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RECOVERY POTENTIAL ASSESSMENT OF NORTHERN BROOK LAMPREY (*ICHTHYOMYZON FOSSOR*) – SASKATCHEWAN-NELSON RIVER POPULATIONS (DESIGNATABLE UNIT 2)

*Adult Northern Brook Lamprey (*Ichthyomyzon fossor*). Photo by Doug Watkinson.*

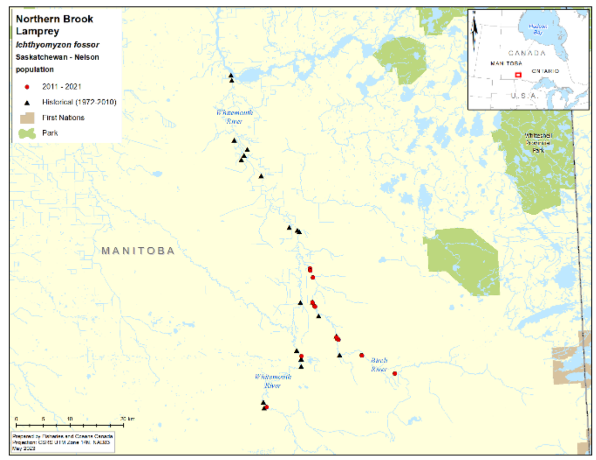

Figure 1. Distribution of Northern Brook Lamprey in the Saskatchewan-Nelson River Designatable Unit.

Context:

In November 2020, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) assessed the Northern Brook Lamprey Great Lakes-Upper St. Lawrence populations (DU1) as Special Concern and the Saskatchewan-Nelson River populations (DU2) were designated Endangered due to their limited distribution, a decline in the number of mature individuals based on observed reductions in extent of occurrence, area of occupancy, and number of locations, and an inferred decline in quantity and quality of aquatic habitat. The Recovery Potential Assessment (RPA) process was developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill requirements of the federal Species at Risk Act *(SARA), including the development of recovery strategies and authorizations to carry out activities that would otherwise violate SARA (DFO 2007).*

*This Science Advisory Report is from the April 19–21, 2023 regional peer review on the Recovery Potential Assessment of Northern Brook Lamprey (*Ichthyomyzon fossor*) – Saskatchewan-Nelson River Population. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.*

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SUMMARY

- The known distribution of Northern Brook Lamprey (*Ichthyomyzon fossor*) in the Saskatchewan-Nelson River designatable unit (DU) is limited to southeastern Manitoba, including the Whitemouth River (~ 3.4 km^2) and its tributary, the Birch River (~ 0.7 km^2).
- The status of Northern Brook Lamprey in the Winnipeg River is unknown. *Ichthyomyzon* larvae, but no Northern Brook Lamprey adults, have been captured in the Winnipeg River at its confluence with the Whitemouth River. Northern Brook Lamprey cannot be distinguished from Silver Lamprey (*I. unicuspis*) at this life stage, and consequently the Winnipeg River does not form part of the species' known distribution.
- Northern Brook Lamprey are typically found in pools and runs of cool streams. Water depths are typically > 0.1 m with slow or moderate velocities. Larval lamprey are found in substrates dominated by sand and some silt, organic detritus, and small gravel that allows for burrowing. Adults typically burrow in coarser substrates prior to spawning. Spawning occurs in late spring to early summer in shallow riffles on gravel dominated substrate when water temperatures are 13 to 22°C.
- The most serious threats to Northern Brook Lamprey are inadequate stream flow and excessive water temperature. Future climate change scenarios are anticipated to exacerbate these threats. Additional threats were considered to have a lower impact, including non-native species (and their complex interactions), agricultural and forestry effluents, dams and water management/use, other ecosystem modifications (e.g., shoreline development), and mining and quarrying.
- Based on a population model, Northern Brook Lamprey were predicted to be highly sensitive to perturbations in vital rates that affect recruitment, and age 1–3 larval survival.
- The Northern Brook Lamprey minimum viable population (MVP) size for a 1% probability of extinction over 60 years was estimated as 8,752 [95% confidence interval: 3,924, 16,316] adults. The minimum area required to support a recovered population is highly dependent on the density of Northern Brook Lamprey that could be supported in available habitat, both of which are poorly understood for the Whitemouth and Birch rivers.
- Very little is known about the Northern Brook Lamprey Saskatchewan-Nelson River DU. Key knowledge gaps exist around co-occurrence and biological distinction from Silver Lamprey, population distribution and abundance, availability of suitable habitat, life-history characteristics, and sensitivity to, and frequency of threats.

BACKGROUND

Northern Brook Lamprey was considered a single designatable unit (DU) in Canada and was assessed as Special Concern in April 1991 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Lanteigne 1991). The species was split into two DUs in April 2007 based on the species occurring in two national freshwater biogeographic areas; the Great Lakes-Upper St. Lawrence populations (DU1) was designated Special Concern and the Saskatchewan-Nelson River populations (DU2) as Data Deficient (COSEWIC 2007). In the November 2020 COSEWIC assessment, the Saskatchewan-Nelson River were assessed as Endangered, and the Great Lakes-Upper St. Lawrence populations' status of Special Concern was reconfirmed (COSEWIC 2020); these will be referred to as the Saskatchewan-Nelson River DU, and the Great Lakes-Upper St. Lawrence DU throughout this document to avoid confusion around population structure. Fisheries and Oceans Canada (DFO) has developed a Recovery Potential Assessment (RPA) process to provide information and scientific advice related to current population status and trends, threats to survival and recovery, and feasibility of recovery. This advice is needed to fulfill various requirements of the *Species at Risk Act* (SARA), including informing listing decisions, developing recovery documents, and assessing SARA Section 73 permit applications. An RPA for the Northern Brook Lamprey Saskatchewan-Nelson river DU was undertaken April 19–21, 2023. Supporting information is found in Watkinson (2023) and Caskenette (2023).

ASSESSMENT

Biology

Lampreys, including Northern Brook Lamprey, are distinguished from most other fishes by their elongate body shape, jawless mouth (characterized by a toothed oral disc in adults), lack of paired fins and scales, a single large central nostril, and seven pairs of gill pores leading to internal gills (Figure 1; Scott and Crossman 1998, Renaud et al. 2011). Lampreys of the genus *Ichthyomyzon* can be distinguished from all other lamprey genera by possessing a single indented dorsal fin compared to the two distinct dorsal fins possessed by other genera (COSEWIC 2020). The Northern Brook Lamprey averages 115–119 mm total length (TL) at maturity (Hubbs and Trautman 1937, Morman 1979, Docker 2009), has a relatively small eye, small oral disc (which is narrower than the width of the head or body), and poorly developed, knob-like teeth compared to the Silver Lamprey. Despite the pronounced morphological differences between Northern Brook and Silver lampreys after they metamorphose, they are indistinguishable as larvae. Nor are there any diagnostic genetic differences known to date, as mitochondrial DNA (mtDNA) sequence data show that Silver and Northern Brook lampreys are not reciprocally monophyletic and lack fixed species-specific differences (Lang et al. 2009, Docker et al. 2012, Ren et al. 2016).

Northern Brook Lamprey exhibit three distinct life history phases: 1) the larval phase (termed ammocoete) lasts 3–7 years (Purvis 1970, Scott and Crossman 1998), during which the larvae are blind, toothless, and possess an oral hood for filter feeding from burrows built in the soft substrate of slower-flowing portions of streams and rivers; 2) the juvenile phase, which follows metamorphosis from larvae but prior to sexual maturation when fish have a sucking oral disc with knob-like teeth, metamorphosis is thought to begin in early to mid-summer in Manitoba and is a 3- to 4-month process (Leach 1940, Manzon et al. 2015); and, 3) the adult phase, when fish retain the sucking oral disc and teeth and develop mature gametes, lasts 6–8 months (COSEWIC 2020).

All lamprey are oviparous and semelparous, and they invest a considerable amount of biological resources in their single spawning season (Scott and Crossman 1998, Docker et al. 2019).

Distribution

The distribution of Northern Brook Lamprey (Saskatchewan-Nelson River DU) is the Whitemouth River and its tributary, the Birch River, in southeastern Manitoba (Figure 2). In addition, larval lamprey have been collected in the Winnipeg River at the confluence of Whitemouth River and Winnipeg River. It is uncertain if larvae collected below the confluence are Northern Brook or Silver lamprey.

Current Species Status

Population assessment studies targeting Northern Brook Lamprey have not occurred in Manitoba; thus, fluctuations and trends related to the Northern Brook Lamprey Saskatchewan-

Nelson River DU are difficult to accurately assess due to inconsistent sampling equipment and monitoring through time.

Population Assessment

To assess the population status, each population was ranked in terms of abundance (Relative Abundance Index; Extirpated, Low, Medium, High, or Unknown) and trajectory (Population Trajectory; Increasing, Decreasing, Stable, or Unknown). The Relative Abundance Index and Population Trajectory values were combined in the Population Status matrix to determine the Population Status for each population, ranked as Poor, Fair, Good, Unknown or Extirpated (Table 1).

The relative abundance is unknown for Whitemouth and Birch rivers. Additional standardized surveys are required at all locations to determine the population abundance, and long-term monitoring would be required to determine population trajectory through time.

Table 1. Population Status for populations of Northern Brook Lamprey in the Saskatchewan-Nelson River DU, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status (Certainty)
Birch River	Unknown (3)
Whitemouth River	Unknown (3)

Habitat Requirements

Spawn To Hatch

Nests of 7.6–10.2 cm in diameter are built by male lamprey in gravel dominated shallows with some sand, often just above riffles (Hankinson 1932, Manion and Hanson 1980, Scott and Crossman 1998), sometimes between or under larger stones (Reighard and Cummins 1916, Morman 1979). Nest sites are free of silt and clay from either site selection or nest-building activities themselves (Gardner et al. 2012). Therefore, appropriate rivers for spawning must have both gravel substrate for spawning and silty/sandy depositional areas downstream for subsequent larval rearing (Dawson et al. 2015).

Northern Brook Lamprey spawns in relatively shallow water, 0.1 to 0.6 m deep with water velocity at nest sites typically between 0.1 and 0.6 $m \cdot s^{-1}$ (Morman 1979). The optimal spawning temperature for Northern Brook Lamprey varies by region (Michigan – June, 18–22°C [Reighard and Cummins 1916], 16.5–20.5°C [Morman 1979]; Quebec – May, 13–16°C [Vladykov 1949]). Incubation temperature is likely optimal at ~ 18°C given egg survival (Smith et al. 1968), but this is based on Great Lakes individuals and may differ for Northern Brook Lamprey from Manitoba.

Larval, Juvenile, And Adult

The habitat selection by larval, juvenile, and adult Northern Brook Lamprey is generally similar across the life stages. The appropriate substrate size is essential for the development of larval lamprey, as it allows for burrow construction as well as maintaining water flow through the substrate (Dawson et al. 2015). Substrate particle size determines the distribution of larval lampreys, as substrates that allow larval burrowing typically consists of sand or silt-dominated areas, with burrowing made difficult in areas of cobble, clay, or bedrock (Becker 1983, Beamish and Lowartz 1996), or burrowing is prevented entirely (e.g., bedrock). Adult lamprey have a tendency to occur in somewhat coarse substrate (Dawson et al. 2015). Ideal substrate typically occurs in slower-flowing depositional areas and is mainly sand with some silt or organic material (Reighard and Cummins 1916, Leach 1940, Yap and Bowen 2003, Dawson et al. 2015). Collerone (2014) found that Northern Brook Lamprey larvae in Manitoba were more likely to be found in fine/very fine sand as defined on the Wentworth scale (Wentworth 1922).

In Manitoba, Northern Brook Lamprey adults were collected at water depths averaging 0.6 m (D. Watkinson, DFO, unpublished data; M.F. Docker, University of Manitoba, unpublished data) during summer months. However, the depths lamprey are collected in is likely influenced by sampling gear and timing.

Functions, Features, and Attributes

A description of the functions, features, and attributes associated with the habitat of Northern Brook Lamprey in the Saskatchewan-Nelson River DU can be found in Table 2. The habitat required for each life stage has been assigned a life history function that corresponds to a biological requirement of Northern Brook Lamprey. In addition to the life history function, a habitat feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the species. Habitat attributes have also been provided; these are measurable components describing how the habitat features support the life history function for each life stage.

Table 2. Summary of the essential habitat functions, features, and attributes for each life stage of Northern Brook Lamprey in the Saskatchewan-Nelson River DU.

Life Stage	Function	Feature	Attributes		
			Literature	Current Knowledge	For Identification of Critical Habitat
Spawning (egg to hatch)	Spawning	Spawns in a nest that is built in shallow riffles over clean gravel substrate	• The optimal spawning temperature for Northern Brook Lamprey varies by region (Michigan - June, 18–22°C (Reighard and Cummins 1916), 16.5–20.5°C (Morman 1979); Quebec - May, 13–16°C (Vladykov 1949). Incubation temperature is likely optimal at ~ 18°C (Smith et al. 1968). • Spawning occurs in shallow 0.1–0.6 m deep water (Morman 1979), high-gradient pool-riffle reaches of the stream (Scott and Crossman 1998) with water velocity at nest sites typically between 0.1–0.6 $m \cdot s^{-1}$ (Morman 1979). • Spawning lamprey are usually concentrated in a small area with nests located in spaces between large stones (Morman 1979) or, occasionally, under rocks (Cooper 1983, Cochran and Gripentrog 1992). • Male lamprey build nests measuring approximately 7.6–10.2 cm in diameter by moving gravel with their oral disc and sand with vigorous swimming (Scott and Crossman 1998). • In Manitoba, spawning has been observed in mid-June in clean gravel and cobble in riffles up to 0.3 m deep (Stewart and Watkinson 2004).	-	• Shallow riffles with gravel substrate, mean depth 0.1–0.6 m. • Water velocities of 0.1–0.6 $m \cdot s^{-1}$ • Water temperature 13–22°C

Life Stage	Function	Feature	Attributes		
			Literature	Current Knowledge	For Identification of Critical Habitat
Larvae	Feeding Cover	• Slower water velocity shallow runs, and depositional edges of riffles • Substrate dominated by sand with some silt and organic detritus	• The appropriate substrate size is essential for the development of larval lamprey, as it allows for burrow construction as well as maintaining water flux (Dawson et al. 2015). Larval lamprey are found in mainly sand with some silt or organic material (Reighard and Cummins 1916, Leach 1940, Yap and Bowen 2003, Dawson et al. 2015). • Water depth is usually 0.7 m deep on average in Wisconsin (Becker 1983). • Water temperature of 30.5°C is the lethal upper limit (Potter and Beamish 1975).	• In Manitoba, larval lamprey have been collected in 0.11–1.5 m water (median 0.35 m), this is gear dependent (boat electroshocker in deeper water, backpack electroshocker in shallow water). Typically collected in low gradient reaches with slow to moderate velocities (0.01–0.25 $cm \cdot s^{-1}$); silt/sand/gravel/cobble substrate are present at collection sites, with sand being the dominant substrate (D. Watkinson, DFO, unpublished data).	•Slow to moderate flow with substrate dominated by sand with some silt, organic detritus, and small gravel irenaudn shallow pools and runs. • Depths typically > 0.1 m • Water velocities > 0 – < 0.6 $m \cdot s^{-1}$ • Water temperature 0 – < 30.5°C
Juvenile (from the beginning of metamorphosis to maturation)	Cover	See larvae	See larvae • during metamorphosis lampreys tend to move to coarser substrates with better oxygenated water and higher water velocities (see Dawson et al. 2015)	See larvae	See larvae
Adult	Cover	See larvae	See larvae	• In Manitoba, Northern Brook Lamprey adults were collected at water depths averaging 0.6 m (M.F. Docker, University of Manitoba, unpublished data).	See larvae

Threat Level Assessment

The threat most relevant to Northern Brook Lamprey habitat is climate change, specifically the sub-categories drought and temperature extremes. Drought can reduce the available wetted stream habitat as well as flowing water required for oxygenation of the substrata and movement of food particles. Temperature extremes can exclude organisms from a system when they exceed their physiological tolerances (30.5°C). Sublethal effects are expected at temperatures < 30.5°C, but have not been measured.

Dams and water management/use, other ecosystem modifications, pollution, agricultural and forestry effluents, and mining and quarrying can all impact extensive areas of habitat through changes in quality and quantity. Any dam built within the current distribution of Northern Brook Lamprey would result in habitat loss in the majority of the forebay and impair spawning migrations and population connectivity.

Housing and urban areas, and tourism and recreation could alter habitat and impact the species locally, near the disturbance.

Climate change and severe weather (high-low)

Climate change has the potential to reduce precipitation and water levels in the Whitemouth River drainage (ECCC 2023), which will exacerbate the effects of high temperatures. The Birch River has experienced low flow and oxygen conditions in summer and winter (Clarke 1998). This river may be particularly vulnerable, with temperatures in July and August already approaching this species' upper thermal limits. In 2011, data loggers at two sites in the Birch River showed water temperatures above the substrate reaching near 30°C by the third week of July, when flow was negligible and water depth had decreased from 1.2–2.4 m in the spring to only 0.1 m (D. Watkinson, DFO unpublished. data). At 30.5°C, Northern Brook Lamprey larvae have been observed in a laboratory study emerging from their burrows and dying (Potter and Beamish 1975). Higher temperatures less than the observed maximum would still have a negative consequence to individuals, as it would limit their aerobic metabolic scope, which determines the amount of energy available for processes including growth, digestion, locomotion and reproduction (Schulte 2015, Wilkie et al. 2022).

Natural systems modifications (low)

Dams and water management/use

Dams can alter the natural flow, transform the biological and physical characteristics of river channels and floodplains, and limit the exchange of sediment, nutrients, and organisms between aquatic and terrestrial areas (Bednarek 2001). There is only one permanent dam in the Whitemouth River, a fixed-head rock weir at the outlet of Whitemouth Lake that influences the hydrology of the Whitemouth River at its headwaters. Any dam construction would have negative impacts, as the forebay would create mostly unsuitable habitat and the dam could restrict spawning migrations. Several large hydroelectric dams regulate flows on the Winnipeg River.

A number of activities such as farming, highways, peat mines, and removal of nearby vegetation for forestry or agriculture affect drainage and water flow patterns in the Whitemouth River system. Water removal for domestic use, lawn or agricultural irrigation, and watering livestock could reduce flow, particularly during dry years (DFO 2013) as low or no flows have occurred. In the past, water was periodically withdrawn during the winter from the Whitemouth River for hydrostatic testing of pipelines; however, this practice ended in the mid-1990s as it was deemed a risk to aquatic life through potential dewatering and freezing of shallows or through water discharge causing flooding, scouring of the stream bed, and bank erosion (DFO 2013). There is renewed interest in the use of water from the area for hydrostatic testing of the TransCanada Pipeline.

Other ecosystem modifications

Small-scale habitat alterations (e.g., boulder removal, beach building) are present in the Whitemouth River drainage, but are limited for the most part. Riparian areas in the agricultural portions of the drainage are under a high degree of threat due to development and habitat conversion (Becker and Hamel 2017).

Invasive and other problematic species and genes (low)

Invasive non-native/alien species

Invasive Rusty Crayfish (*Faxonius rusticus*) was detected in the Birch River in 2011 (DFO 2013) and is expected to alter the fauna if a population establishes. Rusty Crayfish typically reduces aquatic vegetation, which may increase erosion and sedimentation that is detrimental to spawning lampreys and embryos (COSEWIC 2020). Non-directed sampling in 2021 did not collect any Rusty Crayfish in the Birch River (D. Watkinson, DFO unpublished data). A number of invasive species currently absent in the Whitemouth River drainage have a high risk of becoming established and problematic in the region within the next 10 years, including Zebra Mussel (*Dreissena polymorpha*), Emerald Ash Borer (*Agrilus planipennis*), and Phragmites or European Common Reed (*Phragmites australis* ssp. *australis*; COSEWIC 2020). Zebra Mussel is not expected to significantly impact the Winnipeg River as low carbonate in the water chemistry is not conducive to shell building (Claudi et al. 2012); however, the Whitemouth River drainage water chemistry may be more favourable to colonization where Zebra Mussel could compete with lamprey ammocoetes for food and alter the substrate, which would negatively affect burrowing. Emerald Ash Borer was detected in the city of Winnipeg in late 2017 (Manitoba Sustainable Development 2017). This terrestrial invertebrate has caused the complete loss of entire stands of ash trees in Ontario. Black Ash dominates the swamps in the southern portion of the drainage as well as the riparian floodplain along the Whitemouth River (J. Becker, Nature Conservancy of Canada, 2019 in COSEWIC 2020, pers. comm.). A reduction in canopy cover and shading on riverbanks could influence water temperatures and increase erosion, thereby altering Northern Brook Lamprey spawning and larval rearing sites. Phragmites has only established in a few places within Manitoba. Further expansion is expected because of transport routes through this watershed. Emerald Ash Borer has the potential to remove ash stands, increasing the suitability of wetland areas to infestation by Phragmites (COSEWIC 2020). Phragmites has high levels of water transpiration (OFAH and OMNRF 2012), which coupled with climate change has the potential to reduce flows, but only if its abundance was to increase substantially.

Walleye (*Sander vitreus*), a known predator of lamprey (Cochran 2009), has been stocked outside its native range in Manitoba into Whitemouth Lake by the Province of Manitoba since 1960 (DFO 2013). Walleye, Brook Trout (*Salvelinus fontinalis*), Rainbow Trout (*Oncorhynchus mykiss*), and Brown Trout (*Salmo trutta*) have been stocked in the Birch or Whitemouth rivers, with the last salmonid stocking in the 1980s and the last Walleye stocking in 1997. Of these introductions, only Walleye remains in the Whitemouth and Birch rivers where the impacts of this introduced species on Northern Brook Lamprey in Manitoba remains unknown.

Pollution (low)

Agricultural and forestry effluents

Agricultural runoff carrying pollutants (farm fertilizers, herbicides, and pesticides), sediment, and nutrient inputs could negatively affect Northern Brook Lamprey. Nutrient input from barnyards or intensive livestock operations is an ongoing problem that is being addressed by the Province of Manitoba (COSEWIC 2020). Elevated levels of phosphorus and nitrogen could negatively affect Northern Brook Lamprey specifically by altering water quality to unfavourable conditions.

Energy production and mining (low)

Mining and quarrying

Extensive peatland and several peat mines occur in the Whitemouth River drainage. The Province of Manitoba's Forestry and Peatlands Management Branch has established guidelines on sedimentation pond establishment. However, there is potential for these ponds to release some mining sediment (peat) when waters are released into the Whitemouth and Birch rivers (J. Becker, Nature Conservancy of Canada, 2019 in COSEWIC 2020, pers. comm.), which could negatively affect spawning lamprey and embryos. The mines also require extensive drainage near the mine site and may have some impact on watershed hydrology, this may decrease habitat quantity.

Residential and commercial development (negligible)

Limited residential and commercial development occurs within the drainage. Clearing of riparian vegetation to the water's edge can destabilize banks and increase erosion (DFO 2013) and may decrease habitat quality.

Housing and urban areas/Tourism and recreation areas

Shoreline development related to residences, vacation communities, and seasonal homes or cottages has occurred in the northern reaches of the Whitemouth River drainage, and to a more limited extent at the western end of Whitemouth Lake (DFO 2013). Development has resulted in, and likely will continue to result in, riparian forest clearing, yard sites, laneways, and associated infrastructure. Bank destabilization and increased erosion caused by clearing riparian vegetation could adversely affect Northern Brook Lamprey spawning habitat by causing physical disturbances or changes in water quality.

Threat Assessment

The species-level Threat Assessment in Table 3 is a roll-up of the population-level threats.

Table 3. Species-level Threat Assessment for Northern Brook Lamprey in Saskatchewan-Nelson River DU, resulting from a roll-up of the population-level Threat Assessment. The species-level Threat Assessment retains the highest level of risk for any population, all categories of Threat Occurrence and Threat Frequency are retained, and the species-level Threat Extent is the mode of the population-level Threat Extent.

Threat Category	Sub-category	Species-level Threat Risk	Species-level Threat Occurrence	Species-Level Threat Frequency	Species-level Threat Extent
(11) Climate change and severe weather (high-low)	(11.2) Droughts	High	Current, Anticipatory	Recurrent	Extensive
	(11.3) Temperature extremes	High	Current, Anticipatory	Recurrent	Extensive
(7) Natural systems modifications (low)	(7.2) Dams and water management/use	Low	Current	Continuous	Extensive
	7.3) Other ecosystem modifications	Low	Current	Continuous	Restricted
(8) Invasive and other problematic species and genes (low)	(8.1) Invasive non-native/alien species	Low	Current, Anticipatory	Continuous	Extensive
(9) Pollution (low)	(9.3) Agricultural and forestry effluents	Low	Current	Continuous	Extensive
(3) Energy production and mining (low)	(3.3) Mining and quarrying	Low	Current	Continuous	Restricted
(1) Residential and commercial development (negligible)	(1.1) Housing and urban areas	Low	Current	Continuous	Restricted
	(1.3) Tourism and recreation areas	Low	Current	Continuous	Restricted

Mitigations and Alternatives

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in Northern Brook Lamprey habitat (Saskatchewan-Nelson River DU). The DFO Program Activity Tracking for Habitat (PATH) database was queried for a variety of works, undertakings, and activities that occurred within the known distribution of Northern Brook Lamprey during the previous five years (2018–2022) that could harm or destroy its habitat. Only two projects were identified in the Birch River (Table 4), where the primary work and impact was dredging/excavating. Many of the works, undertakings, and activities that occur within the distribution of Northern Brook Lamprey are likely unreported in PATH.

Habitat-related threats can be linked to the Pathways of Effects developed by DFO's Fish and Fish Habitat Protection Program (FFHPP) in Coker et al. (2010). The document provides guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region. Coker et al. (2010) should be referred to when considering mitigation and alternative strategies for habitat-related threats. Additional mitigation and alternative measures related to non-habitat related threats such as invasive species are listed below.

Table 4. Threats to Northern Brook Lamprey in the Saskatchewan-Nelson River DU and the Pathways of Effect associated with each threat (Coker et al. 2010) – this table is intended to accompany Coker et al. (2010) for details on mitigations to each habitat-related threat. 1 – Vegetation clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal. The status of Northern Brook Lamprey in the Winnipeg River is unknown, but projects are included there as they may have impacts.

Work/Project/Activity	**Threats** (associated with work/project/activity)						**Watercourse / Waterbody** (number of works/projects/activities between 2018–2022)		
-	**Habitat removal and alteration**	**Nutrient loading**	**Turbidity and sediment loading**	**Contaminants and toxic substances**	**Exotic species and disease**	**Incidental harvest**	Winnipeg R.	Whitemouth R.	Birch R.
Applicable pathways of effects for threat mitigation and project alternatives	5,7,9,10, 11,12,13, 15,16,18	1,4,7,8, 11,12, 13,14, 15,16	1,2,3,4, 5,6,7,8,10, 11,12,13, 15,16,18	1,4,5,6, 7,11,12, 13,14, 15,16,18	-	-	-	-	-
Water crossings (bridges, culverts, open cut crossings)	X	-	X	X	-	-	-	-	1
Shoreline, streambank work (stabilization, infilling, riparian vegetation management)	X	X	X	X	-	-	2	-	-
Instream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	X	X	X	X	-	-	-	-	1
Water management (timing, duration and frequency of flow, water withdrawal)	X	X	X	X	-	-	1	-	-
Structures in water (effluent outfalls, water intakes, dams)	X	X	X	X	-	-	-	-	-
Baitfishing	-	-	-	-	-	X	-	-	-
Use of Explosives	-	X	X	X	-	-	1	-	-
Invasive species introductions (accidental and intentional)	-	-	-	-	X	-	-	-	-

Non-Habitat Threat Mitigation

Invasive and other problematic species and genes

Rusty Crayfish, Zebra Mussel, Emerald Ash Borer, and Phragmites or European Common Reed may negatively impact Northern Brook Lamprey populations in the future. Rusty Crayfish were collected in the Birch River in 2011 and may still be present in the system.

Mitigations

- Removal/control of introduced species from areas inhabited by Northern Brook Lamprey.
- Monitor for introduced species that may negatively affect Northern Brook Lamprey populations or preferred habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of introduced species.
- Initiate a public awareness campaign and encourage the use of existing invasive species reporting systems.
- Do not stock non-native species in areas inhabited by Northern Brook Lamprey.
- Do not enhance habitat for non-native species in areas inhabited by Northern Brook Lamprey.

Alternatives

- Unauthorized introductions - There are no alternatives for unauthorized introduction because unauthorized introductions should not occur.
- Authorized introductions - Use only native species. Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2017).

Recovery Modelling

Population modelling was conducted to assess the impact of anthropogenic harm to populations, identify recovery targets, and project population recovery with associated uncertainties. This work is based on a demographic approach developed for this process. Information on vital rates was compiled to build projection matrices that incorporate environmental stochasticity and density-dependence acting on recruitment. The impact of anthropogenic harm to populations was quantified with the use of elasticity and simulation analyses. Estimates of recovery targets for abundance and habitat were made with estimation of the minimum viable population (MVP) and the minimum area for population viability (MAPV). Refer to Caskenette (2023) for complete methods.

Allowable harm

Elasticity analysis was used to determine how sensitive the population growth rate was to changes in vital rates. Most individual vital rates had similar elasticities (ϵ_λ) of just under 0.17 including survival to age one, larval survival of ages one to three, fecundity, and transformation survival. This indicates that, for example, a 10% decrease in survival during metamorphosis could result in a stable population growth rate (λ = 1) decreasing to λ= 0.98 (i.e., 1·(1-0.1·(0.17)) = 0.98). Elasticities are additive, therefore a 10% decrease in survival that would affect all larval ages would result in a larger decrease in population growth rate (i.e., 1·(1-0.1·(0.17+0.17+0.17+0.08)) = 0.94). Northern Brook Lamprey populations were least sensitive to changes in the survival of larvae ages 4+ and transition probabilities.

When the population was growing ($\lambda > 1$) Northern Brook Lamprey population growth rate became increasingly sensitive to all vital rates except for the survival of larvae aged 4+, likely due to the majority of larvae having already metamorphosed by age five. This indicates that efforts to improve larval survival, survival through metamorphosis, and recruitment will have the greatest impact on population growth rates and sizes. Elasticity estimates were also affected by the value of uncertain life-history parameters. The elasticities of vital rates generally increased with increasing age-five transition probability, and transition probability elasticities decreased with higher larval survival rates.

Simulation analyses were used to determine the effect of decreasing survival rates on population size while accounting for density-dependence. This information is useful for estimating maximum allowable harm. There was a ~ 25% reduction in population size with only a ~ 5% increase in harm applied annually; the population crashed with only a ~ 25% increase in harm applied annually to both the larval stage and recruitment. This is a large effect from a small level of mortality indicating a high degree of population sensitivity to potential harm to the larval stage. Increasing the rate at which harm was applied from annually to biannually had minimal impact on allowable harm, however there was a substantial decrease in the impact of harm when harm was only applied every five or 10 years. When harm was only applied every five or 10 years the population was unlikely to crash, even at the highest levels of harm applied, likely due to the generation time being six years for this population, allowing the population to recover between harm events. Since there are no current estimates of population growth rates, maximum allowable harm was not estimated for the Northern Brook Lamprey, however the following equation:

Maximum allowable harm = $(1/\epsilon_{\lambda})\big((1-\lambda)/\lambda\big)$

can be applied, using the elasticities from the vital rates, when population growth rates are made available, if the population is growing ($\lambda > 1$).

Recovery Targets

Abundance (MVP)

Estimates of potential recovery targets for population abundance were provided using simulation analysis to determine the population size required for demographic stability through estimates of minimum viable population size. The estimate of the number of adult females required for a 1% chance of extinction over 60 years was 2,569 [95% confidence interval: 1,110, 4,950] which equates to 10,276 [95% confidence interval: 4,408, 19,800] adults if a 3:1 male:female sex ratio is assumed. Uncertain life-history characteristics did not have an impact on MVP estimates, likely due to the manner in which recruitment was determined. Survival until recruitment into the larval stage was determined by finding the value that gave a stable population, therefore the same number of larvae would result regardless of life-history characteristics. When not formulated in this manner, the highest risk of extinction faced by semelparous species has been shown to change depending on developmental rate; with delayed metamorphosis leading to greater sensitivity to variable juvenile survival, and earlier metamorphosis leading to greater sensitivity to variable developmental rate (Jonsson and Ebenman 2001). The MVP simulation only represented ~ 10 generations (60 years) for Northern Brook Lamprey. With longer simulations (e.g., 500 years) some life-history characteristics, such as maximum population growth rate and transition probability, may influence persistence probability and MVP size as they impact how quickly a population can respond to a perturbation.

Habitat (MAPV)

The mean MAPV was 6.3 km^2 for the smallest density estimates paired with the largest MVP estimates, and 0.0026 km^2 for the highest density estimates paired with the smallest MVP estimates. The range of MAPV values provided in Figure 3 provides a starting point to work from when determining the amount of habitat required for a MVP sized population, however more work is needed to determine average density estimates for the Northern Brook Lamprey populations before a specific estimate can be provided.

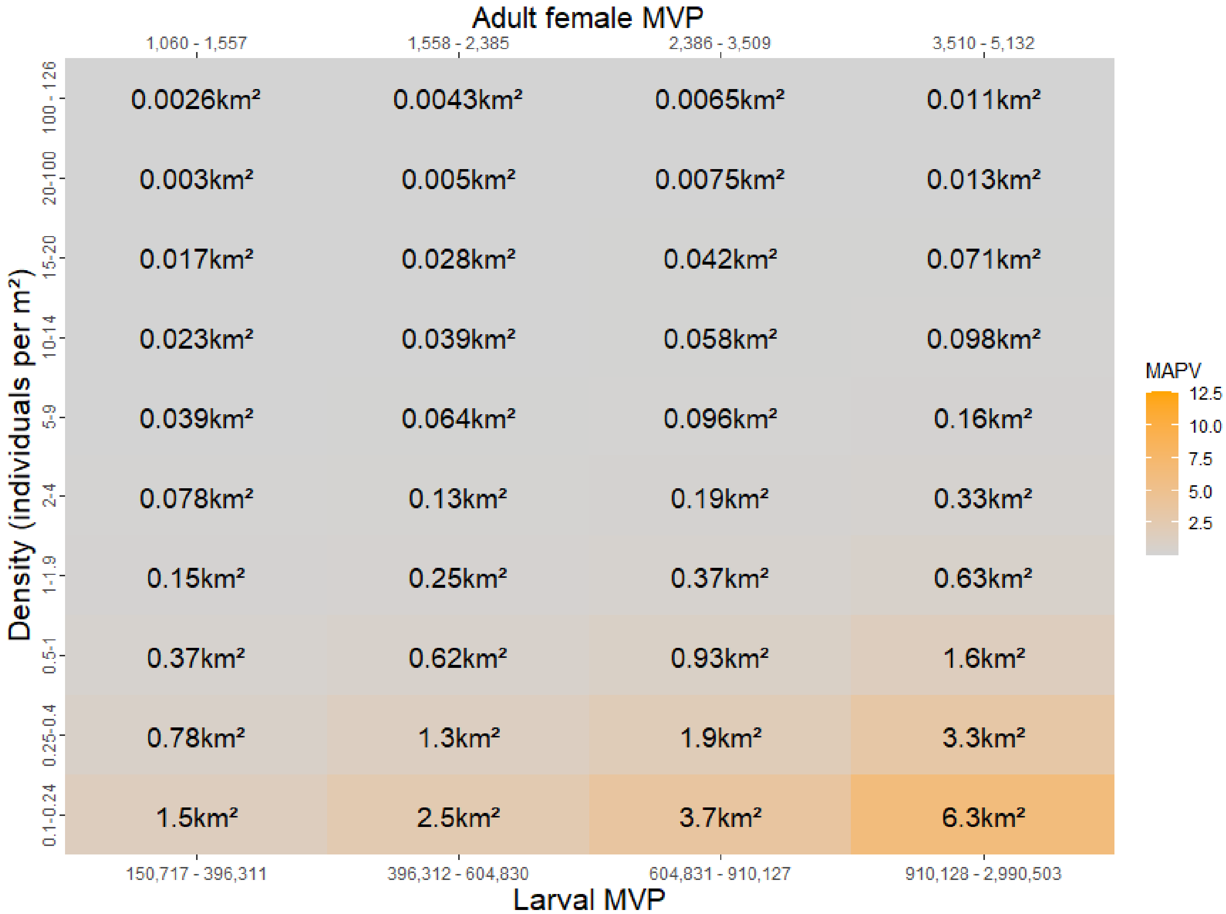

Figure 2. Estimates of the minimum area for population viability (MAPV) for a range of larval densities and minimum viable population (MVP) estimates (total larval and adult female).

Time to Recovery

The current Northern Brook Lamprey population sizes and growth rates are unknown; therefore, recovery times were estimated for a range of starting female population sizes, from 10% of MVP to MVP, and population growth rates, from one to a maximum population growth rate. The mean recovery time was 51 years for the slowest population growth rates paired with the smallest initial female population sizes, and one year for the fastest population growth rates paired with the highest initial female population sizes. The range of recovery times provided in Figure 4 provides a starting point to work from, however more work is needed to determine average abundance estimates for the Northern Brook Lamprey populations before a specific estimate can be provided.

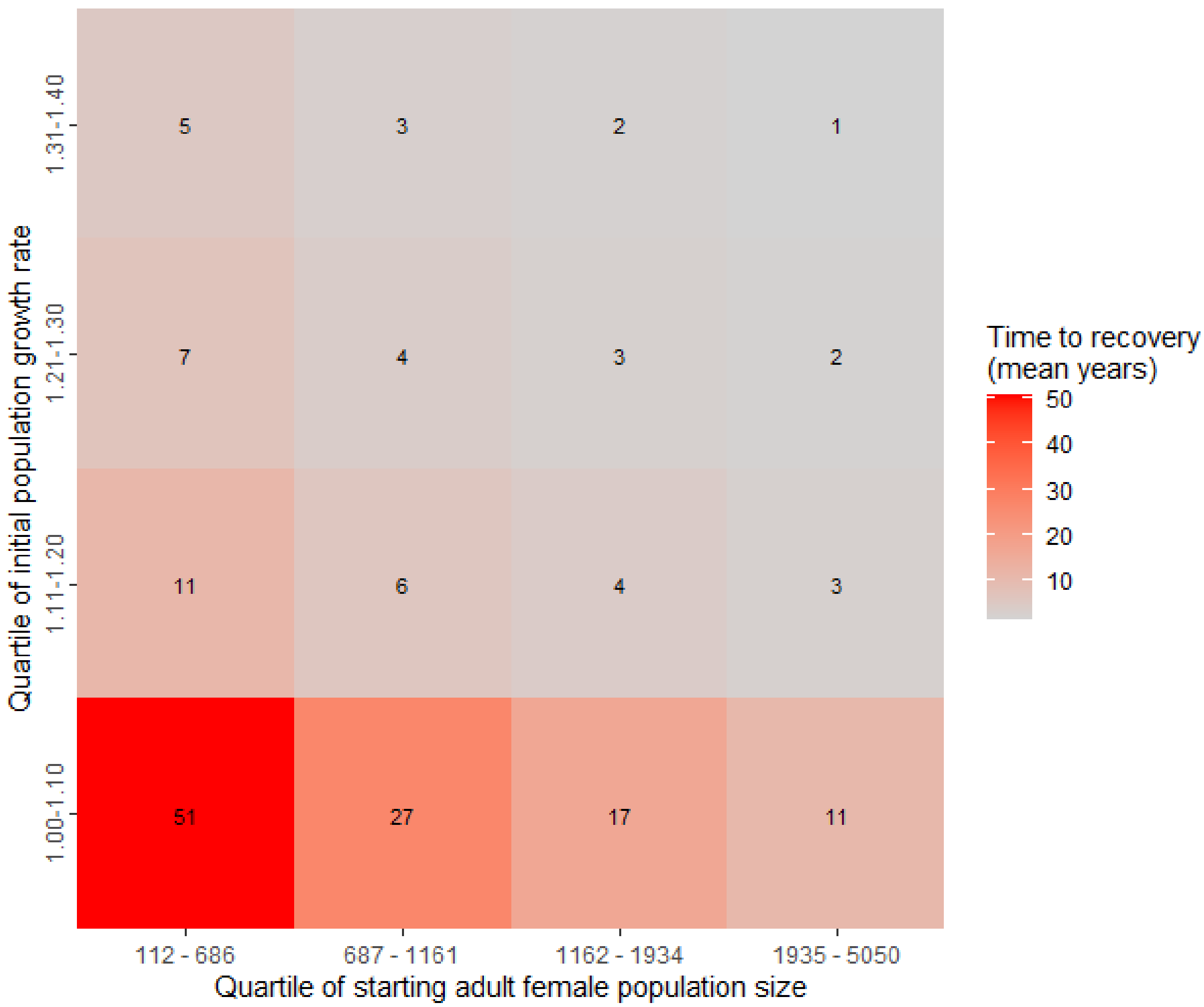

Figure 3. The mean number of years it would take for a Northern Brook Lamprey population to reach the minimum viable population size based on the quartile of initial female adult population size and population growth rate.

Sources of Uncertainty

- There are several knowledge gaps related to the abundance and distribution of Northern Brook Lamprey in the Saskatchewan-Nelson River DU.
    - There are currently no population size estimates available for any of the populations; thus, trends/trajectories cannot be evaluated.
    - The species' current distribution within the known watersheds is likely understood, but most records are spatially and temporally sporadic.
    - Standardized (targeted) monitoring may resolve questions about density and abundance (level and trends).
    - Exploratory sampling in proximity to the currently known occurrences may resolve questions about the species' distribution.
- Physical habitat requirements (e.g., flow, oxygen, water quality, and temperature) by life stage for the Saskatchewan-Nelson River DU are poorly understood.

- The distribution of suitable habitat for Northern Brook Lamprey within the Birch and Whitemouth rivers is poorly understood.
- Co-occurrence with Silver Lamprey (in the Winnipeg River) and whether they are truly distinct species is uncertain. The protection and recovery implications of assuming Northern Brook Lamprey and Silver Lamprey are distinct species instead of alternative morphs of a single species is uncertain.
- The impact of most threats to Northern Brook Lamprey are poorly understood. There is a need for causative studies to evaluate the impact of threats, individually and cumulatively, on Northern Brook Lamprey physiology, mortality, life-history, ecology, and productivity.
- Life history characteristics from other lamprey species were used in population model parameterization because of a paucity of specific information on Northern Brook Lamprey (e.g., recruitment, survival, age specific transformation probabilities, and maximum population growth rate).

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This Science Advisory Report is from the April 19–21, 2023 regional peer review on the Recovery Potential Assessment – Northern Brook Lamprey (*Ichthyomyzon fossor*) – Saskatchewan-Nelson River Population. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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