COSEWIC
Assessment and Status Report

on the

Eastern Pondmussel
Ligumia nasuta

in Canada

SPECIAL CONCERN
2017

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

COSEWIC 2007. COSEWIC assessment and status report on the Eastern Pondmussel *Ligumia nasuta* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 34 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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COSEWIC
Assessment Summary

Assessment Summary – April 2017

Common name
Eastern Pondmussel

Scientific name
Ligumia nasuta

Status
Special Concern

Reason 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.

Occurrence
Ontario

Status history
Designated Endangered in April 2007. Status re-examined and designated Special Concern in April 2017.

COSEWIC
Executive Summary

Eastern Pondmussel
Ligumia nasuta

Wildlife Species Description and Significance

Eastern Pondmussel, *Ligumia nasuta*, is a medium-sized freshwater mussel with an average length of 74 mm. It has a compressed, elongate shell with a distinctive, bluntly pointed posterior end. The outside of the shell varies in colour from yellowish- or greenish-black in juveniles to dark brown or black in adults. Narrow green rays, concentrated at the posterior end of the shell, are often visible in juveniles and light-coloured adults. The nacre (interior lining of shell) is usually silvery-white or bluish-white in specimens from the Great Lakes basin. The species was a large component of the Great Lakes mussel fauna historically and contributed significantly to the function of freshwater mussel communities in the Great Lakes ecosystem.

Distribution

Eastern Pondmussel is restricted to eastern North America, from the lower Great Lakes east through New York to New Hampshire and south, in coastal rivers, to South Carolina. In Canada, the species is only known to be from the Great Lakes region of Ontario. Eastern Pondmussel is found in most waterbodies it occupied historically, including lakes St. Clair, Erie and Ontario, their connecting channels, and Lyn Creek. Moreover, the species has been discovered in localities that were not surveyed (and not represented) in the last assessment period, particularly inland lakes in eastern Ontario. Comparing historical to current occurrences, an 18 - 87% loss in range is estimated.

Habitat

Based on habitat data from collection sites, Eastern Pondmussel prefers sediment composed of clay, silt/organics and/or sand/gravel where macrophytes are absent or at low densities. The species occurs in sheltered areas of lakes or in slack-water areas of rivers at depths ranging from 0.3 to 4.5 m.

Biology

Eastern Pondmussel has separate sexes, but males and females differ slightly in shell shape and are often difficult to tell apart. The glochidia (larvae) of Eastern Pondmussel are obligate parasites of fishes. The species is a long-term brooder that spawns in late summer, broods its glochidia over the winter and releases them in the spring. Hosts in Canada likely include Brook Stickleback, Largemouth Bass, Pumpkinseed and Yellow Perch, but this needs to be verified in the field. Adult mussels feed on bacteria, algae and other organic particles that are filtered from the water column. Juveniles live completely buried in the substrate and feed on similar food items obtained directly from the substrate or interstitial water.

Population Sizes and Trends

Eastern Pondmussel was one of the most common species of freshwater mussel in the lower Great Lakes, prior to the invasion of dreissenids in the late 1980s. It appears to have been eliminated from the offshore waters of Lake St. Clair and Lake Erie in Canada due to the impacts of dreissenids. A remnant subpopulation of Eastern Pondmussel, with an estimated size of 270,000 – 1,200,000 individuals, currently occupies the nearshore areas of the St. Clair River delta. Extant subpopulations (of unknown sizes) exist in the coastal wetlands of lakes Erie and Ontario, several eastern Ontario inland lakes, as well as Lyn Creek, a tributary of the upper St. Lawrence River.

Threats and Limiting Factors

Invasive species and aquatic pollution constitute the most significant threats to Eastern Pondmussel in Canada. More than 90% of historical records for the species are from areas now infested with invasive Zebra and Quagga dreissenid mussels. Infestation rates continue at levels deemed harmful to freshwater mussels and Eastern Pondmussel seems to be particularly susceptible. Two localities, Fishing Lake and White/Ingelsby Lake have no evidence of dreissenids. The majority of sites occupied by Eastern Pondmussel are near urban areas, the effluent from which contains known toxins to mussels including road salt (chloride), wastewater (ammonia, heavy metals and personal care products), as well as agricultural (phosphorus, nitrogen and suspended solids) and industrial effluents (arsenic, copper and mercury). Potential limiting factors include hosts and predation (Muskrat and Raccoon).

Protection, Status and Ranks

Eastern Pondmussel was assessed as Endangered by COSEWIC in 2007 and subsequently listed as Endangered under the federal *Species at Risk Act* (SARA) in 2013 and Ontario’s *Endangered Species Act* (ESA) in 2009.. Eastern Pondmussel is ranked critically imperiled (N1) in Canada and extremely rare (S1) in Ontario, and is apparently secure globally (G4) and in the U.S. (N4). There are four states where the mussel species is listed as Endangered or Threatened.

TECHNICAL SUMMARY

Ligumia nasuta

Eastern Pondmussel

Ligumie pointue

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

Demographic Information

Generation time (usually average age of parents in the population)	6-9 yrs (inferred from other short-lived lampsilines)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	43,522 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	164 km² (discrete 2 x 2 grid) 268 km² (continuous 2 x 2 grid)
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Not applicable. >10 which exceeds thresholds

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Is there an [observed, inferred, or projected] decline in extent of occurrence?	There is an observed decline of 18% from the historical EOO, but this decline has abated since the previous assessment
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	There is an observed decline from historical IAO of 63-87% (discrete and continuous grids, respectively, but this decline has abated since the previous assessment)
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Not applicable
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Observed historical decline and a projected continuing decline in quality of habitat.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"?	Not applicable
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Detroit River	Unknown
St. Clair River Delta	270,000 – 1,200,000
Lake Erie	Unknown
Sydenham River	0
Grand River	0
Coyle Creek (Welland River)	Unknown
Niagara River	Unknown
Lake Ontario	Unknown
Mill (Milne) Dam Pond (Rouge River)	0
White/Ingelsby Lake	Unknown
Beaver Lake	Unknown
Loughborough Lake	Unknown
Fishing Lake	Unknown
Whitefish Lake	0
Lyn and Golden Creeks	Unknown
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown

Threats (direct, from highest impact to least, as per IUCN Threats Calculator, Appendix I))

Was a threats calculator completed for this species? Yes

i. Invasive species (Dreissenid mussels)
ii. Ecosystem modifications (*Phragmites*) and pollution (household sewage and urban wastewater, industrial and military effluents, agricultural and forestry effluents)

What additional limiting factors are relevant? Predation (Raccoons)

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Michigan SNR Ohio S1 Pennsylvania S1 New York S2S3
Is immigration known or possible?	Possible for St. Clair River delta subpopulation. Unknown, for all others.
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Likely
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source population deteriorating?[+]	Unknown, but likely
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Possible for St. Clair River delta subpopulation. Unknown, but possible for all others.

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC:
Designated Endangered in April 2007. Status re-examined and designated Special Concern in April 2017.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** not applicable

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Reasons for designation:
This medium to large freshwater mussel is widely distributed across southern Ontario, where it occurs in isolated wetland patches 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 subpopulation 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.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):
Does not meet criteria. The number of mature individuals is unknown for most of the subpopulations. It is also unknown if there is a continuing decline.

Criterion B (Small Distribution Range and Decline or Fluctuation):
Does not meet criteria. While the IAO is calculated as 268 km^2, which is below the threshold for Endangered (<500 km^2: B2), the species is found at more than 10 locations and is not severely fragmented. The species does not undergo extreme fluctuations.

Criterion C (Small and Declining Number of Mature Individuals):
Does not meet criteria. The number of mature individuals is unknown but at a minimum is 270,000 in the St. Clair River Delta alone, which is over the threshold.

Criterion D (Very Small or Restricted Population):
D1 is not applicable as the number of mature individuals is at least greater than 270,000 which exceeds thresholds.

Does not meet criteria. Index of area of occupancy is 268 km^2 (continuous) and number of locations is above the threshold. The IAO is above the thresholds (< 20 km^2 IAO), and therefore does not meet Threatened D2 criteria.

Criterion E (Quantitative Analysis):
Not applicable. Analyses have not been done.

Special Concern

(a) the wildlife species has declined to a level of abundance at which its persistence is increasingly threatened by genetic, demographic or environmental stochasticity, but the decline is not sufficient to qualify the wildlife species as Threatened:

Yes, the species has declined due to the invasion of Zebra and Quagga mussels (however, this is beyond the 10 year 3 generation criteria that can be used). The remaining subpopulations appear to be small, therefore their persistence could be threatened by genetic, demographic or environmental stochasticity

(b) the wildlife species may become Threatened if factors suspected of negatively influencing the persistence of the wildlife species are neither reversed nor managed with demonstrable effectiveness:

Yes, if the factors that negatively influence this species are not managed effectively, this species may become threatened. Although the impact of dreissenids is now outside the 3 generation window, this threat may limit the recovery of the species. Low impact threats from Pollution (9) and Natural System Modifications (7), if not effectively managed, may negatively affect the species resulting in it becoming Threatened.

(c) the wildlife species is near to qualifying, under any criterion, for Threatened status

This species has a small IAO and meets criteria of B2bi, ii, iii

(d) the wildlife species qualifies for Threatened status but there is clear indication of rescue effect from extra-limital subpopulations:

No – does not apply.

PREFACE

Since Eastern Pondmussel was assessed as Endangered by COSEWIC in 2007, an extensive amount of targeted survey work has been undertaken in the Great Lakes and eastern Ontario. In particular, the species was newly found throughout the coastal wetlands of Lake Erie and Lake Ontario, in addition to several eastern Ontario inland lakes (Beaver, White/Ingelsby, Loughborough and Fishing lakes) that were not represented in the previous assessment. These new data significantly increase estimates of the current area of occupancy and number of locations. Increase in abundance has been noted for the St. Clair River delta subpopulation and abundance estimates have been updated. The decline from historical distributions (both EOO and IAO) and abundances associated with invasions by Zebra and Quagga mussels appear to have abated.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2017)

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

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

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

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

Environment and Climate Change Canada / Environnement et Changement climatique Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

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Eastern Pondmussel
Ligumia nasuta

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2017

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Ligumia nasuta* (Say, 1817)

English common name: Eastern Pondmussel

French common name: Ligumie pointue

The recognized authorities for the classification of aquatic molluscs in the United States and Canada are Turgeon *et al*. (1998), Graf and Cummings (2007), and the Integrated Taxonomic Information System (2015). The current accepted classification of this species is as follows:

Phylum: Mollusca
Class: Bivalvia
Subclass: Paleoheterodonta
Order: Unionoida
Superfamily: Unionoidea
Family: Unionidae
Subfamily: Ambleminae
Tribe: Lampsilini
Genus: *Ligumia*
Species: *nasuta*

Zanatta and Murphy (2006) used mitochondrial DNA sequence data (COI, 16S and ND1) to create a molecular phylogeny for several species of unionids (freshwater mussels belonging to the Family Unionidae). They clearly show that the genus *Ligumia* is not monophytic and that *L. nasuta* should be redesignated into an existing or newly described genus. Recent work by Kuehnl (2009) will lead to taxonomic revisions of the Lampsilini.

Morphological Description

The following description of Eastern Pondmussel was adapted from Clarke (1981), Strayer and Jirka (1997), Nedeau *et al*. (2000) and Bogan (2002). Eastern Pondmussel is a medium-sized to large mussel with a long-elliptical, laterally compressed shell that is thin but strong (Figure 1). The posterior ridge is well developed, distinct, and angled near the beak, but becomes rounded posteriorly. The anterior end is rounded; the ventral margin is broadly curved, and the posterior end is rounded and drawn out into a blunt point near the midline of the shell. Females can be distinguished from males by a swelling along the posterior ventral margin. In both males and females, beaks are low, barely raised above the hinge line and located in the anterior quarter of the shell. Beak sculpture consists of 5-8 fine double-looped bars. Lateral and pseudocardinal teeth are well-developed and sharp, but delicate. The surface of the shell (periostracum) is rough with concentric wrinkles and clearly visible lines of growth. The colour of the periostracum varies from yellowish- or greenish-black in juveniles to dark brown or black in adults. Narrow green rays, concentrated posteriorly, are often visible in juveniles and light-coloured adults. The nacre is usually silvery-white or bluish-white in specimens from the Great Lakes basin, and pinkish or purple in specimens from the Atlantic drainage. Glochidia (larvae) are subelliptical in shape with an undulate hinge line and measure approximately 142 µm in length and 273 µm in height (Tremblay *et al.* 2015).

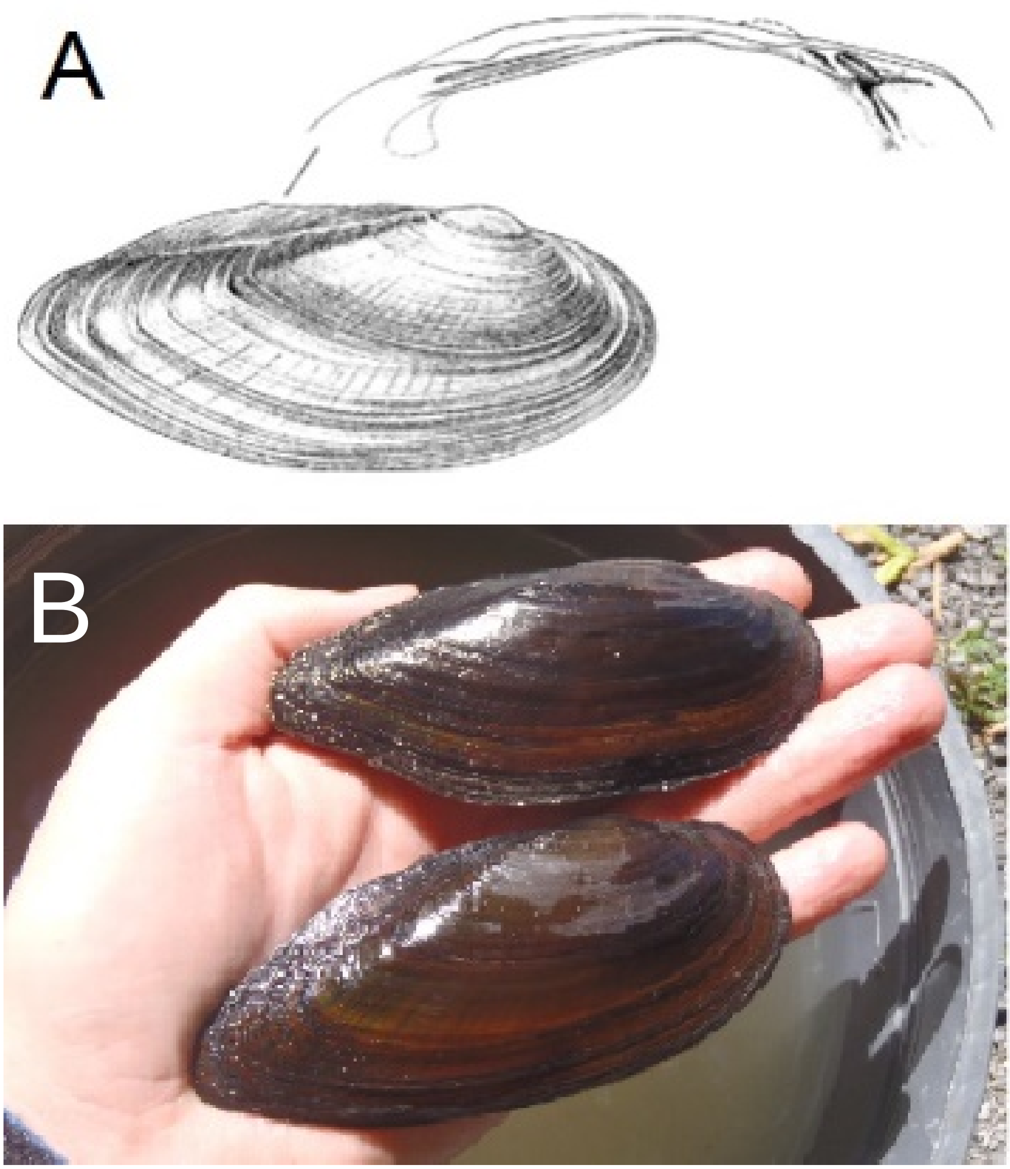

Figure 1. (A) Line drawing of the external features of the shell and internal structure of the left valve of Eastern Pondmussel. Reproduced with permission from Burch (1975). (B) Live adult male (top) and female (bottom; credit: S. Hogg, MNRF).

Eastern Pondmussel reaches a maximum length of approximately 126 mm in Canada. The average length of an adult shell is 74 mm based on over 250 live specimens measured by the writers and their associates between 1997 and 2016. Eastern Pondmussel can be distinguished from all other species of freshwater mussel in Canada by its elongate shell with distinctive, bluntly pointed posterior end, rough periostracum and delicate hinge teeth.

Population Spatial Structure and Variability

A recent genetic study (Scott *et al.* 2014) based on mitochondrial DNA (mtDNA regions CO1 and ND1) revealed Great Lakes Eastern Pondmussel subpopulations have relatively low genetic diversity. Haplotype differentiation (Φ_{ST}) among pairs of Great Lake subpopulations was not significantly different. However, Great Lakes subpopulations were significantly different from Atlantic Coast subpopulations. Distribution and subpopulation data indicate that current subpopulations are small and spatially segregated from each other. As well, any migration between subpopulations is limited/dependent on the movements by infested host fish. The species is unique among unionids in that it did not establish from the Mississippi River basin, but through a small founder group from the Atlantic coast river system. Although Eastern Pondmussel is an Atlantic slope species, it does not appear to have followed an east to west migration route. Stansbery (1961) proposed that the species entered the Great Lakes via an eastward-flowing outlet of Lake Erie meltwater that would have provided access to host fishes from the Mohawk or Hudson Rivers to the east. Glacial geology has established the existence of this Mohawk-Hudson or Susquehanna Outlet (Hough 1950 cited in Stansbery 1961). The Great Lakes population is genetically distinct from Atlantic Coast population therefore translocation efforts would introduce non-native haplotypes (Scott *et al.* 2014).

Designatable Units

All Canadian subpopulations are found within the Great Lakes-Upper St. Lawrence National Freshwater Biogeographic Zone (NFBZ) of the NFBZ classification system adopted by COSEWIC and constitute a single designatable unit (DU) in Canada.

Special Significance

Freshwater mussels are sensitive indicators of the health of freshwater ecosystems, including water and habitat quality, as well as the fish community that they depend on for successful reproduction. Eastern Pondmussel was historically a significant component of the Great Lakes mussel fauna, being the fourth most common species in the lower Great Lakes and connecting channels prior to 1990 (Lower Great Lakes Unionid Database).

DISTRIBUTION

Global Range

Eastern Pondmussel is endemic to eastern North America, having been recorded from 15 states (Michigan, Ohio, Pennsylvania, New York, New Hampshire, Massachusetts, Connecticut, New Jersey, Delaware, Maryland, District of Columbia, Virginia, Rhode Island, North Carolina and South Carolina) and the Province of Ontario (Figure 2; NatureServe 2015). NatureServe (2015) also lists the species as occurring in Vermont, but this is believed to be erroneous (Nedeau pers. comm. 2005).

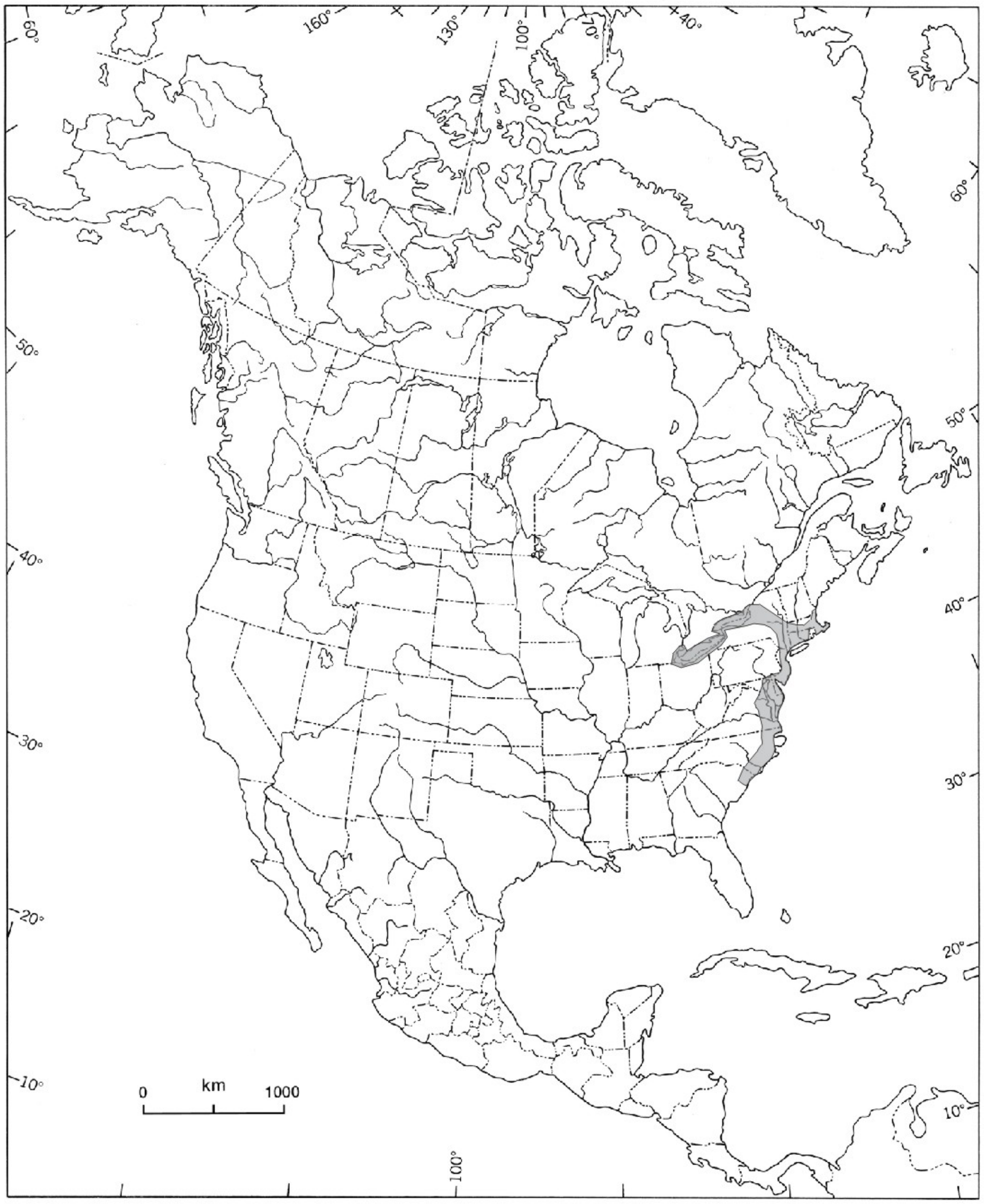

Figure 2. North American distribution (shaded area) of Eastern Pondmussel based on records from the Lower Great Lakes Unionid Database and data obtained from NatureServe (2015) and jurisdictional authorities. North America is the only continent with Eastern Pondmussel.

The current distribution of Eastern Pondmussel is similar to its historical distribution, but the species is declining, particularly in the Great Lakes (NatureServe 2015). *Dreissena polymorpha* (Zebra Mussel) caused widespread and major losses in abundance and occurrence of the species, but small subpopulations of uncertain viability persist across its Canadian distribution. Small, isolated subpopulations of native mussels are still found in some nearshore areas where densities of dreissenids remain low; such localities are termed "refuge sites." There are four known refuge sites for unionids in U.S. waters along the south shore of Lake Erie. Eastern Pondmussel was not among the species found alive in the western basin refuge in 1993 (Schloesser *et al*. 1997), in Metzger Marsh in 1996 (Nichols and Amberg 1999), or in Crane Creek Marsh in 2001 (Bowers and de Szalay 2004); however, it was one of the most abundant of nine species occupying the Thomson Bay refuge near Erie, PA in 2000 (Masteller pers. comm. 2002). Unionids, including Eastern Pondmussel, have been found beyond these refuges along the coast of Lake Erie (Crail *et al.* 2011).

Canadian Range

In Canada, Eastern Pondmussel is endemic to the lower Great Lakes region of southern Ontario. The Fisheries and Oceans Canada (DFO) Lower Great Lakes Unionid Database was used to identify occurrence records for Eastern Pondmussel (see **COLLECTIONS EXAMINED**).

The earliest records of this species in Canada were collected in the 1890s by J. Macoun, who found specimens in the Detroit River near Windsor and in Lake Erie near Rondeau Provincial Park. Figure 3 shows the historical distribution of the Eastern Pondmussel in Ontario based on 255 records collected between 1860 and 2006. Only about 20% of these records are for known live occurrences; the rest are for shells that, in many cases, could have washed up on the shore from deeper water. In addition to historical sites, the following section describes new occurrences including inland lakes in eastern Ontario: Fishing, Loughborough and White/Ingelsby lakes; and new sites along the Lake Ontario nearshore (the lower Trent River, Rouge River Marsh, Carruthers Creek, Lynde Creek Marsh, Presqu'ile Bay (shells only), Weller's Bay and Pleasant Bay Marsh) within the previously known distribution of Eastern Pondmussel (Figure 3). Sampling effort can be found in Table 1 and a map of current records (including shell condition) can be found in Figure 4.

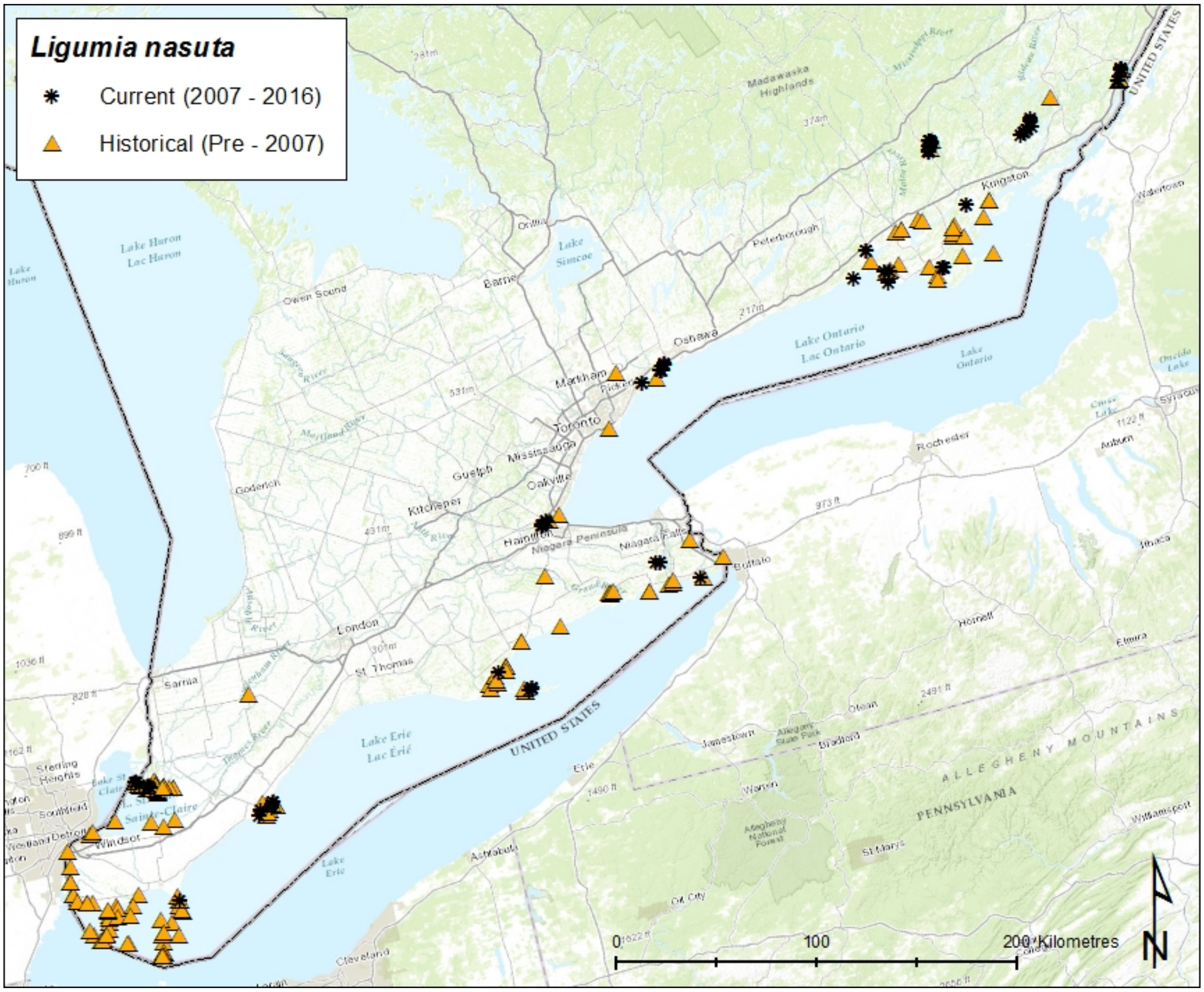

Figure 3. Historical (1894-2006) and current distribution (2007-2015) of Eastern Pondmussel in Canadian water (based on records from the Lower Great Lakes Unionid Database). Historical distributions are based on 255 records where 20% are known live occurrences; the rest are for shells that, in many cases, could have washed up on the shore from deeper water.

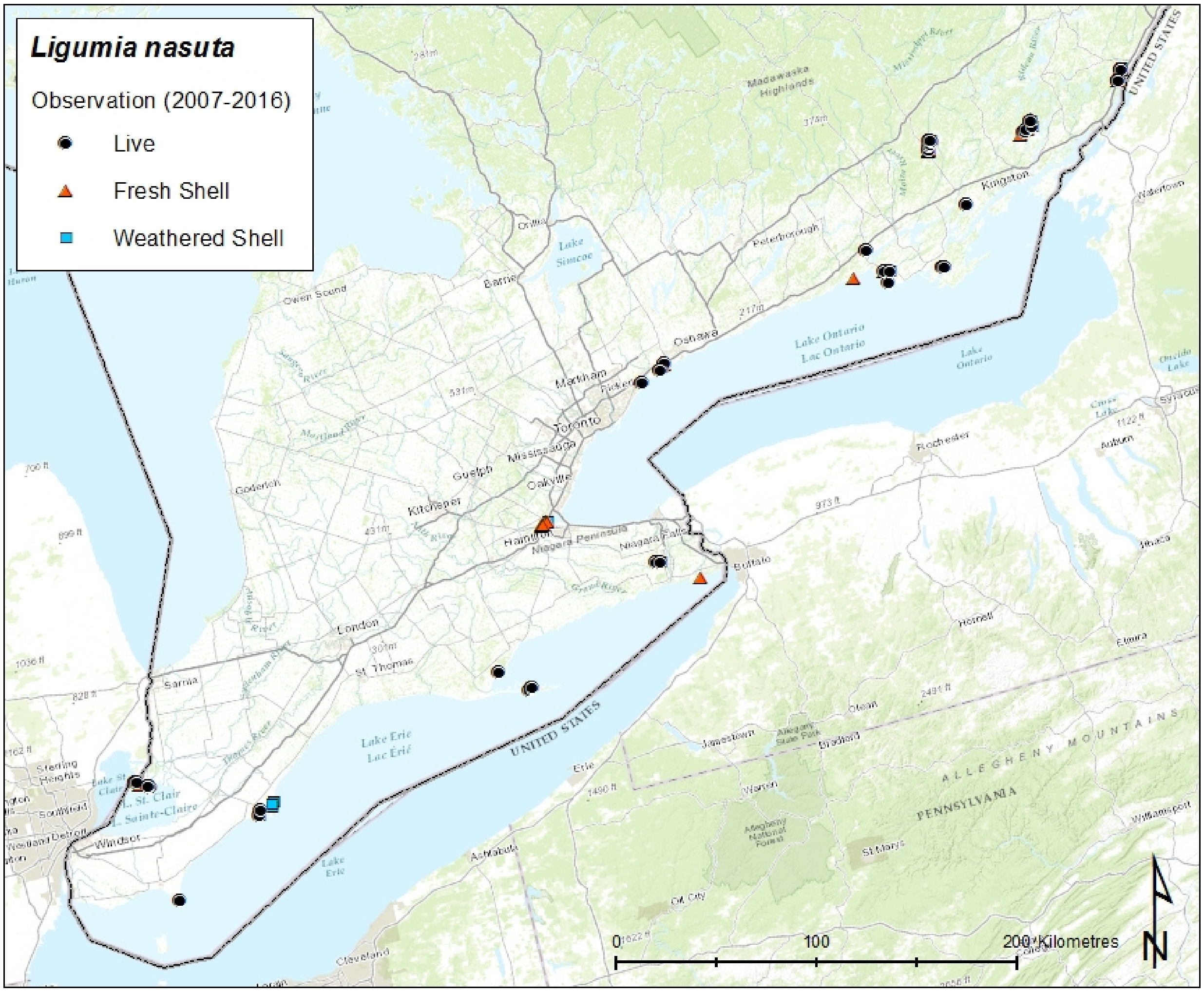

Figure 4 Current distribution of Eastern Pondmussel in Canadian water with condition of specimen indicated (live, fresh shell or weathered shell).

Table 1. Summary of current (2007 onwards) unionid sampling effort within the Canadian range of Eastern Pondmussel (EPM). PH refers to the number of person-hours searched and numbers in superscript signify the sites where only shells were found.

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort (per site)	Notes	Source
Beaver Lake	$0/1^{1}$	2012	Shoreline search		Schueler unpubl. data
	$9/12^{1}$	2015	2 PH clam rake and visual/tactile	Targeted EPM surveys	Reid unpub. data
Fishing Lake	$2/7^{5}$	2015	Shoreline search	Targeted EPM surveys	McRae and Schueler unpubl. Data
Grand River	0/11	2007	Visual and shoreline searches	Targeted Rainbow surveys	Timmerman unpubl. data

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort (per site)	Notes	Source
	0/2	2007	Hand searching and excavation		Mackie unpubl. data
	0/4	2007	48-65 x 1 m^2 quadrats	All sites included in Metcalfe-Smith *et al.* 2000b	Morris unpubl. data
	0/11	2008	Visual and shoreline searches	Targeted surveys for Rainbow	Timmerman unpubl. data
	0/7	2008	Unknown		Zanatta unpubl. data
	0/1	2008	825 x 1 m^2 quadrats	Grand River relocation project (Region of Waterloo and Stantec)	Mackie 2008a
	0/5	2009	Visual and shoreline searches	Targeted surveys for Rainbow	Timmerman unpubl. data
	0/1	2009	1525 x 1 m^2 quadrats	Grand River relocation project (Bot Construction)	Mackie 2009
	0/4	2010	Visual and shoreline searches	Targeted surveys for Rainbow	Timmerman unpubl. data
	0/1	2010	3.8 PH timed search		Morris unpubl. data
	0/2	2010	78 and 93 x 1 m^2 quadrats	Grand River relocation project (Region of Waterloo and Ecoplans)	Mackie 2010
	0/4	2011	6 PH timed search/half-hectare method		Morris unpubl. data
	0/6	2011	4.5 – 6 PH timed search	Resurveys	Morris unpubl. data
	0/1	2011	10 PH timed search		Gillis unpubl. data
	0/1	2011	435 x 1 m^2 quadrats	Grand River relocation project (Natural Resource Solutions)	Mackie 2011
	0/15	2012	Visual and shoreline searches	Targeted Rainbow surveys	Timmerman unpubl. data
	0/1	2012	Timed search 3 PH	Resurvey	Morris unpubl. data
	0/2	2012	8 PH timed search		Gillis unpubl. data
	0/1	2012	3640 x 1 m^2 quadrats	Grand River relocation project (Natural Resource Solutions)	Mackie 2012
	0/1	2012	289 x 1 m^2 quadrats	Grand River relocation project (Ministry of Transportation and Dufferin Construction)	Mackie *et al.* 2012
	0/1	2013	Visual search	Informal survey before potential relocation project	Mackie pers. comm. 2014
	0/2	2013	2.25 and 8 PH timed search	Resurvey	Ackerman unpubl. data
	0/1	2013	5 PH timed search	Resurvey	Morris unpubl. data
	0/1	2014	30 PH timed search	Resurvey	Morris unpubl. data
	0/2	2015	17.5 PH timed search	Resurvey	Morris unpubl. data
Lake Erie	0/3	2007	Unknown	Long Point	Gilbert unpubl. data
	1/2	2008	6 PH timed search	Cedar Creek Marsh (live EPM) and Crown Marsh	Gilbert and Oldenburg 2013

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort (per site)	Notes	Source
	0/1	2009	28 PH timed search	Cedar Creek Marsh Targeted EPM survey	Gilbert and Oldenburg 2013
	1/1	2009	3 PH	Turkey Point	Gilbert and Oldenburg 2013
	0/1[1]	2013	Shoreline search	Bay Beach	Schueler unpubl. data
	1/1	2013	4.5 PH timed search	McGeachy Pond	Morris unpubl. data
	0/12[6]	2014	4.5 PH visual/tactile search with viewers	Rondeau Bay Targeted Rainbow survey	Reid and Morris unpubl. data
	1/21[2]	2015	4.5 PH visual/tactile search with viewers	Rondeau Bay (live and shells), Gravelly Bay, Nickel Beach, Lynn River, Port Dover Beach, Selkirk Provincial Park Beach and Wetland (15 sites Rondeau Bay, 1 site each for the rest). Targeted EPM survey	Reid unpubl.data
	0/1	2015	Incidental Search	Lake Henry, Pelee Island	Ontario Parks unpubl. data
	0/1	2016	20 x 50 x 50 m blocks tactile search	Lake Henry, Pelee Island	Ontario Parks unpubl. data
	1/10	2016	4.5 PH tactile and clam rake	Lake Pond (live EPM and shells; 5 sites surveyed), East Cranberry Pond (1 site), Sanctuary Pond (3 sites) and West Cranberry Pond (1 site) in Point Pelee National Park	Reid and Morris unpubl. data
Lake Ontario	0/4[4]	2007	Shoreline search	Blackbird Marsh, Hopkin's Bay, Carroll's Bay	Royal Botanical Gardens unpubl. data
	0/1[1]	2008	Shoreline search	Carrol's Bay	Royal Botanical Gardens unpubl. data
	0/1[1]	2009	Shoreline search	Sunfish Pond	Royal Botanical Gardens unpubl. data
	0/1[1]	2010	Shoreline search	Spencer Creek	Royal Botanical Gardens unpubl. data
	8/72[6]	2011	2 PH visual/tactile and clam rake	Targeted SAR surveys in coastal wetlands. Live EPM found in Lynde Creek and Marsh, and Hay Bay/Wilton Creek. Shells found in Presqu'ile Bay. None in Duffin's Creek Marsh, Port Britain Marsh, Oshawa Second Marsh.	Reid unpubl.data
	0/3	2011	3.5 PH scoops – half-hectare method	Sunfish Pond, Grindstone Creek, Carrolls Bay	Morris unpubl. data

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort (per site)	Notes	Source
	12/206[3]	2012	2 PH visual/tactile and clam rake	Targeted SAR surveys in coastal wetlands. Live EPM found in Rouge River Marsh, Carruthers Creek, Pleasant Bay Marsh and East Lake Marsh. Shells found in Presqu'ile Bay. None in Humber River Marsh, Huyck's Bay, Jordan Station, Big Island Marsh, Big Sand Bay, Bowmanville Marsh, McLaughlin Bay, Parrott Bay, Sawguin Creek Marsh, West Lake Marsh, Wilmot Creek and West Side Marsh. 12 sites per wetland. Live EPM at Lynde Creek resurvey (2 sites, approx. 20 PH total)	Reid unpubl.data
	3/180[3]	2013	2 PH clam rake and visual/tactile or 4.5 PH timed search (Trent River Tributaries)	Targeted SAR surveys in coastal wetlands and Trent River tributaries. Live EPM found in Consecon Lake and the Lower Trent River. None found in Bell Creek Complex, Belleville Marsh, Cootes Paradise, Great Cataraqui Marsh, Hills Island, Johnson Bay, Jones Creek, Landon's Bay, Lower Napanee River, Presqu'ile Bay, Sixteen and Seventeen Mile Creek, Thompson Bay or Trent River tributaries. 12 sites per wetland/locality.	Reid unpubl.data
	0/10	2013	2 – 3 PH quadrat survey	Targeted EPM surveys in the Rouge River	Whibbs (Toronto Zoo) unpubl. data
	0/2	2014	1 and 10 PH timed search with scoops	Jordan Harbour	T.J. Morris unpubl. data
	0/9	2014	2 – 3 PH quadrat survey	Targeted EPM surveys in the Rouge River	Whibbs (Toronto Zoo) unpubl. data
	2/89[1]	2015	2 PH clam rake and visual/tactile	Targeted SAR surveys in coastal wetlands and Trent River. EPM shell found in Weller's Bay. None in Black River, Dead Creek, Martindale Pond, Milne Pond, Trent River and Wesleyville Wetland. Live EPM in East Lake Marsh resurvey (10 PH at 1 site) and Rouge River resurvey (9 PH at 1 site)	Reid unpubl.data
	0/21	2015	1 – 7.5 PH timed search	Includes Sixteen Mile Creek Pond and Wetland, Four Mile Creek and Pond, Fifteen Mile Creek and Pond, and Martindale Pond.	Wright *et al.* in Prep (b)
	0/10[1]	2015	4.5 – 5 PH timed search	EPM & Mapleleaf survey in Cootes Paradise.	Wright *et al.* in Prep (b)
Loughborough Lake	0/1[1]	2009	Shoreline search		Schueler unpubl. data

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort (per site)	Notes	Source
	5/12	2015	2 PH clam rake and visual/tactile	Targeted EPM surveys	Reid unpubl. data
Lyn and Golden creeks	1/1	2007	Shoreline survey	Targeted EPM surveys at the Lyn Creek and Golden Creek confluence.	Schueler unpubl. data
	1/1	2008	Unknown	Targeted EPM survey	McNichols-O'Rourke and Ackerman unpubl. data
	4/4	2008	Shoreline survey	Targeted EPM surveys	Schueler unpubl. data
	0/1[1]	2009	Shoreline survey	Targeted EPM survey	Schueler unpubl. data
	1/1	2009	4.5 PH timed search	Targeted EPM survey	Morris unpubl. data
	1/1	2011	13 PH timed search	Targeted EPM survey	Ackerman unpubl. data
	1/1	2012	12.5 PH timed search	Targeted EPM survey	Ackerman unpubl. data
	1/1	2013	7.5 PH timed search	Targeted EPM survey	Ackerman unpubl. data
	0/3[3]	2013	Shoreline survey	Targeted EPM surveys at Golden Creek	Schueler unpub. data
	2/2	2014	7.5 – 10 PH timed search	Targeted EPM re-surveys	Ackerman unpubl. data
Mill (Milne) Dam Pond, Rouge River	0/1	2015	4.5 PH timed search	Targeted EPM survey	Reid unpubl. data
St. Clair River delta	5/9[1]	2011	5 – 101 x 65 m^2 circular plots snorkelling (stake and rope survey), or 2 – 3 PH timed search	Resurveys of Metcalfe-Smith *et al.* 2004 sites	Morris unpubl. data
Sydenham River	0/4	2007	~ 20 PH timed search with excavation	Targeted surveys for SAR females, all sites previously surveyed in 1999 - 2003	McNichols-O'Rourke pers. comm. 2014
	0/2	2007	Excavation	Mussel identification course; all sites previously surveyed in 1999-2003	Morris unpubl. data
	0/4	2008	~ 41 PH timed search with excavation	Targeted surveys for SAR females, all sites previously surveyed in 1999 - 2003	McNichols-O'Rourke pers. comm. 2014
	0/2	2008	Excavation	Mussel identification course; all sites previously surveyed in 1999-2003	Morris unpubl. data
	0/1	2008	167 x 1 m^2 quadrats	Sydenham River relocation project (Wallaceburg Community Task Force and Chatham-Kent Economic Development Services)	Mackie 2008b
	0/at least 11	2008 - 2009	Unknown		Zanatta unpubl. data
	0/3	2009	~ 35 PH timed search with excavation	Targeted surveys for SAR females, all sites previously surveyed in 1999 - 2003	McNichols-O'Rourke pers. comm. 2014
	0/2	2009	Excavation	Mussel identification course; all sites previously surveyed in 1999-2003	Morris unpubl. data

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort (per site)	Notes	Source
	0/3	2010	~ 39 PH timed search with excavation	Targeted surveys for SAR females, all sites previously surveyed in 1999 - 2003	McNichols-O'Rourke pers. comm. 2014
	0/2	2010	Excavation	Mussel identification course; all sites previously surveyed in 1999-2003	Morris unpubl. data
	0/2	2011	~ 61 PH timed search with excavation	Targeted surveys for SAR females, all sites previously surveyed in 1999 - 2003	McNichols-O'Rourke pers. comm. 2014
	0/2	2011 - 2015	Excavation	Mussel identification course; all sites previously surveyed in 1999-2003	Morris unpubl. data
	0/1	2011	4.5 PH timed search		Morris unpubl. data
	0/13	2012 - 2015	69 – 75 x 1 m^2 quadrats	All sites previously surveyed in 1999 -2003. One site was a full excavation where 375 m^2 quadrats were completed	Morris unpubl. data
	0/2	2013	60 and 60.5 PH timed search	Targeted surveys for SAR, all sites previously surveyed in 1999 - 2003	Ackerman unpubl. data
	0/1	2015	14 PH timed search	Targeted search for grad student project	Ackerman unpubl. data
	0/1	2015	2 PH timed search	Targeted search for grad student project	Morris unpubl. data
Welland River	0/8	2008	4.5 PH timed search	Includes Lyon and Oswego creeks	Morris unpubl data
	0/1	2014	14.5 PH visual search and scoops	Targeted Mapleleaf surveys	Morris unpubl data
	2/13	2015	1.5 – 9 PH timed search	Welland River and Coyle Creek (live EPM)	Wright *et al*. in Prep (a)
White/Ingelsby Lake	0/1[1]	2012	Shoreline search		Schueler unpubl. data
	0/1[1]	2013	Shoreline search	White/Ingelsby lakes resurvey	Schueler unpubl. data
	2/12	2015	2 PH clam rake and visual/tactile	Targeted EPM surveys	Reid unpubl. data
Whitefish Lake	0/12	2015	2 PH clam rake and visual/tactile	Targeted EPM surveys	Reid unpubl. data

Detroit River

Eastern Pondmussel has been known to exist in the Detroit River for nearly a century, based on an 1890 record of fresh shells. The United States Geological Survey (USGS) completed surveys in 1982, confirming low numbers of live individuals (≤ 4) at three Canadian sites and at numerous U.S. sites. During resurveys 10 years later, no live Eastern Pondmussel were collected from the Canadian side (Schloesser *et al.* 1998). USGS surveys in 1998 indicate that the species had likely been eliminated from the U.S. side as well (Schloesser *et al.* 2006). Central Michigan University surveyed the river again in 2012, and recorded one live Eastern Pondmussel on the U.S. side. However, it was located at the mouth of the Huron River, which is in the most southern portion of the Detroit River at Lake

Erie (Zanatta *et al*. 2015). No live individuals were collected from four U.S. sites surveyed further upstream.

Lake St. Clair Watershed

Eastern Pondmussel appeared to have been eliminated from the offshore waters of Lake St. Clair after the dreissenid invasion (1986-1990; Nalepa *et al.* 1996; Zanatta *et al.* 2002). Recent surveys of St. Clair River delta in 2011 confirmed the continued presence of Eastern Pondmussel in nearshore habitats. DFO collected 33 live individuals in total from five sites. The species was found at Bass Bay (Squirrel Island), Chematogan Bay, and in and around Pocket Bay (Basset Island). The species is still found in the same areas that they occupied in the early 2000s, although not all areas have been resurveyed.

Sydenham River: there is only one record of Eastern Pondmussel near Alvinston in 1992. The specimen is of an unknown condition. Considering the Sydenham River is one of the most thoroughly searched rivers in southern Ontario (over 300 person-hours (PH) in timed searches), it is likely that the species was never widespread.

Lake Erie Watershed

There are over 100 records of Eastern Pondmussel scattered throughout Lake Erie. Historically, live individuals were observed at Middle Sister Island, East Sister Island and western Lake Erie, whereas fresh shells were observed at Colchester, Pelee Island, Point Pelee, Rondeau Bay, Long Point Bay, and Port Dover. Additionally, areas with records lacking sampling particulars include Turkey Point, Long Beach, Nanticoke, Port Colbourne and Crystal Beach. The following sites have been surveyed within the last 10 years; some surveys were successful at locating live individuals and before this, the last collection of a live Eastern Pondmussel in Lake Erie was in 1968.

Grand River: historical records indicate that fresh shells were found in Mackenzie Creek (a tributary to the lower reach of the river). Four other occurrences are grouped along the main channel about 6.5 km north of the mouth of the river (near Bing and Dunnville). Since 2006, extensive timed searches (upwards of 100 PH) and quadrat surveys (7145 m^2 total excavated) have been completed in the Grand River; from the river mouth upstream to its northern tributaries (e.g., Conestogo, Mallet and Nith rivers). No live Eastern Pondmussel or fresh shells have been collected as a result of these surveys.

Lake Pond (Point Pelee National Park): records of Eastern Pondmussel at Point Pelee date back to 1936 (condition unknown). Multiple fresh shells were collected from Point Pelee National Park in the 1960s. In July of 2016, MNRF (Ontario Ministry of Natural Resources and Forestry) and DFO surveyed four ponds within the National Park and reported the first live Eastern Pondmussel at Lake Pond. Attempts were made to resurvey the 1960s sites that had fresh shells, but upon inspection, they were too deep for surveying.

Lake Henry (Pelee Island): the earliest record of Eastern Pondmussel on Pelee Island was from 1937 in Mosquito Bay (condition unknown). Fresh shells were inventoried from South Bay, Fish Point, and the north and south beaches of Pelee Island in the 1960s. No live or remnant evidence of Eastern Pondmussel was found during formal surveys of Lake Henry on Pelee Island in 2016 or informal surveys in 2015 by Ontario Parks.

McGeachy Pond: DFO discovered four live Eastern Pondmussel (and a weathered shell) in McGeachy Pond in 2013. McGeachy Pond is adjacent to Lake Erie and Rondeau Bay. There is a small break wall separating the pond from the lake.

Rondeau Bay: in 2014 and 2015, MNRF conducted targeted surveys for Rainbow (*Villosa iris*) and Eastern Pondmussel in Rondeau Bay. In 2014, 28 weathered Eastern Pondmussel shells were collected and in 2015, one live individual was collected near Blenheim. Records of Eastern Pondmussel in Rondeau Bay date back as far as 1894, but the 2015 survey yielded the only confirmed live specimen.

Cedar Creek Marsh (Long Point): in 2008, 34 live individuals were collected by MNRF; however, a survey in 2009 recorded no Eastern Pondmussel. Although there are no historical records for Cedar Creek Marsh, there are eight records for Long Point, including one for fresh shells.

Turkey Point: there are four historical records of Eastern Pondmussel from Turkey point; however, the first live individuals (n = 4) were collected from marshes in 2009.

Port Dover: no shells or live individuals were collected during MNRF surveys of the mouth of the Lynn River and Port Dover beach in 2015.

Nanticoke: Selkirk Provincial Park beach and wetland habitats were searched for Eastern Pondmussel in 2015 by MNRF. No shells or live individuals were found.

Port Colbourne: surveys by MNRF in 2015 revealed no evidence of live unionids in Gravelly Bay or Nickel Beach. These two locations were sampled due to their close proximity to historically occupied sites.

Bay Beach: F. Schueler (Bishops Mills Natural History Centre) found a fresh shell at Bay Beach in 2013 while conducting a shoreline search. Bay Beach is adjacent to Crystal Beach, which has one historical Eastern Pondmussel record from 1934 (of unknown condition).

Niagara River Watershed

Coyle Creek (Welland River): surveys conducted by DFO in 2015 confirmed live Eastern Pondmussel in Coyle Creek, a tributary of the Welland River (Wright *et al.* In Prep. a). Six live individuals (plus a weathered shell) were collected from two of three sites searched. The only other evidence of Eastern Pondmussel was a 1988 record of fresh shells from the Welland River main channel, near Niagara Falls. Surveys of Lyon and

Oswego creeks and the Welland River main channel by DFO in 2008 did not detect Eastern Pondmussel (Morris *et al.* 2008).

One record from 1983 demonstrates that Eastern Pondmussel once resided in the Canadian waters of the Niagara River: one live animal was found in the Black Rock Canal near Squaw Island. Ten years later, surveys for the New York Power Authority confirmed that no live Eastern Pondmussel were present in proximity to this area (Riveredge Associates 2005). In 2011, Zanatta *et al.* (2015) found two live specimens on the eastern side of Grand Isle (outlet of Spicer Creek) and in 2015 Riveredge Environmental, Inc (2015) found one live adult at Strawberry Island on the U.S. side.

<u>Lake Ontario Watershed</u>

Twenty-nine historical records indicate that Eastern Pondmussel was widely distributed along the nearshore of Lake Ontario, from Hamilton Harbour to the Bay of Quinte. The first confirmed live animals in Canadian waters were collected in 1996 (East Lake and Consecon Lake). Since then, there have been 31 records of the species representing upwards of 90 live individuals. Twelve individuals have been found in the eastern, U.S. side of the lake (Salmon River mouth, North Pond and Black River Bay) and account for <1% of the 11 species found (Zanatta pers. comm. 2016). The following paragraphs describe the most recent Eastern Pondmussel collections from Lake Ontario (2007 – present). These records are the result of a substantial amount of search effort undertaken at coastal wetlands and river mouths. Twenty-two of the Lake Ontario coastal wetlands surveyed had no live individuals or shells collected.

Mill (Milne) Dam Pond: there is one historical record (circa 1860) of 15 fresh Eastern Pondmussel shells from the Mill Dam in the City of Markham, Ontario, which is located in the upper part of the Rouge River watershed. In 2015, MNRF surveys at Milne Dam Conservation Park (near the location at which fresh shells were observed historically) did not collect any live Eastern Pondmussel or shells.

Hamilton Harbour: Eastern Pondmussel is known from four areas in the western end of Cootes Paradise. It was first collected as fresh shells from Hopkin's Bay (1 whole), Blackbird Marsh (1 whole) and Carroll's Bay (3 valves) in 2007, and later a sixth shell (whole) was discovered at Spencer Creek in 2010. In 2015, the status report writers surveyed ten sites along the southern and northern shoreline of Cootes Paradise and the outlet of Spencer Creek. Only a single fresh shell was collected from Bull's Point. Separate surveys by Royal Botanical Garden (RBG) staff and MNRF in 2013 found only several weathered shells. Targeted sampling has turned up no live animals and very little shell material.

Rouge River Marsh: in 2012, MNRF collected the first live Eastern Pondmussel from the Rouge River Marsh just upstream of the river's outlet into Lake Ontario. A second visit in 2015 yielded four live individuals from one site. The Toronto Zoo completed quadrat surveys throughout the Rouge River proper at 10 sites in 2013 and 9 sites in 2014, but with no further evidence of this species.

Carruthers Creek: seven live Eastern Pondmussel were collected at the mouth of Carruthers Creek in the City of Ajax in 2012 by MNRF. In 2015, surveys of the same area yielded no live individuals.

Lynde Creek Marsh: at the mouth of Lynde Creek, between the cities of Ajax and Whitby, 23 live Eastern Pondmussel and one fresh shell were collected by MNRF in 2011. A resurvey in 2012 produced 10 live individuals.

Presqu'ile Bay: MNRF conducted multiple surveys in 2011 and 2012 throughout Presqu'ile Bay and found 16 weathered shells. One of the sites along the southern shore of the bay had 11 fresh shells.

Weller's Bay: in 2015, one weathered Eastern Pondmussel shell was collected from Weller's Bay at Barrier Beach.

Pleasant Bay Marsh: one live Eastern Pondmussel was collected during surveys by MNRF in 2012.

Consecon Lake: nine records of Eastern Pondmussel for Consecon Lake exist. The first is a fresh shell collected in 1949. There is a second record, but the collection date and condition of the individual is unknown. Fourteen live individuals were collected by Environment and Climate Change Canada (ECCC) in 1996, but nine years later only two fresh shells were discovered in the vicinity of that site. In 2013, six live individuals, one fresh shell and 42 weathered shells were collected by MNRF as a result of surveys throughout the lake.

East Lake: there are two historical records of Eastern Pondmussel for East Lake. One from 1962 of unknown condition and the other reporting two live individuals in the lake's outlet in 1996. In 2012, MNRF surveys confirmed the continued presence of Eastern Pondmussel when eight live individuals were collected. Ten live individuals were also collected by MNRF in 2015.

Bay of Quinte: there are 16 historical records of Eastern Pondmussel in the Bay of Quinte (and two more on the outskirts); however, only five of these report the condition of the animals, none of which were live. In 2011, the MNRF surveyed the bay and found one live individual near Hay Bay and Wilton Creek.

Lower Trent River: in 2013, one live Eastern Pondmussel was collected by MNRF in the City of Trenton (~2 km upstream of the Trent River confluence with the Bay of Quinte). Extensive surveys of the Trent River (main channel or tributaries) by MNRF in 2013 and 2015 (over 50 sites) did not result in the collection of live Eastern Pondmussel or shells.

<u>Eastern Ontario Inland Lakes</u>

White/Ingelsby Lake: the presence of Eastern Pondmussel in White/Ingelsby Lake was discovered during shoreline searches by F. Schueler in 2012 and 2013. Four fresh and four weathered shells were collected. In 2015, MNRF collected 26 live individuals and numerous fresh and weathered shells.

Beaver Lake: the presence of Eastern Pondmussel in Beaver Lake was discovered by F. Schueler in 1998. Fresh shells were collected during a shoreline search at the south end in 2012. In 2015, 24 live Eastern Pondmussel were collected by MNRF along the shoreline of Beaver Lake. Of the 12 sites searched, 10 showed evidence of the species.

Loughborough Lake: in 2009, Eastern Pondmussel was detected from Loughborough Lake. F. Schueler collected a fresh shell during a shoreline search. MNRF surveys in 2015 produced 19 live individuals across five of the 12 sites surveyed.

Fishing Lake: in 2015, F. Schueler and Nancy and Rob McRae (Fishing Lake Association) collected two live individuals and 10 fresh and eight weathered shells from Fishing Lake. This is the first record for Fishing Lake.

Whitefish Lake: a weathered Eastern Pondmussel shell was collected by F. Schueler from the shores of Whitefish Lake in 1995. In 2015, MNRF surveyed the lake but no live individuals or shells were collected.

Upper St. Lawrence River

Lyn and Golden Creeks: in the previous status assessment, Eastern Pondmussel was known from Lyn and Golden creeks, as well as their confluence. Numerous live animals (over 40) and shells (11) had been collected during shoreline searches in 2005 - 2006 by F. Schueler. The distribution, however, was unknown. Additional shoreline searches (by F. Schueler) and eight timed searches at four sites (by DFO and the University of Guelph) revealed the subpopulation exists along at least an 8.7 km reach of Lyn Creek between Lyn and Yonge Mills and a 0.3 km reach of Golden Creek upstream of the confluence. Although it is not uncommon to find records of more than 10 live specimens per survey event, one site seemed to be especially productive as 7.5-10 PH of searching yielded between 22-51 live Eastern Pondmussel. A total of 168 live individuals were found over the current timeframe (2007-2016). Lyn Creek represents the easternmost occurrence of Eastern Pondmussel in Canada.

Extent of Occurrence and Area of Occupancy

Using the minimum convex polygon technique, the current extent of occurrence (EOO) is approximately 43,522 km^2 (2007-2015) as compared to 52,771 km^2 historically (1894-2006). Therefore, the species has been lost from nearly 18% of its range in Canada. The previous assessment (1997-2006) estimated the species had been lost from 93% of its range given that the EOO at that point in time was calculated as 3,400 km^2 compared with 50,500 km^2 historically. The difference in EOO since the last assessment represents new survey effort that was more successful at detecting Eastern Pondmussel, rather than a known range expansion. The index of area of occupancy (IAO) was calculated using a continuous 2 km x 2 km grid overlay technique. Using discrete grids, the current IAO was calculated as 164 km^2 compared to 448 km^2 historically, indicating a 63% loss in range. When using continuous grids, the current IAO totals 268 km^2 compared to 2,060 km^2 historically, representing an 87% loss. The previous assessment (1997-2006) estimated a 45 km^2 IAO which is about one-third of the new estimate. There were two records without geographic coordinates that could not be mapped (Beaver Lake circa 2009 and Bay of Quinte circa 1944).

Search Effort

Historical surveys

Approximately 80% of the Canadian Eastern Pondmussel records prior to the current assessment period (1860-2006) are based on either museum specimens or occurrence data. For most of these records, there is little if any information on sampling method, search effort, numbers of sites visited where the species did *not* occur, or even if the animals were dead or alive when collected. Data on relative abundance or density of unionids are available for the remaining 20% of records from the western basin of Lake Erie (Nalepa *et al*. 1991; Schloesser and Nalepa 1994; Schloesser *et al*. 1997), the Detroit River (Schloesser *et al*. 1998), Lake St. Clair (Nalepa *et al*. 1996) and East Lake and Consecon Lake in Prince Edward County (Metcalfe-Smith *et al*. unpubl. data).

Recent surveys

In contrast to the historical data, almost all of the current records (2007-2015) for Eastern Pondmussel in Canada include information on sampling method and sampling effort, data on both presence and absence, and descriptions of the condition of the specimens collected (i.e., live animals, fresh shells or weathered shells). Surveys conducted within the range of the species during this time period used either semi-quantitative (timed-search, clam raking and visual/tactile techniques) or quantitative sampling methods (quadrats or stake and rope) thus providing data on relative abundance or density, respectively. Sampling efforts for these surveys are described in Table 1. Descriptions of sampling techniques can be found under **Sampling Effort and Methods** in **POPULATION SIZES AND TRENDS.**

HABITAT

Habitat Requirements

Eastern Pondmussel occurs in sheltered areas of lakes, in slack-water areas of rivers and in canals, where it prefers substrates of fine sand and mud at depths ranging from 0.3 to 4.5 m (Clarke 1981; Strayer and Jirka 1997; Bogan 2002). Based on habitat information from the Eastern Pondmussel Lake Ontario coastal wetland collection sites, the mean composition of substrate was 43% clay, 23% silt/organics and 34% sand/gravel. The inland lakes collection sites had a mean substrate composition of 47% silt/organics and 52%

sand/gravel. In both cases, two-thirds of the collections of live individuals were from sites where aquatic macrophytes were absent, or present only at low densities. In the St. Clair River delta the species is found on substrates composed of over 95% sand (Metcalfe-Smith *et al*. 2004). In rivers, the species is restricted to the lowermost reaches (Strayer 1983). Additionally, larvae (glochidia) require a host fish for survival (see **BIOLOGY**).

Habitat Trends

Lake St. Clair

Lake St. Clair has been long impacted by invasive species, toxic outflow from the St. Clair River/tributaries and periodic algal blooms. *Dreissena polymorpha* (Zebra Mussel) first invaded the lake roughly 30 years ago, but began declining by 50% 8-9 years after invasion (Hunter and Simons 2004). The delta has poor water quality in general, receiving input from tributaries and the St. Clair River, which are high in phosphorus (0.09 and 0.16 mg•L^{-1}, respectively; 0.03 mg•L^{-1} provincial guideline; SCRCA 2013a and b). Treated wastewater effluent is received in the delta from six localities (SCRCA 2013a, b). In 2015 there was a massive algal bloom captured in satellite images that covered the delta and lake's southern shores (NASA 2015). The St. Clair River is also a source of mercury contamination leading to 0.000-0.486 µg/g in delta sediment and closure of the commercial fishery for ten years (1970-1980; CWCC 2008).

Lake Erie Coastal Wetlands

Resident mussels in the Lake Erie coastal wetlands are subject to the impacts of dreissenids and decades of pollution, namely phosphorus, leading to dense, toxic algal blooms. Dreissenids were established in the western basin of Lake Erie as early as 1986 and spread eastward (Hebert *et al*. 1989). The coastal wetlands have notoriously high levels of phosphorus, the worst being in the western portions (Point Pelee area) where concentrations range between 1 - 9 mg•L^{-1} with peaks up to 28 mg•L^{-1} (ERCA 2012; PWQMN 2015). The middle and northeastern area (Rondeau Bay eastward) have lower P values (0.061- 0.245 mg•L^{-1}), but are still well over provincial guidelines (0.030 mg•L^{-1}; NPCA 2012; LTVCA 2013; LPRCA 2013; PWQMN 2015). Nitrate levels follow similar patterns, with the western portions in the range of 10-70 mg•L^{-1} (peaks up to 140 mg•L^{-1}), but only 2 mg•L^{-1} in middle and northeastern portions (PWQMN 2015). Not surprisingly, the lake has regular and severe cyanobacteria blooms, the latest being in 2015 (spanning westward of Point Pelee; NASA 2015); the worst in history was in 2011 and surpassed the scale of severity ratings (Michalak *et al.* 2013). Levels of suspended solids (turbidity) and chloride (road salt) seem uniformly high across the coastal wetlands, averaging roughly 70 mg•L^{-1} (peaks up to 540 mg•L^{-1}) for suspended solids and 40 - 70 mg•L^{-1} (peaks up to 240 mg•L^{-1}) for chloride (PQWMN 2015). The northeastern portions also have occasional exceedances of copper (> 5 µg•L^{-1}; NPCA 2012).

Lake Ontario Coastal Wetlands

Dreissenids are present in Lake Ontario wetlands, but not at all areas surveyed within the current assessment (see **THREATS**). It has been estimated that *Dreissena rostiformis bugensis* (Quagga Mussel) covers 66% of the nearshore substrate and has replaced *Dressenia polymorpha* (Wilson *et al.* 2006). A recent study of the Great Lakes points out that infestation has decreased ten-fold since the 1990s and that infestation is dependent on species: Quagga Mussels infest less often, and in lower densities, than Zebra Mussels (Burlakova *et al.* 2014). Lake Ontario water quality is degraded largely because of road salt runoff (chloride) and pollution, namely in Hamilton Harbour and the Bay of Quinte. Both are designated Areas of Concern with a longtime history of industrial and wastewater pollution, including coal tar/pesticide/personal care products/legacy chemicals in Hamilton Harbour (PCBs, PAHs, DDT, Chlordane, dioxins; Hughes *et al.* 2016; deSolla pers. comm. 2015), and mining/pulp and paper byproducts in the Bay of Quinte (PCBs, mercury, arsenic, dioxins and furans; QC 2008). Both are also subject to localized algal blooms, the most recent in Hamilton Harbour during summer 2015 (EC 2010; Vanden Byllaardt pers. obs.). Phosphate levels are generally uniform across the coastal wetlands (< 0.50 mg mg•L^{-1}), with the highest peaks near Toronto and Pickering (up to 2.2 mg•L^{-1}; PQWMN 2015). Similarly, nitrate concentrations are generally < 2 mg•L^{-1}, but peak as high as 44 mg•L^{-1} downstream of city centres including Toronto, Oshawa, Lower Trent River and in Hamilton Harbour and the Bay of Quinte. Suspended solids are typically < 50 mg•L^{-1}, but levels up to 1200 mg•L^{-1} are found west of Oshawa (PWQMN 2015). As tributaries are becoming increasingly urbanized, chloride levels (road salt) are of greater concern in Lake Ontario. Non-city centre areas are subject to levels typically < 100 mg•L^{-1}, whereas coastal wetlands spanning Mississauga to Oshawa have levels between 200 - 500 mg•L^{-1} generally, but reaching up to 55,000 mg•L^{-1} in some instances (PWQMN 2015).

Eastern Ontario Inland Lakes

Several of the inland lakes sustaining Eastern Pondmussel have dreissenid infestations, most notably Beaver and Loughborough lakes. Fishing Lake is a locality in which the unionid community is likely undisturbed by these invasive species (Schueler pers. comm. 2015). Dreissenids were not present at sites sampled on White/Ingelsby Lake or on live individuals collected. Although water quality information specific to these inland lakes is not available, all are situated in relatively undisturbed areas, where nearby waterbodies have generally low phosphorus (< 0.03 mg•L^{-1}), nitrate (< 0.05 mg•L^{-1}), suspended solids (< 1.50 mg•L^{-1}) and chloride (< 14 mg•L^{-1}) concentrations (CRCA 2013; QC 2013; PWQMN 2015).

Upper St. Lawrence River

No information is available for Lyn and Golden creeks, but they are positioned amongst relatively undisturbed forest in the Cataraqui region, which generally has fair surface water quality (CRCA 2013).

BIOLOGY

Eastern Pondmussel, like all freshwater mussels, is a sedentary animal that buries itself partially or completely in the substrates of rivers or lakes. Adult freshwater mussels are filter-feeders that obtain nourishment by siphoning particles of organic detritus, algae and bacteria from the water column and, as recently shown, sediments (Nichols *et al*. 2005; Haag 2012). 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). Aspects of the life history of Eastern Pondmussel summarized in the following sections were derived from a review of the available literature as well as the status report writers' knowledge of the species.

Life Cycle and Reproduction

The life cycle of Eastern Pondmussel is similar to that of all freshwater mussels (adapted from Watters *et al.* 2009; Haag 2012): during spawning, males release sperm into the water and females living downstream filter the sperm out of the water with their gills. Ova are fertilized in a specialized region of the female gills, called marsupium, where they are held until they reach a larval stage called the glochidium. The female mussel then releases the glochidia, which must attach to an appropriate vertebrate host, usually a fish. The glochidia become encysted on the host and are nourished by the host's body fluids until they metamorphose into juveniles. The juveniles then release themselves from the host and fall to the substrate to begin life as free-living mussels. The proportion of glochidia that survive to the juvenile stage is estimated to be as low as 0.000001% (Bauer and Wächtler 2001). Mussels overcome the extremely high mortality associated with this life cycle by producing large numbers of glochidia – often more than a million, and by increasing the chances of glochidial attachment by luring the appropriate host species. Juvenile mussels are difficult to find because of their small size and because they quickly burrow into the sediment upon release. Juvenile mussels remain buried until they are sexually mature, at which point they move to the surface for the dispersal/intake of gametes.

Eastern Pondmussel is dioecious and there are subtle differences in the external shell features of males and females (see **Morphological Description**). The species is bradytictic (long-term brooder); fertilization occurs in late summer and glochidia are released the following spring (Ortmann 1919 cited in Watters *et al.* 2009). It is estimated that the species lives for 10 years or more (Watters *et al.* 2009). The generation time of Eastern Pondmussel is unknown, but is estimated to be 6-9 years based on other short-lived lampsilines (Vanden Byllaardt *et al.* in prep). The age at maturity is also unknown.

Physiology and Adaptability

The requirements or tolerances for physical characteristics (e.g., turbidity, water velocity, temperature, depth) and/or chemical characteristics (e.g., pH, alkalinity, calcium and total hardness, salinity/conductivity) are not specifically known for Eastern Pondmussel. Other members of the family Unionidae, especially the glochidia and juveniles, have known sensitivities to heavy metals (Strayer 2008; Gillis *et al.* 2008, 2010) ammonia (Goudreau *et al.* 1993; Mummert *et al.* 2003), acidity (Huebner and Pynnonen 1992), salinity (Gillis 2011), and suspended solids (Gascho Landis *et al.* 2013).

Only one relocation involving Eastern Pondmussel is known to the status report writers and occurred in 2015 in the U.S. waters of the Niagara River (Riveredge Environmental 2015).

Dispersal and Migration

Freshwater mussels are basically sedentary as adults, with movement limited to a few metres of the lake or river bottom (Strayer 2008). The only time that significant dispersal can take place is during the parasitic glochidia phase. Infected host fishes can transport larval unionids into new habitats and replenish depleted subpopulations with new individuals. Schwalb *et al.* (2011) found that mussels' conservation status is linked to hosts' dispersal ability, in that species that were more imperilled likely relied on hosts with limited dispersal distance; however, Eastern Pondmussel was not included in the study.

Interspecific Interactions

Female Eastern Pondmussel use a visual display to attract their hosts. Corey and Strayer (1999) described it taking the likeness of a swimming amphipod. White papillae ripple up and down the mantle margin in an uninterrupted, synchronized rippling. A complete down and back motion along the mantle margin takes an average of 0.8 seconds. This display was observed to strongly attract fish in both natural and laboratory settings (Corey *et al.* 2006). When a fish struck at the lure, the female mussel would expel a stream of glochidia in close proximity to the fish, thus facilitating the attachment of glochidia to the fish's gills. The University of Guelph experimentally determined the host fish of Eastern Pondmussel in Canada: Brook Stickleback (*Culaea inconstans*), Pumpkinseed (*Lepomis gibbosus*) and Yellow Perch (*Perca flavescens*). Yellow Perch had the highest transformation rates (glochidia metamorphosing into juveniles) and is the most likely functional host (McNichols *et al.* 2009). Logperch (*Percina caprodes*), Johnny Darter (*Etheostoma nigrum*) and Rock Bass (*Ambloplites rupestris*) did not support juvenile development. In the U.S., propagation of Eastern Pondmussel in the lab has been successful using Largemouth Bass (*Micropterus salmoides*), which may also be a functional host (Watson pers. comm. 2016). Hosts have yet to be determined in the field.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Historical records, in most cases, provided little information on specimen condition (live, fresh dead or spent), location, how the individual was found (shoreline searches, excavation, etc.), size or sex. It was only around 1997 that mussel surveyors in Canada started to record detailed site and specimen information and started developing more quantitative techniques for unionid detection. There are currently a variety of semi-quantitative techniques used to detect Eastern Pondmussel; the methodology of each is described below. Quantitative techniques, such as quadrat surveys, are difficult to implement in the preferred habitat of this species, which generally consists of soft and muddy substrate (see **Habitat Requirements**).

Timed Search

In rivers and lakes with more compact substrate (e.g., Welland River), surveys were conducted using an intensive timed-search technique, as described in Metcalfe-Smith *et al.* (2000a) (Table 1). Briefly, the riverbed is visually searched by a crew using waders, polarized sunglasses, and underwater viewers for a designated number of PH. Where visibility is poor, searching is done by feel (e.g., Cootes Paradise in Hamilton Harbour, Lake Ontario). The length of reach searched varies depending on river width, but is generally 100 to 300 m. Live mussels are held in the water in mesh diver's bags until the end of the search period when they are identified to species, counted, measured (shell length), sexed (if sexually dimorphic) and returned to the riverbed.

Stake and Rope

Stake and rope surveys were conducted in the St. Clair River delta (Table 1). At each site, sampling was performed by several (usually three) two-person teams, with each team consisting of a snorkeller and an assistant to carry the gear and mussels. Each snorkeller swam until a mussel was seen, then placed a stake in the water and surveyed a 65-m^2 circular area around the mussel and collected any other live mussels found. Each team surveyed a maximum of 10 circle plots or until the shore was reached. All live mussels were identified, counted, measured, sexed and returned to the lake bottom. Methods are described in detail in Metcalfe-Smith *et al.* (2004).

Visual/tactile and Clam Rake Searches

Areas with particularly soft substrate and poor visibility, like coastal wetlands, were sampled via visual/tactile techniques as described in Reid *et al.* (2014). Sampling was done by a team of two to three people equipped with wetsuits and flotation devices. Prior to sampling, a grid would be placed on a site map and 12 random points would be chosen for sampling. For one hour, the area around each point was surveyed using visual and/or tactile techniques without overlapping areas sampled by each method. Any mussels found would be brought to the surface to be identified, measured and sexed, if possible. At the same sampling points, mussels were collected by scooping sediment into a clam rake for one hour. As with timed searches, effort is measured in PH. This type of surveying has been conducted across the Lake Ontario and Lake Erie coastal wetlands as well as inland lakes, such as Beaver, White/Ingelsby, Loughborough and Whitefish lakes (Table 1).

Half-hectare

The half-hectare method has been employed in soft, turbid aquatic environments with variable depths that are difficult to search by conventional methods (Minke-Martin *et al.* 2015; Table 1). A 5000 m^2 area was marked and subdivided into 1 – 5 equal-sized blocks, as determined by the length and width of searchable area. Blocks were searched by visual methods (e.g., water viewers) or scoops by a crew of two to four persons. The number of scoops, thus the area covered, was tallied using clicker-counters and the PH recorded. Mussels were removed from the substrate and kept in mesh diver's bags until the end of the sampling period where they were counted, identified, sexed (if possible) and returned to the substrate. Hamilton Harbour and the lower Grand River were surveyed by this method.

Abundance

The St. Clair River delta is only Canadian locality where Eastern Pondmussel density has been estimated (individuals•m^{-2}; Table 2). Information on catch-per-unit-effort (CPUE; number live individuals per PH of search effort), relative abundance (% live individuals relative to live individuals of all unionid species) and frequency of occurrence (percentage of sites with live specimens detected) is available for most other localities (Lake Erie, Coyle Creek, Lake Ontario, White Lake, Beaver Lake, Loughborough Lake and Lyn Creek) throughout 2007 - 2015 and is summarized in Table 2.

Table 2. Estimates of catch-per-unit-effort (CPUE; number live individuals per person-hour (PH) of search effort), relative abundance (% live individuals relative to live individuals of all unionid species), frequency of occurrence (percentage of sites with live specimens detected), average density (individuals•m^{-2} ± standard error of the mean), Index of area of occupancy (IAO; km^2) and abundance (# of individuals) for Eastern Pondmussel in Canadian waters based on surveys conducted between 2007- 2016, where available. Order is from west to east. IAO was calculated using the 2 x 2 km grid technique for live animals or fresh shells documented in the last (1997-2006) and current assessment period (2007-2016) combined.

Locality	CPUE (Ind•PH^{-1})	Relative abun. (%)	Freq. of occur. (%)	Avg. density (live•m^{-2} ±SE)	IAO (km^2)	Abund. (# individs)	Survey Year(s)
St. Clair River delta	1.0	4	50	0.016 ± 0.010	44	270,000 – 1,200,00	2011
Lake Erie	1.5	20	10	NA	28	NA	2008-2016
Coyle Creek*	0.3	9	67	NA	8	NA	2015
Lake Ontario	0.9	3	4	NA	52	NA	2011-2015
White/Ingelsby Lake	6.5	3	17	NA	8	NA	2015
Beaver Lake	1.2	3	83	NA	12	NA	2015
Loughborough Lake	1.9	45	42	NA	20	NA	2015
Fishing Lake	NA	NA	NA	NA	8	NA	2015
Lyn/Golden Creek*	6.8	7	100	NA	24	NA	2008-2014

* Indicates the IAO estimate was calculated using continuous grids.
NA = information not available.

Table 3. Description of threats and their impacts on Eastern Pondmussel using a Threats Calculator.

Threat Number	Threat Description	Threat Impact	Scope	Severity	Timing
8	Invasive & other problematic species	CD Medium/Low	Pervasive	Moderate/Slight	High
8.1	Invasive non-native/alien species	CD Medium/Low	Pervasive	Moderate/Slight	High
7	Natural system modifications	D Low	Restricted	Slight	High
7.3	Other ecosystem modifications	D Low	Restricted	Slight	High
9	Pollution	D Low	Restricted/Small	Moderate/Slight	High
9.1	Household sewage & urban waste	D Low	Restricted/Small	Moderate/Slight	High
9.2	Industrial & military effluents	D Low	Small	Moderate/Slight	High
9.3	Agricultural & forestry effluents	D Low	Large	Slight	High

Eastern Pondmussel abundance in the St. Clair River delta is estimated to be between 270,000 and 1,200,000 individuals. The estimate was calculated by placing 2 x 2 km discrete grids over 27 sites with incidences of live Eastern Pondmussel or fresh shells from the previous and current assessment timeframes combined (1997-2015; encompassing the St. Clair River outlet/Pocket Bay, Bass Bay, Chematogan Bay, Goose Lake, Johnston Bay, Walpole Island and St. Anne Island) to provide an IAO of 44 km^2. The IAO estimate was then multiplied by the mean density (0.016 ± 0.010 individuals•m^{-2}) for the delta, as determined by stake and rope surveys in 2011. The standard error of the mean was used to calculate the higher and lower limits of abundance. Fresh shells are generally indicative of an extant locality with two caveats: shells likely remain fresh longer in lower energy habitats and fresh can be subjective, although it is generally defined as a shell with intact tissue. Estimates for the previous assessment period (1997-2006) were much lower (21,610 – 44,292 individuals), see Current Trends under **Fluctuations and Trends**.

Recent surveys have been conducted in Lake Pond, McGeachy Pond, Rondeau Bay, Cedar Creek Marsh and Turkey Point within the Lake Erie basin. CPUE is estimated to be 0.044 individuals•PH^{-1} in Lake Pond, 0.9 individuals•PH^{-1} in McGeachy Pond, 0.015 individuals•PH^{-1} in Rondeau Bay, 1.0 individuals•PH^{-1} in Turkey Point and 5.7 individuals•PH^{-1} in Cedar Creek Marsh, although a resurvey at Cedar Creek Marsh one year later produced no Eastern Pondmussel. The mean CPUE for all extant Lake Erie subpopulations was 1.5 individuals•PH^{-1}. Live Eastern Pondmussel were found at 5 of 52 sites surveyed, (10% of sites) and was the second most abundant species, comprising 20% of the unionid community, after Giant Floater (*Pyganodon grandis*; 69%).

Eastern Pondmussel CPUE in Coyle Creek is estimated to be 0.3 individuals•PH^{-1} and occurs at 67% of sites (2 of 3 sites surveyed in the creek). The species represents 9% of the unionids in this waterbody, which was otherwise dominated by Giant Floater, Fatmucket (*Lampsilis siliquoidea*) and Mapleleaf (*Quadrula quadrula*).

CPUE for Eastern Pondmussel in recent searches of Lake Ontario coastal wetlands was 0.5 individuals•PH^{-1} in the Rouge River (0.4 individuals•PH^{-1} in a resurvey), 0.7 individuals•PH^{-1} in Carruthers Creek, 2.3 individuals•PH^{-1} in Lynde Creek (0.5 individuals•PH^{-1} in a resurvey), 0.5 individuals•PH^{-1} in Pleasant Bay, 0.6 individuals•PH^{-1} in Consecon Lake, 1.3 individuals•PH^{-1} in East Lake (1.0 individuals•PH^{-1} in a resurvey) and 0.5 individuals•PH^{-1} in Hay Bay/Wilton Creek. Overall this averages to 0.9 individuals•PH^{-1}. Eastern Pondmussel has an overall frequency of occurrence of 4% (present at 25 of 596 sites searched) and a relative abundance of 3%. The unionid community in these coastal wetlands mainly consists of Giant Floater, Mucket (*Actinonias ligamentina*), Eastern Elliptio (*Elliptio complanata*) and Fatmucket.

Eastern Pondmussel CPUE from White/Ingelsby Lake was 6.5 individuals•PH^{-1} and the species occurred at 17% of sites (2 of 12 sites). The unionid community in the lake was heavily dominated by Eastern Elliptio (74% relative abundance), whereas Eastern Pondmussel accounted for 17% of unionids found.

In 2015, Beaver Lake Eastern Pondmussel CPUE was 1.2 individuals•PH^{-1}. The species was collected at 83% of sites sampled (9 of 12 sites). Eastern Pondmussel represented a small percentage of the unionids in the lake (3%), which was dominated by Eastern Elliptio (95%).

Loughborough Lake CPUE for Eastern Pondmussel was 1.9 individuals•PH^{-1}. The species occurred at 42% of sites sampled (5 of 12 sites) and represented 45% of the unionid fauna in the waterbody, similar to Eastern Elliptio (52%).

Lyn/Golden Creek surveys have consistently collected a large number of live Eastern Pondmussel, yielding up to 6.8 individuals•PH^{-1}. All surveyed sites were found to have live individuals, but it should be noted that only two general areas have been searched. Despite the relatively high numbers of Eastern Pondmussel in this watercourse, the species represents only 7% of the unionid community, which is dominated by Eastern Elliptio (86%).

Fluctuations and Trends

As a whole, the number of Eastern Pondmussel records has increased with more targeted and effective surveys, but the number of individuals recorded from most localities is very low (only a few individuals). The proportion of Eastern Pondmussel in records of unionid community composition seems to be fairly consistent, but the overall number of unionids has declined.

It is well documented that unprecedented and widespread declines occurred for all unionids, including Eastern Pondmussel, in the Great Lakes and connecting channels following the dreissenid invasion in the early 1980s (Schloesser and Nalepa 1994; Nalepa *et al.* 1996, 2001; Ricciardi *et al.* 1996; Ecological Specialists 1999; Riveredge Associates 2005; Schloesser *et al.* 2006). A query of the Lower Great Lakes Unionid Database showed that live Eastern Pondmussel accounted for 7.5% of the 1591 records for 39 species in Lake St. Clair, Lake Erie, Lake Ontario and the Detroit and Niagara rivers prior to 1990. From 1997-2006, the species accounted for 8.2% of 502 records for 30 species and 10.1% of 555 records for 25 species from 2007-2015 (also including Lake Ontario inland lakes). In all instances, Eastern Pondmussel represented the fourth most common species, based on live individuals. Currently, Eastern Pondmussel can be collected from most localities that it historically occupied in the lower Great Lakes and St. Clair River delta, although 22 of the Lake Ontario coastal wetlands surveyed had no live individuals or shells collected. Moreover, the species has also been discovered in waterbodies that were not surveyed (and not represented) in the last assessment period, particularly inland lakes in eastern Ontario. Overall, only eight sites have collections numbering to more than a few live individuals: St. Clair River delta, Cedar Creek Marsh (Lake Erie), Lynde Creek, East Lake, White Lake, Beaver Lake, Loughborough Lake and Lyn Creek. The viability of such small subpopulations at other sites is uncertain.

Past Trends

Schloesser *et al*. (1998) surveyed 13 sites in the Canadian and U.S. waters of the Detroit River in 1982-83 before the dreissenid invasion and after (17 sites in 1992, and 9 sites in 1994). Eastern Pondmussel accounted for 3.7% of 1279 live unionids (23 species) collected pre-invasion, 0.2% of 1653 unionids collected in 1992 and none of the 58 live animals collected in 1994 (13 species). Abundance of Eastern Pondmussel at the nine sites declined from 37 to four to zero (1982-83, 1992 and 1994, respectively). Schloesser *et al*. (2006) surveyed four of these sites again in 1998; only four unionids of four species were found alive and none were Eastern Pondmussel.

Long-term trends for Eastern Pondmussel abundance are available for the offshore area of Lake St. Clair. Nalepa *et al*. (1996) surveyed 29 offshore sites pre-invasion (1986) and post-invasion (1990, 1992 and 1994) using the same method; the majority (18 sites) were in Canadian waters. Unionid abundance declined from 281 specimens (18 species) pre-invasion to 6 specimens (5 species) post-invasion (1994). Relative abundance of Eastern Pondmussel in these years was 2.8%, 2.0%, 5.1% and 0%, respectively. Mean density of all unionids in 1986 was 1.9 individuals•m^{-2}, and because Eastern Pondmussel represented 2.8% of specimens, it follows that the species' mean density was roughly 0.05 individuals•m^{-2}. Gillis and Mackie (1994) conducted intensive surveys at two of Nalepa *et al*.'s (1996) sites that were relatively close to shore in 1990-92. The density of Eastern Pondmussel at the site in Canadian waters near Puce, Ontario, declined from 0.01 to 0.004 to 0 individuals•m^{-2} over the period of 1990-1994. Nearshore waters of the St. Clair River delta were not surveyed prior to 1999, so there is little information on changes in subpopulation size in the delta area. However, a decline in unionids, including Eastern Pondmussel, is known to have occurred at one site in Johnston Bay: Zanatta *et al*. (2002) collected 19 live Eastern Pondmussel in 1999, but found only one in 2000, after expending the same effort (1.5 PH). Metcalfe-Smith *et al*. (2004; 2005) surveyed the site again in 2003 and collected two individuals (1.3 PH). Zanatta *et al*. (2002) noted that dreissenid infestation rates in Johnston Bay and nearby Goose Lake (mean = 177 dreissenids•$unionid^{-1}$) were higher than elsewhere in the delta in 1999.

Eastern Pondmussel was the second most abundant species (after *Lampsilis siliquoidea*, Fatmucket) in surveys conducted in the offshore waters of the western basin of Lake Erie in 1930 through to 1982 and shifted to the third most abundant in 1973-74 (Nalepa *et al.* 1991). The status report writers used the data from Nalepa *et al*. (1991) to calculate a decline from 2.5 individuals•m^{-2} in 1961 to 0.46 individuals•m^{-2} in 1972 and 0.95 individuals•m^{-2} in 1982. As such, the abundance of Eastern Pondmussel declined by about 60% in this time period, a likely result of declining water quality (Nalepa *et al.* 1991). Schloesser and Nalepa (1994) surveyed the same 17 sites post-invasion (1991) and found only four live mussels, none of which were Eastern Pondmussel. Schloesser *et al*. (1997) reported a 96% decline in unionids at 15 nearshore sites in the western basin from 1983 to 1993; Eastern Pondmussel was not found during any of these surveys.

Timed search surveys were conducted at one site in East Lake and Consecon Lake (Lake Ontario watershed) in 1996. A total of 14 live Eastern Pondmussel were collected from Consecon Lake, whereas East Lake yielded only two specimens. These sites were re-surveyed in 2005, with an additional site in Consecon Lake, and four sites in nearby West Lake. No live unionids of any species were found (however, live individuals were found more recently – see **Canadian Distribution**).

Current Trends

Current quantitative trends are only available for the St. Clair River delta. Densities in 2011 have increased compared to 2003 – 2004 values, doubling in some cases (Pocket Bay from 0.001 to 0.003 individuals•m^{-2}, Bass Bay from 0.020 to 0.025 individuals•m^{-2} and the remainder of the delta from 0.005 to 0.013 individuals•m^{-2}). The current abundance of Eastern Pondmussel is an estimated 270,000 to 1,200,000 individuals (44 km^2 IAO at an average density of 0.016 ± 0.010 individuals•m^{-2}; see **Abundance)**. Estimates for the previous assessment were much lower (21,610 – 44,292 individuals) because of a lower average density and a 'correction factor' applied for the last assessment (to account for unlikely habitat i.e., dry land and > 1.5 m deep water), which was not done here. Had the previous assessment not applied a correction factor, the abundance estimate would be more similar to the current assessment period (roughly 300,000 – 460,000 individuals, IAO of 44 km^2, density of 0.009 ± 0.002 individuals•m^{-2}). Eastern Pondmussel can be collected from every locality in which it had been found previously (however, Goose Lake, Johnston Bay, Walpole Island and St. Anne Island were not resurveyed recently), and currently accounts for 4% of the unionid community in the St. Clair River delta. It follows that the species is at least consistent in distribution and possibly denser in recent years within the delta. However, there is uncertainty if the density from the current timeframe represents that of the whole delta because density estimates from Goose Lake, Johnston Bay, Walpole Island and St. Anne Island have never been available.

Bass Bay is the most well searched locality in the St. Clair River delta. Similar to the 2003-2005 surveys (49-99 mm, 208 individuals), shell lengths of live Eastern Pondmussel in Bass Bay ranged from 51-84 mm (23 individuals) in the 2011 surveys with good representation in several size classes, suggesting that regular recruitment is still occurring (Figure 5). Only recent length data are available for Cedar Creek Marsh (Lake Erie), Lynde Creek (Lake Ontario), Beaver Lake, White/Ingelsby Lake, Loughborough Lake and Lyn Creek (sites with a sample size, n ≥ 10). The three inland lakes represent new occurrences. The size-frequency plots of live Eastern Pondmussel at these waterbodies show good representation of all size classes, with the exception of Lynde Creek, which appears to have mostly large individuals (Figure 6). However, this location had the smallest sample size of those listed (n=11). Very small specimens were not often encountered in all cases probably because juveniles tend to burrow deeply in the substrate where they would not be detected. In the status report writer's experience, most specimens cannot be reliably sexed on the basis of shell shape; therefore, sex ratios have not been presented.

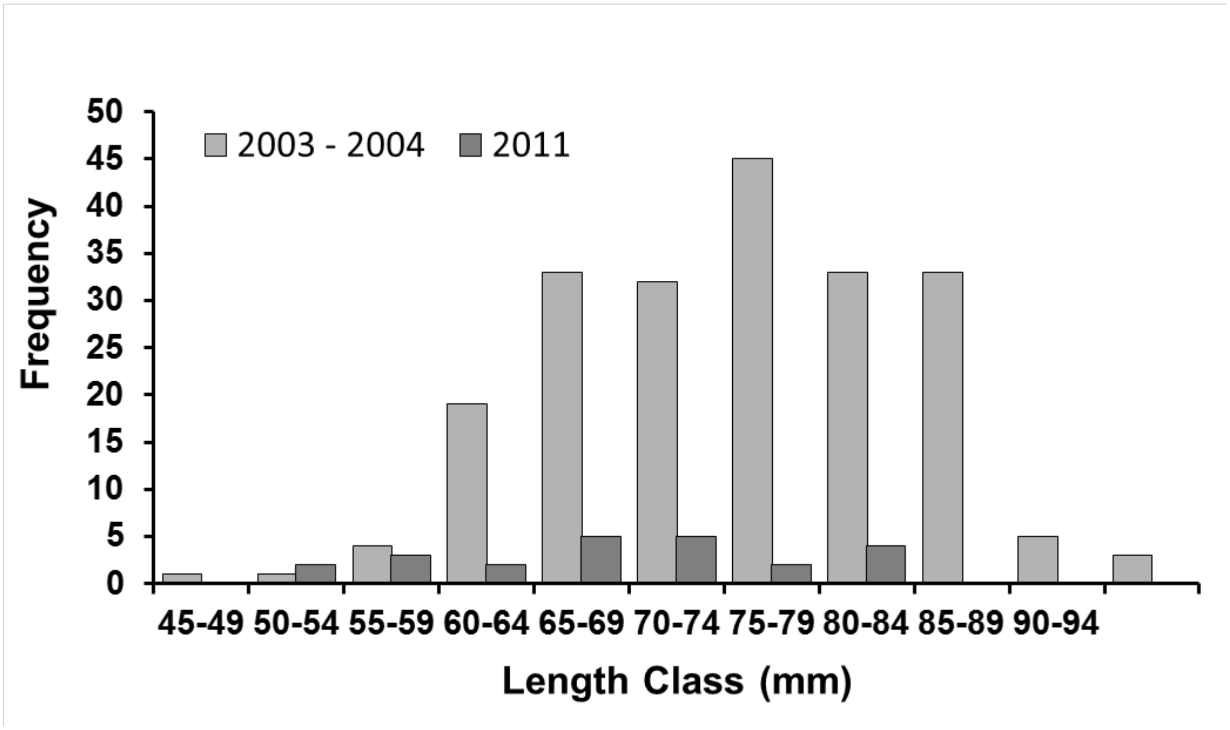

Figure 5. Size-frequency distribution of 209 live Eastern Pondmussel collected from Bass Bay in the Canadian waters of the St. Clair River delta in 2003 and 2004 as compared to the 23 collected in 2011.

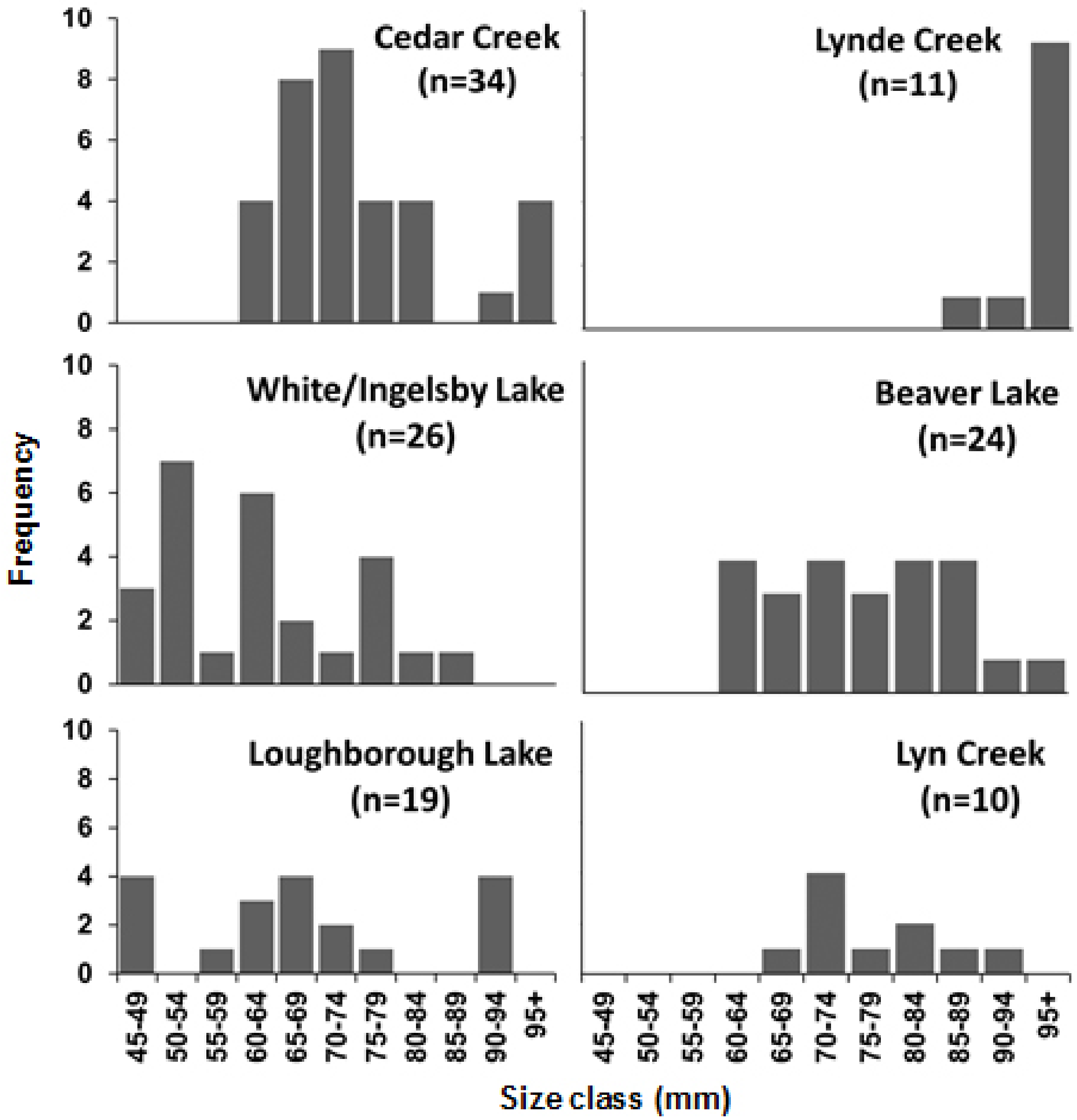

Figure 6. Size-frequency distribution of live Eastern Pondmussel collected from Cedar Creek Marsh (Lake Erie) in 2008, Lynde Creek (Lake Ontario) in 2011, White/Ingelsby Lake in 2015, Beaver Lake in 2015, Loughborough Lake in 2015 and Lyn Creek in 2009. Number in brackets represents the sample size.

Rescue Effect

It is possible that subpopulations of Eastern Pondmussel in Canada could re-establish by natural immigration from the United States given how easily this species seems to disperse into new inland lake habitats (e.g., introduction by fish stocking; Goodrich 1932). If the subpopulation in the Canadian portion of the delta were to disappear, it is possible that the species could return naturally through the movement of host fishes from U.S. waters of the delta (Lucy *et al.* 2014; Zanatta *et al.* 2015). For example, as the navigation channel that bisects the delta is only 8.3 m deep (Edsall *et al*. 1988), the suspected host, Yellow Perch, should be able to move freely across the border (as they are not usually found below 9.2 m and have a home range of up to 0.022 km^2; Scott and Crossman 1973; Fish and Savitz 1983). Rowe and Zanatta (2015) clearly show that populations of Fatmucket on the U.S. and Canadian side of the delta were a single genetic population. Given this, and likely similar host usage, it is expected that Eastern Pondmussel shows a similar pattern and that gene flow is ongoing across the delta (Zanatta pers. comm. 2016).

THREATS AND LIMITING FACTORS

The greatest threat to Eastern Pondmussel are dreissenid mussels (*Dreissena polymorpha* and *Dreissena rostiformis bugensis*) followed by ecosystem modification by *Phragmites australis* (tall emergent grass) and water pollution stemming from a variety of factors including wastewater discharge, road salting, as well as industrial and agricultural effluents. Threats identified here follow those discussed in a peer-reviewed Recovery Potential Assessment for Eastern Pondmussel (Bouvier and Morris 2011). Taking an ecosystem approach, these threats may interact to directly or indirectly influence one another. However, at this point in time interactions are not well understood and therefore each threat is discussed independently.

Medium - Low Threats

<u>Invasive and other problematic species and genes</u>

8.1 Invasive non-native/alien species

The introduction and spread of non-native dreissenid mussels throughout the Great Lakes and connecting channels has led to dramatic declines of native freshwater mussels in colonized areas (Ricciardi *et al.* 1996; Schloesser *et al.* 1996; Nalepa *et al.* 2001; Schloesser *et al.* 2006; see **Habitat Trends**). Over 90% of historical records for Eastern Pondmussel are from areas now infested with dreissenids and, thus, degraded. Several studies estimate that the lethal infestation rate for unionids is >100 dreissenids/unionid (Ricciardi *et al.* 1995; Schloesser *et al.* 1996) and one study concluded that only 10 dreissenids/unionid are necessary to see declines in unionid abundance, as a result of interference with normal functioning (feeding, locomotion, respiration) and to a lesser degree, competition for food (Ricciardi *et al.* 1996; Ward and Ricciardi 2013). Results of an unpublished study showed that Eastern Pondmussel had the lowest rate of survival (30%) and carried the heaviest load of attached dreissenids (relative to their size) of five native mussel species from Lake St. Clair (Hunter pers. comm. 2004). Dreissenids may be a particular threat to Eastern Pondmussel due to the latter’s preference for soft, muddy sediment: unionids become the functional equivalent of substrate for dreissenids as no other hard alternative is present (Jokela and Ricciardi 2008).

Dreissenids continue to threaten and limit the distribution of most Eastern Pondmussel to the St. Clair River delta, namely Bass Bay. Current infestation rates in the delta range from 0 - 42 dreissenids•unionid^{-1}, similar to the previous assessment period (McGoldrick *et al.* 2009; T. Morris unpubl. data). Evidently, some sites have soft enough sediment that unionids burrow to rid themselves of dreissenids, but retain byssal threads as evidence (McGoldrick *et al.* 2009). It is thought that the delta is semi-protected, with offshore currents, prevailing winds and fluctuating water levels mitigating dreissenid veliger settlement as densities are about half of what can be found in the offshore waters (Zanatta *et al.* 2002; McGoldrick *et al.* 2009; Sherman *et al.* 2013).

Dreissenids were established in the western basin of Lake Erie as early as 1986 and spread eastward (Hebert *et al*. 1989). Of the 120 live mussels collected from Rondeau Bay in 2014/2015, 106 had evidence of dreissenids (attached or byssal threads) and shells were present at all 10 sites (of 15) where live native mussels were collected. The mass ratio (g/g) of attached dreissenids to live unionids ranged from 0.0009 to 1.53 (mean = 0.15; S. Reid unpubl. data). Individuals without dreissenids were not included in this calculation. None of the unionids collected from Lake Pond in 2016 and Cedar Creek Marsh in 2008 had dreissenids attached, although all four Eastern Pondmussel collected from neighbouring Turkey Point in 2009 had been colonized (Gilbert and Oldenburg 2013).

Dreissenids are present at 30% of sites surveyed in the Lake Ontario coastal wetlands from 2011 to 2015 and about half of the live unionids collected (820 of 1685) had evidence of dreissenids (attached or byssal threads). Mass ratio (g/g) of attached dreissenids to live unionids ranged from 0.0006 to 2.0 (mean = 0.15; Reid *et al.* 2014).

Several of the inland lakes sustaining Eastern Pondmussel have been invaded by dreissenids. Dreissenids were present at 100% of the Beaver Lake sites where 617 of the 933 live unionids collected had evidence of infestation (attached or byssal threads) and mass ratio (g/g) of attached dreissenids to live unionids ranged from 0.0010 to 2.75 (mean = 0.22). At Loughborough Lake, dreissenids were present at 50% of sites sampled and 32 of the 42 live individuals had evidence of dreissenids in 2015. Mass ratio (g/g) ranged from 0.003 to 1.05 (mean = 0.25). Fishing Lake is likely undisturbed by dreissenids (Schueler pers. comm. 2015). Dreissenids were not present at sites sampled on White/Ingelsby Lake or on collected live Eastern Pondmussel.

Live Asian Clams (*Corbicula fluminea*) were found in McGeachy Pond (adjacent to Rondeau Bay, Lake Erie), where incidentally, live Eastern Pondmussel was also collected. Fortunately, the vast majority of Asian Clams were dead. Although Asian clams are known to have detrimental effects on unionids (Strayer 1999; Cherry *et al.* 2005), there are no studies showing specific negative impacts to Eastern Pondmussel. Furthermore, if Asian Clams did impact Eastern Pondmussel negatively, it would be very limited in this case because the density of this invasive species observed in McGeachy Pond was extremely low (< 1 individual•m^2).

Low Threats

Natural System Modifications

7.3 Other ecosystem modifications

Invasive species not only compete with native mussels for resources, they also tend to modify their habitat in suboptimal ways. For example, dreissenid mussels smother other organisms by forming blankets over lake and river bottoms and effectively remove available habitat. This was especially noticeable in the Trent River, where in some cases, sites occupied by Rainbow were completely covered in dreissenid shells and the river bottom could not be seen (Epp pers. comm. 2014). Unlike lake and river systems, coastal wetlands may not be as susceptible to dreissenid invasions as the entire substrate is not usually dominated by the species.

Phragmites australis (common reed) is an invasive emergent grass that represents a threat to Eastern Pondmussel as it chokes out available aquatic habitat by transforming it into dense, impenetrable monocultures. It is particularly prevalent in the coastal regions of lakes Erie and Ontario (Carlson Mazur *et al.* 2014) and has invasion potential in the eastern Ontario lakes. For example, there has been a 20+ year progression from open/shallow water to *Phragmites* monocultures in areas neighbouring Cedar Creek at Long Point (Wilcox *et al.* 2003), although it is possible that unionids would move out through this timeframe. Carlson Mazur *et al.* (2014) indicate that the western/central Lake Erie coastal zone and St. Clair River delta are particularly vulnerable to invasion due to proximity of land development and elevated nutrients related to agriculture. Recently, removal of *Phragmites* by dredging has improved the interspersion of aquatic organisms and re-created habitat in Long Point ponds (Schummer *et al.* 2012). The creation of additional areas of suitable habitat in Long Point Bay may allow for expansion of Eastern Pondmussel distribution.

Pollution

9.1 Household sewage and urban waste water

Road salt:

Road salt (measured as chloride) is designated 'toxic' under the *Canadian Environmental Protection Act*. The Act specifies acute toxicity for general aquatic life at 860 mg•L^{-1} (one hour) and 230 mg•L^{-1} (four-day average). For unionids, acute sensitivity is most notable in the early life stages: the 24 hr median lethal dose (LC50) for Fatmucket glochidia ranges between 135 - 2953 mg•L^{-1} depending on the collection locality (Gillis 2011). Eastern Pondmussel habitat commonly overlaps that of Fatmucket (see **Abundance** and **Fluctuations and Trends**), and may have a similar range of LC50s. The species is exposed to excessive and chronic chloride inputs well beyond this level in both lakes Erie and Ontario coastal wetlands (see **Habitat Trends**). Todd and Kaltenecker (2012) demonstrated that baseline chloride levels are increasing in mussel habitats across southern Ontario (96% of 24 monitoring stations) and suggested that this will affect recruitment of mussel Species at Risk in the future. Hard water (typical of southern Ontario) acts as a natural buffer to chloride retention, but only to a limited degree (Gillis 2011).

Wastewater discharge:

Contaminants released in wastewater discharge have negative and sometimes profound effects on unionid communities. Studies by Gillis (2012) and Gillis *et al.* (2014) confirmed a dead zone immediately downstream of a wastewater facility effluent outlet on a river where no mussels were detected for several kilometres (Gillis *et al.* 2017). Moreover, that zone was chronically exposed to an array of contaminants including ammonia, chloride, over 100 pharmaceuticals and personal care products and metals such as copper, lead and zinc (see also de Solla *et al.* in press). Recent evidence shows sewage pollution also releases endocrine disruptors including human pharmaceuticals, organochlorine pesticides and paint byproducts, which may have effects in small quantities including the feminization of aquatic organisms and disruption of gonad physiology (Strayer 2008; de Solla *et al.* in press). Gagné *et al.* (2011) have ascertained that mussels downstream of a municipal effluent outlet had two and a half times more females than males, in addition to males displaying female-specific proteins related to egg production. Of particular interest is Hamilton Harbour, a small basin in Lake Ontario that receives input from three relatively close wastewater treatment facilities. Cootes Paradise, the suspected home of Eastern Pondmussel in Hamilton Harbour, has detectable and unprecedented levels of personal care products and drugs (de Solla pers. comm. 2015). The effects of these contaminants on unionids are part of a recent and ongoing study.

9.2 Industrial and military effluents

Arsenic and Copper:

Mining and aggregate extraction have been the focus of development activities in eastern Ontario where mineral formations are bountiful. These activities have particularly affected the Bay of Quinte, which has a 150-year legacy of industrial pollution (see QC 2008). Two concerns are the leaching of arsenic (a byproduct of smelting copper, gold and silver ore) and refined copper from the Deloro Gold Mine site (Moira River). In addition, radioactive waste (uranium used in extraction process) and cobalt are also seeping from contaminated soils (QC 2008). Specific information regarding the toxicity of arsenic to Eastern Pondmussel is not available; however, a study conducted soon after the abandonment of the site in 1961 showed unprecedented declines in mussels and aquatic life in general several kilometres downstream of the mine (Owen and Galloway 1969). Despite cleanup activities, elevated arsenic levels are still an ongoing issue as the element tends to bind in the sediment, releasing into the Bay of Quinte upon disturbance. Concentrations between 0.1 and 8.2 $mg•L^{-1}$ still ensue downstream (QC 2008). In comparison, neighbouring watersheds have naturally occurring arsenic concentrations around 0.001 $mg•L^{-1}$ on average.

Unionids are also particularly sensitive to copper levels, because as with arsenic, it tends to accumulate in the interstitial water of river bottoms (Strayer 2008). While effects of copper on Eastern Pondmussel remain unknown, Fatmucket demonstrates a 4-day half maximal effective concentration (EC50) of 36 $\mu g \cdot L^{-1}$ under conditions of low dissolved organic content (DOC) and up to 150 $\mu g \cdot L^{-1}$ with high DOC (Gillis *et al.* 2010). Concentrations of bioavailable copper in southern Ontario are generally low given the protection of high DOC which acts as a buffer (Gillis *et al.* 2010). Copper can also be released episodically (i.e., lakes Erie and Ontario coastal wetlands; see **Habitat Trends**). Systems without inherently high DOC inputs or hard water would offer little protection (Gillis *et al.* 2008, 2010).

Mercury:

Freshwater mussels are known to be sensitive to mercury (Valenti *et al.* 2005), although no information specific to Eastern Pondmussel is readily available. For Rainbow, whose distribution generally overlaps with Eastern Pondmussel in the Great Lakes, the juvenile and glochidial life stages are particularly sensitive to mercury. Glochidia are more responsive than juveniles to acute exposure, with 72-hour LC50s of 14 $\mu g \cdot L^{-1}$ and 114 $\mu g \cdot L^{-1}$, respectively, but chronic exposure led to sublethal effects including stunted growth for juveniles exposed to levels as low as 8 $\mu g \cdot L^{-1}$ over 21 days (Valenti *et al.* 2005). Only the St. Clair River delta and Bay of Quinte are known for mercury contamination from industrial pollution (see **Habitat Trends**). Other sources could include leaching from landfills (improperly disposed of batteries and fluorescent lamps, for example) or, previously, from old but currently banned pesticides.

9.3 Agricultural and forestry effluents

Erosion:

Anthropogenic stressors such as high turbidity and sediment loading originating from urban and agricultural sources are potential problems in southern Ontario where Eastern Pondmussel occurs. High levels of entrained silt and sand particles are problematic because they clog siphons, gills and digestive tracts of mussels when they are gaping. Although mussels have an innate sorting system whereby organs remove inorganic particles before entering the digestive tract (expelling them out the inhalant siphon as pseudofaeces), the animal’s feeding structures can saturate whereby the animal will close and postpone filtration until conditions improve (Wildish and Kristmanson 1997; Cummings and Graf 2010). Long duration of valve closure could potentially decrease feeding, movement and reproductive behaviours reducing lure displays, intake of sperm or release of glochidia thereby lowering recruitment (Gascho Landis *et al.* 2013). Moreover, host fish may not be able to locate mussel lures in conditions of high turbidity (Bouvier and Morris 2011). Lakes Erie and Ontario coastal wetlands have the highest levels of suspended solids, the peak levels seen in both waterbodies (540 and 1200 $mg \cdot L^{-1}$; see **Habitat Trends**) would undoubtedly be harmful to unionids if sustained over time.

Phosphorus and Nitrogen:

Phosphorous and nitrates/nitrites are not directly toxic to mussels but it is well known that excessive nutrient loading leads to eutrophication of waterbodies, which results in anoxic conditions leading to mussel die-offs (Strayer 2008). The Ontario provincial government considers streams with phosphorus greater than 0.03 mg•L^{-1} to be eutrophic (lakes > 0.02 mg•L^{-1}), as well as waterbodies exceeding 0.10 mg•L^{-1} nitrate (PWQO 2015). Many factors can contribute to excessive nutrient loading, including farming practices (tile drainage, application of fertilizers/pesticides/liquid manure), detergents and storm water runoff. The waterbodies that seem to have regular occurrences of algal blooms include Lake Erie (primarily the western basin), Lake St. Clair, as well as Hamilton Harbour and Bay of Quinte in Lake Ontario. The only region that seems to have phosphorus and nitrate levels below the eutrophic threshold is in eastern Ontario around the inland lakes, as they are in relatively undisturbed surroundings (see **Habitat Trends**).

Limiting Factors

<u>Host Fishes</u>

Unionids will not complete their life cycle without access to the appropriate glochidial host. If host fish populations disappear or decline in abundance to levels below which they can sustain a mussel subpopulation, recruitment will no longer occur and the mussel species may become functionally extinct (Bogan 1993). As noted earlier (see **Interspecific Interactions**), the likely host fishes for Eastern Pondmussel are Brook Stickleback, Largemouth Bass, Pumpkinseed and Yellow Perch. Given that these host species are common throughout the range of Eastern Pondmussel in Ontario, it is unlikely that access to glochidial hosts is a major limiting factor for this mussel.

<u>Predation</u>

Freshwater mussels are known to be food sources for a variety of mammals (Fuller 1974). Predation by Muskrat (*Ondatra zibethicus)* was thought to be a limiting factor for Eastern Pondmussel in particular because the species was found in middens and preferred habitat for both animals is wetlands (NatureServe 2015). However, Muskrat populations have consistently declined since the 1980s (based on harvest data; Bowman pers. comm. 2015) and are not likely a major limiting factor. Raccoon (*Procyon lotor*) is another potential predator. Abundance of this mammal has increased in southern Ontario, and is expected to keep increasing and expand into more northern regions for climate-related reasons (Bowman pers. comm. 2015).

Number of Locations

There were three threats identified. One medium to low (invasive non-native/alien species) could represent the most serious and plausible threat. However, the impact on most Eastern Pondmussel localities as a result of the invasion and establishment of dreissenid mussels has already been realized – therefore, it is not plausible that future new dreissenid invasions will have rapid and substantial impacts on remaining Eastern Pondmussel subpopulations. The other identified threats (natural systems modifications, and pollution) both had a low impact, and by their nature would have a local impact. Therefore, the number of locations is most likely between 12-20, and more may be expected.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Eastern Pondmussel was assessed as Endangered in 2007 by COSEWIC and listed as Endangered under the federal *Species at Risk Act* (SARA) in 2013 and Ontario's *Endangered Species Act* (ESA) in 2009. The two acts afford Eastern Pondmussel legal protection through prohibitions against harming or harassing the animals and damaging or destroying their habitat. However, habitat protection under SARA will only occur after critical habitat has been identified in a final recovery strategy or action plan and the species only receives general habitat protection under the ESA. Eastern Pondmussel and its host fishes are also afforded protection under the federal *Fisheries Act* (Ming pers. comm. 2016). A proposed recovery strategy and action plan have been developed for Eastern Pondmussel (DFO 2016), which identifies critical habitat and key actions that will be implemented. It is not currently listed or proposed for listing under the U.S. *Endangered Species Act.* Eastern Pondmussel is listed as Endangered in Ohio (ODNR 2015) and Delaware (DNREC 2015), Threatened in New Jersey (NJDEP 2015) and North Carolina (NCWRC 2015) and Special Concern in Massachusetts (MDFW 2015), New Hampshire (NHFG 2015), Rhode Island (RIDEM 2015) and Connecticut (CDEEP 2015) and is therefore afforded some protection in these states.

Non-Legal Status and Ranks

Eastern Pondmussel has a General Status rank of At Risk (1) in Canada (CESCC 2011), is Critically Imperiled (N1) nationally and Extremely Rare (S1) in Ontario, but is Apparently Secure globally and in the U.S. (G4 and N4; NatureServe 2015). It is listed as Lower Risk–Near Threatened (LRnt) in North America on the IUCN Red List of Threatened Species (IUCN 2015). Current state ranks for Eastern Pondmussel are: Critically Imperiled (S1) in Delaware, New Hampshire, North Carolina, Ohio, Pennsylvania and Rhode Island; Critically Imperiled/Imperiled (S1S2) in Connecticut and Maryland; Imperiled (S2) in New Jersey and South Carolina; Imperiled/Vulnerable (S2S3) in New York; and Vulnerable (S3) in Massachusetts and Virginia (NatureServe 2015). The species is under review (SNR) in Michigan and the District of Columbia (NatureServe 2015).

Habitat Protection and Ownership

The largest known subpopulation of Eastern Pondmussel in Canada occupies the territorial waters of the Walpole Island First Nation in the delta area of Lake St. Clair. These waters have limited human disturbance and are protected from urban development and certain recreational uses (e.g., jetskis) as special user permits are required to access First Nation territory and waters. The Walpole Island Ecosystem Recovery Strategy (Bowles 2005) provides further governance over species at risk in the territory. Eastern Pondmussel can be found in Point Pelee National Park and the Trent-Severn Waterway, which are governed by Parks Canada. Individuals located along the eastern portion of Rondeau Bay would be protected in Rondeau Provincial Park as well as those found in Cedar Creek Marsh in the Long Point National Wildlife Area. A federal recovery strategy and action plan has been developed for the species which will help facilitate stewardship and protect occupied habitats (DFO 2016).

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Julie Vanden Byllaardt works with aquatic invasive species and ballast water of commercial ships. Previously, she was employed by DFO to conduct field collections, analyze data and write first-author publications regarding the life history and reproduction of mussel species at risk. Julie completed a BSc (Hons) in Botany at the University of Toronto (2009) and an MSc involving unionids at the University of Guelph (2011). She has conducted mussel relocations, has experience teaching identification and is a member of the Ontario Freshwater Mussel Recovery Team. She co-wrote the Rainbow (*Villosa iris*) status report update with Dr. Todd J. Morris.

Dr. Scott Reid is a Research Scientist with the Ministry of Natural Resources and Forestry, and in conjunction with DFO, has conducted nearly all the recent Eastern Pondmussel sampling in Ontario, including the coastal wetlands of lakes Ontario and Erie. Dr. Reid is the Ontario member for COSEWIC, a current member of the Ontario Freshwater Mussel Recovery Team, and has previously served seven years on the Freshwater Fishes SSC. For his education, he completed a BSc in Ecology at the University of Calgary (1993) as well as an MSc (1997) and PhD (2007) in Watershed Ecosystems at Trent University.

Dr. Todd J. Morris is a Benthic Research Scientist with Fisheries and Oceans Canada responsible for leading a scientific research program focusing exclusively on molluscs with a major emphasis on unionid species at risk. He has a BSc (Hons) in Zoology (1993) from the University of Western Ontario, an MSc in Aquatic Ecology from the University of Windsor (1995) and a PhD in Zoology from the University of Toronto (2002). His research interests centre on the biotic and abiotic factors structuring the distributional patterns of freshwater invertebrates of the Great Lakes basin. He began working on the unionid fauna of Ontario in 1993 and is a member of the COSEWIC Mollusc SSC and the American Fisheries Society Endangered Mussel Subcommittee and is a founding member and co-Chair of the Ontario Freshwater Mussel Recovery Team.

COLLECTIONS EXAMINED

In 1996, all available historical and recent data on the occurrences of freshwater mussel species throughout the Lower Great Lakes drainage basin were compiled into a computerized, GIS-linked database referred to as the Lower Great Lakes Unionid Database. The database is housed at the Fisheries and Oceans Canada's Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario. Data sources included the primary literature, natural history museums, federal, provincial, and municipal government agencies (and some American agencies), conservation authorities, Remedial Action Plans for the Great Lakes Areas of Concern, university theses and environmental consulting firms. Mussel collections held by six natural history museums in the Great Lakes region (Canadian Museum of Nature, Ohio State University Museum of Zoology, Royal Ontario Museum, University of Michigan Museum of Zoology, Rochester Museum and Science Center, and Buffalo Museum of Science). Previous report writers (J.L. Metcalfe-Smith) personally examined the collections held by the Royal Ontario Museum, University of Michigan Museum of Zoology and Buffalo Museum of Science, as well as smaller collections held by the Ministry of Natural Resources. The current status report writers have personally verified live specimens from all localities presented in this report.

Appendix I. Threats calculator for Eastern Pondmussel (*Ligumia nasuta*)

Species or Ecosystem Scientific Name	*Ligumia nasuta* (Eastern Pondmussel)		
Element ID		**Elcode**	
Date (Ctrl + ";" for today's date):	2016-04-06		
Assessor(s):	Dwayne Lepitzki (facilitator), Todd Morris (Molluscs SSC, coauthor), Scott Reid (OMNRF, coauthor), Julie Vanden Bylaardt (coauthor), Dave Zanatta (Molluscs SSC), Joe Carney (Molluscs SSC co-chair, Bev McBride (Secretariat)		
References:			

Overall Threat Impact Calculation Help:

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

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	High (Continuing)	Boat launches and marinas represent a small and very localized threat (less than 1%). Therefore there is a negligible perceived threat based on this small footprint. It would be expected that the animals would be relocated as part of the permit to build a launch or marina. Uncertainty in severity related to efficiency of relocation efforts. Rondeau Bay park is rebuilding a dock
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						Because of location (lakes vs. streams) the species is not subject to trampling by livestock
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy						There is a moratorium on offshore wind power
4	Transportation & service corridors		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Moderate - Slight 1-30%)	High (Continuing)	Lyn Creek may have a bridge/road widening (?) Mitigation from relocation of affected animals reduces the severity
4.2	Utility & service lines						Pipelines (e.g. Eastern Gateway) not applicable to this species based on locations
4.3	Shipping lanes		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	Dredging to maintain shipping lanes is a possible threat, but of negligible scope. Mitigation may be less effective due to depth of dredging, therefore higher severity
4.4	Flight paths						
5	Biological resource use		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	The possible threat is based on the effect on host fish (perch); brook stickleback is a legal bait species; other potential hosts such as panfish (sunfish etc.) all are heavily fished recreationally. However, all host populations appear to be healthy and fishing has a negligible effect on Eastern Pondmussel populations

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	There is a possible threat from ATVs driving in the water and boating, but either has a minimal effect on the species.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	The possible threat is from research activities (e.g. handling, collecting). All known subpopulations will be revisited in next 3 generations. Handling would be the threat, but very few individuals in subpopulation would be handled
7	Natural system modifications	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression						
7.2	Dams & water management/use		Not a Threat	Small (1-10%)	Neutral or Potential Benefit	High (Continuing)	The species is not subject to dams as it is not in rivers. The species is not subject to irrigation in the known locations. Lakes in Rideau waterway system may be affected, but there is no noticeable effect other than making the lakes more stable which could be of benefit
7.3	Other ecosystem modifications	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	*Phragmites* spread would choke out the habitat for these mussels in inland lakes and coastal areas of Lake Erie and Lake Ontario resulting in habitat loss and degradation. Modifications by dreissenids, round goby, riparian removal and modification. Round Goby has a neutral effect on hosts. Dreissenids will not result in a habitat modification where these mussels are found.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Dreissenids represent a threat where they do not occur (some of the inland lakes) and represent an ongoing factor that limits recovery of the Eastern Pondmussel where they co-occur

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Raccoon predation has negligible severity.
8.3	Introduced genetic material						
9	Pollution	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Household sewage & urban waste water	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	Inland lakes with cottages produce wastewater, numerous inputs into the Great Lakes from many urban sources. Includes pharmaceuticals (sex ratio changes) and pollutants of many types that can be directly toxic. Uncertainty in scope and severity revolves around the actual impact and better water treatment
9.2	Industrial & military effluents	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Threat from spills; ongoing and existing contamination in substrates (e.g. Hamilton Harbour); mining and quarrying around Bay of Quinte.
9.3	Agricultural & forestry effluents	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Where the species occurs is a bit removed from actual adjacent agricultural activity and is not as exposed as species in riverine systems, but still may be affected by toxic inputs from agricultural activities. Not as affected as riverine systems. Rondeau Bay and Lyn Creek marsh are both affected by agricultural activity. A manure spill in Lyn Creek affected Lyn Creek marsh. Based on expert opinion during the threats call the greatest threat is considered to be 9.1 (better understanding of impacts on mussels) for the purpose of rolling up.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	Moderate - Low	Good evidence that the Great Lakes is affected by climate change. Question is are the mussels being affected. Models regarding impacts are outside our assessment range (3 generations or 10 years). No current evidence that climate change is currently affecting populations and may even be of benefit to host fishes. This species is found in wetland habitat and even small lake level drops will negatively affect habitat. Considering all at once, but projections are outside window. We really do not know what the effects of climate change on this species will be, and any projections are outside the 10 year/3 generation window.
11.1	Habitat shifting & alteration						
11.2	Droughts						
11.3	Temperature extremes						
11.4	Storms & flooding						