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Management Plan Series

Management Plan for the Eastern Pondmussel (*Ligumia nasuta*) in Canada

Eastern Pondmussel

2023

Canada

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Preface

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

The Minister of Fisheries and Oceans and the Minister responsible for the Parks Canada (PC) are the competent ministers under SARA for the Eastern Pondmussel (*Ligumia nasuta*) and have prepared this management plan, as per section 65 of SARA. This management plan has been prepared in cooperation with the Government of Ontario, Environment and Climate Change Canada (Canadian Wildlife Service), Central Michigan University, University of Guelph, Bishop Mills Natural History Centre, the Lower Thames Valley Conservation Authority, and others as per subsection 66(1) of SARA.

Success in the management of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this plan and will not be achieved by Fisheries and Oceans Canada (DFO) and PC, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this plan for the benefit of the Eastern Pondmussel and Canadian society as a whole.

Implementation of this plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Acknowledgments

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Executive summary

The Eastern Pondmussel (*Ligumia nasuta*) was listed as a species of special concern under the *Species at Risk Act* (SARA) in 2019. The Eastern Pondmussel was originally listed as endangered under SARA, but was subsequently listed at the lower risk level of special concern following the 2017 Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reassessment, principally due to an apparent reduction in the rate of decline, and the discovery of new subpopulations. This management plan is considered part of a series of documents for this species that are linked and should be taken into consideration together, including the COSEWIC status report (2017). In addition, Eastern Pondmussel was included in the recovery potential assessment of Eastern Pondmussel, Fawnsfoot, Mapleleaf, and Rainbow in Canada (Bouvier and Morris 2011; Fisheries and Oceans Canada [DFO] 2011), and a proposed recovery strategy and action plan was published in 2016 (DFO 2016) before the species was downlisted to special concern.

The Eastern Pondmussel is a medium-sized freshwater mussel (unionid) with a slender and long shell that is bluntly pointed at the posterior end. The outside of the shell varies in colour from yellowish- or greenish-black in juveniles to dark brown or black in adults, with narrow green rays, concentrated at the posterior end of the shell. The Canadian distribution is restricted to Ontario where it was once one of the most common species in the lower Great Lakes (lakes Erie and St. Clair) and connecting water channels. The species appears to be lost from the offshore waters of lakes Erie and St. Clair and connecting channels (Detroit and Niagara rivers), the Sydenham and Grand rivers, and a variety of coastal locations in the lower Great Lakes.

The current distribution of the species includes the delta area of the St. Clair River, Lake Erie (including Cedar Creek [Long Point National Wildlife Area] and Turkey Point Marsh in Long Point Bay, Rondeau Bay and McGeachy Pond adjacent to Rondeau Bay, Lake Pond [Point Pelee National Park]), several coastal wetlands of Lake Ontario (Rouge River Marsh, Carruthers Creek, Lynde Creek Marsh, Pleasant Bay Marsh, Consecon Lake, East Lake, Hay Bay at Wilton Creek [Bay of Quinte]), the lower Trent River, and Lyn and Golden creeks in the upper St. Lawrence River drainage near the outlet of Lake Ontario. Most recently, Eastern Pondmussel was confirmed within several inland lakes of eastern Ontario, including White/Ingelsby, Beaver, Loughborough, and Fishing lakes, as well as Coyle Creek, a tributary of the Welland River.

The main threats facing the species are described in section 5 and include: invasive species (particularly the presence of dreissenid mussels [Zebra Mussel and Quagga Mussel] in lakes St. Clair and Erie), turbidity and sediment loading, contaminants and toxic substances, nutrient loading, altered flow regimes, habitat removal and alterations, potential loss of host fishes, and the impacts of climate change.

The management objectives (section 6) for the Eastern Pondmussel are to:

- protect self-sustaining populations to prevent decline
- restore degraded populations to healthy self-sustaining levels by improving the extent and quality of habitat (where feasible)

A description of the broad strategies and measures for the conservation of the species that provide the best chance of achieving the management objectives are included in section 7. Four broad strategies were identified to address threats to the species and meet the management objectives: 1) inventory and monitoring; 2) research; 3) management and coordination; and, 4) stewardship and outreach. These conservation efforts are best accomplished through

cooperation with existing single-species and ecosystem-based recovery programs for fish and mussel species at risk. Most of these actions will prove beneficial to all species at risk and will eliminate duplication of effort.

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1 Introduction

The Eastern Pondmussel (*Ligumia nasuta*[1]) was listed as a species of special concern under the *Species at Risk Act* (SARA) in 2019. It was initially listed as endangered based on the assessment completed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2007); however, in 2019, the species was downlisted to special concern under SARA after the species was re-assessed by COSEWIC (COSEWIC 2017). The principal rationale for the change in status as given by COSEWIC relates to an apparent reduction in the rate of decline, and the discovery of several newly found remnant subpopulations throughout the coastal wetlands of lakes Erie and Ontario, and in several eastern Ontario inland lakes.

This management plan is part of a series of documents regarding Eastern Pondmussel that should be taken into consideration together, including the COSEWIC status report (COSEWIC 2017) and a recovery potential assessment (Bouvier and Morris 2011; Fisheries and Oceans Canada [DFO] 2011).

2 COSEWIC species assessment information

Date of assessment: April 2017

Species' common name (population): Eastern Pondmussel

Scientific name: *Ligumia nasuta*

Status: Special concern

Reason(s) for designation: This medium to large freshwater mussel is widely distributed across southern Ontario, where it occurs in isolated wetland patches and inland lakes at low abundance. Following past declines in abundance it appears to have been extirpated from the offshore waters of lakes Erie and St. Clair, although there is a large remnant sub-population in the St. Clair River delta. Threats from invasive species include those from Zebra and Quagga mussels as well as European Common Reed. Other threats include pollution from wastewater discharge, and agricultural and industrial effluents. Recent surveys have located new subpopulations at 17 sites not known at the time of the previous assessment, some of which are currently free of Zebra and Quagga mussels. The increase in sampling effort, the apparent reduction in the rate of decline, and the discovery of new subpopulations since the previous assessment have contributed to the change in status for this species from endangered to special concern.

Canadian occurrence: Ontario

Status history: Designated endangered in April 2007. Status re-examined and designated special concern in April 2017.

[1] The scientific name has recently changed to *Sagittunio nasutus* (Watters 2018); however, *Ligumia nasuta* will be used throughout this document to be consistent with the legal listing name under SARA.

3 Species status information

Table 1. Summary of existing protection or other status designations assigned to the Eastern Pondmussel.

Jurisdiction	Authority/organization	Year(s) assessed and/or listed	Status/description	Designation level
Ontario	Committee on the Status of Species at Risk in Ontario (COSSARO)	2017	Special concern	Population
Ontario	*Endangered Species Act, 2007*	2018	Special concern	Population
Ontario	NatureServe	2013	S1[2] – Critically imperilled	Population
Canada	Committee on the Status of Endangered Wildlife in Canada (COSEWIC)	2017	Special concern	Population
Canada	*Species at Risk Act* (SARA)	2019	Special concern	Population
United States[3]	NatureServe	2011	N4 – Apparently secure	Population
International	NatureServe	2011	G4 – Apparently secure	Species

4 Species information

4.1 Species description

The Eastern Pondmussel is a medium-sized (with an average adult length of 74 mm) freshwater mussel (figure 1). Its shell is slender and long, and the posterior end is bluntly pointed. The outside of the shell varies in colour from yellowish- or greenish-black in juveniles to dark brown or black in adults and the shell surface is rough with concentric wrinkles and visible growth lines. Narrow green rays, concentrated at the posterior end of the shell, are often visible in juveniles and light-coloured adults. Females have a swelling along the back bottom edge that is lacking in males. Eastern Pondmussel can be distinguished from all other species of unionids in Canada by its elongated shell with distinctive, bluntly pointed posterior end, rough shell (periostracum), and delicate hinge teeth. More detailed information can be found in COSEWIC (2017).

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[2] Refer to NatureServe 2021 for full definitions of NatureServe conservation status ranks.
[3] Refer to NatureServe 2021 for state-specific designations.

Figure 1. Eastern Pondmussel. Photograph by Environment and Climate Change Canada.

4.2 Population abundance and distribution

Global range: The Eastern Pondmussel's range is restricted to eastern North America (figure 2) where it is found from the lower Great Lakes east through New York to New Hampshire and south to South Carolina (COSEWIC 2017). A recent study indicated that there are 10 genetically distinct populations in the Great Lakes region, with at least 4 occurring in Ontario (Scott et al. 2020). The authors of that study recommend that conservation and restoration efforts consider these populations in the future.

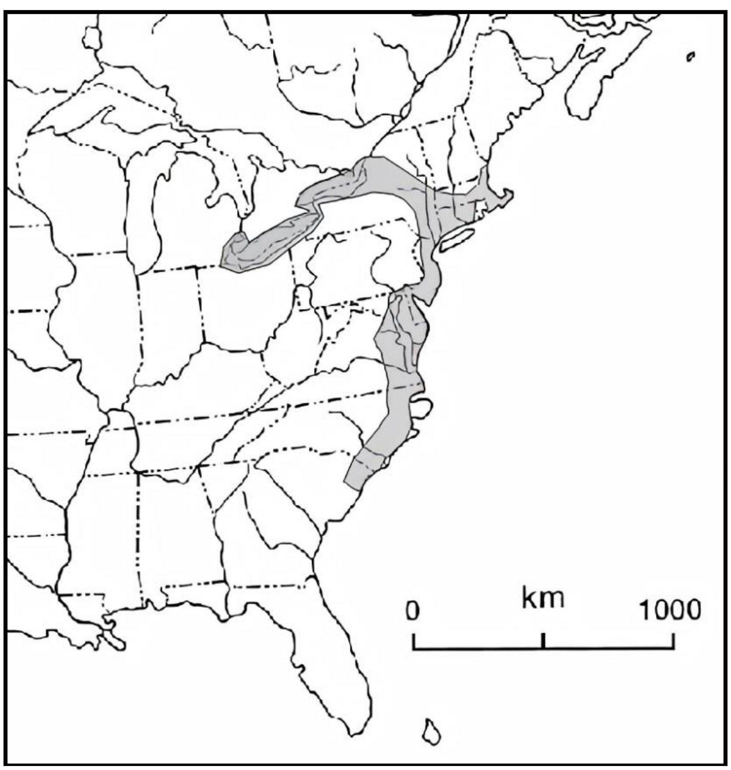

Figure 2. North American distribution (shaded area) of the Eastern Pondmussel (modified from COSEWIC 2017).

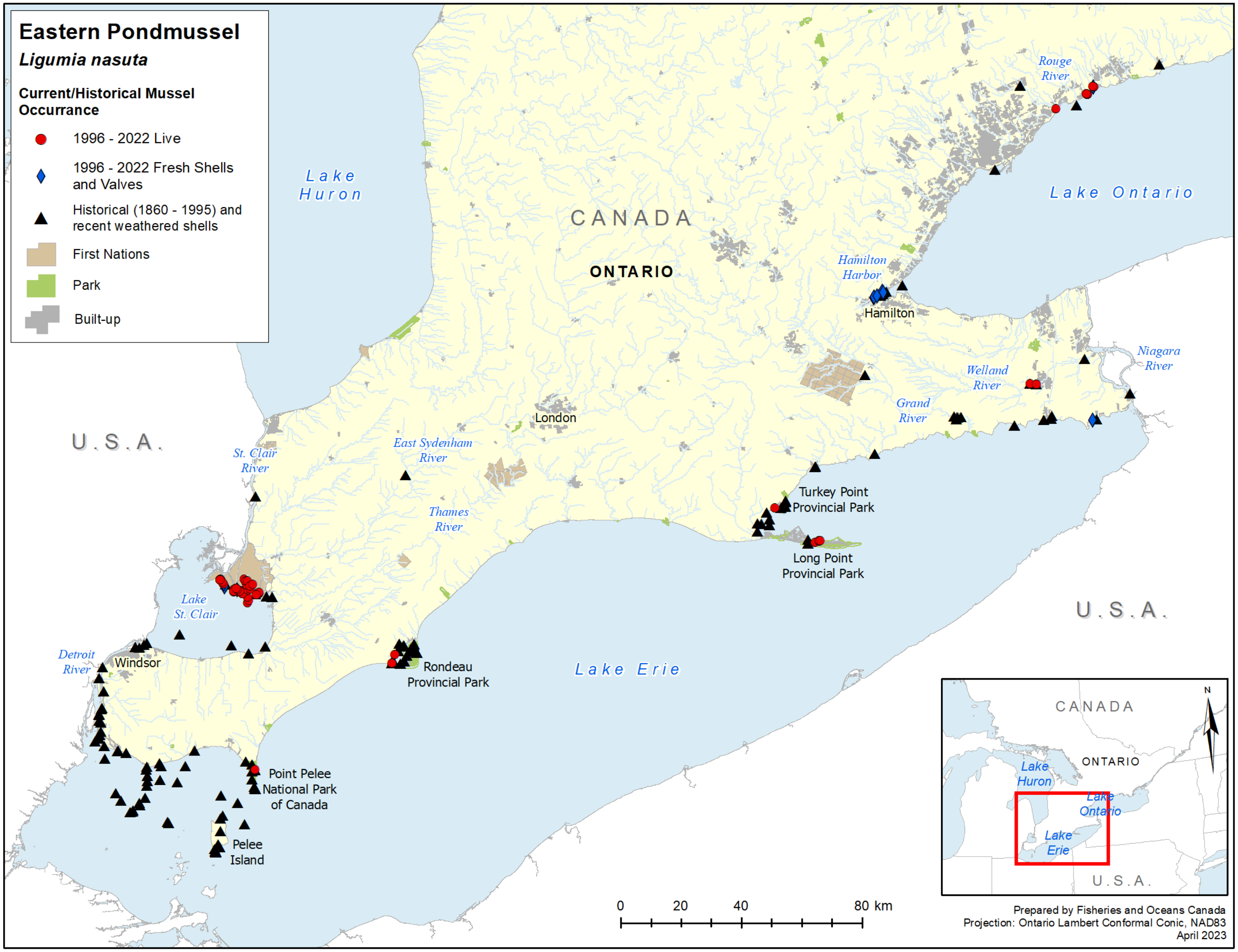

Figure 3(a). Current (1996 to 2022) and historical (pre-1996) distribution of Eastern Pondmussel in southwestern Ontario. Note that the data goes up to 2022; however, no specimens were collected in 2022.

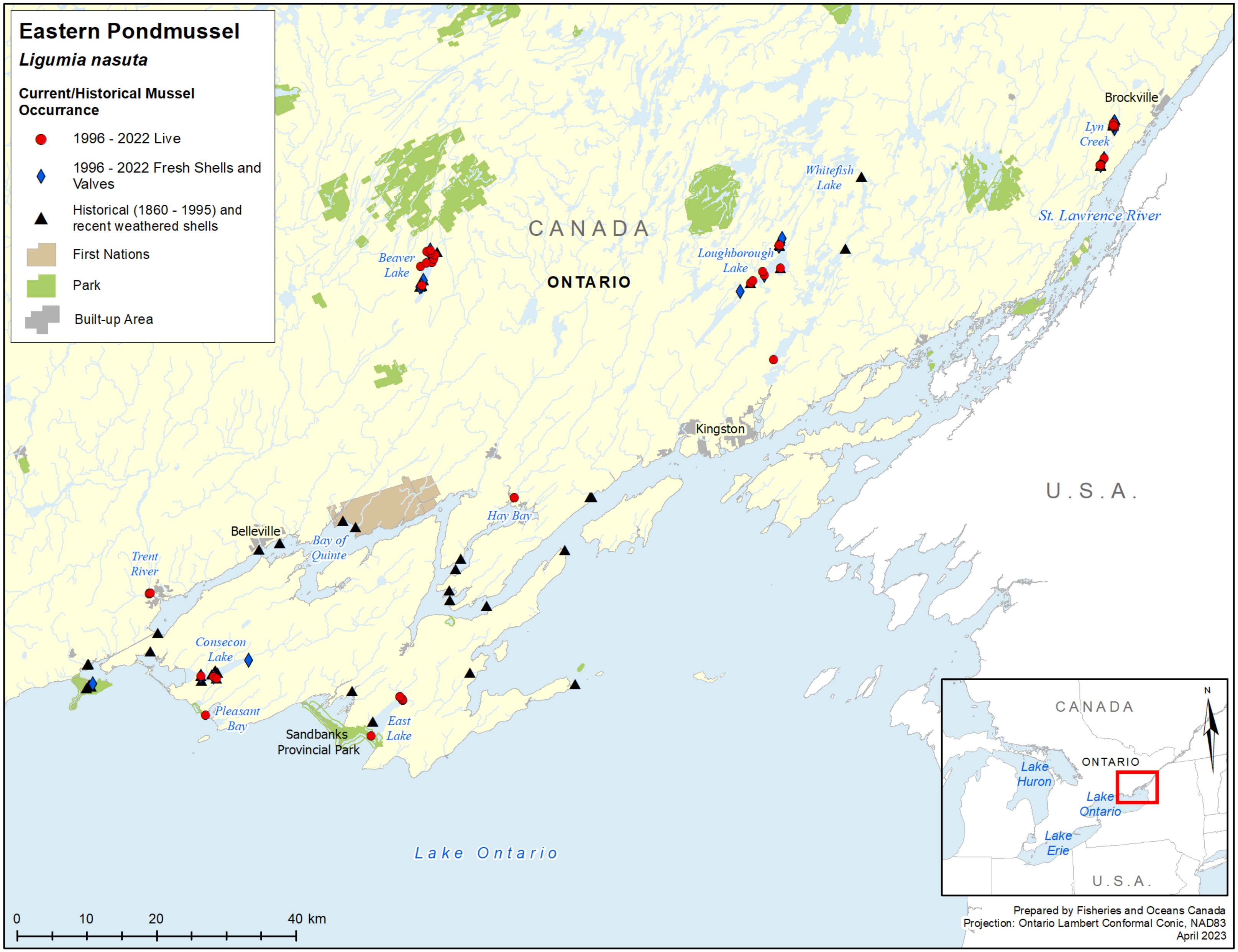

Figure 3(b). Current (1996 to 2022) and historical (pre-1996) distribution of Eastern Pondmussel in eastern Ontario. Note that the data goes up to 2022; however, no specimens were collected in 2022.

Canadian range: In Canada, Eastern Pondmussel is known only from the lower Great Lakes region of Ontario (figures 3a,b), where it occurred historically in the drainages of lakes St. Clair, Erie, and Ontario, and Lyn Creek in the upper St. Lawrence River drainage, near the outlet of Lake Ontario. Recent genetic analyses indicate at least 4 genetically distinct populations occur in Ontario: Lake Ontario, Lake St. Clair, Loughborough Lake, and inland Ontario (Beaver and White lakes) (Scott et al. 2020). However, locations on the Canadian side of Lake Erie were not sampled for genetic analyses.

Canadian population size: The following descriptions of recent records from 2011 to 2022 of the known occurrence of Eastern Pondmussel in Canada were adapted from COSEWIC (2017), while survey data from 2016 to 2022 were obtained from the Lower Great Lakes Unionid Database. For descriptions of pre-2011 records, refer to Bouvier and Morris (2011) and (COSEWIC 2017). Although unionid surveys are increasingly undertaken with quantitative techniques, to date, few have been implemented for Eastern Pondmussel. Locations where the species often inhabit (for example, muddy substrates) present unique challenges to the undertaking of quantitative surveys. As a result, density estimates are only available for the species in the St. Clair River delta. Information on catch-per-unit-effort (number of live individuals per person-hour of search effort) is available for many of the other Eastern Pondmussel locations in COSEWIC (2017).

Lake St. Clair watershed: Historical Eastern Pondmussel records exist for the Detroit River; unionid surveys in the Detroit River in 1997 to 1998 and 2019 did not find any live Eastern Pondmussel on the Canadian side (Schloesser et al. 2006; Allred et al. 2019). However, in 2022, 4 live specimens were collected on the United States of America (USA) side of the river. The records of Eastern Pondmussel within the Lake St. Clair watershed are described below:

- St. Clair River Delta: The largest known remaining population of Eastern Pondmussel can be found in the St. Clair River delta and most of the records are located within Walpole Island First Nation traditional territory. The delta represents a significant refuge site for native unionids, including Eastern Pondmussel, from the dreissenid mussel (Zebra Mussel [*Dreissena polymorpha*] and Quagga Mussel [*D. bugensis*]) invasion (Zanatta et al. 2002). Previously sampled sites were resurveyed in 2011, resulting in the detection of 35 live specimens at 5 of 9 sites (T. Morris, DFO, unpubl. data). Recent surveys in 2016 and 2017, identified 592 live specimens at 13 of 16 sites (T. Morris, DFO, unpubl. data). An abundance estimate of 270,000 to 1,200,000 has been derived for Eastern Pondmussel in the delta where it appears that the species is stable and has possibly increased in density in recent years (COSEWIC 2017)

Lake Erie watershed: The species also historically flourished throughout Lake Erie and its connecting channels; however, in recent years, only a few remnant populations have been detected within coastal wetland habitats of Lake Erie (see below). The records of Eastern Pondmussel within the Lake Erie watershed are described below:

- Point Pelee National Park – Lake Pond: In 2016, 4 ponds within the National Park were surveyed; 1 live specimen was detected in Lake Pond (LeBaron and Reid 2016)

- Rondeau Bay – McGeachy Pond: In 2013, 4 live Eastern Pondmussel were encountered with minimal search effort of 4.5 person-hours plus some informal searching (T. Morris, DFO, unpubl. data). There are no historical records for this location; however, at one time McGeachy Pond is believed to have been connected hydrologically to Rondeau Bay

- Rondeau Bay: Ontario Ministry of Natural Resources and Forestry (OMNRF) surveys completed in 2014 and 2015 uncovered numerous weathered Eastern Pondmussel shells, while only 1 live individual was detected (Reid et al. 2016). Records of Eastern Pondmussel in Rondeau Bay date back to 1894

- Bay Beach: In 2013, one fresh valve was collected relatively close to a historical record

Lake Ontario watershed: Historically, Eastern Pondmussel was widely distributed along the coastal waters of Lake Ontario between Hamilton Harbour to the Bay of Quinte. In recent years, remnant populations have been confirmed and new locations have been discovered (that is, Carruthers Creek, Lynde Creek Marsh, Trent River, Pleasant Bay Marsh, and Hay Bay; see below). The records of Eastern Pondmussel within the Lake Erie watershed are described below:

- Welland River – Coyle Creek: Surveys conducted in 2015 by DFO confirmed the presence of 6 live Eastern Pondmussel from 2 of 3 sites searched in Coyle Creek, a tributary of the Welland River (Wright et al. 2017)

- Rouge River Marsh: Surveys by OMNRF in 2012 detected the first live Eastern Pondmussel from the Rouge River Marsh, just upstream of the river's outlet into Lake Ontario (S. Reid, OMNRF, unpubl. data)

- Carruthers Creek: Seven Eastern Pondmussel were detected at the mouth of Carruthers Creek in the City of Ajax in 2012, while a 2015 survey found no live individuals (S. Reid, OMNRF, unpubl. data)

- Lynde Creek Marsh: Twenty-three Eastern Pondmussel were detected at the mouth of Lynde Creek (Ajax and Whitby) in 2011, and a 2012 survey produced a further 10 live individuals (S. Reid, OMNRF, unpubl. data)

- Bowmanville Creek: In 2008, a weathered valve was discovered; this is the first record of Eastern Pondmussel in Bowmanville Creek and was not previously reported in Bouvier and Morris (2011)

Quinte region:

- Consecon Lake: After the detection of 14 live individuals in 1996, Eastern Pondmussel was not recorded until 2013, when 6 were detected by OMNRF as a result of surveys throughout the lake (S. Reid, OMNRF, unpubl. data)

- Pleasant Bay Marsh: A single Eastern Pondmussel was detected in 2012 (S. Reid, OMNRF, unpubl. data)

- East Lake: In 2012, 8 live individuals were detected, while 10 were counted in 2015 surveys (S. Reid, OMNRF, unpubl. data)

- Lower Trent River: In 2013, 1 live Eastern Pondmussel was detected in the City of Trenton (approximately 2 km upstream of the Trent River confluence with the Bay of

Quinte). Extensive surveys of the Trent River (main channel or tributaries) in 2013 and 2015 found no live Eastern Pondmussel (Reid 2016)

- Bay of Quinte – Hay Bay at Wilton Creek: Historical surveys uncovered Eastern Pondmussel at a variety of sites within the region. Recent surveys have been less successful, with only a single individual detected near Hay Bay and Wilton Creek in 2011 (S. Reid, OMNRF, unpubl. data)

Eastern Ontario inland lakes:

- Beaver Lake: In 2015, 24 live Eastern Pondmussel were detected by OMNRF from a total of 12 sites searched (Reid et al. 2017)

- White/Ingelsby Lake: A moderately fresh Eastern Pondmussel shell was found in this reportedly dreissenid-free lake in 2012 (Schueler 2012). In 2015, OMNRF surveys detected 26 live Eastern Pondmussel, as well as numerous fresh and weathered shells (Reid et al. 2017). This small lake is connected through a short stream channel to Beaver Lake

- Fishing Lake: Independent surveys in 2015 confirmed the presence of the species within Fishing Lake, with the detection of 2 live individuals and numerous fresh and weathered shells (R. McRae, Fishing Lake Association and F. Schueler, the Bishops Mills Natural History Centre [BMNHC], unpubl. data)

- Loughborough Lake: In 2015, OMNRF surveys in Loughborough Lake detected 19 live Eastern Pondmussel from 5 of 12 sites surveyed (Reid et al. 2017). Loughborough Lake is connected to Fishing Lake through a very short channel

Upper St. Lawrence River watershed: The records of Eastern Pondmussel within the Upper St. Lawrence River watershed are described below:

- Lyn and Golden creeks: Eastern Pondmussel is believed to inhabit an 8 km stretch of Lyn Creek. The lowest reaches of Lyn Creek, the Jones Creek estuary into which it empties, and other tributaries of this estuary have not been investigated and may contain dreissenid-free areas or marshes that support Eastern Pondmussel (Schueler 2012). Recent sampling (2011 to 2022) has recorded a total of 140 live individuals in Lyn Creek and 1 live individual in Golden Creek

Population status: To date, it appears that there are 21 systems containing Eastern Pondmussel in Ontario (table 2). The following systems have been excluded from the table as recent evidence of Eastern Pondmussel persistence or surveys are lacking: Great Lakes and connecting channels (for example, open waters of Lake St. Clair, Detroit River, open waters of western Lake Erie, Niagara River including the Welland River), Grand River, including Mackenzie Creek, Sydenham River, Holiday Beach Park, Lake Henry on Pelee Island, Middle Sister and East Sister islands, Port Dover, Long Beach, Nanticoke, Port Colbourne, Bay and Crystal beaches, various locations in Cootes Paradise, Mill Dam Pond, Presqu'ile Bay, Weller's Bay, various locations in Bay of Quinte including the Moira River, and Whitefish Lake. The decline in Eastern Pondmussel distribution can be closely related to the dreissenid invasion, which began in the late 1980s; however, dreissenid-mediated declines appear to have abated (COSEWIC 2017).

Populations of Eastern Pondmussel were ranked by Bouvier and Morris (2011), with respect to abundance and trajectory; the same ranking method was applied to newly discovered populations (table 2). Population abundance and trajectory were then combined to determine the population status. A certainty level was also assigned to the population status, which reflected the lowest level of certainty associated with either population abundance or trajectory. Refer to Bouvier and Morris (2011) for further details on the methodology.

Table 2. Abundance index, population trajectory, and population status of Eastern Pondmussel populations in Canada (table modified from Bouvier and Morris 2011 and updated with data from Brumpton et al. 2013, S. Reid, OMNRF, unpubl data, and T. Morris, DFO, unpubl. data).

Location	Abundance index	Certainty[4]	Population trajectory	Certainty	Population status	Certainty[5]
St. Clair River delta[6]	Medium	1	Unknown	3	Fair	3
Point Pelee National Park – Lake Pond	Low	2	Unknown	3	Poor	3
Rondeau Bay – McGeachy Pond	Low	2	Unknown	3	Poor	3
Rondeau Bay	Low	2	Unknown	3	Poor	3
Long Point Bay – Cedar Creek Marsh[6]	Low	2	Unknown	3	Poor	3
Long Point Bay – Turkey Point Marsh	Low	2	Unknown	3	Poor	3
Grand River	Unknown	3	Unknown	3	Unknown	3
Welland River – Coyle Creek	Low	2	Unknown	3	Poor	3
Rouge River Marsh	Low	2	Unknown	3	Poor	3
Carruthers Creek	Low	2	Unknown	3	Poor	3
Lynde Creek Marsh	Low	2	Unknown	3	Poor	3
Consecon Lake	Low	2	Unknown	3	Poor	3
Pleasant Bay Marsh	Low	2	Unknown	3	Poor	3

[4] Certainty associated with abundance index or population trajectory is listed as: 1=quantitative analysis; 2=standardized sampling; 3=expert opinion.
[5] Certainty for population status reflects the lowest level of certainty associated with either abundance index or population trajectory.
[6] Recently compiled length-frequency distributions suggest recruitment (COSEWIC 2017).

Location	Abundance index	Certainty[4]	Population trajectory	Certainty	Population status	Certainty[5]
East Lake	Low	2	Unknown	3	Poor	3
Lower Trent River	Low	2	Unknown	3	Poor	3
Beaver Lake[6]	Low	2	Unknown	3	Poor	3
White/Ingelsby Lake[6]	Low	2	Unknown	3	Poor	3
Bay of Quinte – Hay Bay at Wilton Creek	Low	2	Unknown	3	Poor	3
Fishing Lake	Low	3	Unknown	3	Poor	3
Loughborough Lake[6]	Low	2	Unknown	3	Poor	3
Lyn and Golden creeks[6]	Low	3	Unknown	3	Poor	3

4.3 Needs of the Eastern Pondmussel

4.3.1 Habitat and biological needs

Spawning: The reproductive biology of the Eastern Pondmussel is similar to that of most unionid mussels (adapted from Clarke 1981; Kat 1984; Watters 1999). During spawning, males release sperm into the water and females living downstream filter the sperm out of the water when filter feeding. Once the ova are fertilized, they are held until they reach a larval stage called the glochidium (plural glochidia). Eastern Pondmussel is believed to be bradytictic (long-term brooder) such that it spawns in late summer, broods the glochidia over the winter and subsequently releases the glochidia in early spring (Watters et al. 2009). The released glochidia must attach to an appropriate host fish to continue their development. Females of this species use a visual display to attract their host fish and thus water clarity may be important for successful reproduction. According to Corey and Strayer (2006), the female positions herself upright in the substrate, with the valves gaping and the mantle exposed. White papillae ripple up and down the mantle margin in an uninterrupted, synchronized rippling, the appearance of which resembles a swimming amphipod (small crustacean). Complete down and back motions along the mantle margin have been observed. When a fish strikes at the lure, the female expels her glochidia, which facilitates the attachment of the glochidia to the gills of the fish. The dependency of unionids, including the Eastern Pondmussel, on a host fish for development may be a limiting factor for many mussel populations, as any changes that affect the host also affect the mussels.

Encysted glochidia stage: The glochidia become encysted on the host and develop, but do not grow in size. Attachment times for the Eastern Pondmussel range from 11 to 89 days (at 17.5 to 22°C), depending on temperature (J. Ackerman, pers. comm. 2021, McNichols et al. 2009). To date, 3 hosts for the Eastern Pondmussel have been identified: Brook Stickleback (*Culaea inconstans*), Pumpkinseed (*Lepomis gibbosus*), and Yellow Perch (*Perca flavescens*), and lab experiments suggest that the Yellow Perch is the preferred host, as it yielded significantly more juveniles (McNichols et al. 2009). Similarly, in laboratory experiments based in the USA, the Yellow Perch also yielded the most juveniles, while the Largemouth Bass (*Micropterus salmoides*), Bluegill (*L. macrochirus*), and Pumpkinseed were also suitable hosts (Eads et al. 2015).

Juvenile: After metamorphosis, juveniles drop off the host and fall to the substrate to begin life as free-living mussels. Juveniles of most species of freshwater mussels live completely buried in the substrate where they feed on similar foods obtained directly from the substrate or from interstitial water (Yeager et al. 1994; Gatenby et al. 1997). Juvenile mussels remain buried until they are sexually mature, at which point they move to the surface for the dispersal/intake of gametes (Watters et al. 2001).

Adult: The Eastern Pondmussel, like all unionids, is a sedentary animal that buries itself partially or completely in the substrates of rivers or lakes at water depths ranging from 0.3 to 4.5 m. It is characterized as a lake species (Bouvier and Morris 2011), but can also be found in the lower reaches of major tributaries (Strayer 1983). The Eastern Pondmussel is most likely to be found in sheltered areas of lakes, in slack-water areas of rivers, and in canals (Metcalfe-Smith et al. 2005; COSEWIC 2017). Within coastal wetland areas of Lake Ontario, it has been found associated with substrates of clay (43%), silt/organics (23%), and sand/gravel (34%), while inland lake sites were 47% silt/organics and 52% sand/gravel (COSEWIC 2017). The St. Clair River delta population is found on substrates composed of over 95% sand at the transition zone between the emergent wetlands and the open waters of Lake St. Clair (Metcalfe-Smith et al. 2004). The habitat in Lyn Creek (eastern Ontario) was described by Schueler (2008, 2012) as slow moving flow over sand, silt, and clay beds that were free of dreissenid mussels. Adult unionids are filter-feeders that obtain nourishment by siphoning particles of organic detritus, algae, and bacteria from the water column and sediments (for example, Nichols et al. 2005).

Ecological role: Unionids play an integral role in the functioning of aquatic ecosystems, including water column and sediment processes (Vaughn 2017); while it is difficult to quantify, the value of their ecosystem functions is appreciable (Strayer 2017). Unionids are sensitive indicators of the health of freshwater ecosystems, including water and habitat quality and especially the fish community on which they depend for successful reproduction. The Eastern Pondmussel was historically a significant component of the Great Lakes mussel fauna, being the fourth most common species detected in the lower Great Lakes and connecting channels (COSEWIC 2017). It is reasonable to assume that this species contributed significantly to the function of unionid communities in the Great Lakes ecosystem prior to the dreissenid invasion. Unionids are also important prey for a few species, including the muskrat (*Ondatra zibethicus*) (Neves and Odom 1989), which results in a transfer of energy from the aquatic to the terrestrial environment. This may specifically be the case of Eastern Pondmussel populations in coastal wetlands of lakes St. Clair, Erie, and Ontario, as they are found in areas near the preferred habitat of muskrats (wetland areas with abundant emergent vegetation).

Limiting factors: Elements of its life cycle involving reproduction and dispersal may be limiting factors for the Eastern Pondmussel. Availability of host fish suitable for glochidial attachment may inhibit unionid population growth and dispersal, and the time frame for glochidia attachment to host fish may be very limited. Adult Eastern Pondmussel have very limited dispersal abilities. Although adult movement can be directed upstream or downstream, studies have found a net downstream movement through time (Balfour and Smock 1995). The primary means for large-scale dispersal, upstream movement, and the invasion of new habitat or evasion of deteriorating habitat, is limited to the encysted glochidial stage on the host fish. Predation by fishes, mammals, and birds can threaten mussel populations and may be inhibiting Eastern Pondmussel populations.

Water temperatures can also greatly impact the fitness and survivorship of unionids. Although limited research has been conducted with respect to the effects of water temperature on Eastern Pondmussel ecology, such effects have been documented for other similar unionids.

Freshwater mussels are known to be food sources for a variety of mammals and fishes (Fuller 1974). Predation by muskrats in particular may be a limiting factor for Eastern Pondmussel in coastal wetland locations with abundant emergent vegetation, the preferred habitat for muskrats. It has been confirmed that muskrats are both size- and species-selective when foraging, and can therefore significantly affect both the size structure and species composition of mussel communities (Tyrrell and Hornbach 1998). There have been several studies of muskrat predation on freshwater mussels (for example, Convey et al. 1998; Tyrrell and Hornbach 1998), but these studies were not conducted in areas likely to support populations of Eastern Pondmussel. However, since muskrats and Eastern Pondmussel are found in very similar habitats in Ontario, there is an increased likelihood of predator/prey interactions, which supports further study.

5 Threats

An assessment and prioritization of threats to the Eastern Pondmussel were informed by the COSEWIC status report (COSEWIC 2017), the recovery potential assessment that included the species (Bouvier and Morris 2011; DFO 2011), and the proposed recovery strategy and action plan published in 2016 (DFO 2016), with input from experts. The current threat assessment and prioritization relies most significantly on expert opinion. The specific assessment categories and associated rankings are presented in tables 3a and 3b. The threat level represents a combination of the current threat impact and threat likelihood at a location. It does not reflect the potential impact a threat might have on a unionid population if it were allowed to occur in the future. For more details on the threat assessment process, refer to the Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk (DFO 2014).

5.1 Threat assessment

Table 3a. Summary of threats to Eastern Pondmussel populations in Canada.

Threats	St. Clair River delta	Point Pelee National Park	Rondeau Bay (McGeachy Pond)	Long Point Bay (Cedar Creek and Turkey Point)	Grand River	Welland River – Coyle Creek	Rouge River Marsh	Carruthers Creek	Lynde Creek Marsh	Consecon Lake
Invasive species	High	Medium	High	High	Medium	High	Low	Low	Medium	Medium
Pollution (turbidity and sediment loading)	Medium	Low	High	Medium	High	Medium	Low	Low	Medium	Low
Pollution (contaminants and toxic substances)	High	Medium	Medium	Medium	High	High	Low	Low	Medium	Medium
Pollution (nutrient loading)	Medium	Low	High	Medium	High	Medium	Low	Low	Medium	Low
Natural system modification (altered flow regimes)	N/A	N/A	N/A	N/A	Medium	Low	Low	Low	Low	Low
Habitat removal and alterations	Medium	Low	High	Medium	High	Medium	Low	Low	Low	Low
Host fish availability	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Human intrusions and disturbance (recreational activities)	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Table 3b. Summary of threats to Eastern Pondmussel populations in Canada.

Threats	Pleasant Bay Marsh	East Lake	Lower Trent River	Bay of Quinte – Hay Bay	Beaver Lake	White / Ingelsby Lake	Loughborough Lake	Fishing Lake	Lyn and Golden creeks
Invasive species	Medium	Medium	High	Medium	High	Low	Medium	Low	Low
Pollution (turbidity and sediment loading)	Low	Low	Medium	Low	Medium	Medium	Low	Low	Medium
Pollution (contaminants and toxic substances)	Medium	Medium	High	Medium	Low	Low	Low	Low	Medium
Pollution (nutrient loading)	Low	Low	Medium	Medium	Unknown	Unknown	Low	Low	Medium
Natural system modification (altered flow regimes)	Low	Low	High	Low	N/A	N/A	Medium	Medium	Low
Habitat removal and alterations	Low	Low	High	Low	Medium	Medium	Unknown	Unknown	Unknown
Host fish availability	Low	Low	Low	Low	Low	Low	Low	Low	Low
Human intrusions and disturbance (recreational activities)	Low	Low	Low	Low	Low	Low	Low	Low	Low

5.2 Description of threats

The following descriptions emphasize the principal threats currently acting on Eastern Pondmussel populations in Canada. Most of the information has been summarized from Bouvier and Morris (2011) and COSEWIC (2017).

Invasive species: Dreissenid mussels have decimated populations of freshwater mussels in the lower Great Lakes by virtually eliminating historical habitat (Gillis and Mackie 1994; Schloesser and Nalepa 1994; Nalepa et al. 1996). Over 90% of historical records for the Eastern Pondmussel, the most for any species of unionid in Canada, are from areas now infested with dreissenid mussels, and are thus uninhabitable. Dreissenid mussels continue to threaten and limit the distribution of this species in the St. Clair River delta, Long Point Bay, inland lakes, and coastal wetlands of Lake Ontario. Dreissenid mussels have been shown to colonize unionids in large numbers and this has many negative effects on the unionids. An infested Eastern Pondmussel can no longer open and close its valves, which can limit movement, feeding and reproduction, and also increases the risk of predation and parasitism (Schloesser et al. 1996; Baker and Hornbach 1997). The attachment of dreissenid mussels can also directly prevent a unionid from feeding and reproducing by covering its siphons. Due to the increased weight of dreissenid individuals on the unionid, it may become immobilized or dislodged and may not have the ability to burrow back into the sediment. In addition, valves of unionids can become deformed via the tension created by dreissenid byssal threads (Schloesser et al. 1996). Dreissenid mussels have been shown to directly reduce available food sources in the water column due to their siphoning ability (Mackie 1991).

The results of an unpublished study on the impacts of dreissenid mussels on 5 species of native mussels in Lake St. Clair indicated that Eastern Pondmussel had the lowest rate of survival, and carried the heaviest load of dreissenid mussels relative to their size (COSEWIC 2017). Reid et al. (2018) determined that Eastern Pondmussel had the greatest mass-ratio of dreissenids to live mussels out of 11 species found in Lake Ontario coastal wetlands, providing further proof of their vulnerability to dreissenid fouling. Despite heavy dreissenid infestations in East Lake and nearby Consecon Lake, recent sampling has confirmed the existence of live Eastern Pondmussel in low numbers at both locations, as well as within 5 other coastal wetlands of Lake Ontario (Brumpton et al. 2013). Although infestation rates may vary, dreissenid mussels remain a threat to all populations within coastal wetlands and inland lakes.

It is unlikely that dreissenid mussels could be introduced into the Lyn Creek drainage, as the only standing waterbodies in the system are 2 small, wetland-surrounded ponds (Lambs Pond south of New Dublin and Lees Pond north of Lillies) with no boat access (BMNHC 2006). Standing waterbodies are required for successful dispersal of dreissenid mussels because they allow the formation of a “source” population, where reproduction can occur; dreissenid larvae (that is, veligers) must remain in the water column for several weeks to complete their development before settling. Natural dispersal of dreissenid mussels is passive and generally occurs downstream of the adult population during the larval stage via water currents. If there is no source population, dreissenids cannot extend populations downstream (Claudi and Mackie 1994). However, upstream movement of dreissenids is due largely to human activities. For example, dreissenid mussels can attach to boat hulls, be transported in ballast water or bait buckets, and be easily moved from one lake to another (Claudi and Mackie 1994). This is unlikely in Lyn Creek, as there is no boat access.

The common reed (*Phragmites australis*), an invasive emergent grass, has also been identified as a potential threat to Eastern Pondmussel (COSEWIC 2017). This species can grow in dense stands that crowd out other plant species, possibly leading to a reduction in aquatic habitat. It is prevalent in the coastal regions of lakes Erie and Ontario (Carlson Mazur 2014) and has invasion potential to eastern Ontario lakes that contain Eastern Pondmussel (COSEWIC 2017).

Predation of juvenile mussels by Common Carp (*Cyprinus carpio*) have the potential to impact populations of Eastern Pondmussel due to their high population densities within some coastal wetland habitats. Round Goby (*Neogobius melanostomus*), is another invasive species that is spreading throughout the lower Great Lakes and tributaries, which may negatively affect Eastern Pondmussel. Round Goby has been shown to prey on dreissenid mussels (Ghedotti et al. 1995; Ray and Corkum 1997) and has been observed to consume juvenile unionids (M. Poesch, University of Alberta, pers. comm., 2015). It is likely that gape size limitations may be restricting predation on larger mussel species (Ray and Corkum 1997); however, unionids at the juvenile life stage may be vulnerable to consumption due to their smaller size.

Pollution (turbidity and sediment loading): High levels of turbidity are often associated with agricultural activities and the loss of riparian vegetation. The loss of riparian buffer zones may have played a key role in the decline of freshwater mussels in southwestern Ontario. Riparian zones are known to play an important role in the mitigation of anthropogenic disturbances (for example, nutrient and sediment inputs from agricultural activities), as the health of riparian zones has been positively correlated with that of freshwater mussel communities (for example, Brown et al. 2010; Atkinson et al. 2012). Increased levels of turbidity may inhibit reproductive success by reducing the odds of visual attraction of a host fish to Eastern Pondmussel for glochidia release, and interfering with sperm uptake. In addition, feeding rates may be reduced as demonstrated by Tuttle-Raycraft et al. (2017) where clearance rates of adult and juvenile Eastern Pondmussel declined with increased concentration of total suspended solids. Research is required to determine the turbidity tolerance levels of the Eastern Pondmussel.

Coastal wetlands of lakes Erie and Ontario can have high recorded levels of suspended solids (see Provincial [Stream] Water Quality Monitoring Network [PWQMN]). The eastern Ontario inland lake locations lack specific water quality information but are situated in relatively undisturbed areas. Areas considered less at risk from this threat are the St. Clair River delta, as a result of its protection through the Walpole Island First Nation territory (for example, access restrictions); Lyn Creek, which is surrounded by relatively undisturbed habitat; and, Cedar Creek, which is located in the Long Point National Wildlife Area (LPNWA) (Bouvier and Morris 2011). Of the recently confirmed locations within coastal wetlands of Lake Ontario, those that are part of estuary systems are likely impacted to some degree by sediment loading and turbidity (for example, Rouge River Marsh, Carruthers Creek, Lynde Creek Marsh, and Hay Bay at Wilton Creek).

Pollution (contaminants and toxic substances): The life-history characteristics of freshwater mussels make them particularly sensitive to increased levels of sediment contamination and water pollution. Mussels are primarily filter feeders, while juveniles remain buried in the sediment feeding on particles associated with the sediment; in both cases, filter feeding increases exposure to water and sediment-associated contaminants. While early life stage freshwater mussels have limited sensitivity to many pesticides (Bringolf et al. 2007; Prosser et al. 2016; Salerno et al. 2018), glochidia are particularly sensitive to heavy metals (Keller and Zam 1990; Wang et al. 2007b; Gillis et al. 2008; Gillis et al. 2010; Wang et al. 2017), ammonia (Augspurger et al. 2003; Mummert et al. 2003; Wang et al. 2007a; Salerno et al. 2020), acidity

(Huebner and Pynnonen 1992), potassium (Gillis et al. 2021a), and salinity (Gillis 2011; Pandolfo et al. 2012; Wang et al. 2018a; Wang et al. 2018b).

Toxicity of road salt to unionids and their glochidia has been demonstrated (Gillis 2011; Pandolfo et al. 2012; Gillis et al. 2021b). Gillis (2011) has shown that glochidia of the Wavyrayed Lampmussel (*Lampsilis fasciola*) were acutely sensitive to sodium chloride. Assuming that the salt sensitivity of the Eastern Pondmussel is comparable to that of the Wavyrayed Lampmussel, chloride from road salt is a substantial threat to early life stages because the species' range is limited to southern Ontario, Canada's most road-dense, and thus heavily salted, region (Gillis 2011). Although federal water quality guidelines for the protection of aquatic life have been set at 120 mg/L for chronic exposure to chloride, this guideline may not be sufficiently protective of glochidia of some species at risk mussels in southern Ontario (Canadian Council of Ministers of the Environment [CCME] 2011). Further work by Todd and Kaltenecker (2012) suggests that long-term road salt use is contributing to increases in baseline chloride concentrations that may affect recruitment of at-risk mussel populations, while Prosser et al. (2017) conducted a study that revealed that chronic exposure to elevated chloride levels could pose a risk to unionids.

The habitat of Eastern Pondmussel in Lyn Creek appears to be of high quality, with clear water and is relatively undisturbed, as the lands adjacent to Lyn Creek are generally privately owned, and there are no bridges or settlements along the stretch of river where Eastern Pondmussel has been observed. Pollution is considered to be a low threat for the Lyn Creek population; however, due to the sensitivity of mussels to contaminants, water quality should be monitored. The areas in Long Point Bay where Eastern Pondmussel populations are found also appear to have good water quality (J. Gilbert, OMNRF, pers. comm.). Degraded water quality is well known from the Lake Ontario Areas of Concern, Hamilton Harbour and the Bay of Quinte. Generally, coastal wetlands of Lake Ontario experience greater pollutant loads than the wetlands of Lake Erie, while the eastern Ontario inland lakes and the Lyn and Golden creeks of the Upper St. Lawrence River are situated in less disturbed areas (see PWQMN).

Freshwater mussels exposed to municipal wastewater effluents are also exposed to chemicals of emerging concern, including pharmaceutics and personal care products (PPCPs). Flutedshell (*Lasmigona costata*) from an urban river that receives municipal wastewater accumulated pharmaceutics from many classes, including stimulants, anti-inflammatory drugs, anti-bacterial agents, antibiotics, antidepressants, and antihistamines, and had progestins in their tissues (de Solla et al. 2016). While only a few of the thousands of PPCPs found in wastewater effluents have been assessed, mussels were not acutely affected (that is, lethality) from exposure to environmentally relevant levels of the PPCPs tested (Gilroy et al. 2014; Gilroy et al. 2017; Gilroy et al. 2020), though sub-lethal impacts, including chronic effects on reproduction, have been reported (Leonard et al. 2014; Leonard et al. 2017). Another potential threat to freshwater mussels is microplastics, although little research has been conducted to determine the extent to which they might impact freshwater mussels. Microplastics have recently been confirmed in Flutedshell in the Grand River (Wardlaw and Prosser 2020) and further research in Ontario is underway.

The use of chemical lampricides is one of several tactics used to control for Sea Lamprey (*Petromyzon marinus*) in natal streams within the Great Lakes basin (DFO 2021); without such controls, Sea Lamprey would have a significant negative effect on many fish populations within the Great Lakes including at-risk species such as Lake Sturgeon (Vélez-Espino and Koops 2008) and deep-water Ciscoes (COSEWIC 2003; Eshenroder et al. 2016). One such lampricide, granular Bayluscide, is an important component of binational control efforts of Sea Lamprey in the Great Lakes and is also a known molluscicide (Andrews et al. 2021). In a laboratory setting, Eastern Pondmussel experienced approximately 16% mortality when individuals were exposed to 3.2% granular Bayluscide for 8 hours (Newton et al. 2017). Andrews et al. (2021) found the risk of granular Bayluscide application to Eastern Pondmussel was moderate, relative to other mussel species at risk in the Great Lakes, under some specific parameters and assumptions about exposure using a risk assessment. Although toxicity was lower than most other unionids, the intensity of past applications where Eastern Pondmussel occurs was high given the parameters of the evaluation. Using a simulation model, Smyth and Drake (2021) found the expected outcome of using Bayluscide as a tool within the Sea Lamprey control program was no or low mortality in over 95% of applications for species at risk Unionids present in the Thames and Sydenham rivers[7]. The binational Sea Lamprey control program continues to utilize the best available science to minimize the treatment threat to native mussels while serving as a cornerstone to rehabilitate native fish assemblages as part of collaborative fishery management.

Pollution (nutrient loading): The primary concern of nutrient loadings for freshwater mussels relates to eutrophication effects, namely algal blooms that can result in oxygen depletion and algal toxins. A study on Fatmucket (*L. siliquoidea*) glochidia and juveniles found that chronic exposure to microcystin-LR, an algal toxin, may present a significant risk to mussel populations (Gene et al. 2019). A negative correlation was found between concentrations of phosphorus and nitrogen and Wavyrayed Lampmussel abundance in a variety of southwestern Ontario streams (Morris et al. 2008), while reduced mussel growth has been observed in unionids when cyanobacteria levels are elevated (Bartsch et al. 2017). Additionally, juvenile mussels may be particularly sensitive to ammonia (for example, Goudreau et al. 1993). Augspurger et al. (2003) and Mummert et al. (2003) found that juvenile unionids are among the most sensitive aquatic organisms to unionized ammonia and that this contaminant may limit their distribution in some systems.

The western basin of Lake Erie, Lake St. Clair, Hamilton Harbour, and the Bay of Quinte have regular occurrences of algal blooms, while relatively low levels of phosphorus and nitrate are detected in eastern Ontario around the inland lakes (COSEWIC 2017). For example, in 2015 there was a massive algal bloom captured in satellite images that covered the St. Clair River delta and the lake's southern shores, as well as the western basin of Lake Erie (National Aeronautics and Space Administration [NASA] 2015), while another significant bloom was observed in 2017.

Habitat removal and alterations: Destruction of habitat through dredging, ditching, and other forms of channelization may compromise this species. River channel modifications, such as dredging, can result in the direct destruction of mussel habitat and lead to siltation accumulation of local and downstream mussel beds. The construction of impoundments can lead to the fragmentation of habitat, altered water levels, habitat conversion, and the clearing of riparian zones, resulting in the loss of cover, increased rates of siltation, and thermal shifts. These are all factors that can be deleterious to Eastern Pondmussel survival in areas under development.

Host fish availability: Any factors that directly or indirectly affect host fish abundances and distributions may impact Eastern Pondmussel distributions. Unionids cannot complete their life cycle without access to the appropriate glochidial host. If host fish populations disappear or decline in abundance to levels below that which can sustain a mussel population, recruitment will no longer occur and the mussel species may become functionally extinct (functionally extinct in this case is defined as a population that is no longer viable, as a crucial part of their life cycle

[7] Note that Eastern Pondmussel is not present in the Thames or Sydenham rivers.

[in this case the host fish] has been removed) (Bogan 1993). Currently, lab experiments suggest that Yellow Perch is the preferred host for the Eastern Pondmussel (followed by Brook Stickleback, Largemouth Bass, and Pumpkinseed). Once functional host relationships have been confirmed in the field, follow-up studies on the host fish populations would then need to be completed to determine if access to glochidial hosts is a limiting factor for this mussel species in Ontario. Introduction of invasive species that may cause a decline in the host fish may indirectly affect Eastern Pondmussel populations. For example, the introduction of the Round Goby has been shown to have negative effects on certain species of fish (for example, Dubs and Corkum 1996); however, whether or not the Round Goby affects host fish of the Eastern Pondmussel is unknown.

Human intrusions and disturbance (recreational activities): Recreational activities that may impact mussel beds include (Bouvier and Morris 2011):

- driving all-terrain vehicles (ATVs) through river beds
- propellers on recreational boats and personal watercraft, propeller channels have been noted through the mussel beds in the St. Clair River delta
- paddling action disturbance (kayaks, etc.) of the mussel bed

Metcalfe-Smith et al. (2000) observed that paddlers in shallow water often disturbed the riverbed, creating the potential for dislodging mussels and promoting downstream transport. Increasing popularity of recreational activities, such as canoeing, may further increase stresses on unstable populations. Mehlhop and Vaughn (1994) found that “recreational activities” were contributing to the decline in many species of native freshwater mussels. Eastern Pondmussel detected in Long Point Bay (that is, Turkey Point Marsh and Cedar Creek Marsh) were found in boat access routes to duck blinds, raising the possibility of mortality via propellers that come in contact with the sediment during low-water periods (Gilbert and Oldenburg 2013).

Climate change: Impacts of climate change on remaining populations of Eastern Pondmussel and other unionids in the Great Lakes are likely to be severe. For example, higher water temperatures can lead to increased respiration and greater metabolic activity and, therefore, may be physiologically stressful to mussels (Huebner 1981); lead to reduced dissolved oxygen levels (Huebner 1981); and, can adversely affect or reduce the survival of larval glochidia (Pandolfo et al. 2010). Fluctuations in stream thermal regimes have also been documented to affect the production of gametes (Galbraith and Vaughn 2009), and to limit reproductive output (Heinricher and Layzer 1999). The potential impact of climate variability and change on the Great Lakes ecosystem is a topic of considerable research effort at present. Although a clear warming trend is indicated, the climate models are variable. Likely responses of the Great Lakes to climate variability and change are discussed in an Environment and Climate Change Canada report on threats to water availability in Canada (Environment Canada 2004). According to one model, net basin supply (precipitation plus runoff minus evaporation) to the lower lakes shows large decreases, with Lake St. Clair showing a dramatic decrease. Other simulations show decreases or even slight increases, but there is general agreement that climate warming will cause lake levels to drop. Impacts of lower lake levels on remnant unionid communities clinging to survival in the shallow (≤ 1.5 m) “flats” area of the St. Clair River delta are likely to be significant. If the flats dry up, these communities would either be lost entirely or the mussels would move out of the flats and into deeper water where they would encounter high densities of dreissenid mussels and suffer high mortality rates (COSEWIC 2007). A decrease in Lake Erie water levels would have a large, negative impact on Eastern Pondmussel populations (J. Gilbert OMNRF, pers. comm.). Similar impacts would be expected for populations within coastal wetlands of Lake Ontario if water levels declined significantly. As the effects of climate change on Eastern Pondmussel are highly speculative, it is difficult to determine the impact this will have on the populations and, as such, it was not included in the threats table.

Harvesting: Harvesting mussels for human consumption could be a potential concern; however, to date, there are no reports of the harvest of Eastern Pondmussel for human consumption (Bouvier and Morris 2011). Poaching[8] of unionid mussels is suspected but unknown in its intensity or occurrence and, as such, it was not included in the threats table.

6 Management objective

The management objectives establish, to the extent possible, the number of individuals and/or populations, and their geographic distribution, that is necessary to prevent Eastern Pondmussel from becoming endangered or threatened. The management objectives for Eastern Pondmussel are to:

- protect self-sustaining populations to prevent decline
- restore degraded populations to healthy self-sustaining levels by improving the extent and quality of habitat (where feasible)

7 Broad strategies and conservation measures

7.1 Actions already completed or currently underway

Many of the recovery measures prescribed for implementation in the original proposed recovery strategy and action plan (DFO 2016) are ongoing. Actions that are underway include surveys (for estimating abundance as well as presence), host fish identification experiments, and genetic studies. Surveys for unionids, including Eastern Pondmussel, in Lake St. Clair have been underway since 1997 (COSEWIC 2017); information on the recently discovered populations is limited. Investigations testing the efficacy of surveying methods for unionids in different environments have been completed (Reid et al. 2014; Minke-Martin et al. 2015; Reid 2016; Reid and Morris 2017). Eastern Pondmussel was included in a study investigating the evolution of active host-attraction strategies in freshwater mussels. Zanatta and Murphy (2006) found that the Eastern Pondmussel was more closely related to members of *Potamilus* and *Leptodea* genera than that of *Ligumia*. They therefore concluded that the Eastern Pondmussel should be reclassified into an existing or newly described genus. Further genetic investigations targeting Eastern Pondmussel have been completed (Scott et al. 2014; Scott et al. 2016; Scott et al. 2020). Eastern Pondmussel was included in a population modelling study on 4 unionid species, representing an initial attempt at the identification of recovery targets and timeframes for recovery (Young and Koops 2011). Furthermore, multi-species action plans for Rouge National Urban Park and Point Pelee National Park, which describe measures to aid in the in the conservation of Eastern Pondmussel, have been developed.

Recovery teams are currently engaged in the implementation of conservation measures within watersheds that will benefit Eastern Pondmussel. Several recovery documents at the species and ecosystem level overlap with the distribution of Eastern Pondmussel, including:

[8] Indigenous harvesting is not considered poaching.

- Recovery Strategy for the Northern Riffleshell (*Epioblasma rangiana*), Snuffbox (*Epioblasma triquetra*), Round Pigtoe (*Pleurobema sintoxia*), Salamander Mussel (*Simpsonaias ambigua*) and Rayed Bean (*Villosa fabalis*) in Canada (DFO 2019)
- Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) in Canada (DFO 2013)
- Management Plan for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada (DFO 2018a)
- Recovery Strategy and Action Plan for the Mapleleaf (*Quadrula quadrula*) in Canada (Great Lakes-Western St. Lawrence population) (DFO 2018b)
- Recovery Strategy and Action Plan for the Rainbow (*Villosa iris*) in Canada (DFO 2018c)
- Walpole Island Ecosystem Recovery Strategy: the Walpole Island Ecosystem Recovery Strategy Team was established in 2001 to develop an ecosystem-based recovery strategy for the area containing the St. Clair River delta, with the goal of outlining steps to maintain or rehabilitate the ecosystem and species at risk (Walpole Island Heritage Centre [WHIC] 2002). Although the strategy is initially focusing on terrestrial ecosystems (Bowles 2005), there are future plans to include aquatic components of the ecosystem
- Multi-species Action Plan for Point Pelee National Park of Canada and Niagara National Historic Sites of Canada (Parks Canada [PC] 2016a)
- Multi-species Action Plan for Thousand Islands National Park of Canada (PC 2016b)

Conservation authorities (for example, Lower Thames, Long Point, Toronto and Region, Central Lake Ontario, Quinte, and Cataraqui) continue to play a vital role in stewardship and public education programs, which have resulted in increased awareness of species at risk and improvements to habitat and water quality throughout the range of Eastern Pondmussel.

7.2 Broad strategies

Four broad strategies were identified to address threats to the species and meet the management objectives: 1) research; 2) management and coordination; 3) stewardship and outreach; and, 4) inventory and monitoring. Approaches are identified for each of the broad strategies. These approaches or activities are further divided into numbered conservation measures with priority ranking (high, medium and low), identification of the threats addressed, and associated timelines (tables 4 to 6). A more detailed narrative for conservation measures is included after the tables (section 7.4).

Implementation of these measures will be accomplished in coordination with relevant ecosystem-based recovery teams and other organizations. Of the broad strategies, higher priority will generally be given to the research and monitoring measures, as the data produced will be used to inform the other 2 strategies (that is, management and coordination, and stewardship and outreach).

7.3 Conservation measures

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

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

Table 4 identifies the measures for the conservation of the species to be undertaken by DFO to manage the conservation of Eastern Pondmussel. Table 5 identifies the measures for the conservation of the species to be undertaken collaboratively between DFO and its partners, other agencies, organizations or individuals. Implementation of these measures will be dependent on a collaborative approach, in which DFO is a partner in conservation efforts, but cannot implement the measures for the conservation of the species alone. As all Canadians are invited to join in supporting and implementing this management plan, table 6 identifies the remaining measures for the conservation of the species that represent responsibilities and/or opportunities for other jurisdictions, organizations or individuals to lead for the conservation of the species. If your organization is interested in participating in one of these measures, please contact the Species at Risk Ontario and Prairie Region office. Federal funding programs for species at risk that may provide opportunities to obtain funding to carry out some of the outlined activities include the Habitat Stewardship Program for Species at Risk, Aboriginal Fund for Species at Risk Program, and the Canada Nature Fund for Aquatic Species at Risk.

While DFO has already commenced efforts to implement the plan, the measures for the conservation of the species included in this management plan that have not yet been implemented by the Department will be subject to the availability of funding and other required resources. As indicated in the tables below, partnerships with specific organizations will provide expertise and capacity to carry out some of the listed measures. However, the identification of partners is intended to be suggestions to other jurisdictions and organizations and carrying out these actions will be subject to each group's priorities and budgetary constraints.

Table 4. Measures to be undertaken by Fisheries and Oceans Canada for the Eastern Pondmussel.

#	Measure for the conservation of the species	Broad strategy	Priority[9]	Threats or objective addressed	Status/ timeline[10]
1	**Habitat requirements:** Determine habitat requirements of all life stages of the Eastern Pondmussel.	Research	High	All	3 to 5 years
2	**Threat evaluation:** Evaluate threats to habitat for all extant populations to guide local stewardship programs to improve conditions within occupied habitats.	Research	High	All threats	1 to 2 years
3	**Feasibility of repatriation:** Determine if existing populations should be augmented or repatriated into historical habitat.	Research	High	Invasive species, host fish	3 to 5 years
4	**Population augmentation:** Develop and implement genetically sound propagation guidelines for freshwater mussels.	Research	High	Invasive species, host fish	2 to 3 years
5	**Host fish populations:** Determine distribution and abundance of the identified host species, once confirmed in the field.	Research	Low	Host fish	3 to 5 years
6	**Coordination of activities:** Promote and enhance expertise in freshwater mussel identification, biology, ecology, and conservation.	Management and coordination	Medium	All threats	Ongoing

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

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

[10] Timeline reflects the amount of time required for the measure to be completed from the time the management plan is published as final on the Species at Risk Public Registry.

#	Measure for the conservation of the species	Broad strategy	Priority[9]	Threats or objective addressed	Status/ timeline[10]
7	**Awareness:** Hold mussel identification workshops that incorporate identification, biology, ecology, threats, and conservation of freshwater mussel species in Ontario.	Stewardship and outreach	High	All threats	Ongoing
8	**Awareness:** Encourage public support and participation in mussel conservation by developing awareness materials and programs. This will encourage participation in local stewardship programs to improve and protect habitat for Eastern Pondmussel.	Stewardship and outreach	Medium	All threats	Ongoing

Table 5. Measures to be undertaken collaboratively between Fisheries and Oceans Canada and its partners for the Eastern Pondmussel.

#	Measure for the conservation of the species	Broad strategies	Priority[11]	Threats or objective addressed	Status/ timeline	Potential partnerships
9	**Inventory:** Conduct further surveys within the historical distribution of Eastern Pondmussel to detect new populations (focus on historical records and un-sampled coastal wetlands); determine extent and abundance of any new populations detected.	Inventory and monitoring	High	All threats	Underway/ 1 to 2 years	Provincial government, conservation authorities, academia
10	**Inventory:** Conduct intensive surveys to quantify distribution and abundance of extant populations, with emphasis on newly discovered populations.	Inventory and monitoring	High	All threats	Underway/ 1 to 2 years	Provincial government, conservation authorities, academia
11	**Population assessment:** Establish routine quantitative surveys to monitor changes in the distribution and abundance of extant Eastern Pondmussel populations and invasive species in the area.	Inventory and monitoring	High	Invasive species	3 to 5 years	Provincial government, conservation authorities, academia
12	**Population assessment:** Establish stations to monitor changes to Eastern Pondmussel habitat. This monitoring will complement and be integrated into the routine population surveys.	Inventory and monitoring	High	All habitat threats	3 to 5 years	Provincial government, conservation authorities, academia

[11] "Priority" reflects the degree to which the action contributes directly to the conservation of the species or is an essential precursor to an action that contributes to the conservation of the species:
- "High" priority measures are considered likely to have an immediate and/or direct influence on the conservation of the species
- "Medium" priority measures are important but considered to have an indirect or less immediate influence on the conservation of the species
- "Low" priority measures are considered important contributions to the knowledge base about the species and mitigation of threats

#	Measure for the conservation of the species	Broad strategies	Priority[11]	Threats or objective addressed	Status/ timeline	Potential partnerships
13	**Population assessment:** Develop a mussel monitoring standard specific to lake and wetland habitats to be used in routine surveys to track changes in mussel populations.	Inventory and monitoring	High	All threats	1 to 2 years	Provincial government, conservation authorities, academia
14	**Threat evaluation:** Monitor the distribution and abundance of dreissenids within currently occupied habitats. Quantify infestation rates for live mussels that are present and determine upstream limit of dreissenids within tributaries of the lower Great Lakes occupied by Eastern Pondmussel.	Research	High	Invasive species	3 to 5 years	Provincial government, conservation authorities
15	**Coordination of activities:** Develop an implementation plan to respond to the direct threat of dreissenids on vulnerable Eastern Pondmussel populations in Lake St. Clair, Lake Erie, and Lake Ontario.	Management and coordination	High	All threats	3 to 5 years	Indigenous groups, conservation authorities, Parks Canada (PC)
16	**Coordination of activities:** Work with municipal planning authorities (including Indigenous groups) so that they consider the protection of habitat for Eastern Pondmussel within official plans.	Management and coordination	High	All threats	3 to 7 years	Provincial government, PC, Indigenous groups, municipalities

#	Measure for the conservation of the species	Broad strategies	Priority[11]	Threats or objective addressed	Status/ timeline	Potential partnerships
17	**Coordination of activities:** Investigate the integration of Eastern Pondmussel conservation into existing watershed plans (particularly for areas subject to urban expansion within the Greater Toronto Area; for example, Rouge River Watershed Plan). Threat evaluation research will inform priorities for individual populations at the watershed scale.	Management and coordination	Medium	All threats	3 to 5 years	Conservation authorities, PC
18	**Awareness:** Increase public awareness of the potential impacts of transporting/releasing invasive species (including baitfish).	Stewardship and outreach	High	Invasive species, host fish	3 to 7 years	Ontario Ministry of Natural Resources and Forestry, angling associations, PC
19	**Awareness:** Once the host relationship has been confirmed in the field, increase awareness within the angling community about the importance of the Yellow Perch (and other hosts as they are identified) as a host for the Eastern Pondmussel.	Stewardship and outreach	Low	Host fish	3 to 5 years	Conservation authorities, angling associations, PC

Table 6. Measures that represent opportunities for other jurisdictions, organizations or individuals to lead for the Eastern Pondmussel.

#	Measure for the conservation of the species	Broad strategies	Priority[12]	Threats or objective addressed	Suggested jurisdictions or organizations
20	**Host fish:** Identify/confirm functional host fish species for the Eastern Pondmussel in the field.	Research	Medium	Host fish	Academia
21	**Threat evaluation:** Determine sensitivity of Eastern Pondmussel glochidia, juveniles, and adults to relevant environmental contaminants.	Research	Medium	Contaminants and toxic substances	Academia, Environment and Climate Change Canada
22	**Coordination of activities:** Implement stewardship programs to improve habitat conditions and reduce threats. Priorities and mitigation approaches will be informed through threat evaluation research.	Management and coordination	High	All threats	Conservation authorities, environmental non-governmental organizations

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

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

7.4 Narrative to support implementation schedule

Research

Habitat requirements (measure 1): One of the key gaps in understanding the habitat requirements for this species relates to early life, including spawning and fertilization, encysted glochidia, and the juvenile life stage. Research to better understand the differences in habitat for these life stages will help further refine the identification of important habitat, thus, allowing for targeted stewardship efforts.

Threat evaluation (measures 2, 14, and 21): Some initial research has been completed on selected contaminants for early life stages of freshwater mussels, including chloride, ammonia, and copper. However, further work is required that is specific to the Eastern Pondmussel.

Although some preliminary work has been done to evaluate threats for some populations (refer to section 4), little is known regarding threats to other populations (for example, recently discovered populations found along the Lake Ontario shoreline and some small inland lakes). More comprehensive threat evaluations for all extant populations will help inform stewardship programs to ensure the most efficient and effective use of limited resources while promoting an ecosystem approach when warranted.

Feasibility of repatriation/population augmentation (measures 3 and 4): Additional surveys may show that without direct intervention, some populations are unlikely to persist. One intervention may be to augment existing populations with individuals from a nearby stable population or by stocking with artificially reared juveniles. Research into the feasibility of augmentation for Canadian populations of Eastern Pondmussel has begun with the establishment of laboratory rearing procedures but could also include the identification of genetically suitable stocks for source populations.

Host fish populations (measure 5 and 20): To determine if the Eastern Pondmussel is host-limited, it is necessary to confirm the functional host fish(es) in the field and to confirm that the distributions of the mussel and its host(s) overlap in time and space in a manner that will permit successful encystment. Because adult mussels are essentially sessile, verification can be accomplished by confirming that members of the host species occur in areas with mature female mussels at times when the female mussels possess mature glochidia. The identification of high host specificity in some mussel species requires that hosts be identified for local populations wherever possible. Once the host fish(es) present in Canadian waters have been identified, it is necessary to determine the distribution, abundance, and health of the host species. Other considerations related to the suitability and probability of a successful host fish encounter include the host fish being of appropriate age, health, and immunity to be susceptible to infestation and act as a candidate host fish. A more complete understanding of host fish relationships can also aid in determining potential Eastern Pondmussel habitat based on distribution of host fish species.

Management and coordination

Coordination of activities (measures 6, 15, 16, 17, 22): Expertise in freshwater mussel identification, distribution, life history, and genetics is limited to a small number of biologists in Ontario. This capacity could be increased by training personnel (within government, Indigenous groups, and non-governmental organizations with a conservation focus) and encouraging graduate and post-graduate research directed towards the conservation of freshwater mussels.

Such efforts would enhance partnering opportunities to implement recovery measures for freshwater mussels.

Many of the threats affecting Eastern Pondmussel populations are similar to those impacting other aquatic species. Therefore, efforts to remediate these threats should be done in close connection with other recovery teams and relevant groups (for example, conservation authorities) to allow pooling of resources and to eliminate duplication of efforts. Once threats have been evaluated for extant populations, the results will inform local stewardship programs for threat mitigation. As with other unionids, measures to improve habitat for the Eastern Pondmussel may include stewardship actions involving Best Management Practices (BMPs) for agricultural properties and residential properties.

If new populations of invasive species (dreissenids or fish species that may affect the host fish) are detected via routine monitoring practices, a coordinated plan should ensure a quick response. Dreissenid mussels in the St. Clair River delta and Long Point Bay cannot be eliminated; however, their presence in the delta can be monitored to determine if their numbers are increasing or decreasing. It is unlikely that dreissenid mussels will affect the Eastern Pondmussel population in Lyn Creek as there are only 2 standing waterbodies in the system (wetland surrounded ponds) with no boat access (BMNHC 2006). However, invasive fishes may impact the host fish relationship if they become established.

Stewardship and outreach

Awareness (measures 7, 8, 18, 19): Based on current research, the most likely preferred and functional host of the Eastern Pondmussel is the Yellow Perch (this species produced a significantly higher number of juvenile mussels than did Brook Stickleback and Pumpkinseed in laboratory studies). Outreach activities should be directed at promoting non-destructive sport fisheries at locations and times when Yellow Perch may be infested with Eastern Pondmussel glochidia (March to July); commercial and recreational fisheries are known to be sustainably managed by the OMNRF and are currently not known to impede conservation of the Eastern Pondmussel. Other outreach activities that benefit Eastern Pondmussel include the privately run BMNHC mussel identification course held in eastern Ontario where several populations occur.

Increasing freshwater mussel knowledge and identification can be assisted through the development of awareness material, such as the Photo Field Guide to the Freshwater Mussels of Ontario (Metcalfe-Smith et al. 2005) and the application called Clam Counter, available for free download from the Apple App Store and the Google Play Store. In addition, an annual, hands-on mussel identification workshop is offered by DFO to government, agency, non-governmental organizations, Indigenous Peoples, and the public. Increased public knowledge and understanding of the importance of Eastern Pondmussel, and mussels in general, will play a key role in the conservation of this species.

Inventory and monitoring

Inventory (measures 9 and 10): Further surveys are required to confirm the current distribution and abundance of Eastern Pondmussel in Canada. All known extant populations require further sampling effort, as most are represented by only one or a few sample locations without density information. Similarly, additional sampling effort is required to detect new populations in areas with the greatest potential for harbouring undetected individuals (for example, coastal wetland habitats of lakes Erie, Ontario, or St. Clair, with low dreissenid densities). Sampling methods to determine density and demographic information need to be quantitative and could be informed by the work of Metcalfe-Smith et al. (2007). A thorough understanding of all extant populations is necessary to inform effective conservation actions.

Population assessment (measures 11 to 13): A network of monitoring stations should be established throughout the current range of Eastern Pondmussel, similar to that developed for freshwater mussels within the riverine systems (Metcalfe-Smith et al. 2007; Sheldon et al. 2020). Mussel monitoring methods need to be developed that are specific to lake and wetland habitats where Eastern Pondmussel is found (current methods focus on riverine habitats). The results of the monitoring program will allow for assessment of the progress made towards achieving the management objectives. Monitoring sites should be established in a manner so as to permit:

- quantitative tracking of changes in mussel abundance and demographics (for example, size, age, sex), or those of their hosts
- detailed analysis of habitat use and the ability to track changes in the use or availability
- the ability to detect invasive species: monitoring stations should be set up in areas where there is a likely source location for establishment of dreissenids (for example, reservoirs) to permit early detection of the invasive species. Monitoring of invasive species in the St. Clair River delta, Cedar Creek (LPNWA), and elsewhere will be conducted in close association with the refuge sites

8 Measuring progress

The performance indicators presented below provide a way to define and measure progress toward achieving the management objective:

1. Knowledge of Eastern Pondmussel biology and population characteristics have improved to facilitate management of the species by 2032
2. Comprehensive evaluations for threats, particularly for new populations, have been conducted and actions have been taken to mitigate these threats by 2027
3. Measures have been taken to promote awareness and stewardship actions to conserve the Eastern Pondmussel and its habitat by 2027
4. Measures have been taken to promote continued awareness of and compliance with existing regulations to maintain quality and quantity of Eastern Pondmussel habitat by 2027

Detailed reporting on implementation of this management plan under section 72 of SARA will be done by assessing progress towards implementing the broad strategies and conservation measures. Progress towards the implementation of this management plan will be reported on 5 years after the publication of this management plan on the Species at Risk Public Registry, and every subsequent 5 years.

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Appendix A: Effects on the environment and other species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making.

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

This management plan will benefit the environment by promoting the conservation of the Eastern Pondmussel. In particular, it will encourage the protection and improvement of coastal wetland habitats in the lower Great Lakes. These limited wetland habitats support species at risk from many other taxa (including birds, reptiles, fishes, and plants) and thus the implementation of conservation measures for Eastern Pondmussel will contribute to the preservation of biodiversity in general. The potential for these conservation actions to inadvertently lead to adverse effects on other species was considered. The SEA concluded that the implementation of this document will clearly benefit the environment and will not entail any significant environmental effects.

Appendix B: Record of cooperation and consultation

Management plans are to be prepared in cooperation and consultation with other jurisdictions, organizations, affected parties and others as outlined in SARA section 66. Fisheries and Oceans Canada has utilized a process of reviews by recovery teams to seek input from species experts for the development of this management plan. Information on participation is included below.

Recovery team members

The following members of the Ontario Freshwater Mussel Recovery Team were involved in the development of the management plan for the Eastern Pondmussel:

Member/Attendee	Affiliation
Dr. Josef Ackerman	University of Guelph
Crystal Allan	Grand River Conservation Authority
Muriel Andreae	St. Clair Region Conservation Authority
Dave Balint	Fisheries and Oceans Canada
Amy Boyko	Fisheries and Oceans Canada
Dr. Alan Dextrase	Ontario Ministry of Natural Resources and Forestry
Scott Gibson	Ontario Ministry of Natural Resources and Forestry
Dr. Patricia Gillis	Environment and Climate Change Canada
Clint Jacobs	Walpole Island First Nation
Kari Jean	Ausable Bayfield Conservation Authority
Dr. Gerry Mackie	University of Guelph
Daryl McGoldrick	Environment and Climate Change Canada
Kelly McNichols-O’Rourke	Fisheries and Oceans Canada
Dr. Todd Morris (Co-chair)	Fisheries and Oceans Canada
Dr. Scott Reid	Ontario Ministry Natural Resources and Forestry
Dr. Frederick Schueler	Bishop Mills Natural History Centre
Dr. Astrid Schwalb	University of Waterloo
John Schwindt	Upper Thames River Conservation Authority
Shawn Staton (co-chair)	Fisheries and Oceans Canada
Valerie Towsley	Lower Thames Valley Conservation Authority
Mari Veliz	Ausable Bayfield Conservation Authority
Dr. Daelyn Woolnough	Central Michigan University
Dr. Dave Zanatta	Central Michigan University

In addition, consultation on the draft management plan occurred through letter sent to potentially impacted Indigenous groups. Additional stakeholder, Indigenous, and public input was sought through the publication of the proposed document on the Species at Risk Public Registry for a 60-day public comment period. Comments received informed the final document.