COSEWIC
Assessment and Status Report

on the

Purple Wartyback
Cyclonaias tuberculata

in Canada

THREATENED
2021

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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COSEWIC would like to acknowledge Todd J. Morris, Kelly McNichols-O'Rourke and Meg Sheldon for writing the status report on the Purple Wartyback, *Cyclonaias tuberculata*, in Canada. It was prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by Joseph Carney, Co-chair of the COSEWIC Molluscs Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
www.cosewic.ca

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Purple Wartyback — Provided by authors.

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COSEWIC
Assessment Summary

Assessment Summary – April 2021

Common name
Purple Wartyback

Scientific name
Cyclonaias tuberculata

Status
Threatened

Reason for designation
In Canada, this long-lived, medium-sized, heavy-shelled fresh water mussel is restricted to southwestern Ontario. The species occupies small to large rivers with a range of flow conditions and favours a substrate comprised of cobble, gravel, and sand. It is believed to be extirpated from its historical distribution in the Detroit River and Lake Erie, but still persists in the Ausable, Sydenham, and Thames rivers. The habitat in which this species occurs is projected to continue to decline in quality, as a result of threats that include pollution (agricultural and urban runoff), climate change (droughts), invasive species (dreissenids and Round Goby), and dredging.

Occurrence
Ontario

Status history
Designated Threatened in May 2021

COSEWIC
Executive Summary

Purple Wartyback
Cyclonaias tuberculata

Wildlife Species Description and Significance

Purple Wartyback is a medium-sized freshwater mussel reaching a maximum adult size of approximately 200 mm in Canada. The exterior of the shell is covered in many pustules (raised bumps) which are concentrated on the posterior portion of the shell and extend up onto the beak. The interior of the shell (nacre) is purple in most specimens with heavy serrated pseudocardinal teeth and complete lateral teeth. The species is not sexually dimorphic.

Distribution

Purple Wartyback was historically widespread throughout eastern North America having been recorded in 20 American states and one Canadian province. The historical distribution ranged from southwestern Ontario south to Mississippi, east to North Carolina, and west to Oklahoma. In Canada, this species is only known from southwestern Ontario having been historically recorded in the Detroit, Sydenham, and Thames rivers as well as Lake Erie. The current distribution of Purple Wartyback is similar to its historical distribution but it is believed to now be extirpated from the Detroit River and Lake Erie. In recent surveys, this species has also been observed in the Ausable River and Black Creek (a tributary of the Sydenham River) in southwestern Ontario.

Habitat

Purple Wartyback can be found in small to large rivers in moderate to swift current with various types of substrate including: areas of cobble, gravel, mixed gravel and sand, and mud.

Biology

Purple Wartyback is a dioecious but not sexually dimorphic freshwater mussel species. They are short-term brooders who spawn in Spring and early Summer and release their glochidia (immature juveniles) in late Summer to early Fall. The glochidia are obligate parasites and the Canadian hosts are believed to be Channel Catfish, Black Bullhead and Yellow Bullhead. Age at first maturity is believed to be approximately six years, generation time 10-20 years and maximum age up to 40 years. Adult Purple Wartyback are suspension feeders primarily on algae whereas juvenile mussels feed on interstitial pore water through a combination of pedal (foot) feeding and suspension feeding on algae, detritus and bacteria.

Population Sizes and Trends

Purple Wartyback is believed to be extirpated from its historical distribution in the Detroit River and Lake Erie. Canadian subpopulations still persist in the Ausable River, Sydenham River, and Thames River as well as Black Creek, a North Sydenham River tributary. The estimated subpopulation size of Purple Wartyback in the Ausable, Sydenham, and Thames rivers is 24,000, 5.4 million, and 2.4 million individuals, respectively. The Sydenham and Thames river subpopulations seem to be increasing over time but the Ausable River subpopulation may have decreased in recent years. This species has never been widespread in Canada and its current range mirrors its historical range in riverine systems.

Threats and Limiting Factors

Pollution and Climate Change & Severe Weather represent the two most significant threats to Purple Wartyback in Canada. The three southern Ontario watersheds where the species is still found are predominantly agricultural with high inputs of agricultural runoff, largely through tile drainage systems. Freshwater mussels are sensitive to elevated levels of phosphorus and nitrogen and agricultural waste products. Elevated total suspended solids associated with agricultural watersheds can impair reproduction and lead to decreased feeding in mussels. Freshwater mussels have been identified as a group likely to be highly impacted by climate change in Ontario in part because of their sessile nature and dependence on another animal to complete their life cycle. Data suggest that the Ausable, Sydenham and Thames rivers are highly to extremely vulnerable to the effects of climate change.

Protection, Status and Ranks

Purple Wartyback is not currently federally listed in either Canada or the United States. It is state-listed as endangered in both Mississippi and Wisconsin. The species is not currently listed under Ontario's *Endangered Species Act*.

TECHNICAL SUMMARY

Cyclonaias tuberculata

Purple Wartyback

Mulette verruqueuse

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

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	10-20 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown. Suspected decline based on continuing declines in habitat, but there are insufficient data to determine.
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.unknown b.no c.no
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	5015 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	664 km²
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)	4 (1-5) 1. Ausable River 2. Sydenham River 3. Thames River (including the South Thames and Thames River) 4. North Thames River (above Fanshawe Reservoir) 5. Black Creek (may not be viable population)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown. There has been a decline from historical values prior to Dreissenid mussel invasion of the Great Lakes. There may be a continued decline based on continuing declines in habitat, but there are insufficient data to determine.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown. There has been a decline from historical values prior to Dreissenid mussel invasion of the Great Lakes. There may be a continued decline based on continuing declines in habitat, but there are insufficient data to determine.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown. Suspected decline based on continuing declines in habitat, but there are insufficient data to determine.
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown. Suspected decline based on continuing declines in habitat, but there are insufficient data to determine.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. There is 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"*?	No.
Are there extreme fluctuations in extent of occurrence?	No.
Are there extreme fluctuations in index of area of occupancy?	No.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Ausable R,	24,000 (± 7,000)
Sydenham R.	5,400,000 (± 1,600,000)
Thames R.	2,400,000 (± 1,100,000)
Total	7,824,000 (± 2,707,000)

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

Quantitative Analysis

Is the probability of extinction in the wild 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)

Was a threats calculator completed for this species?
Yes. Completed October 17, 2019.

i. Threat 9: Pollution (MEDIUM impact)
ii. Threat 11: Climate Change and Severe Weather (MEDIUM – LOW impact)
iii. Threat 8: Invasive and other problematic species and genes (LOW impact)

What additional limiting factors are relevant?
Freshwater mussels of the Family Unionidae are obligate parasites and cannot complete their life cycle without a period of encystment on a vertebrate host. Purple Wartyback hosts are believed to be Channel Catfish, Black Bullhead, and Yellow Bullhead.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	U.S. populations in the adjacent Great Lakes states range from vulnerable to possibly extirpated.
Is immigration known or possible?	Possible.
Would immigrants be adapted to survive in Canada?	Likely.
Is there sufficient habitat for immigrants in Canada?	Yes.
Are conditions deteriorating in Canada?[+]	Yes.
Are conditions for the source (i.e., outside) population deteriorating?[+]	Yes.
Is the Canadian population considered to be a sink?[+]	No.
Is rescue from outside populations likely?	No.

Data Sensitive Species

Is this a data sensitive species?	No.

Status History

COSEWIC: Designated Threatened in May 2021

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** B1ab(iii)+2ab(iii)

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

Reasons for designation:
In Canada, this long-lived, medium-sized, heavy-shelled fresh water mussel is restricted to southwestern Ontario. The species occupies small to large rivers with a range of flow conditions and favours a substrate comprised of cobble, gravel, and sand. It is believed to be extirpated from its historical distribution in the Detroit River and Lake Erie, but still persists in the Ausable, Sydenham, and Thames rivers. The habitat in which this species occurs is projected to continue to decline in quality, as a result of threats that include pollution (agricultural and urban runoff), climate change (droughts), invasive species (dreissenids and Round Goby), and dredging.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Population trends are unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened B1ab(iii)+2ab(iii). The EOO (5015 km^2) and IAO (664 km^2) are both below thresholds for Threatened (20,000 km^2 and 5,000 km^2 respectively). There are 5 or fewer locations (a), and there is an observed and projected decline in habitat quality (iii) based on threats from pollution, invasive species, dredging, and climate change.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Estimated number of mature individuals exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Estimated number of mature individuals exceeds thresholds.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

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
(2021)

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
Canadian Wildlife Service

Environnement et Changement climatique Canada
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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Cyclonaias tuberculata

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2021

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Cyclonaias tuberculata* (Rafinesque, 1820)
English common name: Purple Wartyback
French common name: Mulette verruqueuse

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 Williams *et al*. (2017). The authority for French common names in Canada is Martel *et al*. (2007). The current accepted classification of this species is as follows:

Phylum: Mollusca
Class: Bivalvia
Subclass: Paleoheterodonta
Order: Unionida
Superfamily: Unionoidea
Family: Unionidae
Subfamily: Ambleminae
Tribe: Quadrulini
Genus: *Cyclonaias*
Species: *Cyclonaias tuberculata*

Campbell *et al.* (2005) undertook a thorough phylogeny of the North American subfamily Ambleminae and confirmed its place in the Tribe Quadrulini despite the fact that females of the species only use the outer two demibranchs for brooding (ectobranchy) (see **Life Cycle and Reproduction**).

Morphological Description

The following description of Purple Wartyback was adapted from Clarke (1981), Parmalee and Bogan (1998), Metcalfe-Smith *et al.* (2005) and Watters *et al.* (2009) (Figure 1). *Cyclonaias tuberculata* (Purple Wartyback) is laterally compressed to moderately inflated with a circular to sub-quadrate shape. The periostracum is yellow or yellow-green in juveniles and may possess fine green rays. In adults the colour is often yellow-green progressing to reddish-brown and the rays are usually lost. The anterior of the shell remains smooth while the rest of the shell surface is covered in prominent pustules that follow the growth lines. The pustules extend onto the beak (umbonal) region and may form ridges along the dorsal wing. Beaks are low and wide and beak sculpture consists of numerous fine ridges that form a chevron pattern. In Canada adults reach a maximum length of 200 mm.

Figure 1. Live adult Purple Wartyback (*Cyclonaias tuberculata*) (photo from Fisheries and Oceans Canada).

Teeth are massive, heavy and complete. Pseudocardinal teeth are wide and serrated; the lateral teeth are short and slightly curved. Adductor muscle scars are obvious and the pallial line is complete and well-removed from the ventral margin. Nacre is usually purple but may be centrally white with purple outside the pallial line.

Purple Wartyback is one of the most easily identifiable mussels in Canada.

Population Spatial Structure and Variability

There are 3 extant subpopulations of Purple Wartyback in Canada corresponding to the 3 watersheds within which it can still be found (Ausable River, Sydenham River, Thames River).

There is no information specific to the population genetic structure of Purple Wartyback within the Great Lakes. COSEWIC (2016) summarizes the available information on *Quadrula quadrula*, a closely related species within the Tribe Quadrulini and one which also uses catfish/bullheads as hosts. According to microsatellite data, *Q. quadrula* across the Great Lakes represent a single population with high levels of gene flow. Galbraith *et al*. (2015) showed high genetic diversity of *Q. quadrula* within the Sydenham and Thames River subpopulations while Paterson *et al*. (2015) demonstrated evidence of gene flow and isolation by distance within Lake Erie indicating evidence of connectivity. COSEWIC (2016) recommended a single designatable unit for *Q. quadrula* within the Great Lakes – Upper St

Lawrence National Freshwater Biogeographic Zone. Given the taxonomic relatedness and similarity of hosts it is likely that Purple Wartyback demonstrates similar population spatial structure.

Designatable Units

All Canadian subpopulations are located within the Great Lakes – Upper St Lawrence National Freshwater Biogeographic Zone. There is no evidence to suggest the presence of local adaptations (e.g., morphological differences) or significant genetic structure within any Canadian subpopulation.

Special Significance

Freshwater mussels in general play an integral role in the functioning of aquatic ecosystems. They are responsible for numerous water column and sediment processes (size-selective filter-feeding; species-specific phytoplankton selection; nutrient cycling; control of phosphorus abundance; deposit feeding, which decreases sediment organic matter; biodeposition of feces and pseudofeces; and shell colonization) and these have been described in various studies (Welker and Walz 1998; Vaughn and Hakenkamp 2001; Newton *et al.* 2011). Mussels also play a role in the transfer of energy to the terrestrial environment via Muskrat (*Ondatra zibethicus*) and Raccoon (*Procyon lotor*) predation (Neves and Odum 1989).

There is no species-specific Aboriginal Traditional Knowledge in the report. However, Purple Wartyback, like all species, is important to Indigenous peoples who recognize all interrelationships within an ecosystem.

DISTRIBUTION

Global Range

Purple Wartyback was historically widespread throughout eastern North America having been recorded in 20 American states and one Canadian province. The historical distribution ranged from southwestern Ontario south to Mississippi, east to North Carolina, and west to Oklahoma (Figure 2). In the United States it has been recorded in Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, North Carolina, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Virginia, West Virginia, and Wisconsin (NatureServe 2018). Purple Wartyback is now thought to be extirpated from Pennsylvania and South Dakota (NatureServe 2018).

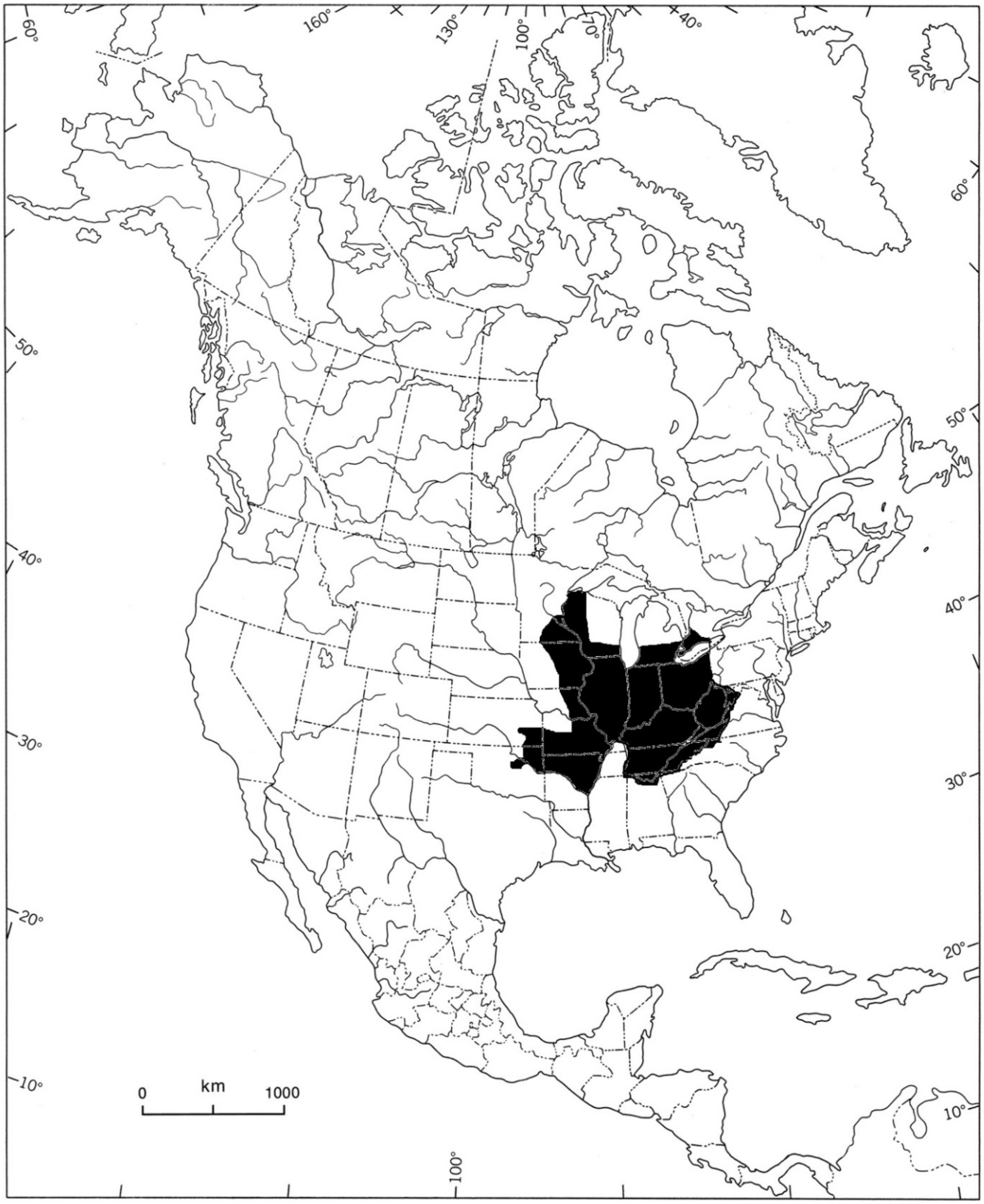

Figure 2. Global distribution of Purple Wartyback (*Cyclonaias tuberculata*).

Canadian Range

In Canada, Purple Wartyback was historically and is currently restricted to southwestern Ontario within the Great Lakes – Upper St. Lawrence National Freshwater Biogeographic Zone. Historical collections of Purple Wartyback included the Detroit, Sydenham, and Thames rivers as well as Lake Erie (Lower Great Lakes Unionid Database 2018; NatureServe 2018). The earliest record of this species in Ontario was an individual of unknown condition (i.e., alive or shell) reported by B. Walker in 1934 from the Detroit River (Lower Great Lakes Unionid Database 2018). The first specified live occurrence was recorded in 1963 in the East Sydenham River by H. D. Athearn (Lower Great Lakes Unionid Database 2018). Since this initial record, 202 records of just under 7,000 live Purple Wartyback have been documented in Ontario (Lower Great Lakes Unionid Database 2018). The Fisheries and Oceans Canada Lower Great Lakes Unionid Database (2018) was used to identify occurrence records for Purple Wartyback. The discussion below is a summary of information contained within this database and where additional data sources or publications were available they have been included (see **COLLECTIONS EXAMINED**).

Historically (prior to 1997), Purple Wartyback was recorded in the Detroit, Sydenham, and Thames rivers and Lake Erie. This historical distribution is based on 66 surveys completed between 1934 and 1996 (Figure 3). Forty-two percent of the historical collections detected live individuals while the remaining 58% represented shell observations or records with individuals of unknown condition. The majority of these records were from incidental observations and no effort details were recorded for any of these historical detections. Recent surveys (1997 to present) have confirmed the persistence of Purple Wartyback subpopulations in the East Sydenham and Thames rivers through both qualitative and quantitative surveys (Figure 4). Additionally, surveys in the Ausable River and Black Creek, a tributary of the North Sydenham River, detected Purple Wartyback expanding its known range to include these southwestern Ontario rivers (Baitz *et al.* 2008). It is believed that this apparent range expansion is the result of increased survey effort resulting in the detection of an existing subpopulation and not a recent physical expansion of the species' range into new habitats.

Surveys detected striking declines of unionid populations after the invasion of Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*D. rostriformis*) in the Detroit River, noting extirpations of numerous species (Schloesser *et al.* 1998). More recent surveys re-examined sites in the Detroit River and determined unionid densities were too low to support viable reproducing populations, concluding that all unionid species have been extirpated from the Detroit River (Schloesser *et al.* 2006).

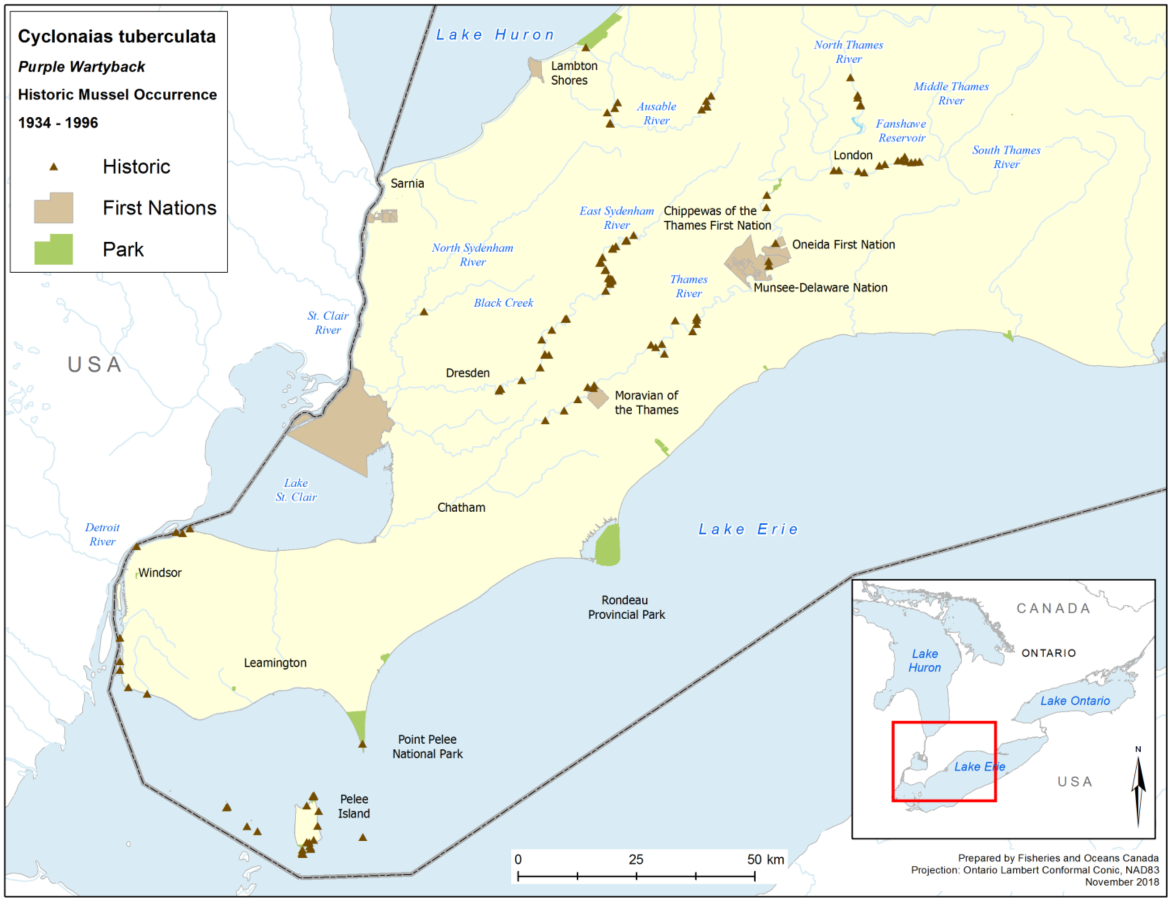

Figure 3. Historical (1934-1996) distribution of Purple Wartyback (*Cyclonaias tuberculata*) in Canada.

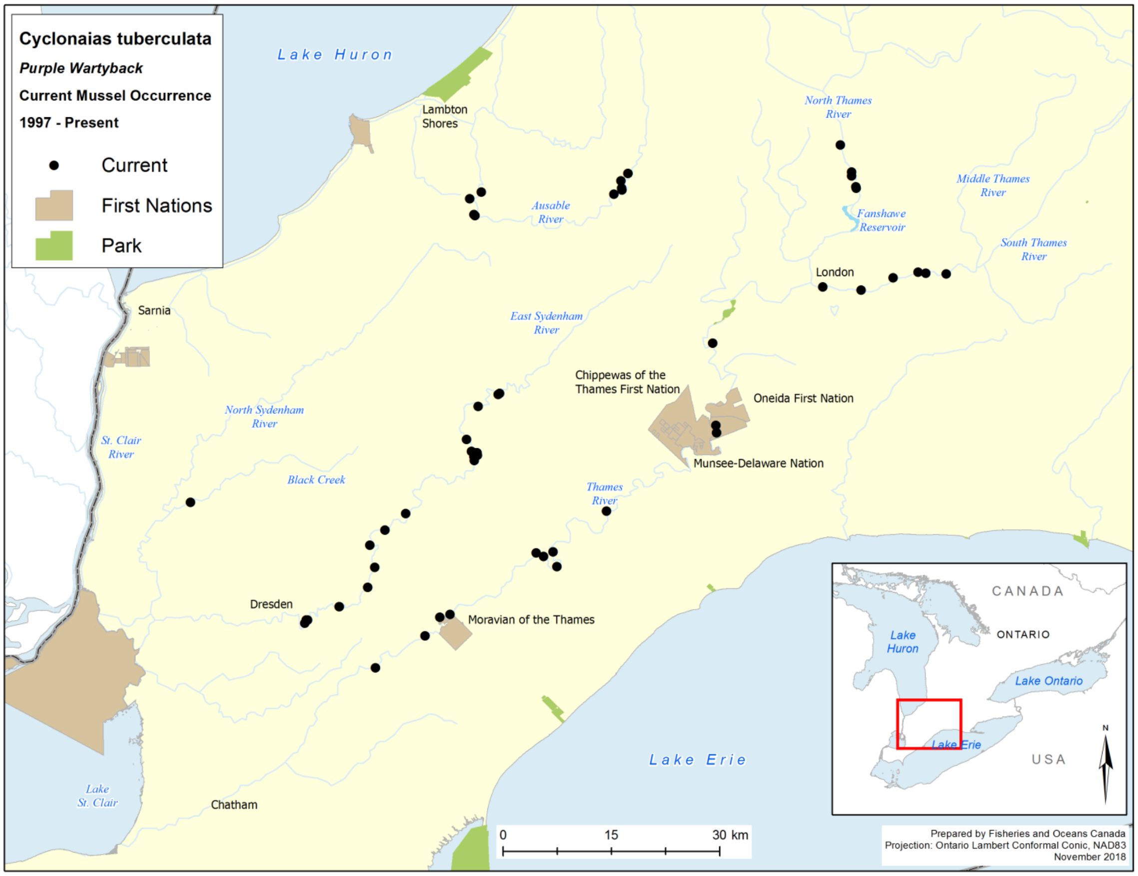

Figure 4. Current (1997-2018) distribution of Purple Wartyback (*Cyclonaias tuberculata*) in Canada.

Ausable River

No historical records exist for Purple Wartyback in the Ausable River as sampling did not begin formally in this waterbody until recent years. Any change in distribution within this system is unknown. The first record in the Ausable River was from a 1998 timed-search survey near Arkona by Environment and Climate Change Canada (previously Environment Canada). Since this initial record, 150 live Purple Wartyback have been observed in the Ausable River between 1998 and 2018 during 19 surveys at 11 unique sites. The current distribution in the Ausable River based on live occurrences is segmented into two separate sections of the river, the first is located around Nairn and the second is north of Arkona.

Sydenham River

The Sydenham River supports the largest Canadian subpopulation of Purple Wartyback. The first record of Purple Wartyback in the Sydenham River watershed was in the East Sydenham River northeast of Shetland in 1963 when five live individuals were observed by H. D. Athearn. Since this initial observation, 6,411 live individuals have been observed during 88 timed-search and quadrat surveys throughout the waterbody. Between

1963 and 1991, 74 live individuals were observed during 23 timed-search surveys or from incidental detections. Live individuals were observed during 91% of these historical surveys. Between 1997 and 2018, 6,337 live Purple Wartyback have been observed during 64 surveys at 23 unique sites. These current occurrences in the Sydenham River stretch from Napier to just upstream of Dresden.

Recent surveys have also occurred in Black Creek, a tributary of the North Sydenham River. There are no historical records of Purple Wartyback in this waterbody but a single live individual was observed as an incidental detection by M. H. King in 2013. This represents the only record of Purple Wartyback in the Sydenham River watershed outside of the East Sydenham River. Whether this single individual indicates the existence of a viable population in Black Creek is undetermined.

Thames River

Purple Wartyback occurs in both the upper Thames River subwatershed, which for the purposes of this report includes the South, Middle, and North branches, and the lower Thames River subwatershed. All sites upstream of the confluence of the three upper Thames River branches, termed The Forks, are considered to be in the upper Thames River subwatershed. All sites downstream of the confluence are considered to be in the lower Thames River subwatershed.

The first record of Purple Wartyback in the upper Thames River subwatershed occurred downstream of the confluence of the Middle and South branches in Dorchester when one fresh shell was reported by the Royal Ontario Museum (ROM) in 1936. The first live Purple Wartyback record in the upper Thames River was also in Dorchester when two individuals were detected during a 1997 timed-search survey. The North Thames River subpopulation was first detected in 2004 when nine live individuals were observed during a timed-search survey (Morris and Edwards 2007). Prior to 1997, four surveys at four unique sites were completed in the upper Thames River which detected no live Purple Wartyback. Since 1997, 157 live Purple Wartyback have been detected during 23 surveys at 15 unique sites. Live individuals were detected at 73% of the sites. The current distribution of Purple Wartyback in the upper Thames River includes a small stretch of the North Thames River directly upstream of Fanshawe Dam to Elginfield Rd (7.1 km) and in the South Branch from Dorchester downstream to London (21.4 km) after the confluence of the Middle Branch (approximately 28.5 km in total).

Purple Wartyback were first recorded in the lower Thames River subwatershed in 1935 when four fresh shells were detected north of Thamesville by J. P. Oughton. The first live record of this species came 30 years later when a single individual was detected at Tate’s Bridge in 1985 by W. G. Stewart. Prior to 1997, a total of two live individuals were recorded during four surveys or incidental detections. Since 1997, recent surveys have detected 239 live Purple Wartyback during 26 surveys at 20 unique sites (Morris and Edwards 2007). Live individuals were detected at 70% of the sites. The known current distribution of Purple Wartyback in the lower Thames River spans from Delaware downstream to Kent Bridge. Because Purple Wartyback has been collected as far downstream as formal surveys have been conducted and because habitat is known to be similar and suitable between the lowest collection point and the river mouth it is believed that Purple Wartyback are likely found downstream of Kent Bridge to the mouth of the river (188.8 km).

Extent of Occurrence and Area of Occupancy

The historical extent of occurrence (EOO) is based on all records collected between 1934 and 2018. All records are included because it is believed that new collection sites during the current period (1997 – 2018) reflect increased sampling effort and do not indicate a range expansion for the species (i.e., Purple Wartyback was likely present at these sites during the historical period; however, these sites were not sampled during that period). Using the convex polygon approach, the historical EOO is 13,643 km^2. By comparison, the current EOO based on collection records between 1997 and 2018 is 5,015 km^2 and represents a 63.2% decline. This decline reflects historical losses due to Dreissenid mussel invasion of the Great Lakes in the late 1980s. The current distribution is believed to be essentially stable since then.

Index of area of occupancy (IAO) was calculated using a 2 km x 2 km grid of non-overlapping squares. A continuous approach was used in areas where Purple Wartyback is found at all or most sites and where habitat is considered to be homogenous and suitable for the species (see **Habitat Requirements**) (e.g., lower Thames River). Areas of Purple Wartyback occurrence separated by unsuitable habitat (e.g., East Sydenham River) or areas of seemingly suitable habitat but where sampling has been conducted without the detection of Purple Wartyback (e.g., East Sydenham River, Ausable River, upper Thames River) have been addressed using a discontinuous approach. The historical (1934 – 2018) IAO is estimated at 896 km^2 while the current (1997 – 2018) IAO is estimated to be 664 km^2. IAO has declined by 25.9%. This decline reflects historical losses due to Dreissenid mussel invasion of the Great Lakes in the late 1980s, due to the loss of sites in and around Lake Erie, and in the Detroit River. The current distribution is believed to be essentially stable since then.

Search Effort

Historical surveys

There are 66 historical records (1934-1994) of Purple Wartyback in Ontario from the Detroit, Sydenham, and Thames rivers as well as Lake Erie around Pelee Island. All of these historical records are incomplete with missing information regarding search effort, sampling method, the condition of the individual (i.e., live individual, fresh shell, weathered shell), and/or the number of individuals detected. The majority of these records come from museum collections and incidental data for which many details, such as search effort, are not known. Of the historical surveys, 42% are based on detections of specified live individuals while the remaining surveys are shell records or specimens of unknown condition.

Current surveys

In comparison to the historical records, almost all of the 135 current Purple Wartyback records (1997-2018) have complete details including information regarding search effort, sampling method, and the condition of the individual. The majority of the surveys in recent years were conducted using either qualitative (timed-search) or quantitative (quadrat) sampling methods; some recent records are still represented by incidental detections which do not include complete details regarding search effort and sampling method. The timed-search and quadrat surveys with complete details provide data on relative abundance or density, respectively. In the Ausable River, ten timed-search surveys (27 person-hours; effort recorded for 6/10 surveys) and nine quadrat surveys (654 m^2 excavated area; Baitz *et al.* 2008; Upsdell *et al.* 2012) have detected live Purple Wartyback. In the Sydenham River, 42 timed-search surveys or incidental detections (436.17 person-hours; effort recorded for 28/42 surveys; Metcalfe-Smith *et al*. 1998; Metcalfe-Smith *et al.* 2000) and 22 quadrat surveys (1,817 m^2; Metcalfe-Smith *et al.* 2007) have detected live Purple Wartyback. In the Thames River, 34 timed-search surveys (121.5 person-hours; effort recorded for 25/34 surveys; Morris and Edwards 2007) and 15 quadrat surveys (1,029 m^2) have detected live Purple Wartyback. None of these surveys were targeting Purple Wartyback but were general searches during which this species was detected. Table 1 summarizes the search effort and sampling methods for all current surveys within the current range of Purple Wartyback. Descriptions of these sampling methods can be found under **Sampling Effort and Methods** in **POPULATION SIZES AND TRENDS**. Figure 5 depicts all historical and current sites surveyed for freshwater mussels within the Canadian range of Purple Wartyback.

Table 1. Summary of current (1997-2018) mussel sampling effort within the current range of the Purple Wartyback (*Cyclonaias tuberculata*). Data include sites surveyed using different methods as well as incidental/observation records. PH refers to the number of person-hours searched for sites where these data were available; the number of PH was not always recorded for each site. Data summarized from the Lower Great Lakes Unionid Database (2018). Additional data sources are listed where applicable. Superscript indicates number of sites with shells only.

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Total Effort	Notes	Other Sources
Ausable River	$2^{1}/10$	1998	39.75 PH (1.5-4.5 PH per site)	Timed-search surveys	
	0/1	1999	No effort recorded.	Timed-search survey	
	0/1	2001	No effort recorded.	Timed-search survey	
	1/4	2002	18 PH (4.5 PH per site)	Timed-search surveys	
	0/2	2003	No effort recorded.	Observational records	
	$0^{1}/8$	2004	36 PH (4.5 PH per site)	Timed-search surveys	
	0/1	2005	No effort recorded.	Observational records	

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Total Effort	Notes	Other Sources
	3/7	2006	506 x 1 m^2 quadrats with excavation (7 sites; 69-75 quadrats per site)	Index station surveys by ABCA	Baitz *et al.* 2008; Upsdell *et al.* 2012
	1/2	2007	66 x 1 m^2 quadrats with excavation (1 site); 4.5 PH	Index station survey by ABCA; timed-search survey	Ausable Bayfield Conservation Authority, unpub. data
	2[1]/12	2008	234 x 1 m^2 quadrats with excavation (3 sites; 57-96 quadrats per site); 18 PH (4.5 PH at four sites)	Index station surveys by ABCA; timed-search surveys by D. Zanatta	Ausable Bayfield Conservation Authority, unpub. data
	0/~~8~~7	2009	174 x 1 m^2 quadrats with excavation 2 sites; 87 quadrats at each site); 9 PH (4.5 PH at two sites)	Index station surveys by ABCA; timed-search surveys by ABCA; timed-search surveys by D. Zanatta	Ausable Bayfield Conservation Authority, unpub. data
	0/1	2010	No effort recorded.	Observational records from ABCA	Ausable Bayfield Conservation Authority, unpub. data
	2/7	2011	534 x 1 m^2 quadrats with excavation (7 sites; 74-80 quadrats per site)	Index station survey by ABCA	Upsdell *et al.* 2012
	1/1	2012	No effort recorded.	Community behaviour study	
	2/3	2013	75 x 1 m^2 quadrats with excavation; (1 site); 5.0 PH (1 site	Index station survey by ABCA; timed-search surveys ; DFO behaviour study	Ausable Bayfield Conservation Authority, unpub. data
	1/4	2018	300 x 1 m^2 quadrats with excavation (4 sites; 75 quadrats per site)	Index station surveys by ABCA	Ausable Bayfield Conservation Authority, unpub. data
Sydenham River	7/8	1997	36 PH (4.5 PH per site)	Timed-search surveys	
	4[1]/5	1998	18.5 PH (4.5-5 PH per site)	Timed-search surveys	
	2/8	1999	147 x 1 m^2 quadrats with excavation (2 sites; 69-78 quadrats per site)	Index station surveys; timed-search surveys	Metcalfe-Smith *et al.* (2007)
	0/1	2000	No effort	Observational record	

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Total Effort	Notes	Other Sources
			recorded.		
	2/18	2001	230 x 1 m^2 quadrats with excavation (3 sites 75-80 quadrats per site)	Index station surveys; timed-search surveys by the University of Guelph	Metcalfe-Smith *et al.* (2007)
	4/43	2002	381 x 1 m^2 quadrats with excavation (5 sites; 72-81 quadrats per site); 4.5 PH (at one site)	Index station surveys; timed-search surveys by the University of Guelph	Metcalfe-Smith *et al.* (2007)
	3/15	2003	387 x 1 m^2 quadrats with excavation (5 sites; 69-84 quadrats per site); 75.67 PH (6-40.67 PH per site)	Index station surveys; timed-search surveys by the University of Guelph	Metcalfe-Smith *et al.* (2007)
	0/2	2004	46 PH (22.67-23.33 PH per site)	Timed-search surveys	
	0/9	2005	40 PH (7.5-20.5 PH per site)	Timed-search surveys by the University of Guelph	
	0/6	2006	20.5 PH (1.5-19 PH per site)	Timed-search surveys by the University of Guelph	
	0/2	2007	16 PH (1-15 PH per site)	Timed-search surveys	
	5/19	2008	168 m^2; 34.52 PH (1.6-10.67 PH per site)	Excavation using a crane mounted clam bucket by G.L. Mackie; Timed-search surveys by D. Zanatta; Timed-search surveys by the University of Guelph	
	0/14	2009	45.97 PH (1.3-12.75 PH per site)	Timed-search surveys by D. Zanatta	
	2/3	2010	37.5 PH (15-22.5 PH per site)	Timed-search surveys; Observational record	
	0/7	2011	102 PH (4.5-32 PH per site)	Timed-search surveys by the University of Guelph	
	6/12	2012	669 x 1 m^2 quadrats with excavation (5 sites; 69-375 quadrats per site); 235 PH (5-192 PH per site)	Index station surveys; timed-search surveys by the University of Guelph	

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Total Effort	Notes	Other Sources
	6/11	2013	375 x 1 m^2 quadrats with excavation (5 sites; 75 quadrats at each site); 120.5 PH (9-60 PH per site)	Index station surveys; timed-search surveys by the University of Guelph; Reproductive study by DFO	
	3/4	2014	60 PH (14-25 PH per site)	Timed-search surveys; Reproductive study by DFO	
	4/7	2015	225 x 1 m^2 quadrats with excavation; 3 sites; 75 quadrats at each site); 24 PH (2-14 PH per site)	Index station surveys; timed-search surveys by the University of Guelph	
	0/5	2016	71 PH (20-27 PH per site)	Timed-search surveys; Observational records by SCRCA	
	8/11	2017	50 x 1 m^2 quadrats with excavation (5 sites; 10 quadrats per site); 64.5 PH (4.5-42 PH per site)	Quantitative surveys at the Sydenham River Nature Reserve; timed-search surveys; Ontario Freshwater Mussel Identification Workshop	
	2/2	2018	22 PH (at one site)	Ontario Freshwater Mussel Identification Workshop	
Thames River	6[3]/11	1997	49.5 PH (4.5 PH per site)	Timed-search surveys	Metcalfe-Smith *et al.* (1998); Metcalfe-Smith *et al.* (2000)
	0/9	1998	22.5 PH (4.5 PH at five sites)	Timed-search surveys	Metcalfe-Smith *et al.* (2000)
	4[2]/21	2004	336 x 1 m^2 quadrats with excavation (5 sites; 63-72 quadrats per site); 72 PH (4.5 PH per site)	Index station surveys; timed-search surveys	Morris and Edwards (2007); Fisheries and Oceans Canada unpub. data
	9/10	2005	69 x 1 m^2 quadrats with excavation (1 site); 40.5 PH (4.5 PH at nine sites)	Index station survey; timed-search surveys	Morris and Edwards (2007); Fisheries and Oceans Canada unpub. data
	0/1	2006	No effort recorded.	Survey by the University of Guelph	
	3/14	2008	18 PH (4.5 PH at four sites)	Timed-search surveys; temporal study	
	0/2	2009	No effort recorded.	Vertical movement behaviour study	

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Total Effort	Notes	Other Sources
	2/8	2010	318 x 1 m^2 quadrats with excavation (5 sites; 15-78 quadrats per site); 1 PH (at one site)	Index station survey; timed-search survey by the University of Guelph; incidental observation	Fisheries and Oceans Canada unpub. data
	0/12	2011	1,069 x 1 m^2 quadrats with excavation (30-999 quadrats per site); 75 PH (1-18 PH per site)	Timed-search surveys with excavation; incidental observation	
	2/9	2012	696 x 1 m^2 quadrats with excavation (10-318 quadrats per site)	Quantitative surveys	
	1[1]/11	2013	636 x 1 m^2 quadrats with excavation (318 quadrats per site); 70 PH (1-33 PH per site)	Relocation with excavation; timed-search surveys	
	0/4	2014	84 PH (14-30 PH per site)	Timed-search surveys	
	3/7	2015	294 x 1 m^2 quadrats with excavation (4 sites; 69-75 quadrats per site; 45.5 PH (12-17.5 PH per site)	Index station surveys; timed-search surveys	Fisheries and Oceans Canada unpub. data
	2/10	2016	375 x 1 m^2 quadrats with excavation (5 sites;75 quadrats excavated at all five sites); 38 PH (4-10 PH per site)	Index station surveys; timed-search surveys	Fisheries and Oceans Canada unpub. data
	2/4	2017	225 x 1 m^2 quadrats with excavation (3 sites; 75 quadrats per site)	Index station surveys; timed-search surveys	Fisheries and Oceans Canada unpub. data
	2/7	2018	300 x 1 m^2 quadrats with excavation (4 sites; 75 quadrats per site); 6 PH (2.5- 3.5 PH)	Index station surveys; timed-search surveys; LTVCA timed-search survey; UTRCA timed-search survey	Fisheries and Oceans Canada unpub. data

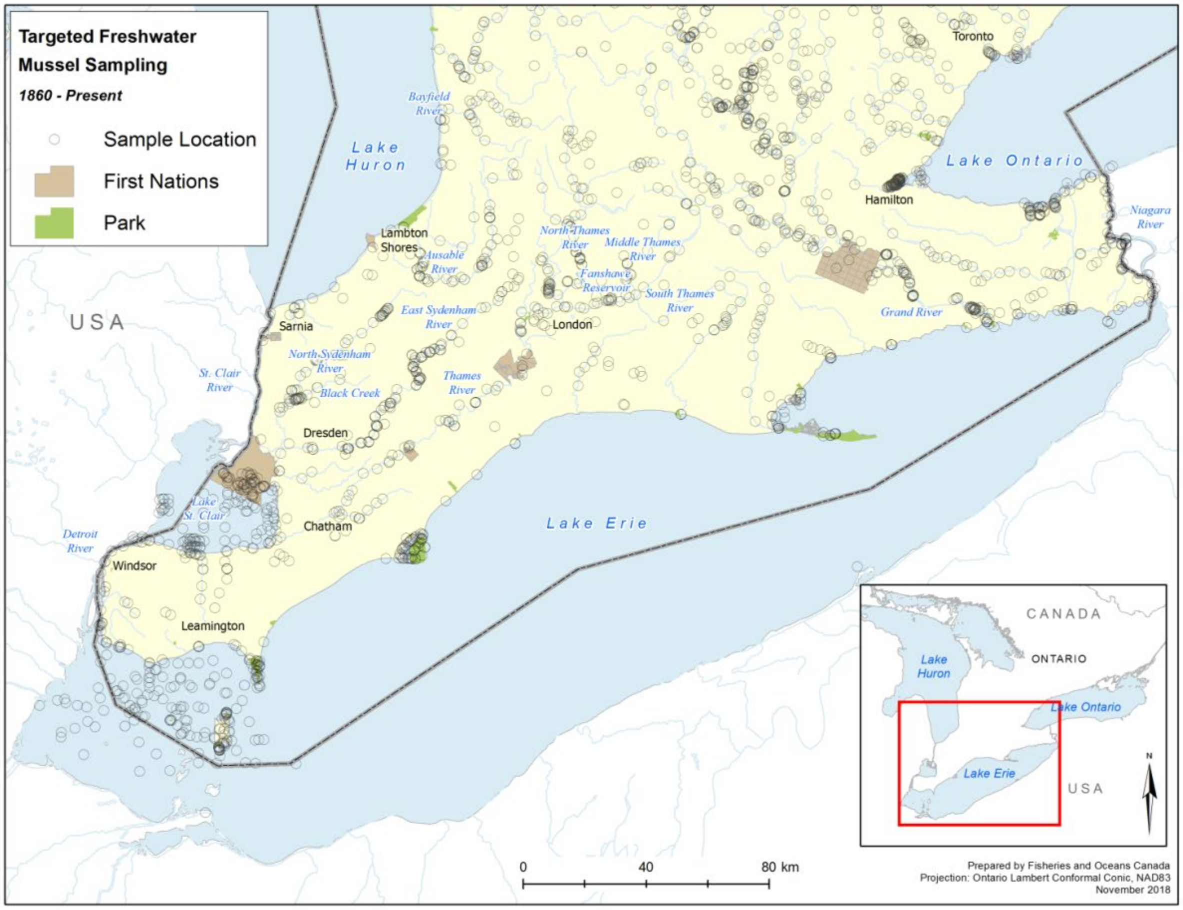

Figure 5. All sites surveyed for freshwater mussels (1860-2018) within the Canadian range of Purple Wartyback (*Cyclonaias tuberculata*).

HABITAT

Habitat Requirements

The following description is a summary of Clarke (1981), Metcalfe-Smith *et al.* (2005), and Watters *et al.* (2009). Purple Wartyback can be found in small to large rivers in moderate to swift current with various types of substrate including: areas of cobble, gravel, mixed gravel and sand, and mud. Specific data on the physical characteristics were available for a number of sites on the Sydenham and Thames rivers where Purple Wartyback have been found (Morris, unpub. data). Purple Wartyback in Ontario are generally found in areas with cobble, gravel, and sand as these made up at least 80% of the substrate in quadrats where the species was observed in both the Sydenham and Thames rivers. Typically, these areas will have moderate to swift current (Metcalfe-Smith *et al.* 2005) and mean water velocities in the Sydenham and Thames rivers were 0.66 and 0.43 m/s, respectively (Morris unpub. data). According to Parmalee and Bogan (1998), Purple Wartyback can be found at depths of 0.6 m up to 6 m; however, during surveys in

Ontario in the summer months, mean water depths were 0.32 m in the Sydenham River and 0.34 m in the Thames River.

Host species for Purple Wartyback have yet to be identified for Canadian populations; however, they have been identified for U.S. populations (see **Life Cycle and Reproduction** below). Channel Catfish, Yellow and Black bullheads are the most likely hosts for Purple Wartyback in Canada. Channel Catfish can be found in moderate to large rivers and lakes (Scott and Crossman 1998; Holm *et al.* 2009) with substrates of sand, gravel or rubble substrate. Unlike bullheads, they do not prefer shallower, turbid areas that are vegetated (Scott and Crossman 1998). The Black Bullhead prefer slow moving streams, backwaters of larger rivers, and lakes that are shallow with soft, silty substrate and cover (e.g., vegetation, logs) (Scott and Crossman 1998; Holm *et al.* 2009). The Yellow Bullhead has similar preferences to the Black Bullhead, although it is generally associated with heavy aquatic vegetation and substrates from muck to gravel (Scott and Crossman 1998).

Habitat Trends

Habitat trends for the Ausable River watershed are summarized from Nelson *et al.* (2003) and Coleman *et al.* (2018). Prior to European settlement, 80% of the basin was covered in forest, 19% was in lowland vegetation, and 1% was marsh. By 1983, 85% of the land area was used for agriculture and over 70% of the basin had some form of tile drainage. Currently, wetlands and forest make up less than 14% of the watershed (Fisheries and Oceans Canada 2018). The population is 45,000 and is largely rural. Phosphorus and nitrate concentrations between 2000 and 2008 were found to be high, often exceeding guidelines; however, nitrate did show a slight decreasing trend during that same timeframe (Upsdell *et al.* 2010). The natural course of the lower portion of the river was destroyed in the late 1800s, when it was diverted in two places to alleviate flooding. The Ausable River has been described as “event responsive”, which means that there are large increases in flow during runoff events following storms. There are 21 dams in the watershed that cause sediment retention upstream and scouring downstream.

Habitat trends for the Sydenham River watershed are summarized from Staton *et al.* (2003), SCRCA (2008, 2018a). Prior to European settlement, the Sydenham River watershed was 70% forest and 30% swamp. Today, the St. Clair region has just over 11% and 1% forest cover and wetland cover, respectively. Sixty percent of the watershed is tile drained. Total phosphorus (TP) concentrations continue to exceed the provincial water quality objective (PWQO – 0.03 mg/L) (Ontario Ministry of Environment and Energy 1994), as they have over the past 30 years. Although levels in the middle and lower east branch of the Sydenham River are some of the lowest in the watershed, they remain 3 and 4 times above the PWQO. According to SCRCA (2008) and Staton *et al.* (2003), since 1990, chloride levels in the Sydenham River have been relatively low but are slowly increasing. Between 2006 and 2016, levels in the Sydenham ranged from 9.4-61 ug/L (SCRCA pers. comm. 2018b). Sediment loadings from overland runoff and tile drains are high and the north branch of the river is particularly turbid. Riparian buffers are important for aquatic health (e.g., bank stabilization, filter nutrients, moderate temperatures), yet they are very limited along parts of the Sydenham River, with only 12-35% within the Purple Wartyback distribution. The human population of the St. Clair Region Conservation Authority is approximately 160,000 (SCRCA 2013) with only two communities along the Sydenham river with a population of over 10,000 (Strathroy and Wallaceburg; SCRCA 2018c). There are sewage treatment plants within the Purple Wartyback distribution that treat effluent before it enters the river and "…an environmental assessment has been initiated for a municipal treatment system for Florence" (SCRCA 2018c). To improve water quality, SCRCA (2013, 2018a) suggests fixing faulty septic systems and establishing a septic maintenance plan.

The Thames River habitat trends are summarized from Taylor *et al.* (2004), UTRCA (2017), and LTVCA (2017, 2019). Agriculture is the dominant form of land use throughout the Thames River watershed (Nürnberg and LaZerte 2015), with 71% of the land area in the upper Thames and 88% in the lower Thames in agricultural use. Forest cover, on the other hand, accounts for only 11% of the land area in the upper Thames and 10.5% in the lower Thames (Lower Thames River Valley Conservation Authority unpub. data). The upper subwatershed is mainly rural, with a population of 539,500 concentrated in the cities of London, Stratford, and Woodstock (UTRCA 2018a). The lower subwatershed is home to almost 100,000 people. As the land was cleared, flooding became a serious problem. To reduce the damages caused by flooding, three large dams and reservoirs were constructed in the upper watershed between 1952 and 1965. Since then, numerous private dams and weirs have been installed and there are now 188 verified structures in the upper subwatershed and 65 in the lower subwatershed. Tile drainage dominates 59% of the land in the entire watershed (Nürnberg and LaZerte 2015). Water quality data collected since the 1970s show that concentrations of phosphorus are stable or declining throughout some parts of the watershed; however, they still remain above the PWQO. In 2017, three large cyanobacteria blooms were observed in the lower subwatershed and the Thames River has been identified as a priority watershed that requires a reduction in phosphorus levels. The upper Thames River hosts 22 wastewater treatment facilities, and the lower Thames River has 8; however, there has been improvement in the treatment facilities' phosphorus levels over time (Maaskant 2014). Nitrate and chloride levels appear to be increasing (UTRCA 2004; PWQMN 2018). The number of reported pollution spills in the upper subwatershed was 390 between 2011-2015, which is lower than the 666 reported between 2006-2010.

BIOLOGY

Purple Wartyback is similar to all freshwater mussels of the unionid family. They are sedentary and as adults live partially or completed burrowed in the substrate found at the bottom of waterbodies. As adults, freshwater mussels suspension feed and obtain nourishment by removing various sizes of particles of organic detritus, algae, and bacteria from the water column, as well as the sediment (Beck and Neves 2003; Nichols *et al.* 2005, Tran 2017). Adult mussels are typically found at the substrate surface during the summer months and are known to burrow below the substrate surface during the winter in response to changing water temperatures and flow regimes (Schwalb and Pusch 2007). Juvenile mussels are believed to burrow completely below the substrate surface where they will spend the first 3-5 years of their life (Neves & Widlak 1987; Balfour and Smock 1995;

Schwalb and Pusch 2007). During this time, growth is accelerated (for two-three years; Watters *et al.* 2009) and they are likely feeding on a combination of detritus, algae, and bacteria obtained from the interstitial pore water or through pedal feeding (Gatenby *et al.* 1997). Purple Wartyback is thought to live up to approximately 40 years of age (Watters *et al.* 2009). Work is underway at Fisheries and Oceans Canada to age Purple Wartyback shells collected from the Sydenham and Thames rivers (Fisheries and Oceans Canada unpub. data). The life history information summarized below comes from a literature review as well as the report writers' knowledge of the species.

Life Cycle and Reproduction

Purple Wartyback, like all members of the Unionidae family, has a complex reproductive cycle that involves the use of a vertebrate host. They are, for the most part, dioecious – out of 233 individuals, Haggerty *et al.* (1995) observed just one instance of hermaphrodism – however, the shell does not exhibit a pronounced sexual dimorphism (Watters *et al.* 2009). During spawning, male Purple Wartyback release sperm into the water and females living downstream filter it out of the water and into their gills. Purple Wartyback are tachytictic (short-term brooder), where spawning occurs in the spring and glochidia are released in that same summer. According to previous studies (Jirka and Neves 1992; Haggerty *et al.* 1995; Boyles 2004), Purple Wartyback spawn between the months of mid-March and June (Jirka and Neves 1992) in the New River (West Virginia and Virginia) and between March and August in the Tennessee River (Tennessee) (Haggerty *et al.* 1995). In Ontario, low numbers of sperm and eggs were observed between early June and August. In October, a much higher number of sperm and unfertilized eggs were observed using fluid samples collected from live individuals (Morris, unpub. data). Both of these observations are consistent with Jirka and Neves (1992) and Haggerty *et al.* (1995) who observed lower numbers of sperm and eggs using histological sections during the summer followed by an increase into the fall. The highest number of sperm and eggs in Jirka and Neves (1992) and Haggerty *et al.* (1995) occurred during the spring and early summer during the spawning period. No data have been collected on Purple Wartyback in Ontario in the early spring.

Female mussels brood their young from the egg to the larval stage in specialized regions of their gills known as marsupia. Purple Wartyback glochidia (immature juveniles) were observed in July 2019 for the first time in Ontario during surveys in the Sydenham River. This is similar to observations by Sietman *et al*. (2012) from the St. Croix River (Minnesota and Wisconsin), where they have been seen from June to August. Jirka and Neves (1992) observed glochidia in the New River (Virginia and West Virginia) from March through June. It is thought that Purple Wartyback brood their glochidia in the outer of the two sets of gills; however, there has been a suggestion that this species can sometimes use all four gills (Frierson 1927 cited in Watters *et al*. 2009). Glochidia develop within the marsupial gills and are released into the water column by the female mussel (see below for further detail). Glochidia are approximately 264 µm in length and 325 µm in height (subelliptical) and lack hooks, which suggests that they are gill parasites (Barnhart *et al.* 2008; Watters *et al.* 2009; Tremblay *et al.* 2015). Further development to the juvenile stage cannot continue without a period of encystment on a vertebrate host, generally a fish.

During encystment the immature juvenile will feed from the body fluids of the host and undergo significant differentiation. Natural glochidial mortality is difficult to estimate but is assumed to be extremely high. In several studies, juvenile metamorphosis and excystment occurred between 17-38 days post-infestation for the Purple Wartyback (Hove *et al.* 1994; Hove 1997; Hove and Kurth 1997). Hove *et al*. (1994) reported a development time of 23-24 days at a temperature of 19±2 ºC.

Laboratory experiments in the United States have shown that host fish for the Purple Wartyback are Black Bullhead (*Ameiurus melas*), Yellow Bullhead (*Ameiurus natalis*), Channel Catfish (*Ictalurus punctatus*), and Flathead Catfish (*Pylodictus olivaris)* (Hove *et al.* 1994; Hove 1997; Hove and Kurth 1997). Host fish identification experiments have not been completed in Ontario; however, similar species are expected to serve as hosts in Ontario. A few Flathead Catfish have been caught in the lower Thames River (Colm *et al.* 2018; Colm, pers. comm. 2018); however, their numbers were not high and they would not be considered a primary host at this time for the Purple Wartyback in Canada. Distributions of Channel Catfish, Black Bullhead and Yellow Bullhead for Ontario are shown in Figures 6, 7, and 8 (Fisheries and Oceans Canada unpub. data). It is likely that Purple Wartyback are using a combination of hosts in the Ausable, Sydenham, and lower portion of the Thames rivers. However, no Channel Catfish have been caught above London in the Upper Thames River watershed (Figure 6); therefore, host use is most likely limited to the bullhead species in this area (Figures 7, 8).

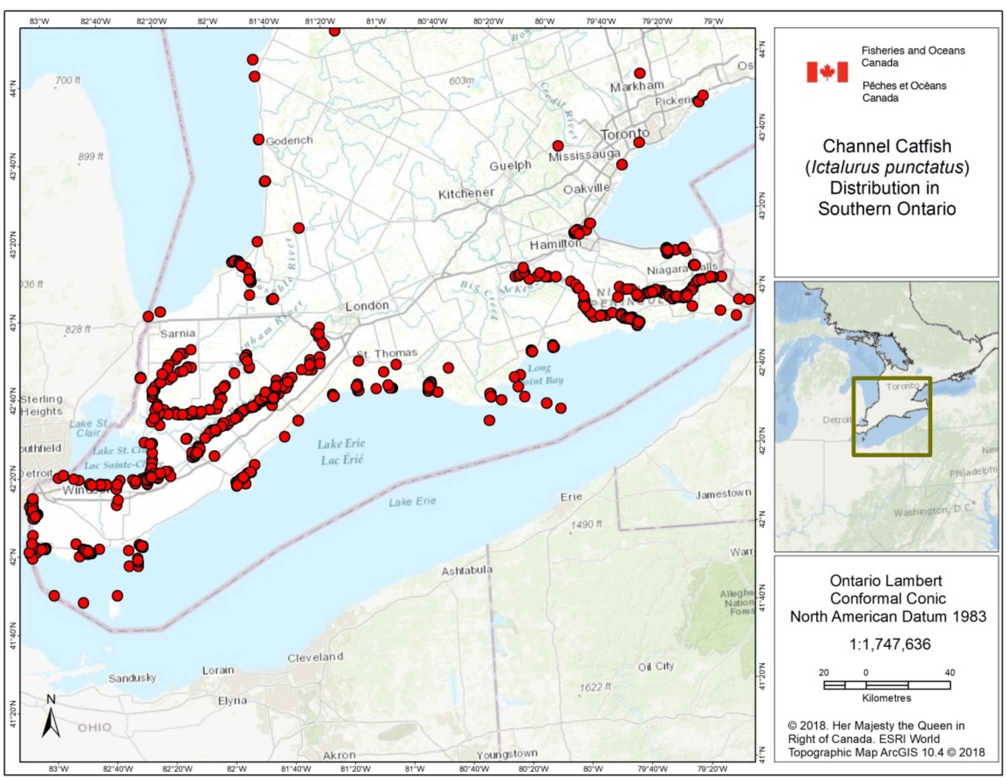

Figure 6. Channel Catfish (*Ictalurus punctatus*) distribution in southwestern Ontario. Data from Fisheries and Oceans Canada.

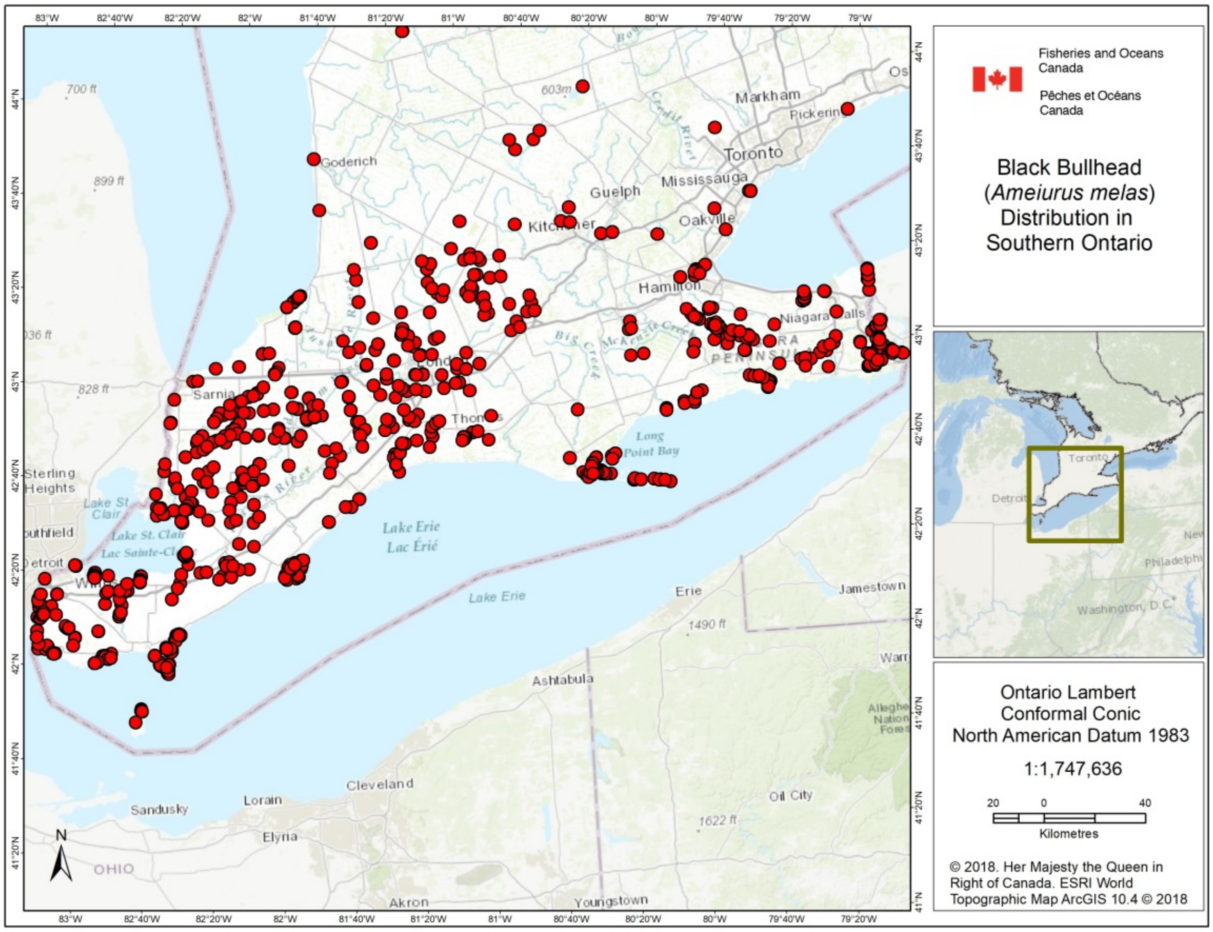

Figure 7. Black Bullhead (*Ameiurus melas*) distribution in southwestern Ontario. Data from Fisheries and Oceans Canada.

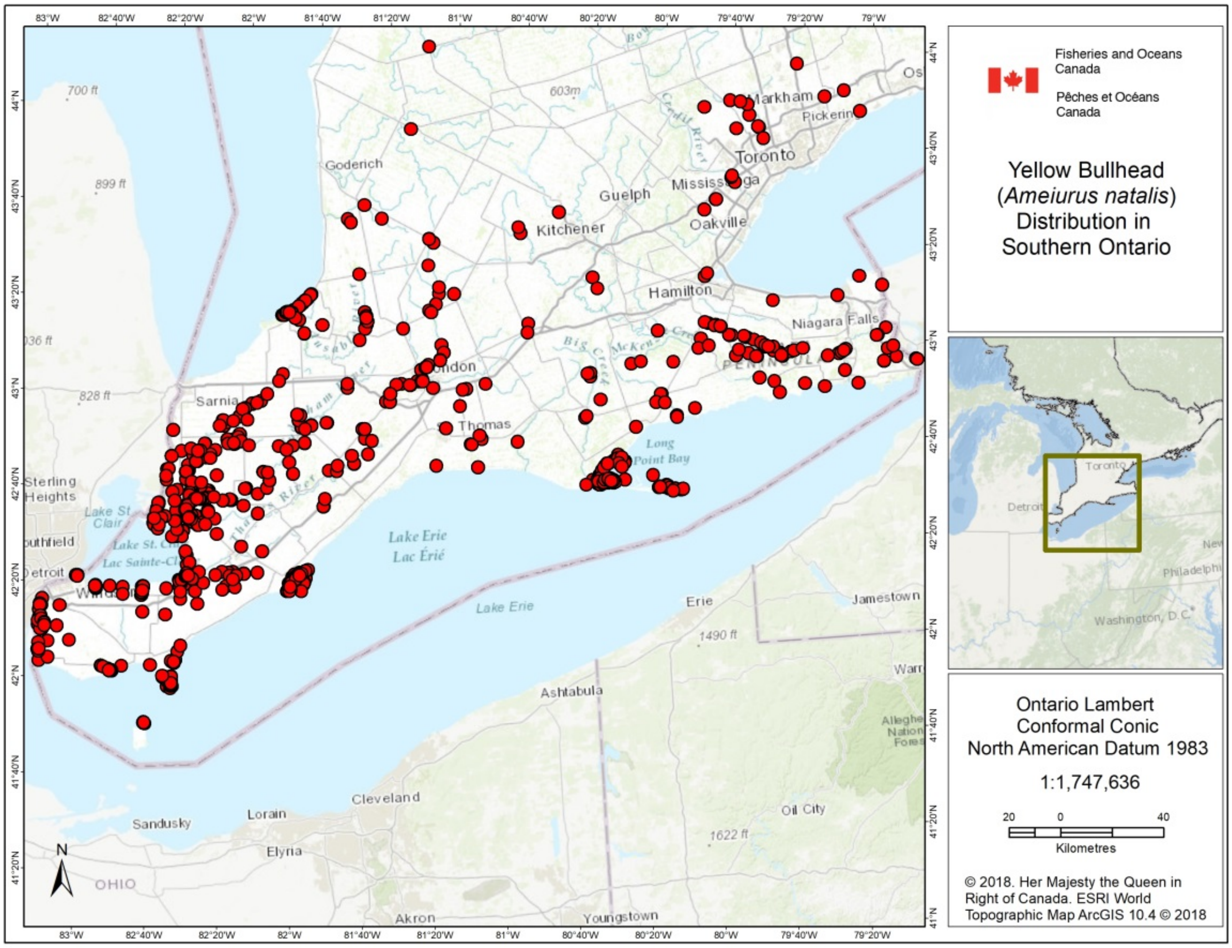

Figure 8. Yellow Bullhead (*Ameiurus natalis*) distribution in southwestern Ontario. Data from Fisheries and Oceans Canada.

After releasing from the host, juveniles settle to the river bottom and begin life as free-living mussels. Juvenile mussels remain burrowed in the sediment for several years until sexual maturity is reached, at which point they migrate to the substrate surface and begin the cycle again (Balfour and Smock 1995). Jirka and Neves (1992) found the youngest sexually mature Purple Wartyback (n = 90) to be 6 years old. Individuals live to between 25 and 40 years of age (Badra 2004; Watters *et al.* 2009; Henley *et al.* 2013; Ecological Specialists, Inc. 2014). Generation time is estimated at between 10-20 years (Woolnough and Bogan 2017).

Many species of freshwater mussels have evolved complex host attraction strategies (e.g., lures, conglutinates, or host-capture tactics) to increase the probability of encountering a suitable host (Barnhart *et al.* 2008). Purple Wartyback appear to exhibit both mantle display and an amorphous conglutinate (Sietman *et al.* 2012). Individuals of this species appear to enact one strategy or the other (i.e., they do not switch between mantle display and conglutinate release). Sietman *et al.* (2012) describe the mantle displays (brooding females) as “stomate-shaped” with a blueish grey colour and faint, dark, spectacles. In the St. Croix River, displays were observed from June into August when temperatures were between 19 and 27°C (Sietman *et al.* 2012). Individuals that release the gelatinous conglutinates were observed during the same time frame as brooding females. The conglutinates (i.e., packages of glochidia) are amorphous and transparent, ranging in size from 5 to 20 cm in length (Sietman *et al.* 2012). Release of conglutinates tends to elicit a predatory response in the host fish causing the rupture of the conglutinate and the release of glochidia.

Physiology and Adaptability

Purple Wartyback, like all freshwater mussels, are heterothermic, and therefore sensitive and responsive to temperature (Mulcrone 2005). Freshwater mussels of the family Unionidae are generally indicators of a healthy ecosystem. They are sensitive to a number of environmental parameters including: turbidity, heavy metals, ammonia, acidity, salinity, urban runoff, wastewater treatment effluents, and copper (Keller and Zam 1991; Huebner and Pynnonen 1992; Goudreau *et al.* 1993; Mummert *et al.* 2003; Gillis *et al.* 2008; Gillis 2011, 2012; Gillis *et al.* 2014; Gillis *et al*. 2017; Tuttle-Raycraft *et al.* 2017). The early life stages (glochidia and juveniles) are the most sensitive to contaminant exposures (Ingersoll *et al.* 2007) (See **THREATS AND LIMITING FACTORS**). Scavia and Mitchell (1989) suggested that recolonization of this species in the Huron River in Michigan occurred because of improved water quality in the area and Watters *et al.* (2009) state that this species requires high water quality. Detailed physiological requirements and tolerances for Purple Wartyback appear to be unknown.

Purple Wartyback are indicative of large river habitats with stable substrate and flowing water (The Adaptive Management Group 2007). Using canonical correspondence analysis and cluster analysis, Ostby (2005) grouped them as a “slow-flow” tolerant guild, but noted that most species in this guild appear to tolerate a wide range of flow conditions. A single relocation project that included moving 68 tagged Purple Wartyback occurred in 2011 in the Thames River in Ontario. Recovery rates were 49.3% and 54.7% after one month and one year, respectively, which is within the average recovery rates found in the literature (Vandenbyllaardt and Morris, unpub. data), suggesting that Purple Wartyback can adapt to certain environmental changes. According to Boyles (2004), Purple Wartyback do have the ability to be held in captive holding conditions for up to 23 months without significant differences in biochemical composition when compared to wild populations.

Dispersal and Migration

Freshwater mussel movement can be directed upstream or downstream in a river system; however, studies have found a net downstream movement through time (Balfour and Smock 1995; Villella *et al.* 2004). Glochidia and juvenile mussels can move downstream after release from the female mussel and fish excystment; however, movement is variable and depends on water flow, hydrodynamics, water temperature and, in the case of juveniles, behaviour (Schwalb *et al.* 2010; Schwalb *et al.* 2011; French and Ackerman 2014). No information was found on movements of adult Purple Wartyback; however, the primary means for unionid dispersal, including upstream movement, and the movement into novel habitats is limited to the encysted glochidial stage on the host fish. Of the host fishes, Channel Catfish are known to move the longest distances as adults at certain times of the year – Channel Catfish have travelled greater than 500 km (Funk 1957; Siddons 2015). Bullhead are capable of small-scale movements; however, no specific information on home range or distance travelled by Black Bullhead was found. Funk (1957) found that most Yellow Bullheads remained within the same 1.6 km or less, and Ball (1944) found that they moved from 0.14 km to 0.91 km.

Interspecific Interactions

Purple Wartyback, like all unionids, rely on a host to complete their lifecycle. Although host fishes have not been confirmed for Purple Wartyback in Canada, host fishes for this species in the United States include Black Bullhead, Yellow Bullhead, Channel Catfish, and Flathead Catfish (Hove *et al.* 1994; Hove 1997; Hove and Kurth 1997). Without the obligate parasitic phase on their host, Purple Wartyback would not be able to complete their lifecycle.

Negative interactions with invasive species in the Great Lakes region have severely impacted freshwater mussel populations. Dreissenid mussels colonize unionids in large numbers leading to detrimental effects on feeding, respiration, movement, and reproduction (Haag *et al*. 1993; Ricciardi *et al.* 1995; Schloesser *et al.* 1997; 1998). In addition, juvenile unionids have been found in gut content analysis from Round Goby caught in the Sydenham River (Poos pers. comm. 2011) and are a sink for glochidial attachment that limits successful recruitment in unionids (Tremblay *et al.* 2016). See **THREATS AND LIMITING FACTORS** for more details.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

None of the historical collections provided details regarding sampling method or survey effort. Estimates of relative abundance (catch-per-unit-effort: CPUE) or density at a site cannot be determined without these data, making it impossible to determine population fluctuations with any level of confidence. While quantitative comparisons between historical and current surveys cannot be made due to unavailable data, these historical surveys provide the foundation of knowledge regarding Purple Wartyback in these waterbodies, and indicate the persistence of the subpopulations over time. It was not until 1997 that wide-scale systematic surveys were completed across southwestern Ontario. In recent surveys, there have been two formal sampling methods that have detected Purple Wartyback; the methodology of each is described below. A number of the recent records represent incidental detections that were not observed using a formal sampling method; these records also do not provide details regarding search effort.

Timed-search survey

In the Ausable, Sydenham, and Thames rivers, Purple Wartyback was detected using an intensive timed-search survey technique. This method is described in detail in Metcalfe-Smith *et al.* (2000) and is summarized briefly here. The riverbed is searched visually for a designated amount of search effort, measured in person-hours (PH). The search effort is generally 4.5 PH, a standard determined to be the suitable amount of effort to detect a high proportion of the rare species at a site. Where visibility is poor and does not accommodate the use of viewers, searching is done by touch. Where water depths do not accommodate the use of viewers or tactile searching, mesh mussel scoops are used. The length of reach searched varies depending on river width, but is generally 100 to 300 m. All live mussels found are identified to species, counted, measured (shell length), sexed (if sexually dimorphic), and returned to the riverbed. Since 1997, 60 timed-search surveys with complete effort details have been completed in the Ausable, Sydenham, and Thames rivers by various researchers (Table 1). Effort varied between sites: 4.5 PH were completed at all Ausable River sites (Baitz *et al.* 2008), effort ranged from 2-192 PH in the Sydenham River (Metcalfe-Smith *et al.* 1998; Metcalfe-Smith *et al.* 2003), and effort ranged from 4.5-12 PH in the Thames River (Metcalfe-Smith *et al.* 1998; Morris and Edwards 2007). One site in the Ausable River was surveyed in 2008 with effort measured by the area hand searched (300 m^2) instead of PH. These surveys were conducted between 1997 and 2017. An additional 27 sites (1998-2018) across the three waterbodies and Black Creek had been surveyed using the visual/tactile methods of a timed-search survey but no effort data were recorded. These records represent informal timed-search surveys, or incidental data, for which CPUE cannot be estimated due to the lack of effort information.

Quantitative survey

Quantitative quadrat surveys detected Purple Wartyback in the Ausable, Sydenham, and Thames rivers. These surveys allowed the generation of precise estimates of demographic variables such as density, size class frequencies, and recruitment levels. The monitoring protocol was adopted from Strayer and Smith (2003) and is summarized briefly here. Sampling was completed by a minimum three-person team over a minimum of two days of work. There was variation in effort, measured by the number of quadrats (area) excavated so the method will be described using the general area sampled at a site. At a site, a 375 m^2 area of the most productive portion of a reach was selected for sampling. This area was often selected based on results of previous qualitative surveys (Metcalfe-Smith *et al.* 2003; Morris and Edwards 2007; Baitz *et al.* 2008). Sites were delineated into 25 blocks of equal size (5 m long x 3 m wide) and each block was subdivided into fifteen 1 m^2 quadrats. Within each block, three quadrats were randomly selected to be sampled and the same three quadrats were sampled in all 25 blocks at a site. This provided a 20% cover of the area (75 m^2 of 375 m^2) at a site. Each quadrat was sampled using three techniques: (1) visual search with the naked eye; (2) visual search with a viewing box; and (3) excavation to a depth of 10-15 cm. All substrate (except large boulders) was removed and the required depth was reached in order to detect juveniles. Young mussels are known to burrow deeply in the substrate for the first three years of life and are generally not detected during visual/tactile surface surveys. All live mussels found in each quadrat were kept in the water in a mesh diver's bag until excavation was complete. All individuals were then identified to species, counted, measured (shell length), sexed (if sexually dimorphic), and returned to the quadrat from which they were detected. While the basics of this sampling method were followed during all 46 surveys completed between 1999 and 2018 throughout the three waterbodies, the number of quadrats ranged widely from 10 to 375 at a site (Fisheries and Oceans Canada unpub. data; Metcalfe-Smith *et al.* 2007; Upsdell *et al.* 2012). One of the Sydenham River sites at Croton was a full site excavation and all 375 m^2 was excavated.

Abundance

To the best of our knowledge, Purple Wartyback no longer occur in the Detroit River (Schloesser *et al.* 2006) or in Lake Erie (Schloesser and Nalepa 1994). At present, this species is restricted to the Ausable, Sydenham, and Thames rivers (Table 2).

Table 2. Current Catch-Per-Unit-Effort (CPUE), density, and population estimates of Purple Wartyback (*Cyclonaias tuberculata*) in the Ausable, Sydenham, and Thames rivers. See Population Sizes and Trends for details on methods.

Locality	CPUE (ind/PH ± SE)	Avg. density (live/m^2 ± SE)	Mean Population Estimate (± SE)
Ausable River	0.61 (± 0.17)	0.09 (± 0.03)	24,000 (± 7,000)
Sydenham River	6.63 (± 2.38)	2.52 (± 0.76)	5,400,000 (± 1,600,000)
Thames River	1.53 (± 0.27)	0.26 (± 0.12)	2,400,000 (± 1,100,000)

<u>Ausable River</u>

Since 1998, 150 live Purple Wartyback have been observed at 20% (9/45) of the sites that have been surveyed in the Ausable River. Shells were observed at an additional three sites. Fifty-four of these individuals were detected during timed-search surveys (1998-2013) at seven sites while the remaining 96 individuals were observed during nine quadrat surveys at five sites (1998-2018). Catch-per-unit-effort (CPUE) for Purple Wartyback in the Ausable River is estimated to be 0.61 (SE ± 0.17) individuals/PH based on data from six sites for which search effort was recorded. Purple Wartyback density in the Ausable River is estimated to be 0.09 (± 0.03) individuals/m^2 based on the search effort data recorded for all nine surveys. The Ausable River subpopulation is estimated to support approximately 24,000 (± 7,000) individuals based on the average waterbody density. The current distribution of Purple Wartyback in the Ausable River appears to be segmented with two separate stretches of inhabited area, the first around Nairn and the second upstream of Arkona representing a total of 18.5 km of river. Figure 9 represents the size distribution for the 102 live individuals that were measured after detection in the Ausable River. This depicts a range of size classes including those indicative of recent recruitment into the subpopulation (Haag and Warren 2007; Metcalfe-Smith *et al.* 2007).

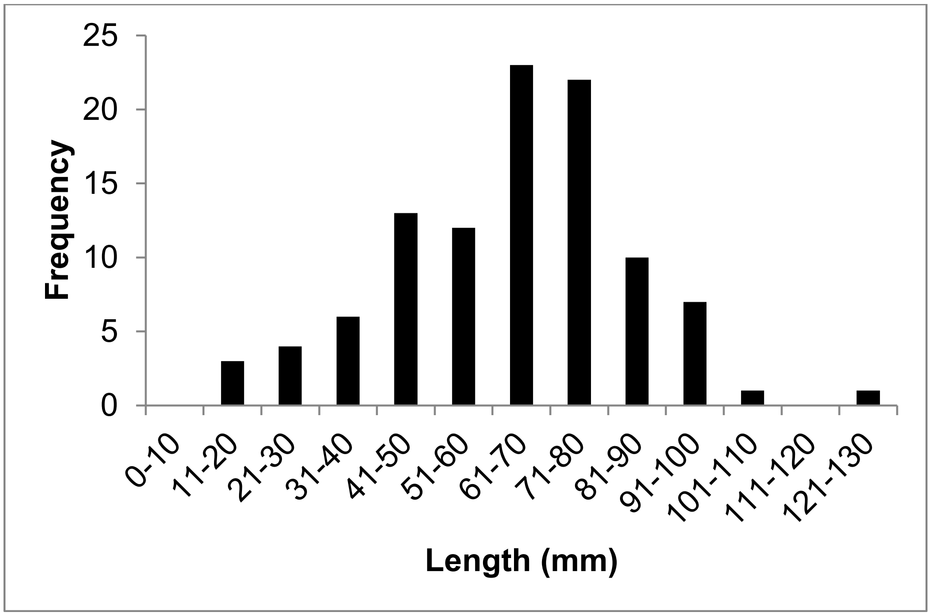

Figure 9. Length frequency distribution of the 102 measured live Purple Wartyback (*Cyclonaias tuberculata*) found during timed-search and quadrat surveys in the Ausable River between 1998 and 2018.

Sydenham River

Since 1997, 6,337 live Purple Wartyback have been observed at 56% (19/34) of the sites that have been surveyed in the Sydenham River and a shell was observed at one additional site. Forty-two timed-search surveys (1997-2018) detected 1,006 of these individuals across 23 sites while 22 quadrat surveys (1999-2015) detected the remaining 5,331 individuals across 12 sites. CPUE for Purple Wartyback in the Sydenham River is 6.63 (± 2.38) individuals/PH based on 28 sites for which search effort was recorded. Purple Wartyback density is estimated to be 2.52 (± 0.76) individuals/m^2 based on the search effort recorded for all 22 surveys. The Sydenham River subpopulation is estimated to support 5.4 million (± 1.6 million) individuals based on the average waterbody density. The current distribution of Purple Wartyback in the Sydenham River is relatively continuous, extending from upstream of Napier to downstream to Dresden (87.2 km of river). Figure 10 represents the size distribution of the 5,807 live individuals that were measured upon detection during timed-search and quadrat surveys in the Sydenham River. Purple Wartyback is represented by a range of size classes in the Sydenham River, including those that indicate recent recruitment into the subpopulation (Haag and Warren 2007; Metcalfe-Smith *et al.* 2007).

A single live Purple Wartyback is the only evidence of this species in Black Creek, a tributary of the Sydenham River. Twenty-seven sites have been surveyed in this waterbody (1997-2018) and this record represents occurrence at 4% of the sites. CPUE and density cannot be estimated as there were no search effort details associated with this record. This individual was not measured; therefore no insight regarding recruitment into the population is available.

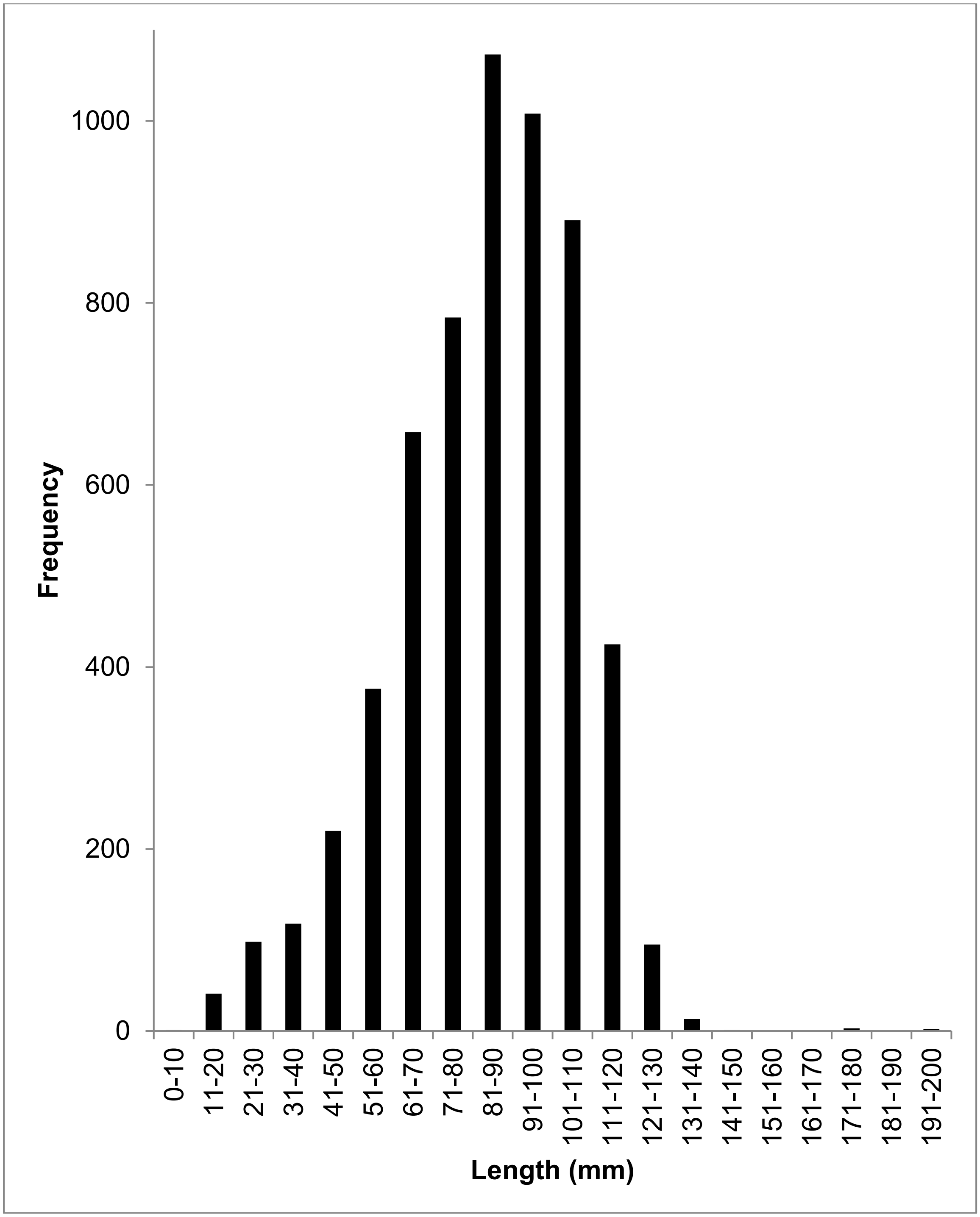

Figure 10. Length-frequency distribution of the 5,807 measured live Purple Wartyback (*Cyclonaias tuberculata*) found during timed-search and quadrat surveys in the Sydenham River between 1997 and 2018.

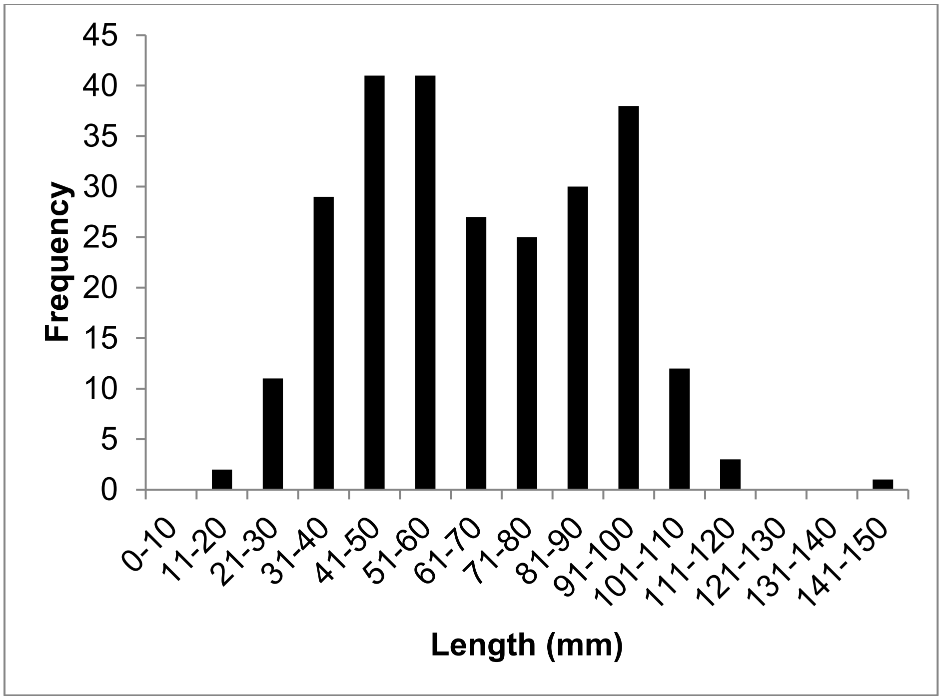

Figure 11. Length-frequency distribution of the 260 measured live Purple Wartyback (*Cyclonaias tuberculata*) found during timed-search and quadrat surveys in the Thames River between 1997 and 2018.

Thames River

Since 1997, 396 live Purple Wartyback have been detected at 29% (22/76) of the sites surveyed in the Thames River. Shells were observed at four additional sites. Thirty-four timed-search surveys detected 194 of these individuals across 30 sites (1997-2016) and the remaining 202 individuals were detected during 15 quadrat surveys across nine sites (2004-2018). Based on search effort data recorded at 24 of these sites, CPUE for Purple Wartyback in the Thames River is calculated to be 1.53 (± 0.27) individuals/PH. Density of Purple Wartyback is calculated to be 0.26 (± 0.12) individuals/m^2 based on search effort data recorded at all 15 surveys. The Thames River subpopulation is estimated to support 2.4 million (± 1.1 million) individuals based on the average waterbody density. The current distribution of Purple Wartyback extends throughout both the upper and lower Thames River. In the upper Thames River subwatershed, Purple Wartyback inhabit the North Thames River above the Fanshawe Dam near Thorndale and the South Thames River from Dorchester to within the City of London boundaries (28.5 km). Distribution is widespread throughout the lower Thames River with live occurrences detected from Delaware to downstream of Thamesville and a likely distribution continuous to the river mouth (188.8 km). Figure 11 represents the size distribution of the 260 live individuals that were measured upon detection during timed-search and quadrat surveys in the Thames River. Purple Wartyback is represented by a range of size classes in the Thames River, including those that indicate recent recruitment into the subpopulation (Haag and Warren 2007; Metcalfe-Smith *et al.* 2007).

Fluctuations and Trends

Ausable River

There can be no comparison between historical and recent distributions because no historical surveys were conducted on the Ausable River. Despite the lack of historical records, it is believed that the Ausable River Purple Wartyback subpopulation existed historically and was only detected during current surveys due to an increase in search effort.

Quadrat surveys in the Ausable River provide the most quantitative insight into fluctuations and trends in Purple Wartyback in recent years. All of the five quadrat sites at which Purple Wartyback have been detected are index stations established as long-term monitoring sites (Upsdell *et al.* 2012). Three of these sites have been surveyed twice, first as an initial survey (2006-2008) and second as a monitoring event (2011-2013; Table 3). The fourth site has been surveyed three times, first as an initial survey (2006) and as a monitoring event for the second and third time (2011, 2018). Density of Purple Wartyback averaged across the four sites from the initial surveys was 0.16 (± 0.06) individuals/m^2. The density during the monitoring events was 25% lower at 0.12 (± 0.05) individuals/m^2. As only one site has been surveyed three times there is no average density but the density at the site decreased from the first monitoring event to the second monitoring event. At the site level, average density of Purple Wartyback decreased at 75% of the sites and remained constant at 25% of the sites. No site experienced an increase in density between the sampling events. Length data was not available for all of the sampling events so a comparison of the presence of recruitment at a site over time is not possible.

Table 3. Comparison of Purple Wartyback (*Cyclonaias tuberculata*) density during initial surveys and monitoring events at four index stations in the Ausable River between 2006 and 2018. * indicates the detection of individuals representing recent recruitment at the sampling event.

[Editorial note: This table has been modified to remove precise location information. Please contact the COSEWIC Secretariat if you require this information.]

Site Code	Latitude	Longitude	Year of Sampling Event	Abundance	Search Effort (m^2)	Density (individuals/m^2)
AUR-AUR-05			2006	2	69	0.03
			2011	0	75	0.00
AUR-AUR-07			2006*	22	69	0.32
			2011	18	75	0.24
			2018	12	75	0.16
AUR-AUR-24			2006*	14	75	0.19
			2011	8	75	0.11
AUR-AUR-36			2008	9	75	0.12
			2013	9	75	0.12

<u>Sydenham River</u>

The lack of search effort data from the historical surveys prevents the comparison of fluctuations and trends between historical and current records. The distribution of Purple Wartyback in the Sydenham River has remained relatively unchanged from historical to current surveys. This species is known from more sites since 1997 but that is related to an increase in search effort in recent years.

The most informative investigation into fluctuations and trends comes from the quadrat surveys completed in the Sydenham River. Ten of the twelve quadrat sites at which Purple Wartyback have been observed are index stations established as long-term monitoring sites (Morris unpub. data). These sites have each been surveyed twice, first as an initial survey between 1999 and 2003 and second as a second follow-up survey between 2012 and 2015 (Table 4). Density of Purple Wartyback averaged across all sites during the initial surveys was 1.56 (± 0.49) individuals/m^2. During the follow-up surveys the density increased to 2.69 (± 0.91) individuals/m^2 (72% increase compared to the initial surveys). At the site level, an increase in density was detected at 80% of the sites. Additionally, during the monitoring events recruitment was detected at 86% (6/7) of the sites where recruitment was detected during the initial surveys (Haag and Warren 2007; Metcalfe-Smith *et al.* 2007). Successful recruitment appears to have remained at a relatively consistent level in the Sydenham River between the two sampling events.

Table 4. Comparison of Purple Wartyback (*Cyclonaias tuberculata*) density during initial surveys and first monitoring events at ten index stations in the Sydenham River between 1999 and 2015. * indicates the detection of individuals representing recent recruitment at the sampling event.

[Editorial note: This table has been modified to remove precise location information. Please contact the COSEWIC Secretariat if you require this information.]

Site Code	Latitude	Longitude	Year of Sampling Event	Abundance	Search Effort (m^2)	Density (individuals/m^2)
SR-01			2002	14	72	0.19
			2012	23	72	0.32
SR-02			2003*	80	78	1.03
			2013*	125	75	1.67
SR-03			1999	11	69	0.16
			2012	30	69	0.43
SR-05			2003*	139	69	2.01
			2015*	251	75	3.35
SR-06			2002*	341	78	4.37
			2012*	2616	375	6.98
SR-07			2003*	173	81	2.14
			2013*	95	75	1.27
SR-10			2001*	47	75	0.63

Site Code	Latitude	Longitude	Year of Sampling Event	Abundance	Search Effort (m^2)	Density (individuals/m^2)
			2013	41	75	0.55
SR-12			1999	33	78	0.42
			2015	123	75	1.64
SR-17			2001*	48	75	0.64
			2012*	166	81	2.05
SR-19			2002*	304	75	4.05
			2013*	646	75	8.61

The single live individual reported in Black Creek does not allow an investigation of the fluctuations and trends of Purple Wartyback in this waterbody. It is not believed that this recent live record is indicative of a range expansion from its historical distribution; this merely represents increased search effort in the waterbody.

Thames River

Similar to the Sydenham River, the lack of search effort data from the historical surveys prevents the comparison of fluctuations and trends between historical and current records. The current distribution of Purple Wartyback in the Thames River is much more extensive than the historical distribution but this is related to a significant increase in search effort in recent years (8 historical surveys vs. 34 current surveys).

The quadrat surveys completed in the Thames River provide valuable insight into current fluctuations and trends of this Purple Wartyback subpopulation. All nine of the quadrat sites at which Purple Wartyback have been detected in the Thames River represent index stations established as long-term monitoring sites (Fisheries and Oceans Canada unpub. data). Seven of these have been surveyed twice, first in an initial survey between 2004 and 2010 and then in a second survey between 2015 and 2017 (Table 5). The average density of Purple Wartyback across the initial surveys was 0.10 (± 0.05) individuals/m^2. During the second survey, Purple Wartyback density was 0.31 (± 0.15) individuals/m^2 (210% increase compared to the initial surveys). Of the seven sites, 86% (6/7) had an increase in density between the sampling events. These seven sites span both the upper and lower Thames River. Additionally, at 43% of the sites individuals representing those recruited into the population within the last 2-3 years were detected and these individuals were not detected at any of the seven sites during the initial surveys (Haag and Warren 2007; Metcalfe-Smith *et al.* 2007). The increased evidence of recently recruited individuals could suggest a shift towards stability at these sites.

Table 5. Comparison of Purple Wartyback (*Cyclonaias tuberculata*) density during initial surveys and first monitoring events at seven index stations in the Thames River between 2004 and 2017. * indicates the detection of individuals representing recent recruitment at the sampling event.

[Editorial note: This table has been modified to remove precise location information. Please contact the COSEWIC Secretariat if you require this information.]

Site Code	Latitude	Longitude	Year of Sampling Event	Abundance	Search Effort (m^2)	Density (individuals/m^2)
TR-03			2004	9	66	0.14
			2015	10	75	0.13
TR-11			2004	3	66	0.05
			2017	8	75	0.11
TR-12			2004	1	63	0.02
			2015	6	75	0.08
TR-25			2010	0	75	0.00
			2017	1	75	0.01
TR-42			2005	6	69	0.09
			2015*	14	75	0.19
TR-50			2010	6	15	0.40
			2016*	85	75	1.13
TR-51			2010	1	75	0.01
			2016*	40	75	0.53

Results relating to fluctuations and trends should be interpreted with caution given the high intra-site and inter-year fluctuations. Reid and Morris (2017) have reported on the difficulty in detecting meaningful changes in densities of freshwater mussel species at risk using the Ontario monitoring protocol because of low population densities and high variability. In addition, little is known about the spatial stability of mussel beds within Ontario rivers.

Rescue Effect

Although some hosts of Purple Wartyback are capable of large-scale movement on the order of tens to hundreds of kilometres (see **Dispersal and Migration**), it is unlikely that the Canadian subpopulations of Purple Wartyback will be subject to rescue from U.S subpopulations as the status of U.S. subpopulations within the Lake Huron and Erie drainages ranges from Vulnerable to Possibly Extirpated (Table 6). In addition, Zanatta *et al.* (2015) surveyed 25 sites in U.S. waters within the Detroit River and the western basin of Lake Erie and found no Purple Wartyback, indicating that rescue of Canadian subpopulations in these waterbodies from U.S. waters is not likely.

Table 6. Sub-national ranks for Purple Wartyback (*Cyclonaias tuberculata*) (NatureServe 2018).

Conservation Rank	Description	Jurisdiction
SH	Possibly extirpated	Pennsylvania, South Dakota
S1	Critically imperiled	Kansas, Minnesota, Mississippi, North Carolina
S2	Imperiled	Illinois, Iowa, Michigan, West Virginia, Wisconsin
S3	Vulnerable	Ohio, Ontario
S4	Apparently secure	Arkansas, Indiana, Kentucky, Missouri, Oklahoma, Tennessee
S5	Secure	Alabama

THREATS AND LIMITING FACTORS

Threats

The main threats to Purple Wartyback populations are pollution and climate change. Additional low impact or negligible threats include invasive species, transportation and service corridors, biological resources, human intrusions and disturbance, and natural systems modifications. The threats identified are based on the Threats Calculator completed on November 27, 2018. It is important to note that these threats may interact directly or indirectly with one another; however, such interactions are not understood, therefore each threat is discussed below in singularity from the highest to lowest calculated impact.

<u>Threat 9: Pollution – MEDIUM IMPACT</u>

Threat 9.3: Agricultural & forestry effluents (Medium-Low)

Globally, water quality is degrading as a result of intense agricultural activities and urbanization of the land (Giri and Qiu 2016). Poole and Downing (2004) suggest that the conversion of natural landscapes to agricultural land is causing habitat destruction and a reduction in biodiversity, using mussels as a specific example in Iowa. As previously mentioned (see **Habitat Trends**), the majority of land in the Ausable, Sydenham, and Thames rivers is used for agricultural purposes, with nutrients often exceeding suggested guidelines.

Freshwater mussels are affected indirectly by poor water quality. Increases in phosphorus and nitrogen loadings can decrease levels of available oxygen by stimulating growth and decomposition of algae and plants as well as loss of habitat (Carpenter *et al.* 1998; NPCA 2010). This will reduce respiration and can cause death (Tetzloff 2001) of mussels, and also have negative impacts on fish communities (Jackson *et al*. 2001), which, in turn, may limit mussel reproduction. Excess nutrients can come from a variety of sources including fertilizers, herbicides, manure, detergents, and waste (Carpenter *et al.* 1998;

UTRCA 2017). Agriculture in southwestern Ontario includes both livestock and crop production, therefore the rivers where Purple Wartyback occur are subject to a variety of these inputs (Nelson *et al.* 2003; Staton *et al.* 2003; Taylor *et al.* 2004).

Loading of suspended solids causing turbidity and siltation is presumed to be one of the primary limiting factors for most aquatic species at risk (SAR) in southern Ontario (DFO 2011; Bouvier *et al.* 2014). Farming practices that may result in increased siltation rates include allowing livestock access to streams (stream bank instability, erosion); installation of tile drainage systems; and clearing of riparian vegetation. Erosion due to poor agricultural practices can result in siltation and shifting substrates that can smother mussels (Williams *et al.* 1993). The transport and increase in abundance of fine particles can degrade stream habitat and interfere with feeding, respiration, growth, and reproduction by clogging gill structures (Wood and Armitage 1997; Strayer and Fetterman 1999; Tuttle-Raycraft *et al.* 2017). In addition, species that burrow completely in the substrate may be more sensitive to sedimentation than most other mussel species because an accumulation of silt on the streambed reduces flow rates and dissolved oxygen concentrations below the surface by clogging interstitial spaces in the stream substrate (Österling *et al.* 2010). Furthermore, the reproductive cycle of this mussel may require visual attraction of a host to either a mantle or conglutinate (Sietman *et al.* 2012) (although there is some suggestion that there could be a chemical cue associated with these lures; Barnhart *et al.* 2008). Increased turbidity would decrease the likelihood that the host fish will be able to visually locate the mantle or conglutinate thereby decreasing overall fitness.

Threat 9.1: Domestic & urban waste water (Medium-Low)

Freshwater mussel life history characteristics make them particularly sensitive to increased levels of sediment contamination and water pollution. Adult mussels feed primarily by filter feeding, while juveniles remain burrowed deep in the sediment feeding on particles associated with the sediment. Evidence suggests that freshwater mussels are sensitive to PCBs, DDT, Malathion, Rotenone, and heavy metals, which can inhibit respiration, accumulate in muscle tissue (Fuller 1974; USFWS 1994,), as well as alter growth, filtration ability, enzyme activity, and behaviour (Naimo 1995). The early life stages (glochidia and juveniles) appear to be particularly sensitive to heavy metals (Keller and Zam 1991; Bringolf *et al.* 2007a, 2007b; Gillis *et al.* 2008), acidity (Huebner and Pynnonen 1992), salinity (Liquori and Insler 1985), and chloride (Gillis 2011). It has been reported that juvenile freshwater mussels are among the most sensitive aquatic organisms to un-ionized ammonia toxicity, typically showing adverse responses at levels well below those used as guidelines for aquatic safety in U.S. waterways (Newton 2003; Newton *et al.* 2003). Roads and urban areas can also contribute significant contaminants to waterways, including oil and grease (Archambault *et al.* 2018b), heavy metals, and chlorides (Gillis 2011). Although most of the surrounding land in the Ausable, Sydenham, and Thames rivers is used for agricultural activities, it is expected that there will be population growth (Ontario Ministry of Finance 2018), especially in the London area of the Thames River. Therefore, it is expected that mussels will continue to be exposed to differing levels of contaminants.

As the population grows and urbanization increases, there is an increase in the amount of wastewater entering aquatic environments. Exposure to municipal effluent can negatively affect unionid health (e.g., Gagné *et al.* (2004), Gagnon *et al.* (2006), Gagné *et al.* (2011)). Pharmaceuticals can enter streams, rivers and lakes, largely via effluent from sewage treatment plants. There is an increasing concern of endocrine and reproductive effects from these chemicals on aquatic biota. Gagné *et al.* (2011) determined that Eastern Elliptio (*Elliptio complanata*) in Quebec showed a dramatic increase in the number of females, and that males showed a female-specific protein downstream of a municipal effluent outfall. This suggests that contaminants and toxic substances are disrupting gonad physiology and reproduction of this species. Experiments by Gillis *et al.* (2014) tested the effect of municipal wastewater effluent on Flutedshell (*Lasmigona costata*) in the Grand River, Ontario. The results showed that mussels placed downstream of the wastewater effluent were negatively impacted based on the physiological stress that was observed through biomarkers and immune status. In addition, Gillis *et al.* (2017) found a 7 km stretch of the Grand River, downstream of a major wastewater treatment plant to be void of mussels and suggested that the poor water quality has either directly or indirectly created an extirpated zone in this system.

<u>Threat 11: Climate Change & Severe Weather – MEDIUM - LOW IMPACT</u>

Threat 11.2: Droughts (MEDIUM - LOW)

At this time, climate change does not appear to be affecting Purple Wartyback sub-populations. A recent paper by Brinker *et al.* (2018) states that “Climate change *will* affect the distribution and abundance of species in the Ontario Great Lakes Basin”; however, the degree to which this will directly affect the riverine mussel populations in the Ausable, Sydenham, and Thames rivers is unknown. Droughts associated with climate change resulting in drying of the river(s) would have a direct lethal impact on this aquatic species. Indirectly, climate change impacts include, but are not limited to: increases in phosphorus, silt and turbidity loadings, altered water flows, flooding, changes to current velocity and water quality, temperature changes, habitat availability, changes in host fish availability or health, as well as interactions between some or all of these, with different effects at different life stages (Hastie *et al.* 2003; Cope *et al.* 2008; Brinker *et al.* 2018; Carpenter *et al.* 2018; Jeffery *et al.* 2018; Modesto *et al.* 2018). Brinker *et al.* (2018) examined the vulnerability of 10 taxonomic groups and molluscs were one of the most vulnerable groups (along with others that depended on water). Purple Wartyback was not specifically included in the six unionid species that were found to be vulnerable (1 extremely, 3 highly, 2 moderately vulnerable). However, much of the vulnerability in unionid mussels is due to the fact that they are sessile animals as adults, and depend on host fishes to complete their lifecycle (Archambault *et al.* 2018a; Brinker *et al.* 2018). Data suggest that the Ausable River, and parts of the Sydenham and Thames rivers are vulnerable to climate change within the Great Lakes basin (Brinker *et al*. 2018).

Threat 8: Invasive & other problematic species & genes – LOW IMPACT

Threat 8.1: Invasive non-native/alien species/diseases (Low)

Since the invasion of Dreissenid mussels (*Dreissena polymorpha*, Zebra Mussel, and *D. rostriformis*, Quagga Mussel) in the 1980s, these species have represented the largest threat to Ontario's freshwater mussels. Almost complete eradication of native unionid mussels has occurred in the lower Great Lakes and their connecting channels including Lake St. Clair, Lake Erie and the Detroit River (Schloesser and Nalepa 1994; Nalepa *et al.* 1996; Schloesser *et al.* 2006). Dreissenids attach to the shells of native mussels using byssal threads and can encrust in the order of hundreds and thousands on one unionid (Schloesser *et al.* 2006). Detrimental effects on unionids are numerous and severe including smothering their siphons, preventing opening and closing of valves, interfering with normal feeding and burrowing activity, and reducing regular function of shell formation, reproduction and survival (Nalepa *et al.* 1996; Schloesser *et al.* 2006). While Dreissenid mussels have been a serious threat to unionids, there is some evidence that the effects from these invasive species are beginning to lessen and are not as pronounced as they had been a decade ago (Strayer and Malcom 2007; Crail *et al.* 2011; Strayer *et al.* 2011). Some evidence has been found that there is a shift towards higher numbers of *D. rostiformis* than *D. polymorpha* in the lower Great Lakes and *D. rostiformis* may have fewer detrimental impacts on native species (Karatayev *et al.* 2015).

The spread of Dreissenids is not extensive within the current distribution of Purple Wartyback, having been detected in the Sydenham and Thames rivers. Zebra Mussel has only been detected in the lower reaches of the Sydenham River, downstream of the known range of the Purple Wartyback subpopulation. Zebra Mussel was first detected in the Fanshawe Reservoir in the North Thames River in 2002 and extend downstream throughout the lower Thames River to Thamesville (UTRCA 2018b). Unionids in rivers are less susceptible to Zebra Mussel invasion as the flowing waters in rivers create a refuge for native species (Metcalfe-Smith *et al.* 1998).

Round Goby (*Neogobius melanostomus*) were first detected in North America in 1990 in the St. Clair River and have since been detected in the lower reaches of the Ausable, Sydenham, and Thames rivers (Poos *et al.* 2010). Round Goby has numerous effects on Ontario's native mussels. Predation on juvenile and small adult unionids and loss of reproductive output are direct effects on unionids (Poos *et al.* 2010; Tremblay *et al.* 2016). Indirect effects on unionids are present in the form of detrimental impacts from Round Goby on host fish species through predation on small individuals, competition for food and habitat, and predation on eggs of native species (Ray and Corkum 1997; Poos *et al.* 2010; Tremblay *et al.* 2016). Round Goby has been documented to compete with and prey on numerous native fish species including darters and sculpins (Ray and Corkum 1997; Poos *et al.* 2010). There has not been an investigation on the impacts of Round Goby on catfish or bullhead species. It was believed that Dreissenid mussels accounted for the highest proportion of Round Goby diet, suggesting that juvenile unionids and small species may be at high risk of predation (Ray and Corkum 1997; Poos *et al.* 2010). However, Round Goby in Lake Ontario was found to prey primarily on non-shelled benthic invertebrates, such as amphipods and chironomids (Brush *et al.* 2012). The risk of predation on unionids from Round Goby may be of a lesser extent than initially thought. While Round Goby has been found within the distribution of Purple Wartyback in the Sydenham and Thames rivers, being found downstream in the Ausable River, it is suggested that upstream invasion is progressing and could be a continued threat for Purple Wartyback subpopulations in the future (Poos *et al.* 2010).

Limiting Factors

The most significant limiting factor for unionid mussels is the availability of suitable host fishes. Unionid mussels cannot complete their lifecycle without a parasitic phase on their host. If the host fish populations decline in numbers or disappear completely, recruitment cannot occur and the mussel population will become functionally extinct (i.e., cannot complete their lifecycle) and then disappear. Fish populations should be monitored to ensure that host species populations are present and healthy. The suspected hosts for the Purple Wartyback are from the Ictaluridae family (Channel Catfish, Black and Yellow bullheads – See **Life Cycle and Reproduction**) which are common and widely distributed throughout southwestern Ontario (Fisheries and Oceans Canada unpub. data). As long as these hosts persist in numbers that are able to sustain the mussel population, it does not appear to be a limiting factor for the Purple Wartyback at this time.

Number of Locations

Given the most likely threat to Purple Wartyback (Pollution) and the linear nature of the riverine habitats where Purple Wartyback occurs, the most likely number of locations is four (Ausable River, Sydenham River, North Thames River and Thames River (including the South Thames)). Because all subpopulations are affected by the same threat (pollution) it is possible to consider them as one location; however, it is unlikely that a single threatening event would impact all subpopulations simultaneously given the spatial isolation of the rivers. The maximum number of locations could be five if we consider the single individual collected from Black Creek to represent a viable subpopulation in that tributary..

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Purple Wartyback is not currently federally listed in either Canada or the United States. It is state-listed as Threatened in Michigan (Michigan State University 2019) and endangered in both Mississippi and Wisconsin (Mississippi Natural Heritage program 2015; Wisconsin Department of Natural Resources 2018). The species is not currently listed under Ontario's *Endangered Species Act*.

The collection of freshwater mussels in Ontario requires a collection permit issued by the Ontario Ministry of Natural Resources and Forestry under authority of the *Fish and Wildlife Conservation Act*.

Non-Legal Status and Ranks

Purple Wartyback is listed as globally secure (G5) by NatureServe (2018); however, it is listed on the IUCN Red List as near threatened (NT) (Woolnough and Bogan 2017) and considered by Williams *et al.* (1993) to be of special concern in Canada and the United States. It is considered nationally secure (N5) within the United States; however, in Canada the species is considered vulnerable (N3) (NatureServe 2018). It can be seen from the provincial and state rankings presented in Table 6 that while the species may be secure within the southern core of its distribution it is in decline across the northern portion of its range both within the Great Lakes and the Upper Mississippi River system.

Habitat Protection and Ownership

Stream-side development in Ontario is managed through floodplain regulations enforced by local conservation authorities (COSEWIC 2013).

Other acts that have come into effect that will improve overall water quality for all mussel species include: (1) *Nutrient Management Act*, which regulates the storage and use of nutrients including manure, farmyard runoff and farm washwater; (2) *Clean Water Act*, which protects Ontario's source water via local committees that list existing and potential threats and implement actions that will reduce or eliminate these (OMECP 2018); (3) *Ontario Water Resources Act*, which is directed towards both ground and surface water throughout the province of Ontario with the goal of conserving, protecting and managing Ontario's water resources (OMECP 2018); and (4) *Environmental Protection Act*, which prohibits the discharge of any contaminants (causing negative effects) into the environment, and requires that any spills of pollutants be reported and cleaned up in a timely fashion (OMECP 2018).

A majority of the land adjacent to the rivers where Purple Wartyback is found is privately owned; however, the river bottom is generally owned by the provincial Crown (COSEWIC 2013). Portions of the Thames River population occur adjacent to the Munsee-Delaware First Nation and the Moravian of the Thames. In 2016, Ontario Nature purchased a 193 acre parcel of land within the upper Sydenham River watershed and established the Sydenham River Nature Reserve which includes an approximately 2 km long stretch of the occupied reach in the Sydenham River (Ontario Nature 2018).

Critical Habitat has been identified for two other freshwater mussel species (Round Hickorynut and Kidneyshell) in the Ausable, Sydenham and Thames rivers (Fisheries and Oceans Canada 2013). Actions directed at protecting Critical Habitat for these two species will benefit the protection of Purple Wartyback within these areas.

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- Dr. Judith Girard, Canadian Wildlife Service, Environment and Climate Change Canada / Government of Canada. Oct 3 2018.

Canadian Museum of Nature:

- Dr. Robert Anderson, Research Scientist, Canadian Museum of Nature, Ottawa, Ontario. October 3 2018.

COSEWIC Aboriginal Traditional Knowledge Mollusc subcommittee representative:

- Daniel Benoit, COSEWIC Aboriginal Traditional Knowledge Subcommittee. October 3 2018.

COSEWIC Non-governmental representatives:

- Dr. Danna Leaman, Consultant. October 3 2018.

- Dr. Arne Mooers, Professor, Simon Fraser University, Burnaby, British Columbia. October 3 2018.

- Dr. John Reynolds, Professor, Simon Fraser University, Burnaby, British Columbia. October 3 2018.

Fisheries and Oceans Canada:

- Jennifer Shaw. Science Advisor, Fisheries and Oceans Canada, Ottawa, Ontario. October 3 2018.

Lower Thames River Valley Conservation Authority:

- Jason Wintermute, Manager, Watershed and Information Services. Dec 5 2018 & Sep 5 2019.

Minnesota Department of Natural Resources:

- Mike Davis, Project Manager, DNR Ecological and Water Resources, Lake City, Minnesota. August 15 2018.

- Bernard Sietman, Malacologist, DNR Ecological and Water Resources, Lake City, Minnesota. August 15 2018.

National Defence:

- Rachel McDonald, Senior Environmental Advisor, National Defence, Ottawa, Ontario. October 3 2018.

Ontario Ministry of Natural Resources and Forestry:

- Dr. Christina Davy, Wildlife Research Scientist, Species at Risk, Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. October 3 2018.
- Colin Jones, Ontario Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. October 3 2018.
- Dr. Scott Reid, Aquatic Endangered Species Research Scientist, Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. October 3 2018.
- Ontario Natural History Information Centre:
- email request, NHICrequests@ontario.ca. October 3 2018.

Parks Canada:

- Dr. Shelley Pruss, Species conservation specialist, Natural Resources Conservation Branch, Parks Canada, Fort Saskatchewan, Alberta. October 3 2018.
- St. Clair Region Conservation Authority:
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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Dr. Todd J. Morris is a Research Scientist with the Great Lakes Laboratory for Fisheries and Aquatic Sciences with Fisheries and Oceans Canada in Burlington, Ontario, Canada. He has a B.Sc. (Hons.) in Zoology from the University of Western Ontario (1993), a Diploma in Honours Standing in Ecology and Evolution from the University of Western Ontario (1994), an M.Sc. in Aquatic Ecology from the University of Windsor (1996) and a Ph.D. in Zoology from the University of Toronto (2002). Dr. Morris's research interests focus on the biotic and abiotic factors structuring aquatic ecosystems and he has worked with a wide variety of aquatic taxa ranging from zooplankton to predatory fishes. He has been studying Ontario's freshwater mussel fauna since 1993, has authored three recovery strategies addressing eight COSEWIC listed freshwater mussel species, has authored or co-authored eight COSEWIC status reports and one COSEWIC status appraisal summary, chairs the Ontario Freshwater Mussel Recovery Team and is a member of the Molluscs Specialist Subcommittee of COSEWIC and the American Fisheries Society Endangered Mussels Subcommittee.

Kelly McNichols-O'Rourke is an Aquatic Science Technician with the Great Lakes Laboratory for Fisheries and Aquatic Sciences with Fisheries and Oceans Canada in Burlington, Ontario, Canada. She has a B.Sc. (Hons.) in Marine and Freshwater Biology from the University of Guelph Ontario (2001), and an M.Sc. in Integrative Biology from the University of Guelph (2007). Ms. McNichols-O'Rourke's research interests focus on the life cycle and distribution of native unionids and their host fishes in aquatic ecosystems. She has been studying Ontario's freshwater mussels of the unionid family since 2000, has authored two recovery strategies (edited/updated four) addressing 11 COSEWIC listed freshwater mussel species, and is a member of a number of Recovery Teams including the Ontario Freshwater Mussel Recovery Team.

Meg Sheldon is an Aquatic Science Technician with the Great Lakes Laboratory for Fisheries and Aquatic Sciences with Fisheries and Oceans Canada in Burlington, Ontario, Canada. She has a B.Sc. (Hons.) in Wildlife Biology and Conservation from the University of Guelph Ontario (2016). She has been studying Ontario's freshwater mussels since 2014 with a focus on species distribution.

COLLECTIONS EXAMINED

The following description of the creation of the Lower Great Lakes Unionid Database was taken from (COSEWIC 2013).

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 Fisheries and Oceans Canada's Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario. Original 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) were the primary sources of information, accounting for over two-thirds of the initial data acquired. Janice 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 Ontario Ministry of Natural Resources. The database continues to be updated with new field data and now contains approximately 8,200 records of unionids from Lake Ontario, Lake Erie, Lake St. Clair and their drainage basins as well as several of the major tributaries to lower Lake Huron. The majority of records in the database are now from recent (post-1990) field collections made by Fisheries and Oceans Canada, Environment and Climate Change Canada, provincial agencies, universities, and conservation authorities. This database is the source for all information on Canadian populations of the Purple Wartyback discussed in this report. The status report writers have personally verified live specimens from all populations described in this report.

Appendix 1: THREATS ASSESSMENT WORKSHEET.

Species or Ecosystem Scientific Name	Purple Wartyback (*Cyclonaias tuberculata*)			
Element ID			**Elcode**	
Date:	2019-10-17			
Assessor(s):	Joseph Carney (co-chair), Christina Davy, Dwayne Leptizki (facilitator), Vicki McKay, Kelly McNichols-O'Rourke (status report writer), Todd Morris (status report writer), Sarah Rabideau, Margaret Sheldon (status report writer), David Zanatta			
References:	draft calculator provided along with 6-month COSEWIC status report; teleconference 17 Oct 2019			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	2	1
	D	Low	2	3
Calculated Overall Threat Impact:			High	High
Assigned Overall Threat Impact:			**B = High**	
Impact Adjustment Reasons:				
Overall Threat Comments			Generation time is 10-20 years therefore timeframe for severity and timing is 30-60 years into the future.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Potential impact from creation of new canoe launches along the lower Thames River as there is interest in developing new canoe routes. No development currently happening but most likely to occur within the next 10 years. Population affected from trampling by feet and dragging canoes along the river bottom when canoes launched/taken out. This is a robust, thick shelled species that would be able to withstand some impact so severity could be very low. In addition, these areas are already recognized as critical habitat for other mussel species, therefore, any development would need to pass through review.
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	No conversion of land for agriculture.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Land is highly agricultural along all three waterbodies with many cow farms along rivers. Risk of trampling from cows entering and crossing river. Low severity as species is robust and thick shelled, able to withstand some impact.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy						
4	Transportation & service corridors	D	Low	Small (1-10%)	Extreme - Moderate (11-100%)	High (Continuing)	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Major construction occurring currently and will continue to occur into the future. Many bridges along the Thames River are old and will need to be replaced and maintained in the future. Purple Wartyback distribution overlaps with other listed species so relocations would be required. Severity would be related to animals that don't survive the relocation.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Same as above. Oil & gas pipelines
4.3	Shipping lanes	D	Low	Small (1-10%)	Extreme - Moderate (11-100%)	High (Continuing)	Dredging has not occurred in the lower Thames River in many years (mid 1950s). None expected by Ausable Bayfield Conservation Authority. Sydenham River does have some dredging - not specific to Purple Wartyback sites but in the tributaries near them (conservative estimate of 500 km of dredging in last 10 years) and include cleanouts and new tile/enclosures - some being enclosed and possibly channelized. Looks like this is ongoing. Severity range is high as it is unknown if, in the event of dredging, mitigation measures would be required in the event of a dredge. If required to go through dredge spoil piles to return mussels to river, severity would be significantly lower but still some mortality occurring as some animals would be missed or if some mortality is associated with a relocation. If dredging not mitigated, severity would be extreme as all mussels in dredge spoil would die.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.4	Flight paths						
5	Biological resource use		Negligible	Negligible (<1%)	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	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Host fish fishing: Channel Catfish would be recreational but perhaps not a large fishery. Catch and release is probably not harmful, catch and keep would cause 100% mortality of glochidia on gills. None of the host fish species are game fish so harvesting of the host would be minimal. Harvesting for research: non-lethal sampling methods are generally employed (e.g., swabbing instead of vouchering for genetic analysis) so mortality for research would be very low.
6	Human intrusions & disturbance		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	We know that people are using these systems for recreational purposes (boats, canoes, fishing). Sydenham River has ATVs. Scope is extensive as these activities occur throughout all three rivers and many individuals are exposed to them. Severity is very low as the species is robust and thick shelled and would be able to survive some impact.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	A SARA permit would be required for any work as this species occurs only in the critical habitat of other Species at Risk.
7	Natural system modifications		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
7.1	Fire & fire suppression						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/use		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Is there any channelization going on? Yes in some drains in the SR, not specific to Purple Wartyback sites but near them. Is there "water taking? Water extraction information from Ministry of Environment, Conservation and Parks. All of them appear to have permits for water taking, so it is not a new threat. All are areas of agriculture so we assume there is water taking…how much is the issue. Difficult to relate mortality to water taking, so we do not know how the water taking is impacting Purple Wartyback, therefore Unknown Severity is suggested. Dams are present on all three waterbodies. Thames River has highest abundance and largest structures (e.g., Fanshawe Dam) that prevent no fish passage. Scope is considered pervasive but towards the lower end of the range and is referring specifically to dams.
7.3	Other ecosystem modifications		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Changes in habitat from Alien Invasive Species - Round goby, Common Carp, *Phragmites* (maybe lower Thames). Severity is very low due to habitat this species is found in (riverine vs. wetland). Minimal effect from removing riparian habitat to reopen old canoe launches and create new launches in the lower Thames River.
8	Invasive & other problematic species & genes	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Round Goby directly impact by eating juvenile mussels (this is the primary threat in this category to Purple Wartyback). Zebra Mussel found in Thames River (Fanshawe) and lower Sydenham River but at low abundances. Have not been observed in Ausable River. Zebra Mussel is not likely to invade new areas and only remain a threat in areas they have already invaded (preventing recovery rather than increasing impact). Are they in the Ausable River? Only at the outlet to Lake Huron in Port Franks. Black Carp (molluscivore) a threat but not likely to invade within the near future.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species/diseases	D	Low	Large - Small (1-70%)	Slight (1-10%)	High (Continuing)	Predation by Raccoon and Freshwater Drum. Suggested that Raccoon populations are increasing in Ontario. Have not found support for this fact; uncertain if this is true at all or at least not true for rural areas. Suggested that freshwater drum populations are also increasing. Have not found support for this. Not enough fish data for St. Clair Region Conservation Authority to comment on this. Ausable Bayfield Conservation Authority has some records in the lower Ausable but they haven't caught many over the years. Movement upstream would be limited due to dams and other structures on the waterbodies (Thames River especially). High uncertainty about the scope as unsure about range of freshwater drum in the waterbodies and about raccoon population size. Scope is based mostly off of raccoon predation.
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	
9.1	Domestic & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	All locations of Purple Wartyback are exposed to these threats (high scope). Ausable, Sydenham, and Thames rivers are all heavily agricultural. Thames River has large urban area so the lower Thames River will be exposed to anything that runs off from London. Looked at road salt, wastewater. Some uncertainty around the severity as we are not seeing catastrophic declines but know there is an impact. Severity is moderate because of the combination of all sources and possible synergy.
9.2	Industrial & military effluents	CD	Medium - Low	Large - Small (1-70%)	Moderate - Slight (1-30%)	High - Moderate	Most likely threat is an oil pipeline break. Timing includes both the continuous threats from chronic pollution sources (mostly only in lower end of waterbodies) and the short-term events (e.g., pipe burst). Scope is a large range to capture the impact of a catastrophic event occurring in the Sydenham River (~69% population) as well as the Ausable River (~3% population). Severity is moderate because of the combination of all sources and possible synergy.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	These are ongoing, chronic threats that all mussels are exposed to in sw Ontario. We are not seeing catastrophic declines but there is likely an impact. Severity is moderate because of the combination of all sources and possible synergy.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10	Volcanoes						
10	Earthquakes/tsunamis						
10	Avalanches/landslides						
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Lots of indirect effects. They are sensitive to climate change because they are sessile as adults and rely on a host to complete their lifecycle.
11	Habitat shifting & alteration						Systems are well buffered from acidification.
11	Droughts	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Only threat that would have solely detrimental effects. Scope is high as potential threat to all subpopulations.
11	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Changes in water temperature (below the upper lethal limit of PWB) could be beneficial. Increased temperatures could benefit host species and/or system productivity, in turn benefiting Purple Wartyback. Unknown severity. Scope is high as potential threat to all subpopulations.
11	Storms & flooding		Unknown	Large (31-70%)	Unknown	High (Continuing)	Sydenham, Thames, and Ausable rivers all have highly variable (flashy) water levels. Severity unknown. Could be low as species is robust and adapted to living in large river systems. Would be able to withstand a scouring/storm/flood event.
12	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							