadian waters of the Great Lakes from 1983-2006 (SLCC data). Of the 232 provided to the SLCC, the mean water depth where the silver lampreys were collected was 21.5 m (range 2.6-133.3 m).

Kawasaki and Rovainen (1988) found that the characteristics of feeding behaviour of adult silver lamprey included low frequency cycles, long duration (hours), variable biphasic pressure changes in the sucker cavity, and protraction of the tongue-like apicalis. They found that a pumping behaviour was used to move excess fluid from the sucker through the pharynx and out the gill pores.

Other than this, little is known about the physiology of the silver lamprey, but 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). It has been found that 18.4°C is the optimal rearing temperature for sea lamprey eggs (Piavis 1961), a temperature that has also been found to be conducive to rearing silver lamprey eggs (Smith *et al.* 1968). 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).

### 1.4.4 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 (Mormon 1979) and 112 km (SLCC, unpublished data) from the river mouth, although these distances may not necessarily represent migration distances, as some silver lamprey may live parasitically within large rivers (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. Therefore, while the lamprey are attached, the host fish dictates their dispersal. Silver lamprey have been observed on lake sturgeon during their migration and spawning season, and it is possible that lampreys that remain attached to hosts, such as lake sturgeon, in the early spring could benefit by being 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 (*Petromyzon marinus*) do not seem to return to their natal stream to spawn. As discussed in the life cycle section, pheromones may play an important role in determining which streams silver lamprey ascend and ultimately use to spawn (Fine *et al.* 2004).

### 1.4.5 Interspecific Interactions

The sea lamprey invaded Lake Erie, likely from Lake Ontario via the Welland Canal, in 1921 and quickly dispersed through the remaining Great Lakes (Applegate 1950). Vladykov (1951) suggested that the high fecundity of 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 co-exist in the same stream systems with northern brook lamprey and sea lamprey, and occasionally American brook lamprey (SLCC, unpublished data). Where ranges overlap, generally only one species is more 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 and chestnut lampreys occur sympatrically, the silver lamprey often migrates furthest upstream (Scott and

Crossman 1998). Mormon (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, American brook and sea lampreys.

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), lamprey prefer habitats such as that found in Green Bay, Wisconsin, which provides a combination of suitable warmer water temperatures and host population densities. The differences in bioenergetics and habitat preferences of different lamprey species may provide a mechanism for the species to coexist (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 employ a similar, relatively unspecialized pheromone (Fine *et al.* 2004).

Interspecific interactions also occur during spawning. Mormon (1979) found that, of the 31 observed nests occupied by silver lamprey, 25 (81%) also contained other lamprey species. Two nests were occupied by silver lamprey exclusively. These two nests contained 10 silver lamprey each, indicating communal spawning. This is common in other species such as the northern brook lamprey (Cochran and Pettinelli 1987; Mormon 1979) and the American brook lamprey, where groups of three to seven individuals coil their bodies around one another (Becker 1983). Of the shared nests reported by Mormon (1979), there were no incidences of antagonistic or territorial behaviour among species sharing a nest. Interspecific mating was not witnessed, but the possibility of cross fertilization cannot be dismissed. The shared nests displayed characteristics typical of sea lamprey construction (Mormon 1979).

Scott and Crossman (1998) speculated that silver and chestnut lamprey may compete for spawning grounds and food, but suggested that this may not occur due to different habitats and behaviour.

### 1.4.6 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 watershed, suggests a 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 (Doug Cuddy, Sea Lamprey Control Centre, pers. comm.), it is likely that there is some degree of adaptability to new areas, and that this species could be a good candidate for translocation.

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. They were found in the Black and rainy Rivers above Alverno Dam (Cheboygan River system) and on the AuSable River above Foote dam (one metamorphosing silver lamprey was found 240 km upstream of the mouth, above a series of 7 dams). They were also found above Sanford and Edenville dams on the Molasses River, above Smallwood Dam on the Sugar River, and above Secord Dam, all part of the Saginaw River. Each of these isolated reaches is associated with inland lakes, which may provide host fishes. One silver lamprey was found attached to a lake sturgeon in Black Lake (Cheboygan River system) above Alverno dam in 1970 (Mormon 1979).

## 1.5 Population Size, Trends, and Uncertainty

### 1.5.1 Search Effort

Given the difficulty in identifying *Ichthyomyzon* ammocoetes to the species level, collection of identifiable silver lamprey is usually limited to post-transformation individuals in the fall, or in early spring before post-spawning mortality. Most of the information in this report is based on incidental catch data obtained through assessment of sea lamprey by sea lamprey control agents, the Department of Fisheries and Oceans (SLCC) and United States Fish and Wildlife Service (USFWS). Silver lamprey data were also provided by museums and other provincial, federal and private organizations, typically from routine fish community assessments using a variety of sampling methods, and usually not specifically targeting lampreys and not standardizing or recording effort. Data for which we can quantify search effort is limited to those collected by the SLCC.

**<u>Ammocoetes</u>**

Silver lamprey ammocoete data was collected 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. The search effort put forth by SLCC since 1989 (in terms of area surveyed and number of sites surveyed during sea lamprey assessment) is quantified in Table 5.

**<u>Adults</u>**

Trapping for spawning phase sea lamprey constitutes the majority of the data for adult silver lamprey. Commercial fisheries in the Great Lakes 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. The search effort undertaken by SLCC since 1989 (in terms of sea lamprey trapping and collections by commercial fisheries) is quantified in Table 6.

In the spring of 2000 and 2001, assessment staff at the SLCC conducted electrofishing surveys explicitly to identify undocumented locations of adult and transformed silver and northern brook lamprey. These efforts identified one previously unknown location in the Lake Nipissing drainage (South River) and confirmed other existing populations in the Great Lakes region.

### 1.5.2 Abundance

NatureServe (2006) estimates global abundance between 10,000 and 1,000,000 individuals, and estimated number of element occurrences (areas with communities present) at 81 to >300. Scott and Crossman (1998) stated that the abundance of this species in Lake Ontario is low, possibly a result of the long presence of the sea lamprey in the lake.

**Ammocoetes**

Population estimates are generally not calculated for *Ichthyomyzon* ammocoetes. One exception is the Black Sturgeon River, on the north shore of Lake Superior, where a population estimate was calculated for *Ichthyomyzon* ammocoetes in 2006. Based on electrofishing and habitat surveys, the population was estimated at 14,583,327 ammocoetes, of which 115,066 would metamorphose in 2006. Because of the location in the watershed, and the lack of silver lamprey records in the system, it is suspected that this population is composed of northern brook lamprey.

Between 2001 and 2006, 8,129 *Ichthyomyzon* ammocoetes were incidentally caught while electrofishing during larval sea lamprey assessment (Table 5) in Canadian tributaries to the Great Lakes. In the previous six year period (1995-2000), 7,917 *Ichthyomyzon* ammocoetes were collected in a slightly lower collecting effort (Table 5) (SLCC, unpublished data). Although these ammocoetes cannot be identified to species, it can be assumed that some of them are silver lamprey, and catch rates have remained constant.

**Adults**

Although population estimates have not been made, recent indirect evidence indicates abundant populations of silver lamprey in areas of Lake St. Clair, the Nelson River and the St. Lawrence River. 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 (Patrick Nelson, North/South Consultants, pers. comm.). Complaints 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 (Kathy Johnson, Greg Lashbrook, Go With The Flow Productions, pers. comm.) and by high wounding rates of lake sturgeon in Lake St. Clair. The Lake St. Clair Fisheries Research Station (Michigan Department of Natural Resources (MDNR)) collected 217 silver lamprey from lake sturgeon in 2006 alone, and observed an average of 5.95 scars per sturgeon in 2005 (Mike Thomas, MDNR, pers. comm.). Renaud (2002) described 15 recent (1992-2001) host-parasite interactions between silver lamprey and muskellunge in the Ottawa River (a large tributary to the St. Lawrence River). Number of wounds per fish ranged from 1-31 (mean=10.6 and SD=10.5) and, in two cases, two silver lamprey were attached to a single muskellunge. In 2000, wounding rates on muskellunge in the Ottawa River was 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).

### 1.5.3 Recent / Historical Trends

**Ammocoetes**

In the Great Lakes basin, 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 that their presence in Canadian streams had dropped from 41 to 17 streams. They hypothesized that the reduction was due to the effects of lampricide treatments. Recent data (1989-2006) indicate that 20 Canadian tributaries to Lake Superior currently have *Ichthyomyzon* ammocoetes, indicating a stabilization of these populations (Table 1). Most of these populations have not been exposed to lampricide treatments. Schuldt and Goold (1980) also discussed pre-treatment (1959) silver lamprey collections from electrical barriers in Lake Superior. When compared to the south-western portion of Lake Superior (in the United States), very few silver lamprey were collected from Canadian streams in 1959 (less than 1% of the of the Lake Superior total). Silver lamprey apparently require more specialized conditions than sea lamprey, and they were often found in rivers associated with bays in Lake Superior (Schuldt and Goold 1980). Having a greater fecundity and mobility than that of other native species might suggest that the silver lamprey are better able to recover from lampricide treatments, but this was not observed in Lake Superior during this time period (Schuldt and Goold 1980). 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. Forty-nine Lake Superior tributaries (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).

Based on data presented in Table 5 (SLCC search effort for *Ichthyomyzon* ammocoetes), regression analysis of catch-per-effort data for *Ichthyomyzon* ammocoetes collected by the SLCC during sea lamprey electrofishing surveys shows no significant trend over the past three generations. For time periods 1989 to 1994, 1995 to 2000 and 2001 to 2006, the CPE values were: 0.047 larvae/$m^2$, 0.086 larvae/$m^2$, and 0.071 larvae/$m^2$, respectively.

**Adults**

It is difficult to examine trends in the distribution and abundance of silver lamprey because of the difficulty in identifying ammocoetes, collecting adults, and limited targeted sampling of native lampreys. Furthermore, effort data were not always available, limiting our ability to evaluate trends in a standardized fashion. The total number of individuals collected in Canada, over several date ranges, irrespective of effort, is summarized in Table 4.

Another potential problem in evaluating trends is mis-identification of adult silver lamprey, particularly in distinguishing them from chestnut lamprey (*Ichthyomyzon castaneus*) (Stewart and Watkinson 2004). In the Great Lakes, Canadian and American Sea Lamprey Control agents hire contractors to monitor sea lamprey traps. Contractors usually have some fish identification experience, which allows them to release incidental native fish (including silver lamprey) from the trap back to the river, or over the associated barrier. However, in the United States, not all contractors are able to distinguish silver lamprey from sea lamprey and, therefore, are not passed over barriers (Jessica Doemel, USFWS, pers. comm.).

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 taken (Trautman 1981).

In recent years, several new waterbodies have been found to harbour silver lamprey (28 streams and lakes in 5 watersheds in the past 10 years). These include 11 waterbodies from the Nelson River watershed, seven from the Lake Huron watershed, five from the St. Lawrence River watershed, four from Lake Ontario, and one from Lake Nipissing. The long-term trend in number of waterbodies where silver lamprey have been collected in two of Canada's ecoregions, over four 18-year time periods, is represented in Figure 3. These new records are likely the result of a lack of earlier directed survey efforts, rather than newly established populations. Similarly, locations where silver lamprey were found historically (Figure 4), but have not been found recently (Figure 5) may be, in part, due to a lack of recent survey efforts.

Commercial fisheries from the Great Lakes have provided the SLCC with a significant portion of the silver lamprey collections over the past 40 years. The silver lamprey are often included in the containers holding preserved sea lamprey, for which the fishermen are paid, and which are received by the SLCC on an annual basis. The number of fishermen taking part in this program has decreased markedly over the past 18 years (Table 6), from 32 fishermen between 1989-1994, to 10 between 1995-2000, to eight between 2001-2006, and the number of silver lamprey provided has also decreased (136, 22 and 3, respectively) (SLCC, unpublished data).

The SLCC operates approximately 30 sea lamprey traps in Canadian Great Lakes tributaries (some of which are treated with TFM on a regular basis), with the primary purpose being assessment of sea lamprey spawner abundance. 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, unpublished data) (Figure 6). However, when all available data prior to 2006 are pooled by lake, Lake Huron ($r^2=0.45$, $p<0.05$) and Lake Superior ($r^2=0.30$, $p<0.05$) show a statistically significant negative trend (Figure 7). The other lakes show no significant trend, suggesting that these populations are more stable. Lake Ontario populations show signs of increasing abundance since trapping started in 1981, as silver lamprey were observed in only one year prior to 1999, but followed by collection of silver lamprey in seven of the past eight years. Regression analysis of catch-per-effort data for silver lamprey captured in sea lamprey traps (based on data shown in Table 6) in Canadian Great Lakes streams (pooled by six year time-periods), shows no statistically significant trend over the past three generations (SLCC, unpublished data). For time periods 1989 to 1994, 1995 to 2000, and 2001 to 2006, the CPE values were: 0.0074 lamprey/trap-day, 0.0089 lamprey/trap-day, and 0.0094 lamprey/trap-day, respectively.

Between 1989 and 2006, silver lamprey were collected in 28 Canadian Great Lakes streams. Of these streams, sea lamprey have been found in 26 of them, and 19 of them have been treated with TFM since 1989. Of the 18 treated streams containing silver lamprey occurrences, 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 (Figure 8). Adult silver lamprey have also been found in lentic habitats in Canadian waters of all of the Great Lakes, as well as Lake St. Clair, and in 25 waterbodies in Canada outside of the Great Lakes since 1989 (see Table 2 for occupied tributaries). In the previous 18-year period (1971-1988), silver lamprey were found in 23 Canadian Great Lakes streams, as well as lentic habitats of the Canadian Great Lakes, Lake St. Clair and 16 waterbodies in Canada outside of the Great Lakes.

The long-term trend in number of silver lamprey collected in two of Canada's ecoregions, over four 18-year time periods, is represented in Figure 9. These data 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 area, as well as in Canada as a whole, followed by the 1989-2006 time period. In the Saskatchewan-Nelson River area, the total number of silver lamprey is highest in the 1989-2006 time period.

Data provided by the United States Fish and Wildlife Service (USFWS) could not be standardized by effort, but the number of individuals captured over the course of many years may show general trends if a relatively constant year-to-year effort is assumed. The yearly total of silver lamprey captured in American portions of the Great Lakes (pooled by lake) show no significant trend over the 1989-2006 time period (Figure 10) (Robert Kahl, USFWS, personal communication).

In the past 10 years, biologists and anglers on Lake St. Clair have witnessed a high number of silver lamprey attachments to lake sturgeon (Mike Thomas, MDNR, collected 217 silver lamprey from sturgeon in 2006 alone), as well as a high incidence of scarring on lake sturgeon and muskellunge (John Cooper, Mike Thomas, MDNR, pers. comm.). Average number of lamprey scars per lake sturgeon (assumed to be inflicted by silver lamprey based characteristics of the mark) in Lake St. Clair since 1996 have shown an increasing trend (range 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) (Mike Thomas, MDNR, pers. comm.). No population estimates have been conducted. It is possible that this resurgence is due to rehabilitation of stream habitat and/or improved water quality in this area.

In Quebec, the silver lamprey was first documented in the St. Lawrence River watershed in 1906 when a specimen was taken from Rivière Richelieu (Centre for Conservation Biology and Biodiversity, Royal Ontario Museum, unpubl. data). The amount and type of data collected does 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 Quebec 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, Quebec Ministère des Ressources naturelles et de la Faune, Royal Ontario Museum, Canadian Museum of Nature, unpubl. 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, Quebec Ministère des Ressources naturelles et de la Faune Royal Ontario Museum, Canadian Museum of Nature, unpublished data). Renaud *et al*. (1995) found that in the Yamaska River in

Quebec, which once had a high density of northern brook lamprey, was found, 40 years later, to not have ammocoetes of any species. He suggested that the population decline in this river may be related to high pesticide contamination. The potential adverse effects of pollution are discussed in the Threats section of this report.

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 (Centre for Conservation Biology and Biodiversity, Royal Ontario Museum, unpubl. data). Too few specimens have been caught to infer trends, but the most recent record caught in 2006 indicates that this population is still extant (Patrick Nelson, North/South Consultants Inc., personal communication). 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 the Winnipeg River, Assiniboine River, Lake of the Woods, Rainy River, several lakes and smaller tributaries to the Nelson River (Doug Watkinson, DFO; Patrick Nelson, North/South Consultants Inc., personal communication). Prior to 1989, only 41 silver lamprey had been collected from about 12 waterbodies in Manitoba (Royal Ontario Museum, Canadian Museum of Nature, unpublished data).

### 1.5.4 Potential for Recovery

No literature on the recovery of at-risk populations of silver lamprey is available. A better understanding of silver lamprey ecology, its relationship to the northern brook lamprey, and threats to this species will provide a better basis for determining recovery potential.

With recent data suggesting stable or increasing populations in areas such as Lake St. Clair, the potential for recovery of the silver lamprey likely exists in some areas. Recovery is likely feasible.

As stated previously, 19 of the 53 waterbodies in Canada containing silver lamprey have been treated since 1989. Therefore, 64% of the known waterbodies containing silver lamprey have not been impacted by lampricide over the past three generations.

### 1.5.5 Rescue Effect

Several aspects of 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 the host fishes. If silver lamprey are non-homing, as is the case with the sea lamprey (Bergstedt and Seelye 1995), it is conceivable that mature individuals could be attracted to tributaries with populations of other lamprey species that release the bile acids. 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. From the data received, the number of silver lamprey occurrences over the past 50 years in the United States (over 28,000 individuals, most from southern Lake Superior and western Lake Michigan) is much higher than the total number of silver lamprey collected in Canada over the same time period (around 1,800 individuals) (USFWS, SLCC data). This difference in the number of occurrences between the United States and Canada was also observed prior to sea lamprey treatment (Schuldt and Goold 1980), and may be indicative of a higher quantity and/or quality of preferred habitat within the United States.

### 1.6 Scope for Harm

#### 1.6.1 Present/recent species trajectory?

All indications, based on catch-per-effort data, yearly total catch, and anecdotal evidence are that the recent species trajectory for the silver lamprey has remained relatively stable over the past three generations in most areas of Canada.

#### 1.6.2 Present/recent species status?

Apparently Secure in Canada (NatureServe 2006).

#### 1.6.3 Expected order of magnitude/target for recovery?

Not available.

#### 1.6.4 Expected general time frame for recovery to the target?

Not available.

#### 1.6.5 Is there scope for harm/mortality to the species that will not impede recovery?

Not available.

#### 1.6.6 What is the maximum harm/mortality that will not impede recovery?

Not available.

## 2. THREATS TO THE SPECIES

### 2.1 Limiting Factors and Threats

#### 2.1.1 List of threats

Silver lamprey, like other native lamprey species, are vulnerable to habitat alterations, dam construction, competition from invasive species, and pollution from anthropogenic sources, including lampricides.

This species is affected by ongoing lampricide applications conducted by Canadian and American agents of the sea lamprey management program in the Great Lakes basin. 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, 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 25% less susceptible to the lampricide than sea lamprey larvae, but this difference is insufficient to allow for selective control of sea lamprey without impacting native lampreys (King and Gabel 1985).

Permanent barriers to sea lamprey migration could offer some refuge to those populations of silver lamprey that are able to complete their life cycle above a barrier (Mormon 1979; Cochran *et al.* 2003; McLaughlin *et al.* 2006), as these portions of the stream are not exposed to the chemical applications. However, barriers can also serve as a threat to this lamprey by denying it access to upper portions of streams (Trautman 1981). SLCC currently maintains about 32 lowhead barrier dams in the Great Lakes. Only one of these 32 has been constructed since 1998 (SLCC, unpubl. data). 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 (OMNR) owns and operates over 300 dams in Ontario alone and many 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).

Fluctuating water levels 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 Quebec, 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. However, Renaud *et al.* (1995) found that persistent organochlorine contaminants, including PCBs, reached higher levels in lamprey from the St. Lawrence basin in samples from 1947-1950, compared to samples from 1990. The St. Lawrence River, especially Lac Saint-Pierre, is vulnerable to contamination by pesticides because it is fed by several tributaries (Yamaska, Nicolet, St. Francois rivers) that drain agricultural land (Environment Canada 2006a). Of these three rivers, the Yamaska River basin has the highest proportion of farmland (52% of its area). 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 2006a). Atrazine is a systemic herbicide that is used to control weeds in cornfields and other crops. This product was introduced to Canada in 1960. Environmental concerns have caused a reduction in its use by half since the 1980s. In the St. Lawrence region, atrazine is still the most frequently detected pesticide in surface waterbodies in summer. At varying concentrations, it can be toxic to fishes, freshwater invertebrates and aquatic plants (Environment Canada 2006a). The Yamaska River, whose daily inputs of atrazine can reach 27.7 kg, is likely to contribute significantly to the contamination of the St. Lawrence River (Environment Canada 2006a). 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). While pesticide concentrations fluctuate greatly on a seasonal basis, no upward or downward trend has been observed in the St. Lawrence River since 1995 (Environment Canada 2006a). A small number of identifiable silver lamprey have been collected in this area: six lamprey between 1989-2006; two lamprey between 1971-1988; zero between 1952-1970, and 11 between 1935-1951.

In addition to pesticides, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB) and mercury contribute to pollution in the St. Lawrence (Environment Canada 2006b). Temporal trends since 1995 show a slight increase in PAHs in suspended particles, while levels in the dissolved phase are unchanged. Mercury concentrations have increased markedly in the St. Lawrence River since 1995 (Environment Canada 2006b). The loads of PCBs and PAHs entering the St. Lawrence from Lake Ontario and the Ottawa River are essentially the same, but loads at Quebec City are five times higher than the combined load of the two inlet stations. Cossa *et al.* (1998) stated that, when comparing levels of PCBs, the St. Lawrence is one of the world's least contaminated rivers. PCB concentrations in the St. Lawrence are 5 to 10 times lower than concentrations measured in Lake Ontario in the 1980s, an indication of how the situation has improved (Cossa *et al.* 1998).

The removal of riparian vegetation is also 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.

#### 2.1.2 Degree of harm from each threat

The degree of harm from each of the above listed threats has not been quantified.

#### 2.1.3 Aggregate total harm/mortality from threats and compare to allowable harm to determine what level of mitigation is needed

Not available.

### 2.2 Assessment of Cross-Jurisdictional Authorities in Relation to Threats

Not available.

### 2.3 Early Identification of "Principal Stakeholders" in relation to Threats

The Great Lakes Fishery Commission (GLFC) is the body responsible for sea lamprey control in the Great Lakes. The Department of Fisheries and Oceans is the Canadian agency responsible for sea lamprey control in Canada. Because the silver lamprey is susceptible to the methods used to control sea lamprey, there may be substantial implications for the sea lamprey control program if the silver lamprey were to be classified as Special Concern, Threatened or Endangered. Recreational and commercial fisheries may be impacted by such a decision as well, especially if it directly (e.g. prohibition on harvesting hosts) or indirectly (e.g. decreased sea lamprey control leads to increased silver lamprey abundance) limits, or makes difficult, their ability to catch fishes. Hydroelectric companies in Ontario, Manitoba and Quebec planning to develop hydroelectric dams on rivers that may contain silver lamprey may also be impacted. Provincial and municipal governments, such as Ontario Ministry of Natural Resources and Conservation Authorities, may be affected if they have barriers present in waterbodies that contain silver lamprey. Property owners with land in the vicinity of waterbodies containing silver lamprey may also be considered stakeholders if this species were to be considered at risk.

## 3. EXISTING PROTECTION

### 3.1 Legislation

Like that of all fish species, the habitat of the silver lamprey is currently protected under the federal Fisheries Act. In Quebec, it is protected by the *Loi sur la conservation et la mise en valeur de la faune* (Act respecting the conservation and development of wildlife).

### 3.2 Existing Status Designations (domestically and internationally)

The silver lamprey has not been assessed by COSEWIC, nor is it listed in the Species at Risk in Ontario List (http://www.mnr.gov.on.ca/mnr/speciesatrisk). Wildspecies 2005 (http://www.wildspecies.ca/wildspecies2005) lists the silver lamprey as 'Sensitive' in Canada. The Ontario Ministry of Natural Resources Natural Heritage Information Centre (http://nhic.mnr.gov.on.ca/nhic_.cfm) uses the same classifications as NatureServe (2006) for Canadian waters, both of which have designated the silver lamprey a Global Rank of G5 (very common), a National Rank of N4 (Apparently Secure) in Canada, and N5 (Secure) in the United States. They are classified as S3 (Vulnerable) in both Manitoba and Ontario and a rank of S3S4 (range between Vulnerable and Apparently Secure) in Quebec. In the United States, the silver lamprey is currently classified 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).

### 3.3 Recovery Measures Currently In Place

Protection and recovery efforts of host fishes (such as the lake sturgeon), along with suppression of invasive species, such as the sea lamprey (which may compete with silver lamprey) are ongoing. Removal of dams, depending on location, may provide silver lamprey with a greater ability to successfully reproduce. These measures may provide the basis for a recovery plan.

## 4. POTENTIAL CONSERVATION TARGETS

### 4.1 Goal of Conservation Measures

Based on historical and recent data, Canadian populations of silver lamprey appear to be stable, despite being vulnerable to several threats and limiting factors that they have been adversely affected by in the past. If required, the goal of conservation measures would be to ensure that the conditions necessary to maintain a viable population of silver lamprey are present.

### 4.2 Proposed Species Rebuilding/Habitat Restoration Strategy

Not available.

### 4.3 Recommended Actions/Recovery Schedule

Since several areas in Canada (22 recently documented waterbodies, as well as Lake St. Clair and the Ottawa River) have seemingly undergone resurgence in silver lamprey numbers in recent years, continuation and improvement of current activities is recommended. These activities include, but are not limited to: suppression of sea lamprey populations; lampricide treatments of only those streams with high sea lamprey densities; minimizing pollution entering Canadian waterways; protection and restoration of host fishes and their habitat; continued education of fisheries agencies, commercial fishermen and anglers who may encounter silver lamprey; promoting catch and release; and, passing silver lamprey above barriers where possible.

### 4.4 Other Studies Needed

Expanding the search effort (including search area) for the silver lamprey would provide better distribution and density information of the species.

Further investigation into the relationship between the silver and northern brook lamprey may provide us with a better understanding of the adaptability of the species, as well as the significance of various threats to the species. An evaluation of biotic and abiotic factors that could determine whether the species exhibit plasticity in feeding morphology and behaviour has been proposed.

## 5. SIGNIFICANCE OF THE SPECIES

### 5.1 Scientific

The Canadian populations of silver lamprey are not significant in terms of endemicity, as abundant and stable populations appear to exist in the United States (NatureServe 2006; USFWS unpublished data). Due to the migratory nature of this species, natural immigration (rescue effect) from United States waters is very likely.

Lampreys are the most ancestral living 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 and adult lampreys have been used as biomonitors of organochlorine contaminants in fresh water (Renaud *et al.*. 1995, Renaud *et al.*. 1999).

Further study of the silver lamprey and its parasitic sister species, the northern brook lamprey, may provide insight into the evolution of alternate feeding strategies, and could lead to new ways of controlling the invasive sea lamprey.

### 5.2 Ecological

The filter-feeding silver lamprey larvae likely play a role in nutrient cycling in the streams that they inhabit (Vladykov 1949). Adult silver lamprey are a top predator in the ecosystems in which they are found.

### 5.3 Social/Cultural

Silver lamprey have historically been used as food for humans, as the literature refers to the species caught in Lake Erie being seen in fish markets (Hubbs and Trautman 1937). They have also been used as bait for sportfish (Scott and Crossman 1998).

### 5.4 Aboriginal

No information available.

### 5.5 Economic

An indirect relation to humans involves its parasitism of economically important commercial and sport fishes (Scott and Crossman 1998). The significance of silver lamprey parasitism is much less than that of the sea lamprey, as wounds are usually smaller and shallower and often non-lethal, especially on larger host fishes (Renaud 2002; Scott and Crossman 1998).

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## TECHNICAL SUMMARY

***Ichthyomyzon unicuspis***
Silver Lamprey / Lamproie argentée

Range of Occurrence in Canada: **Manitoba, Ontario and Quebec**

| **Extent and Area Information** | |
|---|---|
| *Extent of occurrence (EO)(km²)* | 1,728,454 km² |
| *Specify trend in EO* | Stable |
| *Are there extreme fluctuations in EO?* | No (moderate fluctuations due to lack of early records from north Nelson River watershed) |
| *Area of occupancy (AO) (km²) – within streams*<br>*– total (including lakes)* | 3,830 km²<br>35,038 km² |
| *Specify trend in AO* | Stable |
| *Are there extreme fluctuations in AO?* | No |
| *Number of known or inferred current locations* | 59 streams and lakes |
| *Specify trend in #* | Increasing (previously 44 streams and lakes) |
| *Are there extreme fluctuations in number of locations?* | No |
| *Specify trend in area, extent or quality of habitat* | Stable |

| **Population Information** | |
|---|---|
| *Generation time (average age of parents in the population)* | 6 years |
| *Number of mature individuals* | Unknown |
| *Total population trend:* | Catch per effort data indicate an increase over the past 18 years in the Great Lakes. |
| *% decline over the last/next 10 years or 3 generations.* | Unknown |
| *Are there extreme fluctuations in number of mature individuals?* | Unknown |
| *Is the total population severely fragmented?* | No |
| *Specify trend in number of populations* | Stable |
| *Are there extreme fluctuations in number of populations?* | No |
| List populations with number of mature individuals in each:<br>Unknown | |

| **Threats (actual or imminent threats to populations or habitats)** |
|---|
| Lampricide treatments of populations co-existing with sea lamprey larvae, stream barriers impeding migration, pollution, sedimentation. |

| **Rescue Effect (immigration from an outside source)** | |
|---|---|
| *Status of outside population(s)?*<br>**USA:** Stable | |
| *Is immigration known or possible?* | Possible, and likely, due to their migratory behaviour |

| | |
|---|---|
| *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** |
| **Current Status:** Global Rank of G5 (very common), National Rank of N4 (Apparently Secure) in Canada, and N5 (Secure) in the United States. Classified as S3 (Vulnerable) in both Manitoba and Ontario and S3S4 (range between Vulnerable and Apparently Secure) in Quebec. | |

***Ichthyomyzon unicuspis***
Silver Lamprey / Lamproie argentée

Range of Occurrence in Canada: **Great Lakes, Upper St. Lawrence Ecological Area**

| **Extent and Area Information** | |
|---|---|
| *Extent of occurrence (EO)(km²)* | 511,000 km² |
| *Specify trend in EO* | Stable |
| *Are there extreme fluctuations in EO?* | No |
| *Area of occupancy (AO) (km²) – within streams*<br>*- total (including lakes)* | 1,750 km²<br>32,962 km² |
| *Specify trend in AO* | Stable |
| *Are there extreme fluctuations in AO?* | No |
| *Number of known or inferred current locations* | 46 streams and lakes |
| *Specify trend in #* | Increasing (previously 38 streams and lakes) |
| *Are there extreme fluctuations in number of locations?* | No |
| *Specify trend in area, extent or quality of habitat* | Stable |

| **Population Information** | |
|---|---|
| *Generation time (average age of parents in the population)* | 6 years |
| *Number of mature individuals* | Unknown |
| *Total population trend:* | Catch per effort data indicate an increase over the past 18 years in the Great Lakes. |
| *% decline over the last/next 10 years or 3 generations.* | Unknown |
| *Are there extreme fluctuations in number of mature individuals?* | No |
| *Is the total population severely fragmented?* | No |
| *Specify trend in number of populations* | Stable |
| *Are there extreme fluctuations in number of populations?* | No |
| List populations with number of mature individuals in each:<br>Unknown | |

| **Threats (actual or imminent threats to populations or habitats)** |
|---|
| Lampricide treatments of populations co-existing with sea lamprey larvae, stream barriers impeding migration, sedimentation, possibly pollution. |

| **Rescue Effect (immigration from an outside source)** | |
|---|---|
| *Status of outside population(s)?*<br>**USA:** Stable | |
| *Is immigration known or possible?* | Possible, and likely, due to their migratory behaviour |
| *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** |
| **Current Status:** Classified as S3 (Vulnerable) Ontario and S3S4 (range between Vulnerable and Apparently Secure) in Quebec. | |

***Ichthyomyzon unicuspis***
Silver Lamprey / Lamproie argentée

Range of Occurrence in Canada: **Saskatchewan – Nelson Ecological Area**

| **Extent and Area Information** | |
|---|---|
| *Extent of occurrence (EO)(km²)* | 256,000 km² |
| *Specify trend in EO* | Stable (short term) or positive (long term) |
| *Are there extreme fluctuations in EO?* | Yes, due to lack of records from lower Nelson River |
| *Area of occupancy (AO) (km²)* | 2,076 km² |
| *Specify trend in AO* | Stable (short term) or positive (long term) |
| *Are there extreme fluctuations in AO?* | No |
| *Number of known or inferred current locations* | 13 streams and lakes |
| *Specify trend in #* | Increasing (previously 6 streams and lakes) |
| *Are there extreme fluctuations in number of locations?* | No |
| *Specify trend in area, extent or quality of habitat* | Stable |

| **Population Information** | |
|---|---|
| *Generation time (average age of parents in the population)* | 6 years |
| *Number of mature individuals* | Unknown |
| *Total population trend:* | Unknown, but more adults documented since 2001 than all previous years combined |
| *% decline over the last/next 10 years or 3 generations.* | Unknown |

| | |
|---|---|
| *Are there extreme fluctuations in number of mature individuals?* | Unknown |
| *Is the total population severely fragmented?* | Unknown |
| *Specify trend in number of populations* | Unknown |
| *Are there extreme fluctuations in number of populations?* | Unknown |
| List populations with number of mature individuals in each<br>Unknown | |

| Threats (actual or imminent threats to populations or habitats) |
|---|
| Stream barriers impeding migration, gene flow, sedimentation. |

| **Rescue Effect (immigration from an outside source)** | |
|---|---|
| *Status of outside population(s)?*<br>**USA:** Stable | |
| *Is immigration known or possible?* | Possible |
| *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** |
| **Current Status:** Classified as S3 (Vulnerable) in both Manitoba and Ontario. | |

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Cuddy, Doug. Sea Lamprey Control Centre, Department of Fisheries and Oceans, Sault Ste Marie, Ontario.

De Lafontaine, Yves. St. Lawrence Centre, Environment Canada, Montreal, Québec.

Doemel, Jessica. Fisheries Assessment Biologist, Marquette Biological Station, United States Fish and Wildlife Service, Marquette, Michigan.

Holm, Erling. Assistant Curator, Royal Ontario Museum, Toronto, Ontario.

Johnson, Kathy and Lashbrook, Greg. Professional underwater videographers, Go With The Flow Productions, Lakeport, Michigan.

Kahl, Robert. Marquette Biological Station, United States Fish and Wildlife Service, Marquette, Michigan.

Laviolette, Nathalie. Quebec Ministère des Ressources naturelles et de la Faune.

Nelson, Patrick. Aquatic Scientist, North/South Consultants Inc., Winnipeg, Manitoba.

Renaud, Claude. Canadian Museum of Nature, Ottawa, Ontario.

Thomas, Mike. Fisheries Research Biologist, Michigan State Department of Natural Resources, Lake St. Clair Fisheries Research Station, Michigan.

Watkinson, Doug. Fish Habitat Research Biologist, Department of Fisheries and Oceans, Winnipeg, Manitoba.

## BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Fraser Neave is a fisheries biologist with the Department of Fisheries and Oceans. He received a Master of Science degree in zoology from the University of Guelph in 2004 working on the taxonomy of lampreys native to the Great Lakes. He has worked at the Sea Lamprey Control Centre since 1994.

Gale Bravener is an assessment technologist with the Department of Fisheries and Oceans. He received a degree in biological sciences from Brock University in 1998. He has worked with DFO since 1999 and at the Sea Lamprey Control Centre since 2000.

Nicholas Mandrak is a research scientist with the Department of Fisheries and Oceans. He has co-authored 24 COSEWIC status reports, has published books and articles on fish distribution, and maintains an extensive database of Canadian fish distributions. His primary research interests are the biogeography, conservation biology and ecology of native and introduced freshwater fishes. He received his doctoral degree from the University of Toronto in 1994.

## TABLES

Table 1. Tributaries in Canada with *Ichthyomyzon* ammocoetes found since 1989, but not identified to species (northern brook lamprey or silver lamprey).

| 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 Floodway |
| | Magnetawan R. | | |
| | Naiscoot R. | | |
| | Shawanaga Landing Cr. | | |
| | Shebeshekong R. | | |
| | Blackstone Cr. | | |
| | Musquash R. | | |
| | Simcoe/Severn System | | |
| | Coldwater R. | | |
| | Sturgeon R. | | |
| | Hog Cr. | | |
| | Wye R. | | |
| | Nottawasaga R. | | |
| | Silver Cr. | | |
| | Beaver R. | | |
| | Bighead R. | | |
| | Sydenham R. | | |
| | Sauble R. | | |
| | Saugeen R. | | |
| | Nine Mile R. | | |
| | Bayfield R. | | |

Table 2. Occupied area of tributaries in Canada with adult or transformed silver lamprey detected since 1989.

| Watershed Name | Stream Name | Occupied Area ($km^2$) |
|---|---|---|
| Lake St. Clair | St. Clair R. (Can. side only) | 101.0 |
| Lake Erie | Big Cr. | 1.143 |
| Lake Erie | Young's Cr. | 0.028 |
| Lake Huron | St. Mary's (Can. Side only) | 11.13 |
| Lake Huron | Garden R. | 0.135 |
| Lake Huron | Echo R. | 0.183 |
| Lake Huron | Koshkawong R. | 0.014 |
| Lake Huron | Thessalon R. | 0.245 |
| Lake Huron | Spanish R. | 10.32 |
| Lake Huron | French R. | 2.500 |
| Lake Huron | Musquash R. | 0.346 |
| Lake Huron | Coldwater Cr. | 0.110 |
| Lake Huron | Sturgeon R. | 0.020 |
| Lake Huron | Hog R. | 0.019 |
| Lake Huron | Nottawasaga R. | 2.753 |
| Lake Huron | Beaver R. | 0.021 |
| Lake Huron | Bighead R. | 0.370 |
| Lake Huron | Saugeen R. | 0.475 |
| Lake Nipissing | South R. | 0.520 |
| Lake Ontario | Humber R. | 0.102 |
| Lake Ontario | Bowmanville R. | 0.055 |
| Lake Ontario | Cobourg Br. | 0.008 |
| Lake Ontario | Shelter Valley Cr. | 0.001 |
| Lake Ontario | Salmon R. | 0.132 |
| Lake Superior | Big Carp R. | 0.010 |
| Lake Superior | Carp R. | 0.074 |
| Lake Superior | Pancake R. | 0.070 |
| Lake Superior | Neebing-McIntyre | 0.438 |
| Nelson River | 12-Mile Creek | 0.050 |
| Nelson River | Assiniboine River | ----- |
| Nelson River | Berry Creek | 3.000 |
| Nelson River | Burntwood River | 15.00 |
| Nelson River | Gull Lake | 52.00 |
| Nelson River | Limestone River | 9.000 |
| Nelson River | MacMillan Creek | 0.100 |
| Nelson River | Nelson River | 811.00 |
| Nelson River | Pinawa channel | 99.0 |
| Nelson River | Rainy River | 150.0 |
| Nelson River | Split Lake | 372.0 |
| Nelson River | Stephens Lake | 374.7 |
| Nelson River | Winnipeg River | 190.0 |
| St. Lawrence River | Gatineau River | 1.284 |
| St. Lawrence River | Ottawa River | 190.0 |
| St. Lawrence River | Rivière Blanche | 0.5 |
| St. Lawrence River | Rivière du Lièvre | 1.220 |
| St. Lawrence River | Rivière Petite Nation | 1.00 |
| St. Lawrence River | Lac Saint-Pierre | 365.0 |
| St. Lawrence River | Lac St-Louis | 154.0 |
| St. Lawrence River | Rivière L'Assomption | 2.500 |
| St. Lawrence River | Riviere Richelieu | 5.000 |
| St. Lawrence River | Ruisseau Hinchinbrook | 8.000 |
| St. Lawrence River | Saint-François River | 1.500 |
| St. Lawrence River | St. Lawrence River | 890.0 |
| St. Lawrence River | Rivière Petite Nation | 1.000 |

Table 3. Natural host fish species for the silver lamprey (adapted from Renaud 2002).

| **Common Name** | **Source** |
|---|---|
| Atlantic Sturgeon | Renaud (2002) |
| Black Buffalo | Renaud (2002) |
| Brook Trout | Renaud (2002) |
| Brown Bullhead | Renaud (2002) |
| Burbot | Cochran and Marks (1995), SLCC unpub. data |
| Common Carp | Renaud (2002) |
| Goldfish | Renaud (2002) |
| Lake Herring | SLCC unpub. data |
| Lake Sturgeon | Renaud (2002), Cochran *et al.* (2003) |
| Lake Trout | Renaud (2002), SLCC unpub. data |
| Lake Whitefish | Renaud (2002), SLCC unpub. data |
| Longnose Gar | Renaud (2002) |
| Longnose Sucker | Renaud (2002) |
| Muskellunge | Renaud (2002) |
| Northern Pike | Renaud (2002) |
| Paddlefish | Renaud (2002) |
| Rock Bass | Renaud (2002) |
| Smallmouth Bass | Renaud (2002) |
| Striped Bass | Renaud (2002) |
| Walleye | Renaud (2002), SLCC unpub. data |
| White Bass | Renaud (2002) |
| White Sucker | Renaud (2002), SLCC unpub. data |
| Yellow Perch | Cochran and Marks (1995), SLCC unpub. data |

Table 4. Number of verified silver lamprey collected in Canada and freshwater ecological areas, 1989-2006.

| **Date range** | **All of Canada** | **Saskatchewan -Nelson R.** | **Great Lakes – west. St. Lawrence** |
|---|---|---|---|
| 1989-1994 | 272 | 0 | 272 |
| 1995-2000 | 185 | 0 | 185 |
| 2001-2006 | 249 | 88 | 161 |

Table 5. Search effort by SLCC directed at assessing larval sea lamprey populations in Great Lakes tributaries.

| | ELECTROFISHING | | | GRANULAR BAYER | | | TFM COLLECTION | |
|---|---|---|---|---|---|---|---|---|
| Time Period | Survey area ($m^2$) | Number of sites | Number of *Ichthyomyzon* spp. larvae (adult silver lamprey) | Survey area ($m^2$) | Number of sites | Number of *Ichthyomyzon* spp. larvae (adult silver lamprey) | Number of sites | Number of *Ichthyomyzon* spp. larvae (adult silver lamprey) |
| 1989-1994 | 163,833 | 2,775 | 7,688 (0) | 864,186 | 947 | 2,310 (1) | 0 | (0) |
| 1995-2000 | 92,174 | 3,154 | 7,917 (29) | 617,176 | 757 | 970 (0) | 63 | 282 (17) |
| 2001-2006 | 114,916 | 5,053 | 8,129 (21) | 1,114,961 | 1,016 | 437 (2) | 117 | 321 (0) |

Table 6. Search effort by SLCC directed at assessing adult sea lamprey populations in the Great Lakes and their tributaries.

| | TRAPPING | | | COMMERCIAL FISHERIES | | |
|---|---|---|---|---|---|---|
| Time Period | Number of different trap sites | Number of trap- days fished | Number of silver lamprey collected | Number of Great Lakes commercial fishermen providing sea lamprey | Number of Great Lakes Statistical Districts where sea lamprey were collected | Number of Silver Lamprey Collected |
| 1989-1994 | 45 | 6,210 | 46 | 34 | 13 | 136 |
| 1995-2000 | 40 | 7,722 | 68 | 10 | 7 | 22 |
| 2001-2006 | 51 | 9,818 | 92 | 8 | 6 | 3 |

## FIGURES

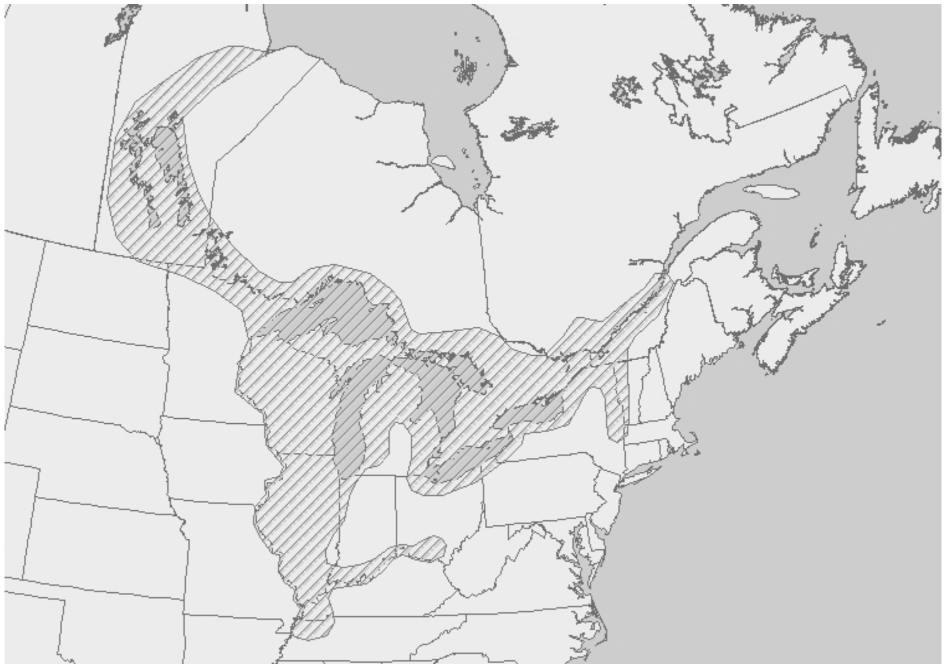

Figure 1.  Distribution of the silver lamprey in North America.

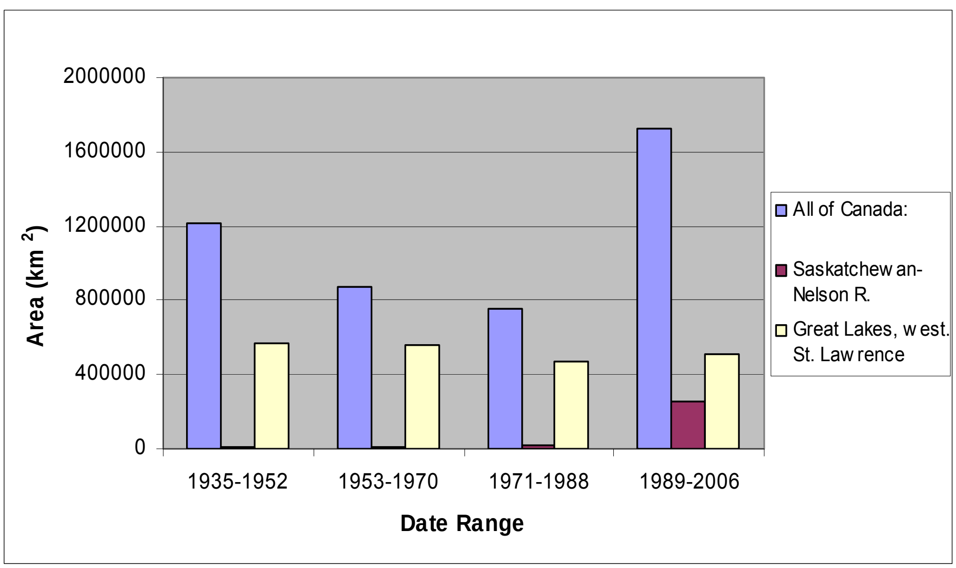


Figure 2.  Trend in silver lamprey Extent of Occurrence in Canada and its two ecoregions.

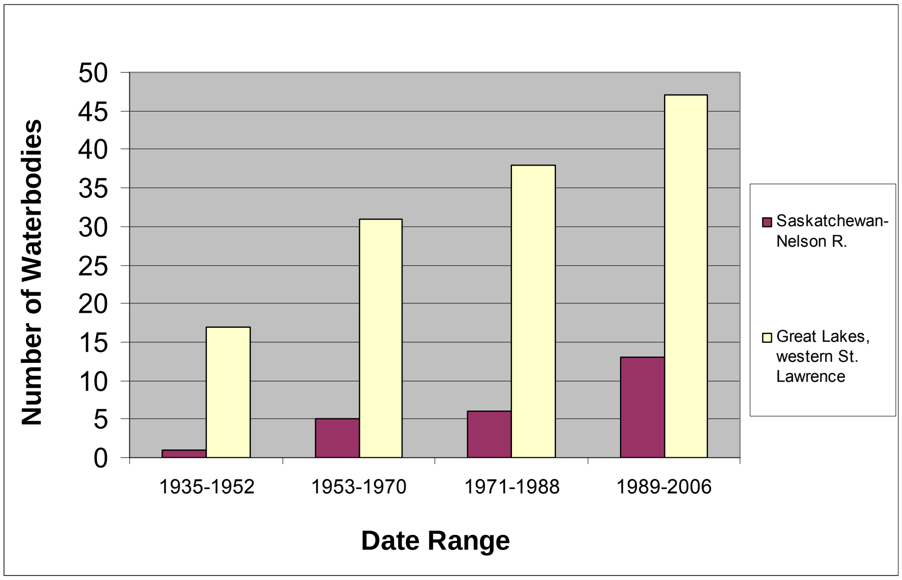


Figure 3. Trend in number of waterbodies harbouring silver lamprey in two ecoregions over several 18 year time periods.

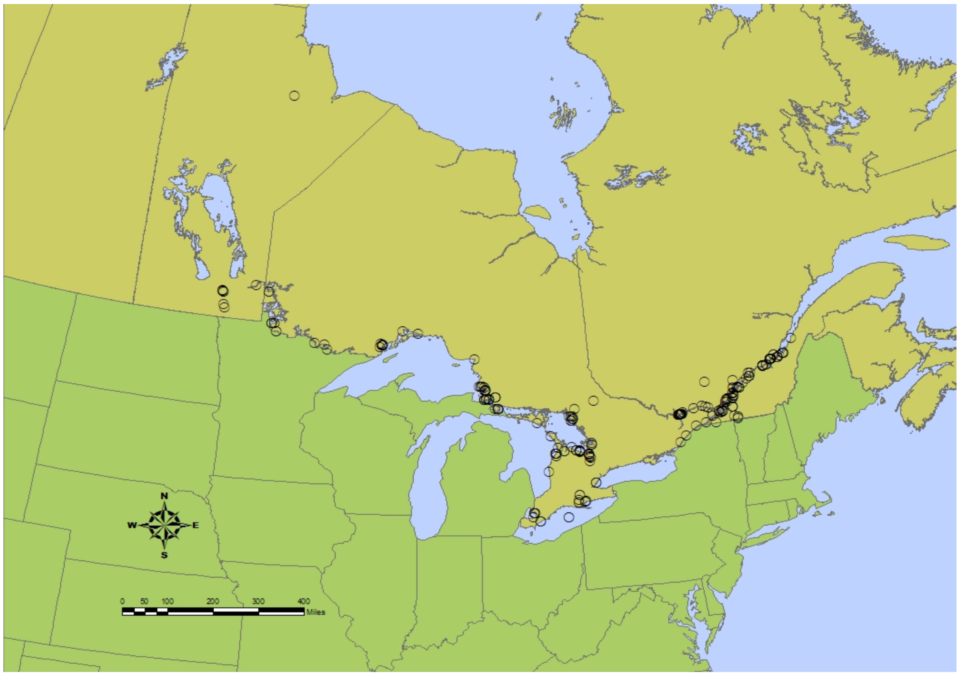

Figure 4. Historical (pre-1989) occurrences of silver lamprey in Canada.

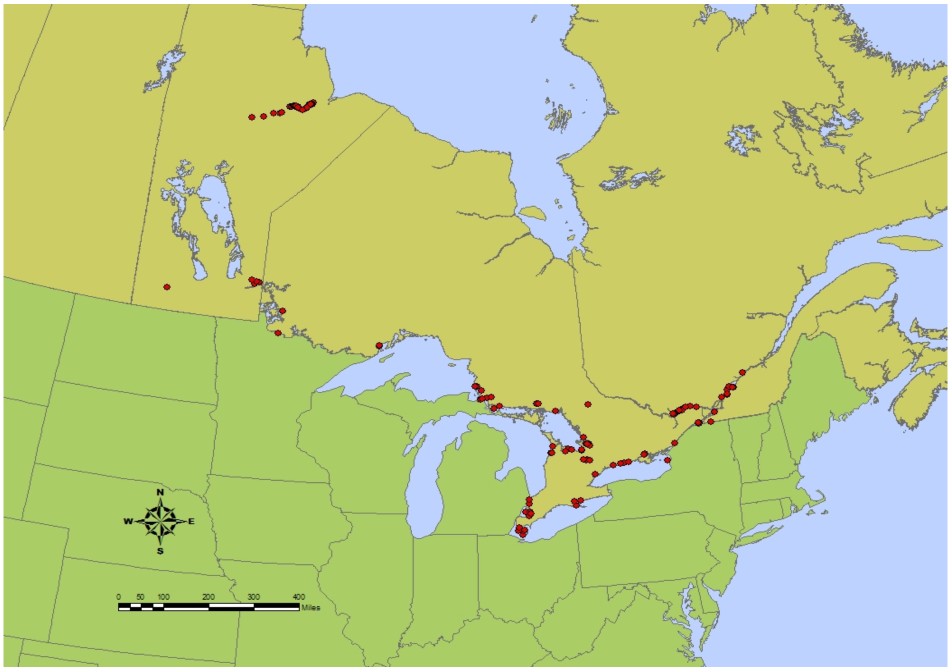


Figure 5. Recent (post-1988) occurrences of silver lamprey in Canada.

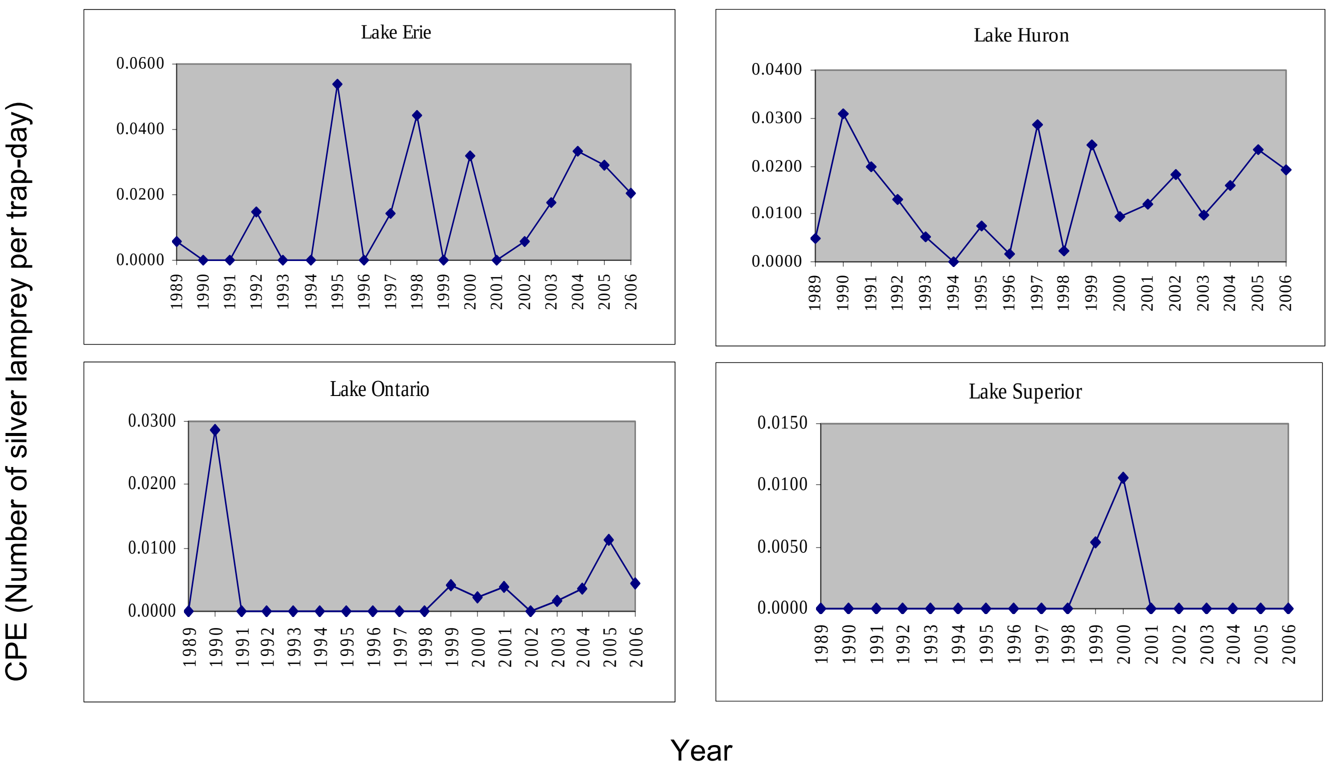


Figure 6. Catch-per-effort (CPE) data for silver lamprey collected in Canadian sea lamprey traps in the Great Lakes, 1989-2006. Note: y-axis scales are different between graphs.

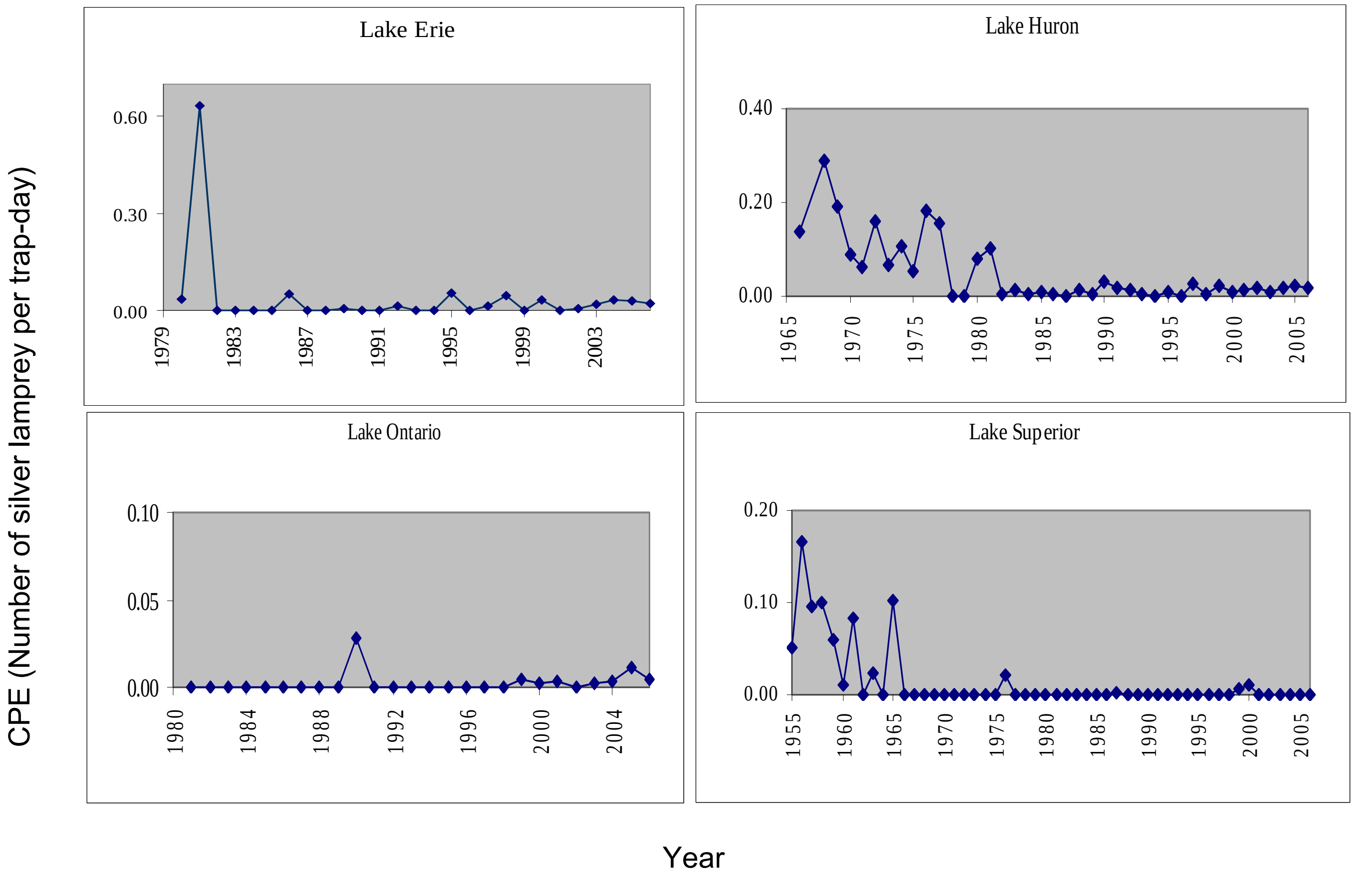


Figure 7. Long-term catch-per-effort (CPE) data for silver lamprey collected in Canadian sea lamprey traps in the Great Lakes. Note: y-axis and x-axis scales are different between graphs.

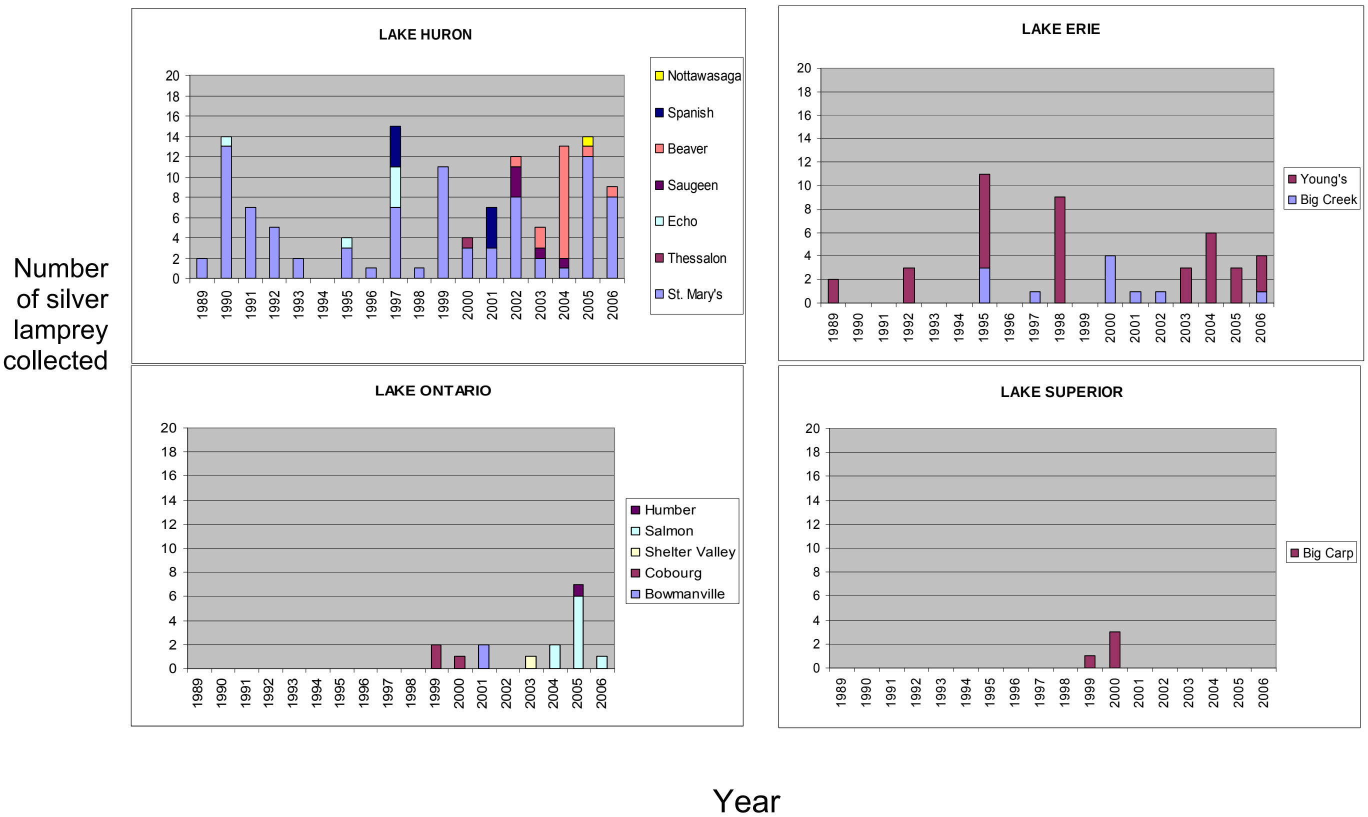


Figure 8. Cumulative silver lamprey collections in SLCC sea lamprey traps by stream (not standardized by effort) 1989-2006.

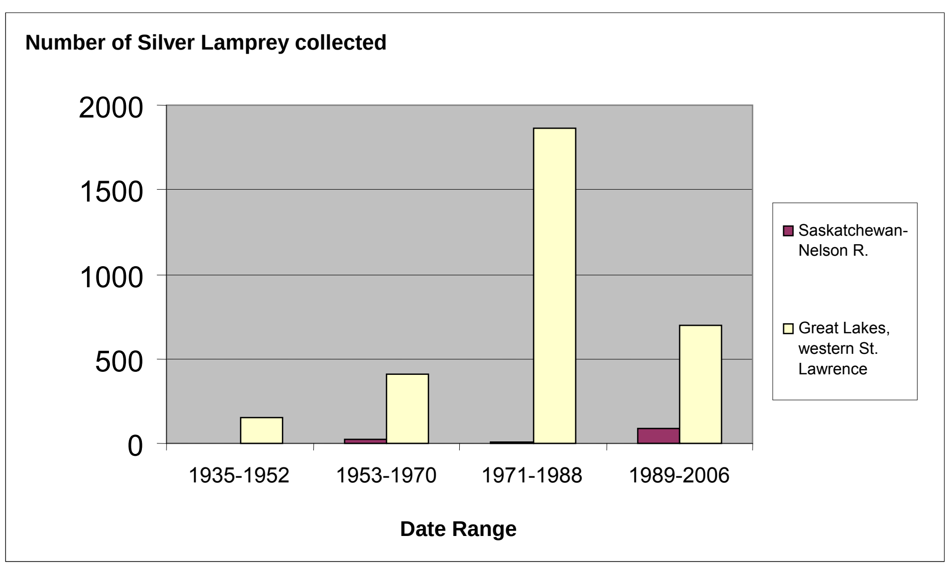


Figure 9. Trend in number of silver lamprey collected in two ecoregions over four 18-year time periods (data not standardized by effort).

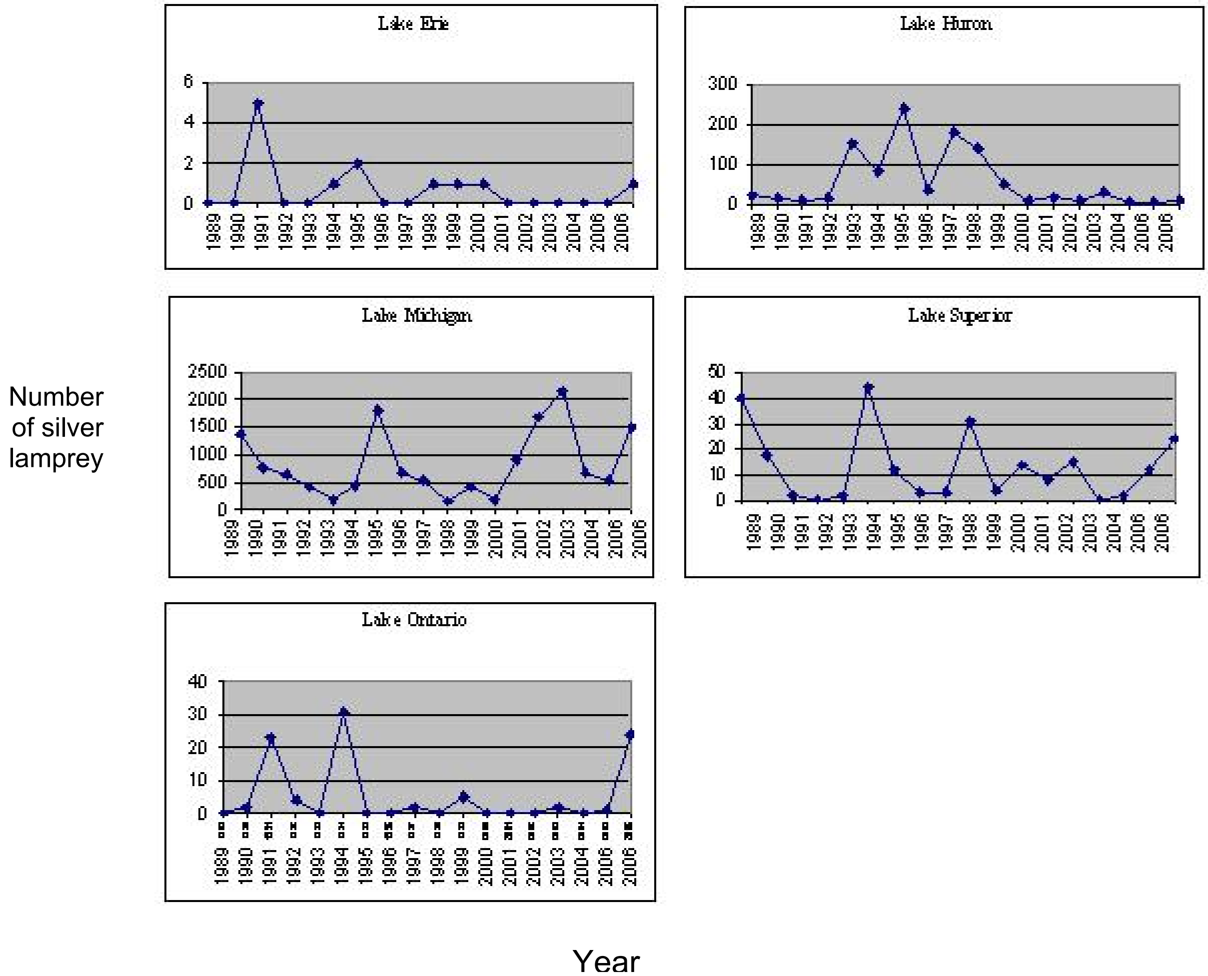


Figure 10. Catch data for silver lamprey collected in United States sea lamprey traps in the Great Lakes, 1989-2006 (not standardized by effort). Note: y-axis scales are different between graphs.

**Contact tracking sheet**

**Required contacts for information on species**

Name of report contractor: Fraser Neave, Gale Bravener
Species: Silver lamprey

| Name of jurisdiction | Name of contact(s) and date(s) |
|---|---|
| Canadian Wildlife Service | Ken Tuininga (cc to Angela McConnell) - Dec. 6, 2006<br>Dave Duncan (cc to David Ingstrup) – Dec. 6, 2006<br>Karine Picard (cc to Isabelle Ringuet) – Dec. 6, 2006 |
| Department of Fisheries and Oceans (aquatic species only) | Lara Cooper – Dec. 6, 2006<br>Doug Watkinson – Dec. 6, 2006 |
| Parks Canada | Peter L. Achuff – Dec. 6, 2006<br>Gilles Seutin – Dec. 7, 2006 |
| | |
| Provincial / territorial representative(s) corresponding to the range of the species | James Duncan (Man.) – Dec. 6, 2006<br>Alan Dextrase (Ont.) – Dec. 6, 2006<br>Daniel Banville (Que.) – Dec. 6, 2006 |
| Conservation Data Centre(s) or Natural Heritage Information Centre(s) corresponding to the range of the species | Manitoba Conservation Data Centre (James Duncan and Nicole Firlotte) – December 18, 2006<br>Ontario Natural Heritage Information Centre (Jim Mackenzie) – Dec. 6, 2006<br>Centre de données sur le patrimoine naturel du Québec (Annie Paquet) – Dec. 19, 2006<br>Canadian Museum of Nature (Claude Renaud and Sylvie Laframboise) – Dec. 7, 2006<br>Royal Ontario Museum (Erling Holm) – Dec. 7, 2006 |
| Wildlife Management Board(s) corresponding to the range of the species (species in British Columbia,Yukon, Northwest Territories, Nunavut or northern Quebec) | Not applicable |
| COSEWIC Secretariat<br>for information on sources of Aboriginal Traditional Knowledge<br>to discuss requirements and methods for preparing distribution maps and calculating the extent of occurrence and area of occupancy. | Gloria Goulet – Dec. 14, 2006 |
| Community Knowledge (CK) contacts provided by COSEWIC through its CK initiative that began in 2005. | |
| Recovery team (if one exists) | |

## APPENDIX I. DESCRIPTION OF RESIDENCE FOR THE SILVER LAMPREY (*Ichthyomyzon unicuspis*) IN CANADA

Although the Silver Lamprey is not currently listed, a COSEWIC status report is in progress. The following is intended as a summary for the:

Workshop on the Pre-COSEWIC Assessment of
Silver Lamprey (*Ichthyomyzon unicuspis)*
Zonal Peer Review Meeting
March 5$^{th}$-6$^{th}$, 2007.

The intent is to identify residence(s) and critical habitat to the fullest extent possible in the pre-COSEWIC phase.

### RESIDENCE

Section 33 of the *Species at Risk Act* (SARA) prohibits damaging or destroying the residence of a listed threatened, endangered, or extirpated species. SARA defines residence as: “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating” [s.2(1)].

The prohibition comes into effect immediately upon listing for all threatened, endangered, and extirpated species on federal lands, and for species under federal jurisdiction on all lands. Species under federal jurisdiction are aquatic species (a wildlife species that is a fish, as defined in section 2 of the *Fisheries Act*, or a marine plant, as defined in section 47 of that Act) or migratory birds under the *Migratory Birds Convention Act*. SARA also contains a provision to prohibit the destruction of non-federal species’ residences on provincial, territorial, and private lands by way of an Order, if the Minister of the Environment deems it necessary to do so [s.34(2), 35(2)].

The following is a description of residence for the Silver Lamprey (*Ichthyomyzon unicuspis*), created for the purposes of increasing public awareness and aiding enforcement of the above prohibition. Silver lamprey are known to have one residence – the nest site.

### 1) NEST SITE

#### Physical Appearance and Context

Silver lamprey nests are usually constructed in streams at the upstream end of a shallow riffle with unidirectional, moderate to rapid water velocity (Mormon 1979). Typical water velocity at the nest is 0.5-1.5 m/s (Manion and Hanson 1980). Water depth at the nest can vary from 13 cm to 500 cm (Mormon 1979; Lamsa and Westman 1972). The substrate is moved by the lamprey to form a somewhat circular nest, with a depression in the middle, with a crescent shaped downstream lip (Scott and Crossman 1998). The average cavity depth of the nest is in the range of 8 cm, and diameter of the nest can vary from 33 cm to 122 cm (Mormon 1979). Silver lamprey nests can be very similar to nests of other lamprey species, such as the sea lamprey (Figure 1). Silver lamprey have been observed sharing nests with sea lamprey and northern brook lamprey (Mormon 1979).

**Function**

The nest site provides the required substrate necessary to build a functional nest where adults can engage in spawning and deposit eggs. The nest site also acts as a container where fertilized eggs develop. To construct the nest, spawning phase silver lamprey transport stones in the mouth, and remove sand and silt by vigorous tail movements (Scott and Crossman 1998). Once the nest has been constructed, the mating pair then release sperm and eggs simultaneously during a rapid vibration of their bodies while the male is attached to the head of the female (Scott and Crossman 1998). Approximately 10,800 eggs per female, measuring just less than one mm in diameter, are laid over the spawning period (Vladykov 1949; Schuldt *et al.* 1987). The nest site is essential to successful reproduction, and accommodates monogamous and polygamous spawning, which is common in silver lamprey (Mormon 1979). After about two to three weeks, the eggs hatch and the ammocoetes subsequently drift downstream to inhabit depositional areas of streams containing sand, silt and detritus (Smith et al. 1968; Scott and Crossman 1998).

**Figure 1. Typical sea lamprey nest (similar to silver lamprey nest, and may contain silver lamprey)**

**Damage/Destruction of Residence**

Any activity that causes silver lamprey to be frightened and flee the nest, or deters them (change in water level, change in stream odours) from using the nest could result in abandonment of the residence. Any physical change that moves or otherwise disturbs the eggs, changes the hydrology of the stream in the vicinity of the nest, or adds material such as gravel, sand or silt could result in damage or destruction of the residence.

**Period and Frequency of Occupancy**

Silver lamprey typically spawn in May to June, depending on water temperatures (Scott and Crossman). They spawn once in their lifetime and die shortly after (Scott and Crossman 1998; Vladykov 1949). A silver lamprey nest may be occupied by spawning silver lamprey for several days and their eggs may remain for about three weeks (Smith et al. 1969; Scott and Crossman 1998). It is unknown whether adult silver lamprey return to their natal stream to spawn, although this homing behaviour does not seem to occur in sea lamprey (Bergstedt and Seelye 1995).

Application of the Residence Concept to Silver Lamprey

Does the concept of residence under SARA apply to this species? Yes

Detailed Rationale:

*(1) Does the ecology of the species include the use of a dwelling place—which is a specific location (or locations) or discrete spatial area that contains features similar to a den or nest, or performs functions similar to a den or nest?*

Yes. Spawning silver lamprey utilize nests, which are specified as residences in the definition of the residence concept by SARA.

*(2) Are these locations occupied or habitually occupied during all or part of the species' life cycle*?

Yes. These locations are occupied during the spawning stage of the lamprey life cycle.

*(3) Are these locations essential to the successful performance of a specific, crucial function of the species' life-cycle?*

Yes. The creation and use of these nests is a crucial function in the life cycle of the silver lamprey.

Summary of Rationale

Silver lamprey (and probably all lampreys) have one form of residence. This occurs during the spawning stage, when they construct and spawn in nests in the stream substrate. These nests fit into the SARA definition of residence, as they are essential for the performance of a critical function.

## APPENDIX II. DESCRIPTION OF CRITICAL HABITAT FOR THE SILVER LAMPREY (*Ichthyomyzon unicuspis*) IN CANADA

SARA section 2 defines Critical Habitat as:

> *"..the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in a recovery strategy or in an action plan for the species."*

Sections 41 and 49 of SARA both refer to the need to "identify" Critical Habitat in Recovery Strategies and Action Plans respectively. The process of Critical Habitat Identification is:

**Step 1:** Description of the Biophysical Attributes of habitat required by the species at risk
**Step 2:** Location, to the greatest extent practically possible, of all habitat in the range.
**Step 3:** Rationalization of this Step 2 habitat area based upon the population target of the species at risk (including the possibility of a need to create/restore habitat) and implementation factors
**Step 4:** Competent Minister Determines Critical Habitat
**Step 5:** Formal Identification of Critical Habitat in the Recovery Strategy and the Public Registry and description in the Canada Gazette

### STEP 1: DESCRIPTION OF THE BIOLOGICAL, PHYSICAL AND/OR FUNCTIONAL ATTRIBUTES OF HABITAT REQUIRED BY THE SPECIES AT RISK.

SPECIES INFORMATION
Scientific Name – *Ichthyomyzon unicuspis*
Common Name – Silver Lamprey
Current COSEWIC Status & Year of Designation – Not listed
Range in Canada –Manitoba, Ontario, Québec (Figure 1)
Rationale for Status – N/A

The silver lamprey life cycle involves three distinct phases, all of which rely on specific habitat requirements, and all of which are critical for the species to persist.

### 1) SPAWNING PHASE

Silver lamprey ascend rivers in the spring when water temperatures reach approximately 10°C (Scott and Crossman 1998). They have been found in rivers with average summer discharges from 0.03 $m^3/s$ to 72 $m^3/s$ (Schuldt and Goold 1980; Mormon 1979, SLCC unpublished data). They have also been observed spawning in the St. Clair River (Lamsa and Westman 1972), which has an average discharge of over 5000 $m^3/s$ (Edsall 1997). They are often found in rivers associated with bays (Schuldt and Goold 1980). In the upper reaches of these rivers, they spawn in shallow nests which they construct in riffle areas of streams containing intermediate-sized gravel mixed with sand (Carpenter et al, 1987; Manion and Hanson 1980). To construct the nest, spawning phase silver lamprey transport stones in the mouth and remove sand and silt with vigorous tail movements (Scott and Crossman 1998). They require unidirectional flow with satisfactory water velocities (0.5-1.5m/s), and depths ranging from 13 cm to 500 cm (Lamsa and

Westman 1972; Manion and Hanson 1980). Nests with silver lamprey spawning were described by Mormon (1979) as constructed at the upper end of a shallow riffle (45-50 cm water depth) with moderate to rapid water velocity, having an average depth of 38 cm, average cavity depth of 8 cm, and diameter varying from 33 to 122 cm. They require a small amount of silt-free sand or some other fine material to which the eggs can adhere (Manion and Hanson 1980).

### 2) LARVAL PHASE

After fertilization, silver lamprey eggs hatch in 2-3 weeks (Smith *et al.* 1968). Once the eggs hatch and reach stage 17, the burrowing prolarvae drift downstream and burrow into sand, silt and detritus, avoiding clayey soil, where they build U shaped burrows, and remain in the larval phase for 4 to 7 years (Scott and Crossman 1998; Vladykov 1949). During this phase, their diet consists of microscopic food such as algae, pollen, diatoms and protozoans (Becker 1983). After several years, the ammocoetes undergo a transformation (metamorphosis), which usually begins in late summer or fall, while they are still in their burrows. Transformation involves development of eyes, strong sharp teeth and a functional intestine (Vladykov 1949; Scott and Crossman 1998). Transformation is completed by early spring, after which they emerge from their burrows and migrate downstream to a large river or lake (Scott and Crossman 1998).

### 3) PARASITIC PHASE

After migrating downstream, parasitic phase silver lamprey feed on fishes, attaching themselves with a suction cup mouth and rasping a hole through the scales and skin, and feeding on flesh and body fluids (Becker 1983; Vladykov 1949). Host fish species for the silver lamprey are numerous, and include lake sturgeon, Atlantic sturgeon, lake trout, rainbow trout, brook trout, lake whitefish, white sucker, longnose sucker, brown bullhead, black buffalo, striped bass, smallmouth bass, rock bass, walleye, yellow perch, northern pike, muskellunge, paddlefish, common carp, white bass, longnose gar, and goldfish (Cochran and Marks 1995; Cochran *et al.* 2003; Renaud 2002; Scott and Crossman 1998, SLCC unpublished data). Cochran and Marks (1995) reported that the majority of parasitic silver lamprey in Lake Michigan seem to be mostly confined to Green Bay proper. It appears that areas such as Green Bay provide a suitable combination of water temperatures and host population densities. In Green Bay, they feed largely on fish such as yellow perch, white suckers and burbot at 6-12 m depths (Cochran and Marks 1995).

**Data for Steps 2 to 5 are unavailable at this time.**