COSEWIC
Assessment and Status Report

on the

Threehorn Wartyback
Obliquaria reflexa

in Canada

THREATENED
2013

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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Threehorn Wartyback — Photo courtesy of Fisheries and Oceans Canada.

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COSEWIC
Assessment Summary

Assessment Summary – May 2013

Common name
Threehorn Wartyback

Scientific name
Obliquaria reflexa

Status
Threatened

Reason for designation
This rare species historically occurred in the Great Lakes drainages including Lake St. Clair, western Lake Erie, and the Grand, Thames, and Detroit rivers. The species has not been found since 1992 in Lake St. Clair and the Detroit River and may be extirpated there due largely to the impacts of Zebra and Quagga mussels. It was last recorded from the Canadian side of Lake Erie in 1997. Pollution (sediment loading, nutrient loading, contaminants and toxic substances) related to both urban and agricultural activities represents a high and continuing threat at the three remaining riverine locations.

Occurrence
Ontario

Status history
Designated Threatened in May 2013.

COSEWIC
Executive Summary

Threehorn Wartyback
Obliquaria reflexa

Wildlife Species Description and Significance

Threehorn Wartyback is a medium-sized freshwater mussel generally reaching 40 mm in adult length (maximum length of 55 and 80 mm reported in Canada and the United States, respectively). The shell is thick, circular to triangular in shape, rounded on the anterior end and bluntly pointed on the posterior. The most obvious characteristic of the Threehorn Wartyback is the single row of 2 - 5 large knobs or “horns” that give rise to the common name of this species. The Threehorn Wartyback is the only member of the genus *Obliquaria* that occurs in Canada.

Distribution

Globally, Threehorn Wartyback is restricted to central North America where it is broadly distributed from the Gulf of Mexico to the Great Lakes. In Canada, the species is only found in the lower Great Lakes region where it historically occurred in Lake St. Clair, the Detroit River, western Lake Erie as well as the Sydenham, Thames and Grand rivers. It is now believed extirpated from the offshore waters of the Great Lakes and connecting channels, remaining only in the Sydenham, Thames and Grand rivers.

Habitat

Threehorn Wartyback are typically found in large rivers with moderate current and stable substrate of gravel, sand and mud.

Biology

Threehorn Wartyback are moderately long-lived (18 years maximum), benthic, burrowing filter-feeders. They are dioecious but lack pronounced sexual dimorphism. Like all other unionid mussels, they are parasitic during the transition from glochidia to juvenile and must attach to a host fish. Common Shiner, Longnose Dace, Silverjaw Minnow and Goldeye have been identified as hosts in the U.S. In Canada, Common Shiner and Longnose Dace are the more likely hosts given distributional overlap.

Population Sizes and Trends

The Great Lakes (lakes St Clair and Erie) and connecting channel (Detroit River) populations appear to have been lost in the last 25 years. Remaining riverine populations in the Sydenham, Thames and Grand rivers are small though appear to still occupy the known historical ranges in these systems. The Thames River population (the only one for which quantitative data exist) is estimated at approximately 100,000 individuals. Threehorn Wartyback appear to have never been a major component of the mussel fauna of Canada, making it difficult to evaluate trends in population sizes.

Threats and Limiting Factors

High-impact threats to extant populations include pollution related to urban and agricultural activities. Of particular importance are sediment loading (which leads to clogging of the gill structures affecting feeding and reproduction), excess nutrient loading (which negatively impacts oxygen content and respiration), and contaminants and toxic substances to which freshwater mussels are highly sensitive. Medium-impact threats include invasive and non-native species including Zebra and Quagga mussels, which have been largely responsible for the loss of the Great Lakes and connecting channel populations, and Round Gobies, which are currently impacting native fish communities including host populations. Recreational activities, including the driving of all-terrain vehicles over sensitive mussel beds in the Sydenham River, are also threatening Threehorn Wartyback populations. Low-impact threats include residential and commercial developments, oil spills and harvest.

Based on the identified high-impact threats, there are 3 locations in Canada: Sydenham River, Thames River and Grand River.

Protection, Status, and Ranks

The federal *Fisheries Act* historically represented the single most important piece of legislation protecting the Threehorn Wartyback and its habitat in Canada. However, recent changes to the *Fisheries Act* have significantly altered protection for this species, and it is unclear at this time if the *Fisheries Act* will continue to provide protection for this species. The collection of freshwater mussels requires a collection permit issued by the Ontario Ministry of Natural Resources under the authority of the *Fish and Wildlife Conservation Act*.

Areas where Threehorn Wartyback populations occur overlap with the distributions of several mussel species protected under Canada's *Species at Risk Act* and the Ontario *Endangered Species Act, 2007*. The Threehorn Wartyback may benefit indirectly from protection afforded to these species or by actions implemented (e.g., research, stewardship and outreach) under the direction of recovery strategies for other mussel species.

TECHNICAL SUMMARY

Obliquaria reflexa
Threehorn Wartyback — Obliquaire à trois cornes
Range of occurrence in Canada (province/territory/ocean): ON

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(2008) is being used)	estimated at 6-12 years or 3 generations (18-36 years)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	inferred decline based on reduction in IAO
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]. The starting point for the current records has been selected as 1997 as it marks the beginning of a more intensive, and ongoing, survey effort throughout the range of the Threehorn Wartyback. Assumes decline in number of individuals is related to decline in IAO.	inferred decline of 73% over 3 generations (18 to 36 years)
[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 (1997 to 2011) and the future.	inferred decline of 73% over 3 generations (18 to 36 years) but rate of decline continuing is not certain
Are the causes of the decline clearly reversible and understood and ceased?	unknown
Are there extreme fluctuations in number of mature individuals?	unknown

Extent and Occupancy Information

Estimated extent of occurrence	7032 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	532 km²
Is the total population severely fragmented?	no
Number of locations∗ Thames River location Sydenham River location Grand River location	3
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	59% decline but rate of decline continuing is not certain
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	73% decline but rate of decline continuing is not certain
Is there an [observed, inferred, or projected] continuing decline in number of populations?	no

∗ See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in number of locations*?	no
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	yes (inferred decline in quality of habitat based on continuing threats to habitat)
Are there extreme fluctuations in number of populations?	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 population)

Population	**N Mature Individuals**
Thames River	est. 100,000
Sydenham River	unknown
Grand River	unknown
Total	100,000+

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

High-impact threats to the three remaining riverine locations have been identified as pollution (sediment loading, nutrient loading and contaminants and toxic substances) relating to both urban and agricultural activities. Medium-level threats include invasive and non-native species (dreissenid mussels and Round Goby) as well as recreational activities (ATV use).

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Threehorn Wartyback are generally in decline throughout the Great Lakes drainage being considered possibly extirpated (SH) in Pennsylvania, imperilled (S2) in Ohio and vulnerable (S3) in Indiana and Wisconsin. They have not been ranked in Michigan. Only Illinois considers the Threehorn Wartyback apparently secure (S4) .	
Is immigration known or possible?	possible but not likely
Would immigrants be adapted to survive in Canada?	likely
Is there sufficient habitat for immigrants in Canada?	likely
Is rescue from outside populations likely?	no

Status History

COSEWIC: Designated Threatened in May 2013.

Status and Reasons for Designation

Status: **Threatened**	**Alpha-numeric code:** B2ab(iii)
Reasons for designation: This rare species historically occurred in the Great Lakes drainages including Lake St. Clair, western Lake Erie, and the Grand, Thames, and Detroit rivers. The species has not been found since 1992 in Lake St. Clair and the Detroit River and may be extirpated there due largely to the impacts of Zebra and Quagga mussels. It was last recorded from the Canadian side of Lake Erie in 1997. Pollution (sediment loading, nutrient loading, contaminants and toxic substances) related to both urban and agricultural activities represents a high and continuing threat at the three remaining riverine locations.	

∗ See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets A criteria but declines of 50% for IAO uncertain.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened B2 with IAO of 532 km^2 (less than 2,000km^2 threshold) with only (a) 3-4 locations, and b(iii), continuing decline in extent and/or quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable
Criterion D (Very Small or Restricted Total Population): Meets D2 Threatened as there are fewer than 5 locations and the species is prone to the effects of human activities that can rapidly alter required habitat but likely not in a short period of time.
Criterion E (Quantitative Analysis): Not performed.

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
(2013)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Obliquaria reflexa* (Rafinesque, 1820)

English common name: Threehorn Wartyback

French common name: Obliquaire à trois cornes

The recognized authority for the classification of aquatic molluscs in Canada is (Turgeon *et al.* 1998). The currently accepted classification for this species is:

Kingdom: Animalia

Phylum: Mollusca

Class: Bivalvia

Subclass: Paleoheterodonta

Order: Unionoida

Superfamily: Unionoidea

Family: Unionidae

Subfamily: Ambleminae

Tribe: Lampsilini

Genus: *Obliquaria*

Species: *Obliquaria reflexa*

Morphological Description

The following description is modified from Watters *et al.* (2009), Metcalfe-Smith *et al.* (2005a), and Clarke (1981). The Threehorn Wartyback (Figure 1) is a medium-sized freshwater mussel generally reaching 40 mm in adult length (maximum length of 55 and 80 mm reported in Canada and the United States respectively). The shell is thick, circular to triangular in shape, rounded on the anterior end and bluntly pointed on the posterior. The most obvious characteristic of the Threehorn Wartyback is the single row of 2 - 5 large knobs or “horns” that give rise to the common name. These knobs extend from the beak to the ventral margin, alternating in position on the left and right valves. The beaks are elevated above the hinge line and curved inward. Beak sculpture is fine with two knobs on the posterior slope (miniature version of adults). The shell can be green, tan or brown with rays (numerous thin rays or a wide, green ray radiating down the row of knobs) present or absent. The posterior slope is often ribbed. The hinge teeth are fully developed and strong. The pseudocardinal teeth (two in the left valve, one in the right) are strong, deeply serrated and triangular in shape. The lateral teeth (two in the left valve, one in the right) are thick, short, and straight or gently curved. The Threehorn Wartyback is easily distinguished from all other Canadian species of freshwater mussels by the large, medial-located knobs that alternate on each valve.

Figure 1. Threehorn Wartyback (*Obliquaria reflexa*) collected from the Grand River. Photo courtesy of Fisheries and Oceans Canada.

Population Spatial Structure and Variability

The remaining Canadian Threehorn Wartyback populations (see **Canadian Range**) are isolated from one another by large distances (12-250 km). Although there is no information available on the genetic structure of this species, Zanatta *et al.* (2007) have shown that genetic isolation exists in Canadian populations of other freshwater mussels over these spatial scales.

Designatable Units

All Canadian populations of Threehorn Wartyback are found within the Great Lakes-Upper St Lawrence National Freshwater Biogeographic Zone. To date, there are no known distinctions among these populations that warrant consideration for designation below the species level.

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 animal 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 Odom 1989). Given that the Threehorn Wartyback appears to have always been a minor component of the freshwater mussel community in Canada, its relative contribution to the above processes is likely minor. The Threehorn Wartyback is the only member of the genus *Obliquaria* found in Canada.

Aboriginal and traditional knowledge (ATK) is not available for *Obliquaria reflexa* (Aboriginal Traditional Knowledge Subcommittee 2012).

DISTRIBUTION

Global Range

The global range (Figure 2) of the Threehorn Wartyback is limited to central North America where it is widely distributed, occurring in 21 American states (Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, West Virginia, and Wisconsin) where it occurs in the Great Lakes, Mississippi River and Mobile River drainages (NatureServe 2011). Within Canada, this species occurs only in the lower Great Lakes drainage of Ontario.

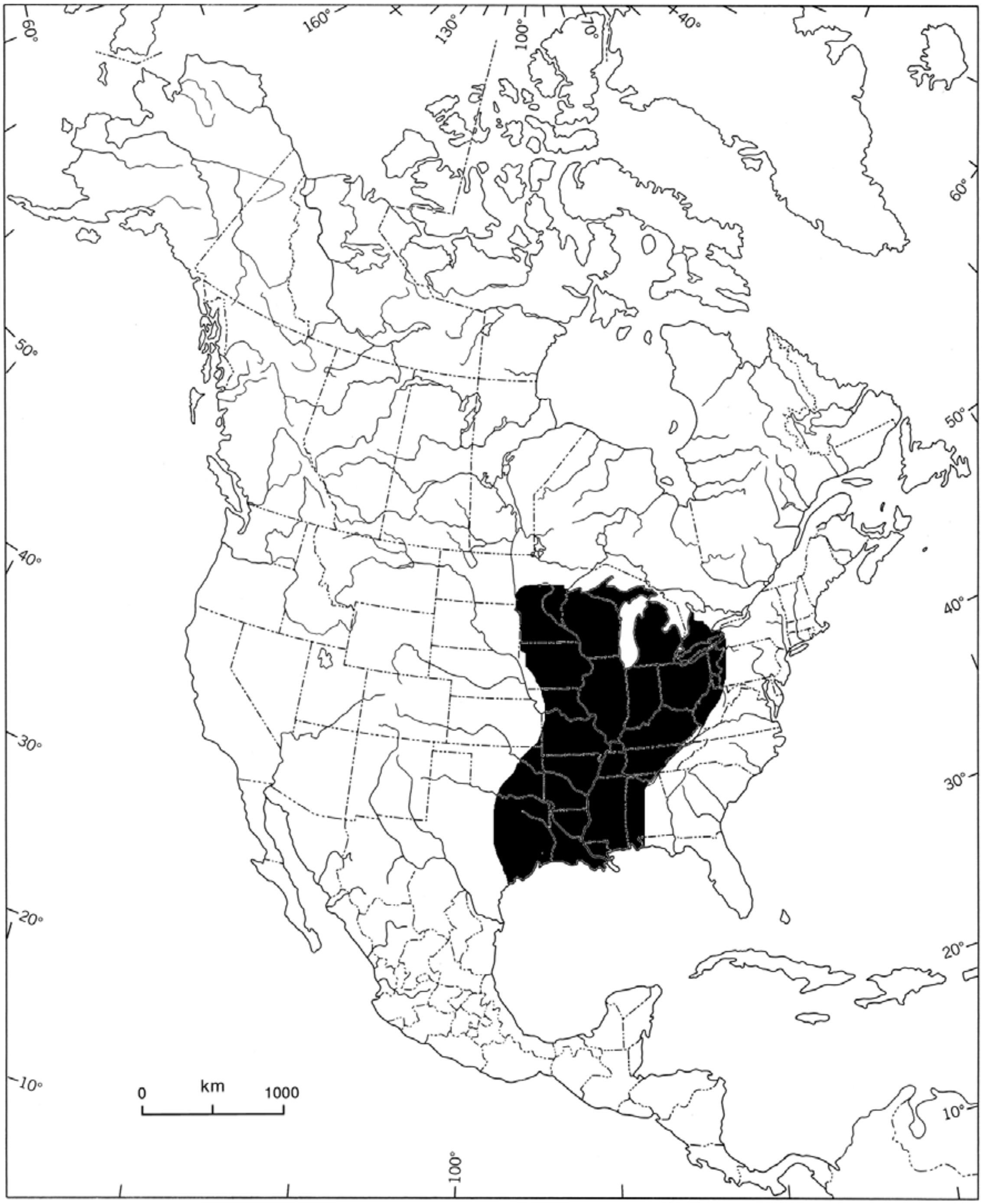

Figure 2. Global distribution of the Threehorn Wartyback (*Obliquaria reflexa*).

Canadian Range

The Threehorn Wartyback historically occurred in the Great Lakes drainage of southern Ontario including Lake St. Clair, western Lake Erie, and the Grand, Thames, and Detroit rivers (Gillis and Mackie 1994; Lower Great Lakes Unionid Database 2011; Figure 3). Currently, it is believed to be extirpated from Lake St. Clair, the Canadian side of Lake Erie and the Detroit River (Schloesser *et al.* 2006; NatureServe 2011), with live individuals remaining in the Sydenham, Thames and Grand rivers.

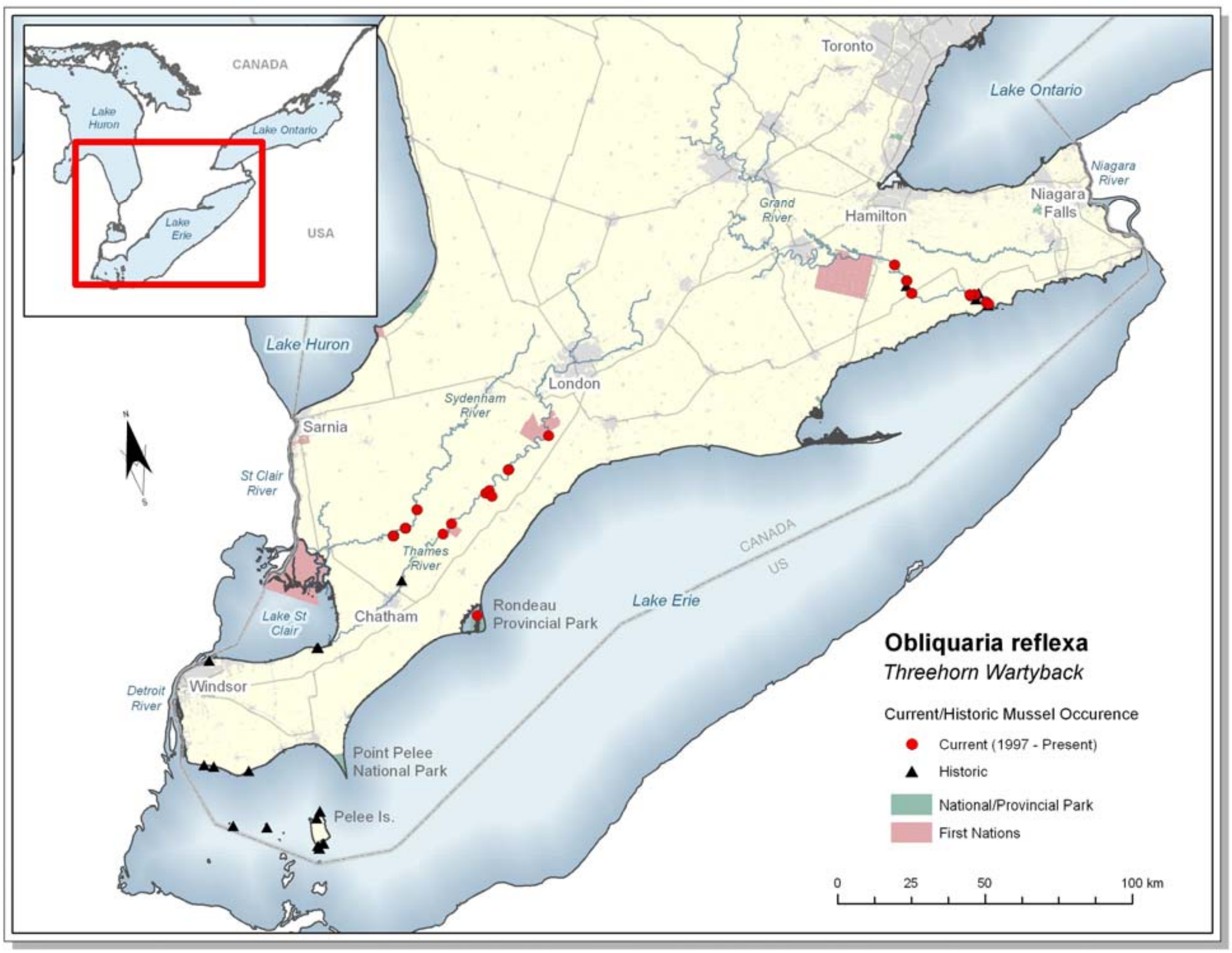

Figure 3. Historical (1890-1996) and current (1997-2011) distribution of the Threehorn Wartyback (*Obliquaria reflexa*) in Canada. Records obtained from the Lower Great Lakes Unionid Database (2011). The 40 sites surveyed in 1961 are not shown because exact locations are unknown.

This species has a fairly restricted range as there are no records of the Threehorn Wartyback from any other Canadian province or territory (Metcalfe-Smith and Cudmore-Vokey 2004). The Threehorn Wartyback has always been a rare species in the faunal record for Canada. One hundred and one records exist for this species in the Lower Great Lakes Unionid Database dating back to 1890 when a fresh valve was detected in the Grand River. The first documented live collection of the Threehorn Wartyback in Canada was not made until 1992 when D.W. Schloesser collected it from the Detroit River. The species was then collected from the Grand River in 1997 and the Thames and Sydenham rivers in 1998. Overall, less than 5% of the Threehorn Wartyback distribution occurs in Canada.

Unionids are dependent on a host, generally a fish, to complete their complex lifecycle (see **Life Cycle and Reproduction**). Although hosts have not been identified for Canadian populations of the Threehorn Wartyback, four fishes have been identified in literature: (1) Common Shiner (*Luxilus cornutus*); (2) Longnose Dace (*Rhinichthys cataractae*); (3) Silverjaw Minnow (*Notropis buccatus*; Watters *et al.* 2009); and (4) Goldeye (*Hiodon alosoides*; Barnhart and Baird 2000). The Common Shiner is native to Ontario and occurs in the southern parts of the Great Lakes-St. Lawrence river drainage (Scott and Crossman 1998; Holm *et al.* 2009). The Longnose Dace is also native to Ontario and is found throughout the province (Holm *et al.* 2009). These two species (Figure 4) have some distributional overlap with the Threehorn Wartyback populations (Figure 5); however, abundances are not high as these fish species tend to prefer small streams and their abundance is not high in areas where this mussel occurs (Barnucz pers. comm. 2011). The Silverjaw Minnow has never been caught in Canada although they are reported as potential invaders (Holm *et al.* 2009). Although Barnhart and Baird (2000) reported natural infestations on Goldeye in the United States, this species does not occur in Southern Ontario (Scott and Crossman 1998; Holm *et al.* 2009). This suggests that other fish species may be acting as hosts in Canada.

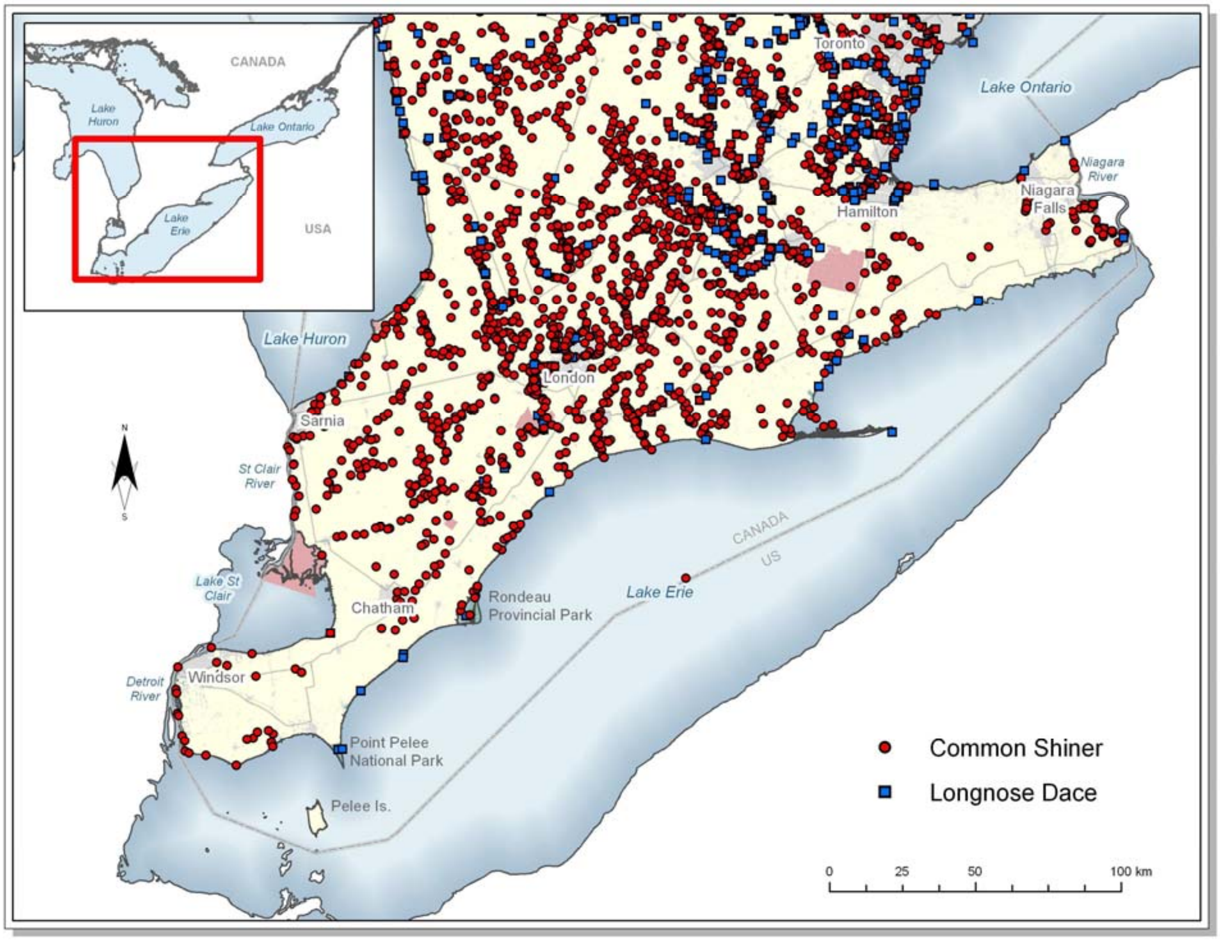

Figure 4. Distribution of the Common Shiner (*Luxilus cornutus*) and Longnose Dace (*Rhinichthys cataractae*). Records obtained from the Species at Risk Fish Database at Fisheries and Oceans Canada.

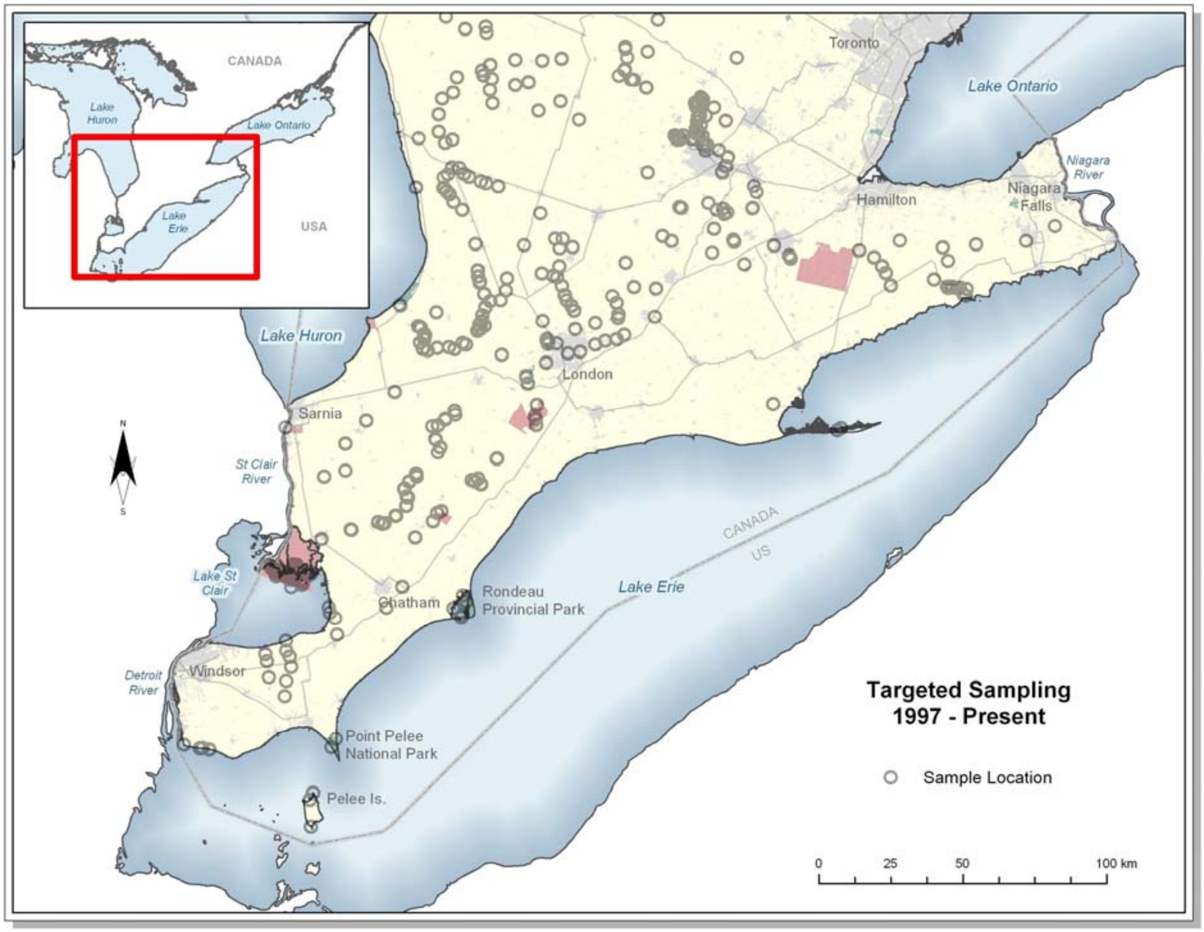

Figure 5. Locations of current (1997-2011) targeted mussel sampling within the range of the Threehorn Wartyback (*Obliquaria reflexa*) in Canada. Records obtained from the Lower Great Lakes Unionid Database (2011).

The following discussion contains a review of historical and current distribution of the species throughout the Great Lakes basin, beginning with the Lake St. Clair drainage and moving downstream through the Great Lakes system.

Results for the first extensive surveys for unionids in Lake St. Clair can be found in Nalepa and Gauvin (1988), who searched in 1984 and Nalepa *et al.* (1996) who surveyed in 1986, 1990 and 1992. Threehorn Wartyback were not reported at any of these 29 sites, which occurred throughout the entire lake. Gillis and Mackie (1994) searched two sites (different from those 29 above) from 1990-1992 and found *O. reflexa* at one of these sites (Puce, Ontario) with a density of 0.013 (no.•m^{-2}). Note that this record is not on the distribution map as a specific location was not available. Zanatta *et al.* (2002) surveyed 95 sites in 1998 and 1999 and found only shells of this species near the mouth of the Thames River (Zanatta pers. comm. 2011). Finally, Metcalfe-Smith *et al.* (2004) surveyed 18 sites in the Lake St. Clair delta and found no occurrence of Threehorn Wartyback. These efforts suggest that Threehorn Wartyback represented a small component of the lake's sizable freshwater mussel community and are most likely extirpated due to the invasion of dreissenid mussels.

There are no historical records for the Threehorn Wartyback in the Sydenham River of the Lake St. Clair drainage. This species was first observed in the Sydenham River at one site in 1997-1998 by Metcalfe-Smith *et al.* (2003). Surveys by the University of Guelph for gravid mussel Species at Risk (SAR) found additional Threehorn Wartyback at three sites between 2002 and 2011 (McNichols pers. comm. 2010; Castanon pers. comm. 2011). This species occupies a 10 km stretch of the Sydenham River between Croton and Dawn Mills (3 sites).

There is only one historical record for the Threehorn Wartyback in the Thames River of the Lake St. Clair drainage, when J.P. Oughton collected the species at Chatham in 1934. This record still represents the downstream limit of the species in this system. Survey efforts by Environment Canada in 1998 (Metcalfe-Smith *et al.* 1999) and Fisheries and Oceans Canada in 2004, 2005 and 2010 (Morris and Edwards 2007) have shown that this species is present in the lower Thames River. Threehorn Wartyback occupy a 110 km stretch of the Thames River between Delaware and Chatham (7 sites).

The first live individual collected on the Canadian side of the Detroit River was in 1992 by Schloesser *et al.* (1998) who surveyed 13 stations within the river (at least six of these on the Canadian side) in 1982-83 and then again in 1992 (plus four additional sites). This species was observed on the American side of the river in 1992 and 1994 (Schloesser *et al.* 1998). Live Threehorn Wartyback were reported on the Canadian side of the river representing ~14% (3 of 21) of the total number of mussels found in 1992 (Schloesser *et al.* 1998); however, none were found in subsequent surveys in 1998 by Schloesser *et al*. (2006), and they concluded "that unionids have been extirpated from main channels of the Detroit River due to dreissenid infestation"

The first observation of the Threehorn Wartyback in Lake Erie was by Walker in 1925, followed by an unknown collector in 1935. More shells were found between 1937 and 1992 by various collectors (Lower Great Lakes Unionid Database 2011). The first live specimens were found by Carr and Hitunen (1965) in 1961 who surveyed 40 sites throughout the lake – unionids were found at 20 of these. According to Nalepa *et al.* (1991), Carr and Hitunen (1965) found that the Threehorn Wartyback made up 2.6% of the total number of unionids found; however, where these live individuals were found is unknown – most likely on the U.S.A. side of Lake Erie. One fresh shell was reported in 2001 from Rondeau Bay (Lower Great Lakes Unionid Database 2011). Eighteen sites along the shore of Lake Erie were revisited in 2005 and 2009 (Table 1) and no Threehorn Wartyback were found. Indeed, no live Threehorn Wartyback have ever been collected or reported from the Canadian waters of Lake Erie. However, Threehorn Wartyback may still occur along the U.S. shoreline of Lake Erie (Crail *et al.* 2011) because they found only fresh dead shells at three of 12 stations. Most of the native mussels have been eradicated in Lake Erie by the Zebra and Quagga mussels. The last lake-wide survey for dreissenid densities in Lake Erie occurred in 2002 (Nalepa *et al.* 2011). Mean abundances in 2002 were little changed since 1992 (2,025 m^{-2} in 2002 compared to 2,636 m^{-2} in 1992), but mean biomass increased four-fold (24.7 g m^{-2} in 2002 compared to 6.8 g m^{-2} in 1992). Most dreissenid biomass (90%) occurs in the eastern basin. Populations in the central basin are limited because of seasonal hypoxia, and populations in the western basin are limited because of poor food quality (cyanophytes, inorganic particulates). Recent surveys (2005-2010) in the western basin indicate that dreissenid populations have fluctuated from year-to-year with no clear trends, and that Quagga Mussels have replaced Zebra Mussels as the dominant species (Nalepa *et al.* 2011).

Table 1. Summary of current (1997-2011) mussel sampling effort within the range of the Threehorn Wartyback. PH refers to the number of person-hours searched.

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort	Notes	Source
Lake St. Clair	0/30	1998	10 transects at 1, 2.5, and 4 m depths with 5 x 1 m^2 quadrats and 20 Ekman grabs in each transect		Zanatta *et al.* (2002)*
	0/77	1999	Sites < 2 m deep employed 0.75 PH of snorkeling effort and if mussels present an additional 0.75 PH was spent; sites > 2 m deep employed 0.5 PH of SCUBA effort	Includes 10 sites surveyed in 1998	Zanatta *et al.* (2002)
	0/10	2000	1.5 PH of snorkeling, 10 x 1m^2 quadrats	Includes 10 most abundant sites from 1999	Zanatta *et al.* (2002)
	0/9	2001	5-21 x 65 m^2 circular plots surveyed using snorkelers	Includes 4 previously sampled sites	Zanatta *et al.* (2002)
	0/18	2003	10 x 65 m^2 circular plots surveyed using snorkelers	9 sites in Canadian waters of delta, 9 sites in U.S. waters, includes 9 previously sampled sites from 2001	Metcalfe-Smith *et al.* (2004)

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort	Notes	Source
	0/10	2003	0.5 PH of snorkeling	2 sites in Canadian waters of delta, 8 sites in U.S. waters	Metcalfe-Smith *et al.* (2004)
	0/4	2005	3-4 PH of snorkeling		Metcalfe-Smith *et al.* (2005b)
	0/2	2006	~ 9 PH of snorkeling	Searching for gravid SAR females, both sites previously surveyed (Metcalfe-Smith *et al.* 2005b)	McNichols pers. comm. (2010)
	0/7	2011	10 x 65 m^2 circular plots surveyed using snorkelers	replication of sites from Metcalfe-Smith *et al.* 2004)	Fisheries and Oceans Canada
Lake Erie	0/6[1]	2001	2 PH snorkeling		D. Zanatta and D. Woolnough unpublished data
	0/17[2]	2005	Timed search (1.5 PH of snorkeling) and beach search		D. McGoldrick unpubl. data
	0/1	2009	Viewing boxes while wading (~ 4.5 PH)	Searching for gravid Eastern Pondmussels	McNichols pers. comm. (2010)
	3/17[1]	2011	20-60 minutes of searching, 1 site = 4 x 100 m^2 quadrats	U.S. side	Crail *et al.* (2011)
Sydenham River	1/17[1]	1997-98	4.5 PH while wading		Metcalfe-Smith *et al.* (2003) Lower Great Lakes Unionid Database (2011)
	1/15[1]	1999-2003	60-80 x 1 m^2 quadrats with excavation	Includes 12 sites surveys in 1997-98	Metcalfe-Smith *et al.* (2007)
	1/11	2002	> 110 PH timed search (excavation)	Searching for gravid SAR females, 10 sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2/7	2003	~ 212 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2/7	2004	~ 176 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2/6	2005	120.5 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2	2005	Excavation	Mussel identification course (field portion), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
	1/4	2006	47.5 PH timed search using excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort	Notes	Source
	2/2	2006	Excavation	Mussel identification SAR course (field), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
	2/4	2007	~ 20 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2	2007	Excavation	Mussel identification course (field portion), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
	1/4	2008	~ 41 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2/2	2008	Excavation	Mussel identification course (field portion), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
	1/3	2009	~ 35 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2	2009	Excavation	Mussel identification course (field), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
	2	2010	Excavation	Mussel identification course (field), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
	0/3	2010	~ 39 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	1/2	2011	~ 61 PH timed search (excavation)	Searching for gravid SAR females, all sites previously surveyed in 1999-2003	McNichols pers. comm. (2010)
	2	2011	Excavation	Mussel identification course (field), all sites previously surveyed in 1999-2003	Fisheries and Oceans Canada
Thames River	0/11	1997	4.5 PH timed search (wading or excavation)		Metcalfe-Smith *et al.* 1998)
	1/5[1]	1998	4.5 PH timed search (wading or excavation)		Metcalfe-Smith *et al.* (1999)

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort	Notes	Source
	5/48[1]	2004-2005	4.5 PH timed search (wading)	27 sites on Upper Thames River, 10 sites on lower Thames River	Morris and Edwards (2007) and unpubl. data
	5/37	2004-2005	60 – 80 x 1m^2 quadrats	Sites included in Morris and Edwards (2007)	Morris and Edwards (2007)
	0/2	2006	720 x 1 m^2 quadrats (360 at each site)	Medway Creek Relocation Project (Stantec)	Mackie pers. comm. (2010)
	0/1	2006	~ 3 PH timed search (viewing boxes)	Searching for gravid SAR females	McNichols pers. comm. (2010)
	0/2	2007	729 x 1 m^2 quadrats (561 quadrats at 1 site and 168 quadrats at the other site)	Medway Creek Relocation Project (Stantec)	Mackie pers. comm. (2011)
	0/1	2008	1 x 444m^2	Plot sampled 14 times between May and October	Morris unpublished data, TM-10 of Morris and Edwards (2007)
	0/2	2008	16 PH timed search	Targeted searches for Rayed Bean	Zanatta, Woolnough and Morris unpubl. data
	0/1	2008	3 PH timed search (viewing boxes or raccooning)	Searching for gravid SAR females, sites previously surveyed in Morris and Edwards (2007)	McNichols pers. comm. (2010)
	0/1	2009	Visual search (viewing boxes)	Searching for gravid SAR females, sites previously surveyed in Morris and Edwards (2007)	McNichols pers. comm. (2010)
	2/6	2010	408 x 1 m^2 quadrats	sites previously surveyed in Morris and Edwards (2007)	Fisheries and Oceans Canada
	0/3	2010	1830 x 1 m^2 quadrats (630, 750, and 450 at each site respectively)	Medway Creek Relocation Project (Stantec)	Mackie pers. comm. (2011)
	0/1	2010	1 PH timed search (viewing box)	Searching for gravid SAR females	McNichols pers. comm. (2010)
	0/4	2011	32 PH timed search, (excavation or viewing box)	Searching for gravid SAR females	McNichols pers. comm. (2010)
	0/1	2011	999 x 1 m^2 quadrats	Thames River Relocation Project (County of Middlesex)	Mackie pers. comm. (2011)
Grand River	3/17[3]	1997	4.5 PH (wading)		Metcalfe-Smith *et al.* (1998)
	0/7	1998	4.5 PH (wading)		Metcalfe-Smith *et al.* (1999)
	0/2	2005	Visual search (viewing boxes)	Searching for gravid SAR females	McNichols pers. comm. (2010)
	0/2	2007	Visual search (viewing boxes)	Searching for gravid SAR females, sites previously surveyed in 2005	McNichols pers. comm. (2010)
	4	2007	48-65 x 1 m^2 quadrats with excavation	All sites included in Metcalfe-Smith *et al.* (2000)	Morris unpublished data

Waterbody	# of sites where live individuals occurred/Total # of sites surveyed	Year	Effort	Notes	Source
	0/2	2007	720 x 1 m^2 quadrats (360 at each site)	Grand River relocation project (Thurber Engineering)	Mackie pers. comm. (2011)
	0/1	2008	825 x 1 m^2 quadrats	Grand River relocation project (Region of Waterloo)	Mackie pers. comm. (2011)
	0/1	2008	Visual search (viewing boxes)	Searching for gravid SAR females, previously surveyed in 2005	McNichols pers. comm. (2010)
	0/1	2009	Visual search (viewing boxes)	Searching for gravid SAR females, previously surveyed in 2005	McNichols pers. comm. (2010)
	1	2009	1200 x 1 m^2 quadrats	Grand River relocation project (BOT Construction)	Mackie pers. comm. (2011)
	0/2	2010	171 x 1 m^2 quadrats (96 at 1 site, 78 at 1 site)	Grand River relocation project (Region of Waterloo)	Mackie pers. comm. (2011)
	0/2	2010	8.5 PH timed search (viewing boxes)	Searching for gravid SAR females, previously surveyed in 2005	McNichols pers. comm. (2010)
	0/3	2011	18 PH timed search (viewing boxes)	Searching for gravid SAR females, previously surveyed in 2005	McNichols pers. comm. (2010)
	0/1	2011	431 x 1 m^2 quadrats	Grand River relocation project (Natural Resource Solutions)	Mackie pers. comm. (2011)
	3/6[3]	2011	4.5 PH	Targeted searches for Threehorn Wartyback	Morris unpublished data
Detroit River	1	1997	4 x 120 m^2 line transects	sites where live unionids were observed in 1990	Schloesser *et al.* (2006) and unpubl. data
	4	1998	500 m^2 area searched for 60 minutes using SCUBA; second 500 m^2 area searched for 25 minutes	sites where live unionids were observed in 1992 and 1994	Schloesser *et al.* (2006)
	1	1998	10 random quadrats within a 10 m x 10 m grid, excavated to a depth of 30 cm	sites where live unionids were observed in 1987	Schloesser *et al.* (2006) and unpubl. data

[*] During these surveys, Zanatta found shells of the Threehorn Wartyback on the south side of Lake St. Clair near the mouth of the Thames River (Zanatta pers. comm. 2011).
[1] Shells found at one additional site
[2] Shells found at two additional sites
[3] Shells found at three additional sites

The first Threehorn Wartyback was recorded from the Grand River in 1890 by Macoun (Lower Great Lakes Unionid Database 2011), who noted the presence of a fresh valve. Detweiler (1918) then completed surveys (near Dunnville) focusing on species that were of commercial value for the pearl button industry. He concluded that the Threehorn Wartyback was of commercial value; however, he did not list it as commonly occurring at this site. Further surveys and studies by La Rocque and Oughton (1937), Robertson and Blakeslee (1948), Clarke, Stansberry, Oughton, Kidd (1973), Berg and Oldham reported only shells of the Threehorn Wartyback (Lower Great Lakes Unionid Database 2011). Kidd (1973), after surveying 115 sites and finding only shells, determined that this species is sparsely distributed and appears to be restricted to the lower portion of the Grand River. The first live specimens were not found until 1997-98 by Metcalfe-Smith *et al.* (2000b). All of the Threehorn Wartyback records (Lower Great Lakes Unionid Database 2011) are from downstream of Caledonia to the mouth of the river. The species occupies a 45 km stretch of the Grand River (5 sites).

Extent of Occurrence and Area of Occupancy

Extent of occurrence (EO) was estimated using the minimum convex polygon approach. The maximal (1890-2011) extent of the species' distribution was estimated at 17,299 km^2 (Figure 6) with the current (2011) EO estimated at 7,032 km^2 (Figure 7) representing a 59% reduction. Index of area of occupancy (IAO) was estimated with a 2 km x 2 km grid approach. Maximal IAO was estimated at 1996 km^2 (Figure 8) whereas the current (2011) IAO, excluding the lower Thames River, was estimated at 356 km^2 (Figure 9). However, the loss of the species in lower Thames River is likely just an artifact of sampling as this stretch of the river is difficult to sample and therefore under-sampled, and the species is likely still present throughout the Thames River. Including the lower Thames River, the IAO is 532 km^2, representing a decline of 73% since 1997 (see **Search Effort**).

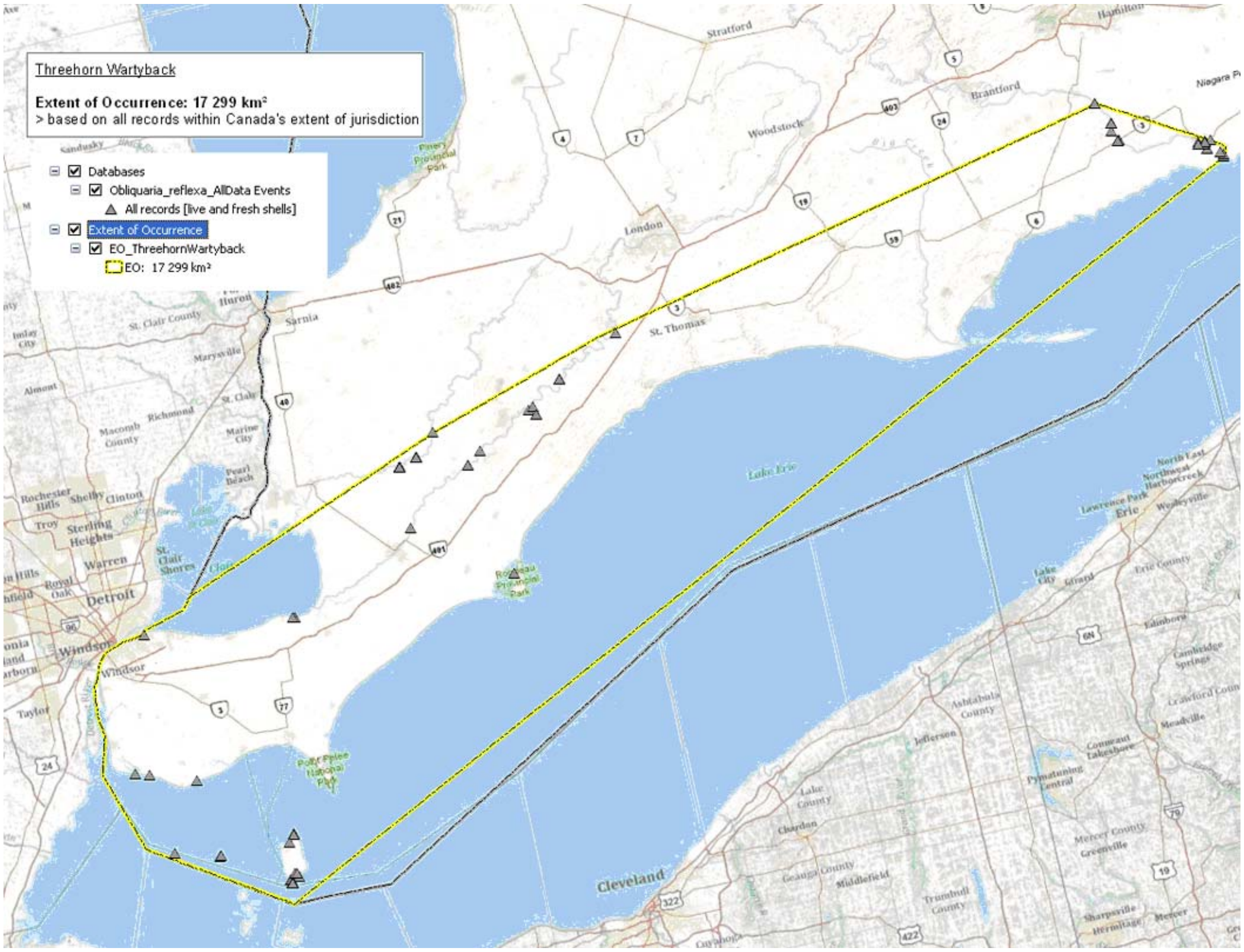

Figure 6. Extent of occurrence of Threehorn Wartyback using all records from 1890 to 2011.

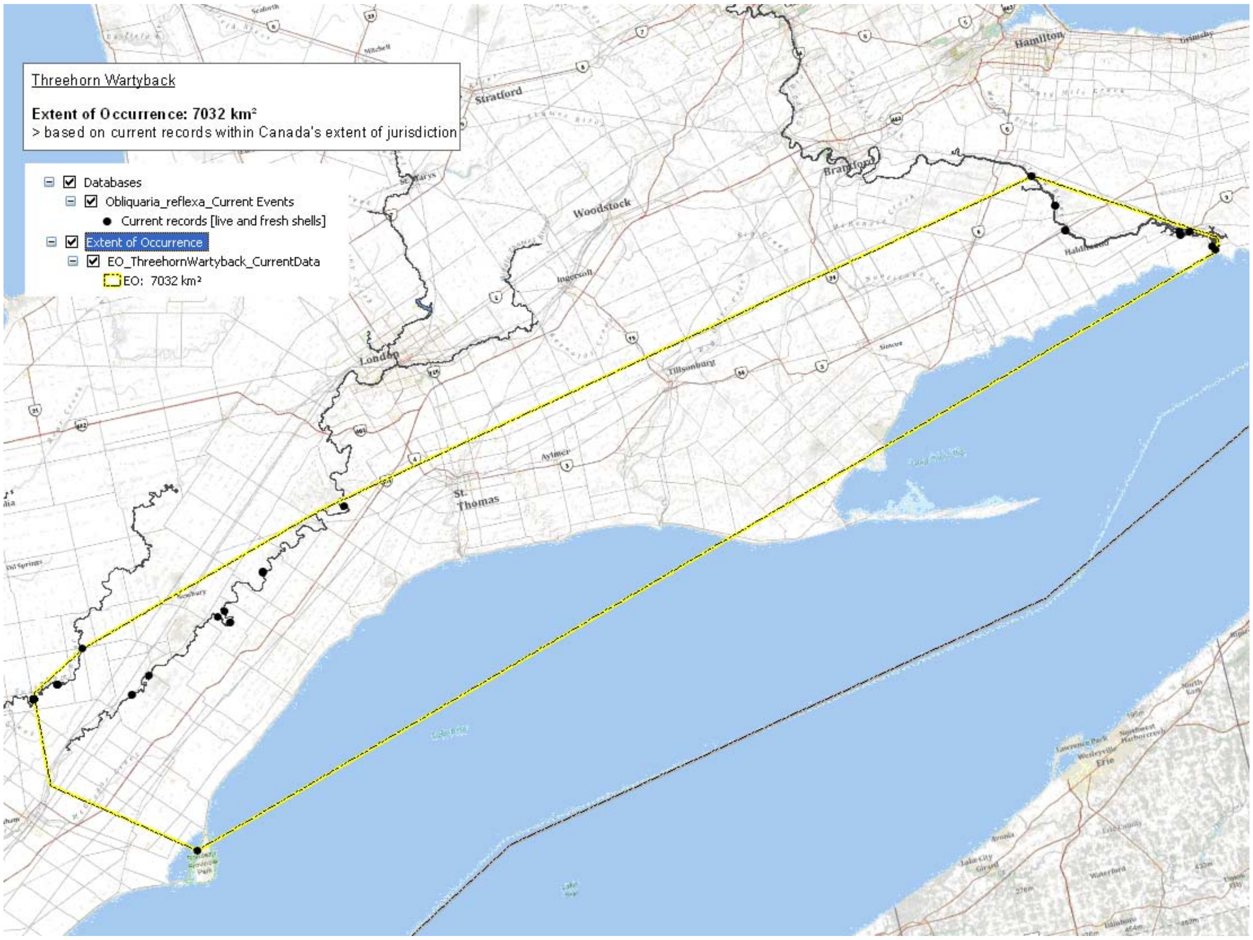

Figure 7. Current (2011) extent of occurrence of Threehorn Wartyback.

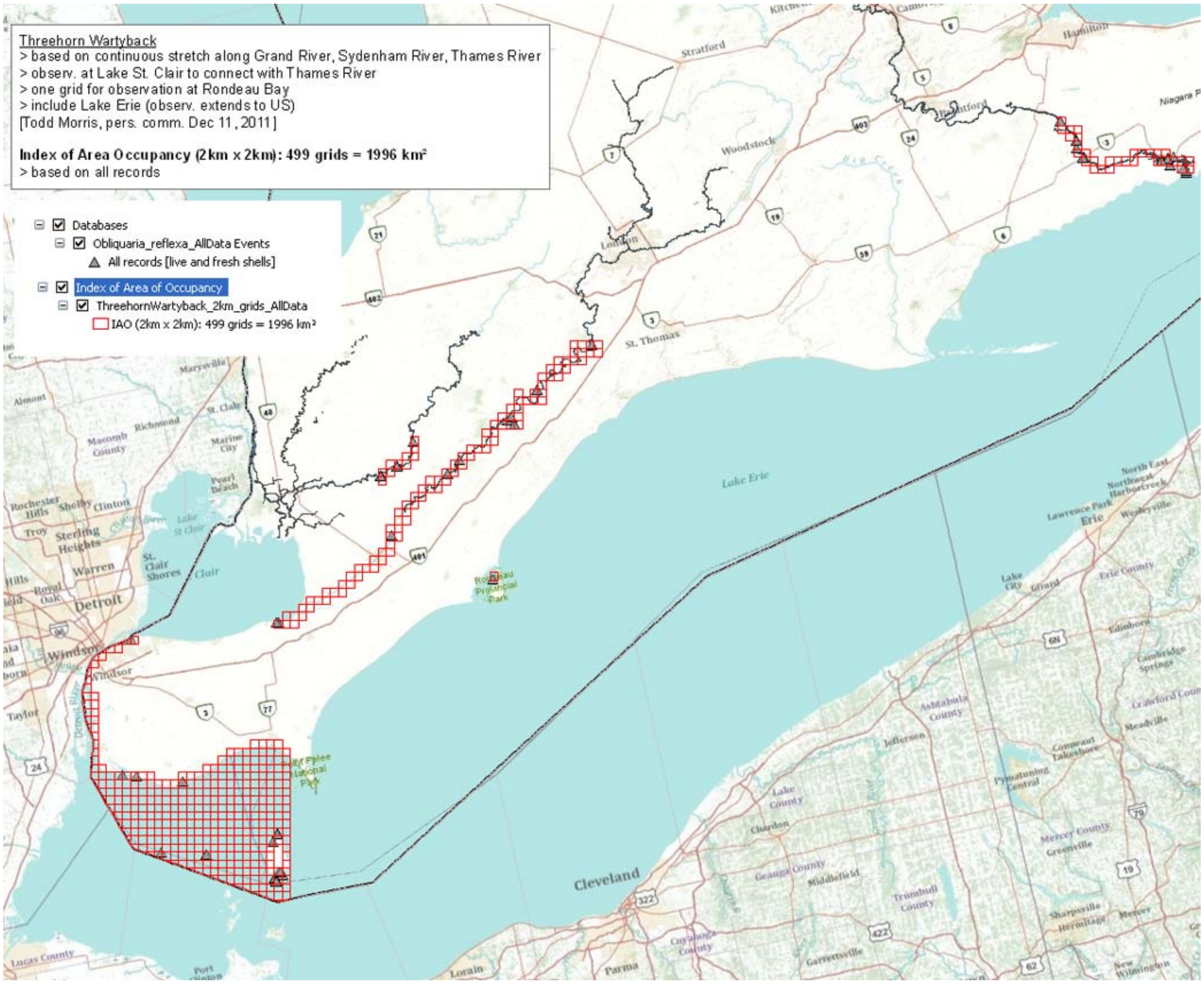

Figure 8. Index of area of occupancy of Threehorn Wartyback in Canada based on all records from 1890-2011 using the 2 km x 2 km grid approach.

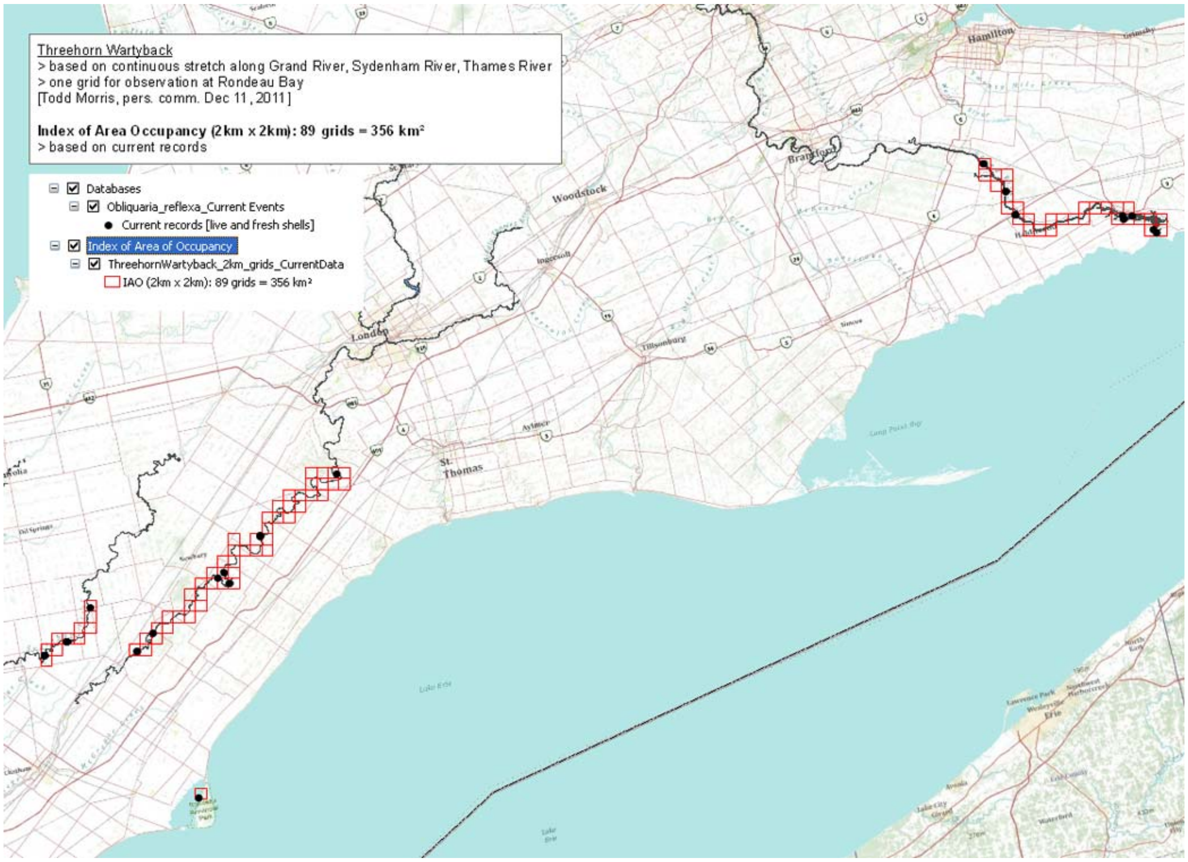

Figure 9. Current (2011) index of area of occupancy of Threehorn Wartyback in Canada using 2 km x 2 km grids.

Search Effort

Based on records from the Lower Great Lakes Unionid Database the Threehorn Wartyback historically (1890-1996) occurred in Lake Erie, Lake St. Clair, and the Thames, Grand and Detroit rivers. This distribution is based on 43 records, of which only five are known live collections representing 10 individuals (Lower Great Lakes Unionid Database 2011). Approximately half of the 43 historical records are from museum specimens that have very little or no information on associated search effort.

The current distribution (1997-2007) as shown in Figure 3 is based on 58 records (40 records for live individuals) reporting 104 live animals. The starting point for the current records has been selected as 1997 as it marks the beginning of a more intensive, and ongoing, survey effort throughout the range of the Threehorn Wartyback. This species is currently reported alive in the Grand, Thames and Sydenham rivers (see **Canadian Range**). During the current time period, intensive, targeted surveys have been conducted at over 280 sites in six systems (lakes Erie and St. Clair, and the Thames, Sydenham, Grand and Detroit rivers; Figure 5). Table 1 provides a summary of the current distribution of Threehorn Wartyback and the sampling methods and search effort used in these surveys.

HABITAT

Habitat Requirements

The Threehorn Wartyback is typically found in large rivers with moderate current, where the stable substrate is made up of gravel, sand and mud. It can also occur in shallow embayments and reservoirs with very little current (Clarke 1981; Metcalfe-Smith *et al.* 2005a; Watters *et al.* 2009). It can be found at depths of 6-7 m; however, it does well in waters less than 2 m deep (Parmalee and Bogan 1998). Specific data on the physical characteristics were available for three sites on the Sydenham River where the Threehorn Wartyback has been found (Metcalfe-Smith *et al.* 2007). These sites had a mean (± standard error) depth of 16 ± 0.93 cm and velocity of 0.237 ± 0.043 $m \cdot s^{-1}$ and were made up of over 55% gravel and sand, and approximately 8% boulder and silt, 23% rubble, 0.45% muck and 3% detritus (Metcalfe-Smith *et al.* 2007). Sites on the Thames River were made up of 70% sand and gravel, 8% boulder, 4% rubble, and 10% silt (Morris unpubl. data). Observational data were available for two sites on the Grand River and they were made up of 26% sand and gravel, 30% rubble, 30% mud and silt and 7.5% clay (Morris unpubl. data).

The Threehorn Wartyback is dependent on host fishes for completion of its lifecycle. Host species have yet to be identified for Canadian populations; however, they have been identified for U.S. populations (see **Lifecycle and Reproduction** below). The two most likely host species in Canada are the Common Shiner and Longnose Dace. The Common Shiner is generally found in cool, shallow riffles and runs of streams but can also occur in the shore waters of clear lakes (Scott and Crossman 1998; Holm *et al.* 2009). Longnose Dace prefer fast-flowing waters of streams with rocky bottoms but can also occur in inshore waters of lakes with similar substrate (Scott and Crossman 1998; Holm *et al.* 2009). Both of these species tend to prefer smaller streams than those typically associated with Threehorn Wartyback (Barnucz pers. comm. 2011)

Habitat Trends

The primary threats to riverine mussels have been identified as high sediment and nutrient loads and toxic chemicals from non-point sources—especially relating to agricultural activities (Richter *et al.* 1997) (see **THREATS AND LIMITING FACTORS**). Agriculture makes up 85% of the main land use in the Sydenham River watershed and 60% of that land is tile drainage (Dextrase *et al.* 2003). Large areas of the river have little to no riparian vegetation and only 12% of the original forest cover remains. Agricultural lands, particularly those with little riparian vegetation and large amounts of tile drain, allow large inputs of sediments to the watercourse. Dextrase *et al.* (2003) reported suspended solid levels in the Sydenham River to be as high as 900 $mg \cdot L^{-1}$, leading to the conclusion that siltation and turbidity are a predominant threat to the freshwater mussel assemblage. Total phosphorus levels range from 0.075 to 0.13 $mg \cdot L^{-1}$ and consistently exceed the 0.03 $mg \cdot L^{-1}$ provincial water quality objective (SCRCA 2008). Nitrogen has therefore replaced phosphorus as the limiting nutrient in this system. Although there has been no significant evidence of blooms of blue-green algae (which can occur when nitrogen is limiting) there is potential for significant reductions in dissolved oxygen at night. Pesticides (herbicides, insecticides, etc.) associated with agricultural practices and urban areas run off into the Sydenham River watershed, which increases concentrations of contaminants and toxic substances that may affect freshwater mussels. For example, chloride levels in the East Sydenham River have been relatively low (rarely exceeding 50 mg•L^{-1}) in the past; however, they are increasing and this may be the result of increased use of road salts for de-icing (Dextrase *et al.* 2003; SCRCA 2008). The human population in the watershed is over 162,000 (SCRCA 2011) and although not highly populated, the lower portion of the river is subject to commercial shipping activities that tend to fluctuate in response to economic conditions. Four aquatic invasive species have been identified as threats to freshwater mussel populations: Zebra Mussel (*Dreissena polymorpha*); Quagga Mussel (*Dreissena bugensis*); Round Goby (*Neogobius melanostomus*); and Common Carp (*Cyprinus carpio*). Dreissenid mussels are found at the mouth of the Sydenham River (below the Threehorn Wartyback population); however, this system does not appear to be at a significant risk from further invasion as there are no large reservoirs that could serve as a continuous source of veligers. Round Goby have been observed at Threehorn Wartyback sites and are continuing to move upstream (Poos *et al.* 2010). Common Carp are present in this system although they are not overly abundant (Barnucz pers. comm. 2011).

Over 88% of the lower Thames River watershed, where Threehorn Wartyback occur, is subject to intense agricultural pressure with less than 5% of the historical forest cover remaining (Taylor *et al.* 2004). Water quality in the Thames River basin has historically suffered greatly from agricultural activities. Tile drainage, wastewater drains, manure storage and spreading, and insufficient soil conservation have all contributed to the observed water quality degradation within this system (Taylor *et al.* 2004). In addition to agriculture, the water quality in the Thames River watershed has been affected by urban sewage treatment, industrial waste management, storm-water management and other land management practices. Many of these are associated with large urban areas such as the city of London, which is the largest urban centre in the watershed with a population of over 350,000. London has undergone a 10-fold population expansion in the last century. Although this city is located upstream of both the historical and current ranges of the Threehorn Wartyback, the impacts listed above of such a large urban centre and its expansion are likely to be observed downstream in the areas where the species occurs. High sediment and nutrient loading occur in the Thames River. Turbidity in the lower portion of the river is considered to be extremely high (Taylor *et al.* 2004). The watershed has some of the highest phosphorus (0.032 - 0.22 mg•L^{-1}) and nitrogen (8-13 mg•L^{-1}) loadings reported in the entire Great Lakes basin, most likely due to the inputs of livestock waste (WQB 1989; UTRCA 2004, 2007). Mean concentrations of copper range from 0.97-4 µg•L^{-1} and have decreased over the past three decades (UTRCA 2004; Morris *et al.* 2008). Most of these concentrations are at or below the 5 µg•L^{-1} provincial water quality objective (Ontario Ministry of Environment and Energy 1994). Chloride levels are continuing to rise throughout the watershed and range from 25-220 mg•L^{-1}, which is now considered above the threshold for the Canadian Water Quality Guidelines for the Protection of Aquatic Species at Risk for chloride, which is 120 mg•L^{-1} (CCME 2011). Dreissenid mussels are found at low densities in the Thames River throughout the range of Threehorn Wartyback (Morris and Edwards 2007). Both Round Goby and Common Carp are present though not considered abundant (Barnucz pers. comm. 2011; Dextrase pers. comm. 2012).

Over the last 35 years, mussel communities in the Grand River have undergone a significant decline and subsequent recovery (Kidd 1973; Mackie 1996; Metcalfe-Smith *et al.* 2000b). Kidd (1973) reported a 55% decrease in species diversity in the river and attributed much of this loss to impaired water quality related to agricultural activity, and habitat fragmentation resulting from the construction of three large and 11 small impoundments. Currently, 93% of the watershed is considered rural, and there are more then 132 dams (GRCA 2011). Twenty-three years later, Mackie (1996) found a total of 18 species and indicated that anthropogenic stressors, particularly below urban centres, were likely driving the species' declines. Eighty-one percent of the urban population in the Grand River watershed is located on only 7% of the land, the majority of which is found in the cities of Kitchener, Waterloo, Cambridge and Guelph (GRCA 2011; Wong 2011). After extensive surveys in 1997-98, Metcalfe-Smith *et al.* (2000b) found 25 species, representing a 50% increase in species richness compared with Kidd's (1973) results. The improvement in mussel communities of the Grand River was associated with improved water quality and the addition of fish ladders promoting fish movement (allowing dispersal through host activity) and reconnection of formerly fragmented habitat (Metcalfe-Smith *et al.* 2000b). Although water quality and habitat are improving, further work is required as sediment and nutrient loads are high and invasive species are present. The primary means of phosphorus loading in the Grand River is soil erosion from cropland, but other sources are runoff from manure, tile drainage, livestock access to the watercourse, and the presence of dams (GRCA 1998; Water Quality Working Group 2011). The median total phosphorus levels in areas where Threehorn Wartyback occur near Dunnville are about four times (0.128 mg•L^{-1}) the provincial objective during high spring flows; however, they can be as high as 12 times the objective (0.360 mg•L^{-1}; Water Quality Working Group 2011). These phosphorus levels consistently exceed the Ontario water quality guidelines (0.03 mg•L^{-1}; Taylor *et al.* 2004). The dams in Caledonia and Dunnville may be playing a large role in the phosphorus concentration as they alter the hydraulic character of the river (Water Quality Working Group 2011). All three invasive species are found in the Grand River. Dreissenid mussels are found downstream of the Dunnville dam, which affects the lower portion of the Threehorn Wartyback distribution (Morris pers. obs. 2005). Round Goby are found in high abundance upstream of Dunnville dam and are also found below the dam. Common Carp are currently found throughout the Grand but they are not overly abundant (Barnucz pers. comm. 2011).

The most significant change in habitat for populations of Threehorn Wartyback occurring in the Great Lakes is associated with the invasion of the dreissenid mussels in the mid-1980s. Within a decade of the first invasion, native unionids had been almost completely eradicated from Lake St. Clair, Lake Erie and the Detroit River (Schloesser and Nalepa 1994; Nalepa *et al.* 1996; Schloesser *et al.* 2006). Although dreissenids have caused significant changes to the ecosystem, it has been suggested that their threat is not as pronounced as it was a decade ago as some macroinvertebrate species appear to be showing signs of recovery (Crail *et al.* 2011; Strayer *et al.* 2011).

BIOLOGY

Freshwater mussels like Threehorn Wartyback are moderately long-lived with the maximum lifespan of 18 years being observed in both Ontario (Morris unpubl. data) and Ohio (Watters *et al.* 2009). They are relatively sedentary and generally filter-feeders as adults, though evidence suggests they may engage in some pedal feeding as well (Nichols *et al.* 2005). Unionids are unique in that they have a complex reproductive cycle involving a period of obligate parasitism on a vertebrate host (see **Life Cycle and Reproduction**). Juvenile mussels are believed to burrow completely below the substrate surface where they will spend the first 3-5 years of their life (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). Adult mussels are found at the substrate surface during the summer months, but are known to burrow below the surface during the winter months likely in response to dropping water temperatures or changing flow regimes (Schwalb and Pusch 2007). The following discussion is based on a survey of the available literature and the personal observations of the report writers.

Life Cycle and Reproduction

During spawning, male Threehorn Wartyback release sperm into the water and females living downstream filter it out of the water with their gills. Female mussels brood their young from the egg to the larval stage in specialized regions of their gills known as marsupia. In the Threehorn Wartyback the marsupia are made up of two to nine water tubes in the middle of each of the outer gills (Haag and Staton 2003). Glochidia (immature juveniles) develop within the marsupial gills and are released into the water column by the female mussel in a conglutinate (see below for further detail). 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, and some growth of encysted immature juveniles has been reported for the Threehorn Wartyback (Barnhart and Baird 2000). Natural glochidial mortality is difficult to estimate but is assumed to be extremely high. Juvenile metamorphosis and exystment occurred between 17-19 days post-infestation for the Threehorn Wartyback (Watters *et al.* 1998). After releasing from the host, the 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 (Watters *et al.* 2001). Age at maturity is unknown for the Threehorn Wartyback, but the average age of maturity for unionids is 6-12 years (McMahon 1991). Given the observed maximum age of 18 years it is likely that age at maturity for Threehorn Wartyback is on the short end of the range reported above.

Threehorn Wartyback is dioecious (i.e., has separate sexes); however, the shell does not exhibit a pronounced sexual dimorphism (Watters *et al.* 2009). This species is believed to be tachytictic (short-term brooder), with glochidia being formed and released from May until the end of July (Clarke 1981; Watters *et al.* 2009; Culp *et al.* 2011). Gravid females have been observed in Ontario in the Sydenham River in June at temperatures of ~20 ˚C (Castanon pers. comm. 2011). Glochidia are approximately 220 µm in length and height (subcircular) and lack hooks (Clarke 1981), suggesting that they are gill parasites. Although there has been some suggestion that the Threehorn Wartyback may not require a host to complete metamorphosis (Utterback 1916), this has not been substantiated.

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 (Zanatta and Murphy 2006). Little is known of the reproductive behaviours of the Threehorn Wartyback; however, the presence of large, solid, white, club-shaped conglutinates (Barnhart and Baird 2000; Barnhart *et al.* 2008; Watters *et al.* 2009; Castanon pers. comm. 2011) that sink (Culp *et al.* 2011) have been reported. The female mussel releases conglutinates (i.e., packages containing many individual glochidia) which elicit a predatory response in the host fish causing the rupture of the conglutinate and the release of the individual glochidia.

Physiology and Adaptability

In general, freshwater mussels of the family Unionidae are indicators of a healthy ecosystem. They are particularly sensitive to heavy metals (Keller and Zam 1991), ammonia (Goudreau *et al.* 1993; Mummert *et al.* 2003), acidity (Huebner and Pynnonen 1992), salinity (Liquori and Insler 1985; Gillis 2011), and copper (Gillis *et al.* 2008). The early life stages (glochidia and juveniles) are the most sensitive to contaminant exposures (Ingersoll *et al.* 2007).

Adult Threehorn Wartyback appear to have fairly broad habitat tolerances with respect to depth, flow and substrate types (see **Habitat Requirements**) suggesting they may be able to tolerate some environmental fluctuations. Spooner *et al.* (2005) studied the effect of temperature on glycogen, body condition index and respiration rates with increasing temperature (5,15, 25, and 35 ºC) and found that Threehorn Wartyback had significantly lower glycogen concentrations at 35ºC when compared to the 5-25ºC. Body condition index did not change as temperature increased and respiration rate only increased at 35ºC, which suggests that these mussels do not experience high stress until temperatures are above 35ºC. More data points are required above this threshold to determine potential critical thermal temperatures. It does appear as though the adult form of this species is tolerant of warm water temperatures. It is important to note that the sedentary nature of adult freshwater mussels, general sensitivity to water quality (see **THREATS AND LIMITING FACTORS**) and host dependency may offset these broader habitat tolerances.

At this time there have been no studies to specifically address the adaptability of the Threehorn Wartyback and, although some host fish identification experiments have been completed in the United States, there have been no attempts to identify host fishes or to artificially rear this species in Canada.

Dispersal and Migration

Movement can be directed upstream or downstream; 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 respectively; however, movement is variable and depends on water flow, water temperature and, in the case of juveniles, behaviour (Schwalb *et al*. 2010; Schwalb *et al.* 2011). Small-scale movements on the order of $cm \bullet d^{-1}$ have been reported by Allen and Vaughn (2009) for adult Threehorn Wartyback; however, the primary means for dispersal, including upstream movement, and the movement into novel habitats is limited to the encysted glochidial stage on the host fish. The suspected Canadian hosts, Common Shiner and Longnose Dace, are capable of small-scale dispersal. Specific movements for the Common Shiner were not found. Hill and Grossman (1987) reported movement ranging from 10-20 m for the Longnose Dace over a mean of 128 days.

Interspecific Interactions

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. In addition, the Round Goby has been labelled as a “voracious consumers of benthic organisms” (Ray and Corkum 1997; Poos *et al.* 2010). Juvenile unionids have been found in gut content analysis from gobies caught in the Sydenham River (Poos pers. comm. 2011). See **THREATS AND LIMITING FACTORS** for more details.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Historical surveys

Based on 43 records from the Lower Great Lakes Unionid Database, the Threehorn Wartyback was historically (1890-1996) found in the Grand, Thames and Detroit rivers and lakes Erie and St. Clair. Though not recorded from the Sydenham River during this time period it is likely that the species was historically present in this system as well. Search effort and/or sampling methods are limited for historical records as most are based on the presence of valves or shells.

Recent Surveys

There are 58 current (1997-2011) records in the Lower Great Lakes Unionid Database. These records indicate that the Threehorn Wartyback are found in the lower Thames, Sydenham and Grand rivers. Table 1 provides a summary of the current information available on search effort and sampling methods. Data were collected using two basic methods:

(1) Timed-Searches:

Any data referenced with person-hours (PH) is based on a timed search method—number of hours searched x number of people searching. This survey method produces data on species presence/absence and can provide relative measures of abundance. Searches are conducted using a visual search (naked eye, view boxes, snorkelling, SCUBA) when visibility is clear, or by manually searching the substrate using hands or scopes when turbidity is high (raccooning). Individual mussels are collected, held in the water (via mesh diver's bags, or bucket) until the end of the sampling period and then identified to species, sexed if possible, counted, measured, and finally returned to the river alive. Metcalfe-Smith *et al.* (2000a) suggests a period equal to 4.5 PH of searching to detect rare species; and

(2) Quadrat surveys:

Quadrat surveys involve the excavation of each quadrat (usually a sub-sample of the entire site) to a depth of approximately 10 cm and removing all mussels. As with the timed-search method, individuals are identified, sexed if possible, counted and measured before being returned to the quadrat alive. This excavation approach allows for the determination of assemblage composition, total and species-specific density estimates, sex ratios, size frequencies and estimates of recruitment.

Abundance

To the best of our knowledge, the Threehorn Wartyback no longer occurs in the Detroit River (Schloesser *et al.* 2006), Lake Erie (on the Canadian side; Schloesser and Nalepa 1994), or Lake St. Clair (Gillis 1993). Extant occurrences are restricted to the lower Thames River, lower Sydenham River, and the lower Grand River.

A total of 18 live specimens of the Threehorn Wartyback were collected from five of 37 sites sampled via timed searches and quadrats in the Thames River in 2005. Six of these sites were re-sampled via quadrat surveys in 2010 and an additional six individuals were found at two of these sites (Morris unpubl. data). All sites were located contiguously over a 110 km stretch of the lower Thames River between London and Chatham. The Threehorn Wartyback appears to be restricted to the lower Thames River with an overall relative abundance of 0.22% (Morris and Edwards 2007) and an average density estimate of 0.024 animals/m^2. Extrapolating this density estimate over the entire occupied range in the Thames River yields a rough population estimate of approximately 100,000 animals. Figure 10 represents the size distribution for the 24 animals collected in the Thames River showing a range of sizes indicative of recent reproduction.

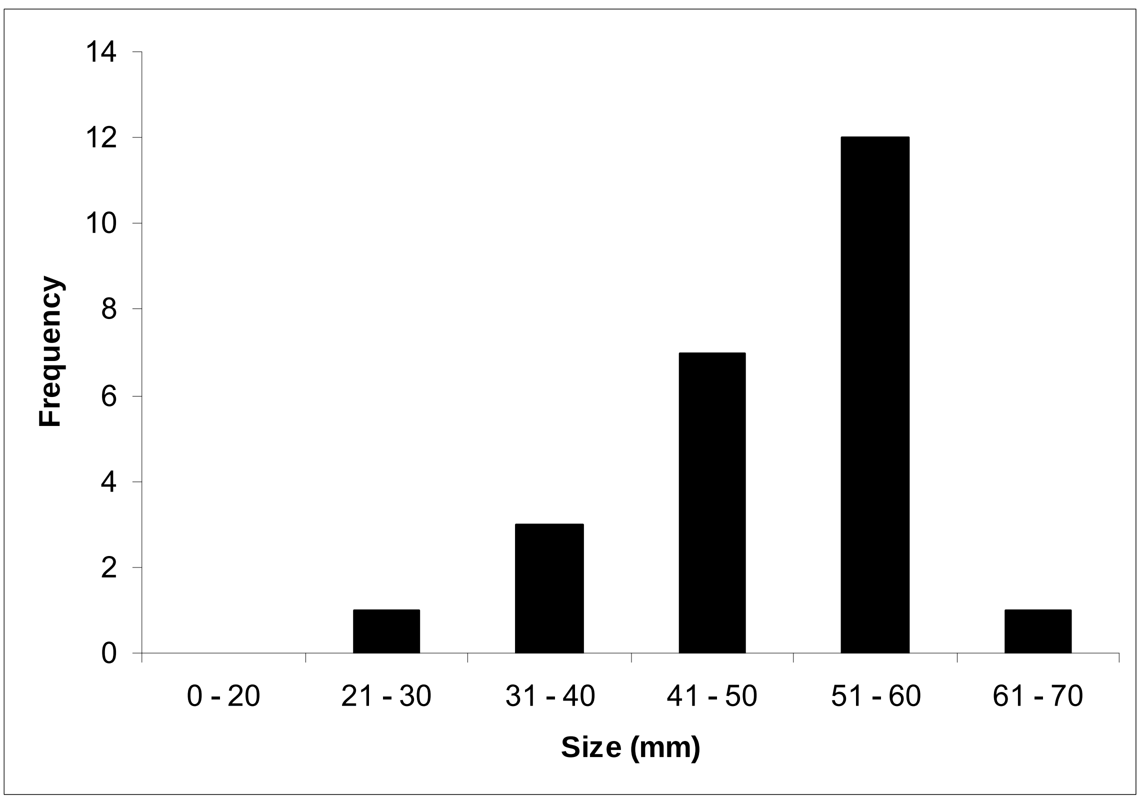

Figure 10. Size distribution of Threehorn Wartyback (*Obliquaria reflexa*) found in the Thames River in 2005 - 2010 (n = 24) using both timed searches and quadrat surveys.

The Threehorn Wartyback was only found at one of the 17 sites sampled in the Sydenham River between 1999 and 2003 (Metcalfe-Smith *et al.* 2007), making up 0.1% of the relative abundance. A further 37 live individuals were found at three sites (two individuals from the site in Metcalfe-Smith *et al.* 2007) during surveys for other species between 2002 and 2010 (McNichols pers. comm. 2010). It is not possible to estimate the population size in the Sydenham River as only a single specimen has ever been found during the quantitative sampling required to produce these estimates. Figure 11 shows the size frequency distribution presented for the Sydenham River indicating evidence of recruitment.

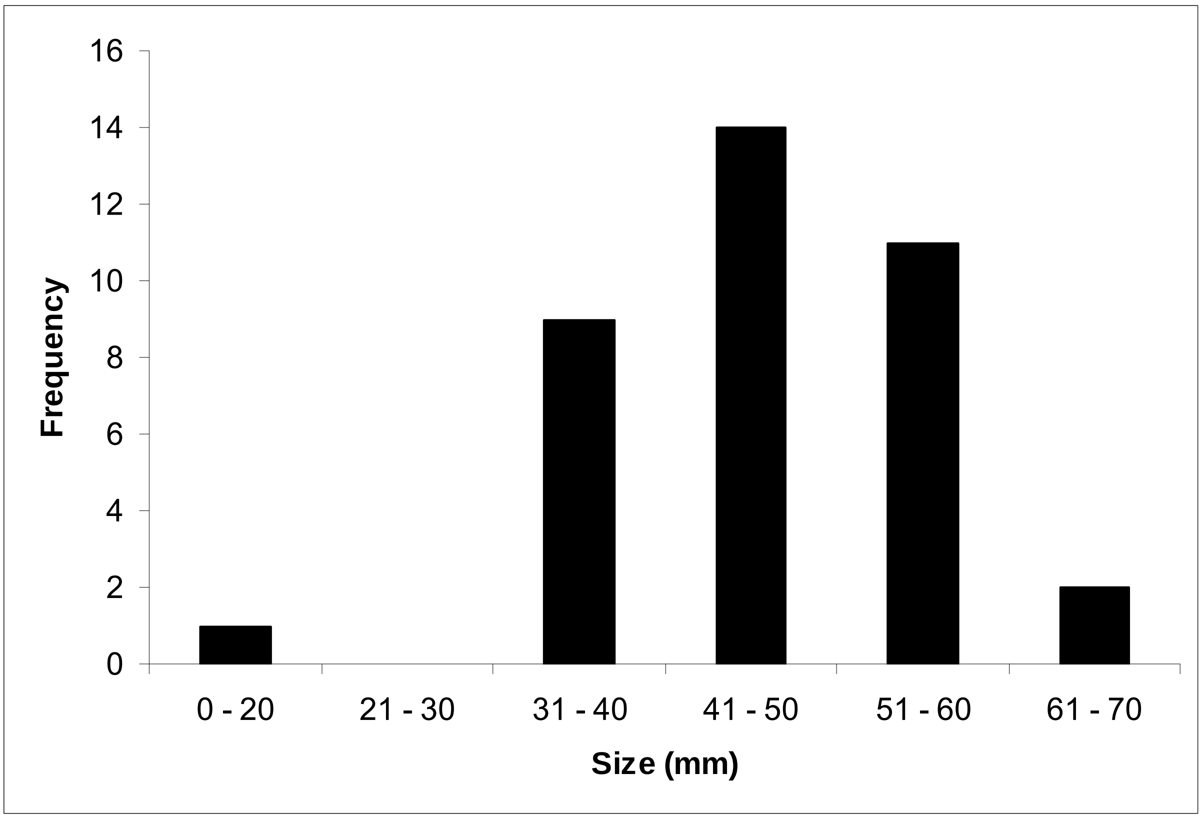

Figure 11. Size distribution of newly marked individuals found during timed search surveys for gravid mussel SAR in the Sydenham River between 2002 - 2005 (n = 37; Castanon pers. comm. 2011).

Metcalfe-Smith *et al.* (2000b) surveyed 24 sites in the Grand River for mussels in 1997-1998, and found one live Threehorn Wartyback each of these sites. Further surveys by Fisheries and Oceans Canada in 2011 found Threehorn Wartyback alive at three sites (two of these from (Metcalfe-Smith *et al.* 2000b)), and shells at an additional three sites (Lower Great Lakes Unionid Database 2011). The four live individuals found in 2011 ranged from 32.5 - 42 mm in length (no figure is provided as n=4). Very little information is available for the historical records in the Lower Great Lakes Unionid Database, and it appears that none are for live specimens. This, and the fact that no Threehorn Wartyback were found during quadrat surveys, makes it impossible to estimate population abundance or trends in the Grand River.

The number of mature individuals and the trend since 1997 are unknown but are assumed to be related to the decline in IAO, which is 73%. However, it is unknown if there is a linear relationship between IAO and abundance of mature individuals.

Fluctuations and Trends

It is very difficult to evaluate population fluctuations or trends in Threehorn Wartyback numbers over time as there are very few records available. There are 58 current records for this species in the Lower Great Lakes Unionid Database and only 23 of these records represent collections of more than a single live animal.

The Threehorn Wartyback appears to be extirpated from the offshore waters of Lake St. Clair and the Canadian side of Lake Erie and the Detroit River most likely as a result of the invasion of dreissenid mussels.

No comment can be made about the fluctuations and trends of abundance for the Threehorn Wartyback in the Thames, Sydenham or Grand rivers. Only one historical record exists for a live specimen in the Thames River and no historical records exist for this species in the Sydenham River. In these two rivers the current range of the Threehorn Wartyback represents the maximum ever recorded. Historically, the Threehorn Wartyback was known from 10 records in the lower Grand River, nine of these downstream of Dunnville and one near Cayuga. Although there is very little information on which to base fluctuations and trends in the Grand River there does not appear to be any change in the range of the Threehorn Wartyback in the Grand River.

Rescue Effect

All of the current Canadian populations of the Threehorn Wartyback are isolated from one another and from American populations by large areas of unsuitable habitat, making the likelihood of re-establishment of extirpated populations by immigration improbable. The two suspected Canadian hosts of the Threehorn Wartyback, Common Shiner and Longnose Dace, are not capable of the large-scale movements required to connect these populations (see **Dispersal and Migration**). Furthermore, Threehorn Wartyback populations in adjacent U.S. states that could act as source populations are not considered large enough to support rescue. For example, Threehorn Wartyback made up < 0.25% of the mussels found during coastal wetland surveys on the U.S. side of Lake Erie (Zanatta pers. comm. 2011). Of the four U.S. states in the Lake St. Clair-Lake Erie corridor, populations in Ohio are considered S2 (imperilled) and those in Pennsylvania are SH (possibly extirpated). This species is not found in New York and has not been ranked in Michigan (NatureServe 2011).

THREATS AND LIMITING FACTORS

Fisheries and Ocean Canada conducted a multi-species Recovery Potential Assessment (RPA) for four mussel species: Eastern Pondmussel (*Ligumia nasuta*), Fawnsfoot (*Truncilla donaciformis*), Mapleleaf (*Quadrula quadrula*), and Rainbow (*Villosa iris*) (DFO 2011) in 2011. This peer-reviewed RPA addresses threats in the watersheds where the Threehorn Wartyback occur. The following discussion of threats and limiting factors concurs with the outcomes of this review and follows the methods of Salafsky *et al.* (2008) and Master *et al.* (2009) for application of the COSEWIC threats calculator.

The following description emphasizes the principal threats currently acting on Threehorn Wartyback populations (Table 2). It is important to note that these threats may also directly impact the feeding, respiration, reproduction, and movement of host fish and this will have detrimental affects on extant Threehorn Wartyback populations. (Nomenclature and numbering follows the sections outlined in the Threats Calculator.)

Table 2. Description of threats and their impacts on current Threehorn Wartyback (*Obliquaria reflexa*) populations – calculated using the Threats Calculator. Threats are arranged from highest to lowest impact.

Threat No.	Threat Description	Threat	Impact	Scope	Severity	Timing
9.1	Household sewage & urban waste water	B	High	Pervasive	Serious	High
9.3	Agricultural & forestry effluents	B	High	Pervasive	Serious	High
8.1	Invasive non-native/alien species	C	Medium	Pervasive	Moderate	High
6.1	Recreational activities	C	Medium	Large	Moderate	High
1.1	Housing & urban areas	D	Low	Small	Extreme	High
4.3	Shipping lanes	D	Low	Small	Extreme	High
9.2	Industrial & military effluents	D	Low	Small	Extreme	Low
6.3	Work & other activities	D	Low	Small	Slight	High
5.4	Fishing & harvesting aquatic resources	D	Low	Small	Slight	Moderate

High-Impact Threats

<u>Pollution (9.1 Household sewage and urban wastewater and 9.3 Agriculture and forestry effluents)</u>

Pollution has been deemed one of the most prominent threats affecting extant populations of Threehorn Wartyback. There are a variety of threats associated with "household sewage and urban waste water" and "agricultural and forestry effluents". These include sediment loading (siltation and turbidity), nutrient loads, contaminants and toxic substances (e.g., runoff of lawn fertilizers and pesticides, road salts). Given the general sensitivity of freshwater mussels, particularly glochidia and juveniles, to aquatic pollutants (Bringolf *et al.* 2007a; Bringolf *et al.* 2007b; Wang *et al.* 2007; Gillis *et al.* 2008), the levels of pollution observed in the Thames, Sydenham and Grand River watersheds may be negatively impacting the remaining riverine populations of the Threehorn Wartyback.

Sediment loading

Loading of suspended solids causing turbidity and siltation is presumed to be one of the primary limiting factors for most aquatic SAR in southern Ontario (COSEWIC 2010; DFO 2011). 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). In addition, species that burrow completely in the substrate, such as Threehorn Wartyback, 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 requires visual attraction of a host to a conglutinate. Increased turbidity would decrease the likelihood that the host fish will be able to visually locate the conglutinate thereby decreasing overall fitness.

Farming practices that may result in increased siltation rates include allowing livestock access to streams, which can result in stream bank instability; 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 smoother mussels.

Nutrient loading

As agriculture is the primary land use in many southwestern Ontario watersheds, it appears to be contributing to poor water quality (high levels of phosphorus, nitrogen) through agricultural runoff and manure seepage; however, other sources include domestic and industrial effluents and urban outputs (GRCA 1998; Taylor *et al.* 2004). Strayer and Fetterman (1999) identified increased nutrient loads from non-point sources, especially those from agricultural activities as a primary threat. Freshwater mussels are affected indirectly by poor water quality as increases in phosphorus and nitrogen loadings can decrease levels of available oxygen by stimulating growth and decomposition of algae and plants (NPCA 2010). This will reduce respiration and can cause death (Tetzloff 2001), as well as changes in fish communities (Jackson *et al.* 2001), which will have a negative impact on reproduction. Accidental spills (e.g., manure) must also be noted and can have significant nutrient-enriching effects, and are acutely toxic to fish and invertebrates.

Contaminants and toxic substances

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, and Rotenone, all of which can inhibit respiration and accumulate in mussel tissue (Fuller 1974; USFWS 1994). The early life stages (glochidia and juveniles) appear to be particularly sensitive to heavy metals (Keller and Zam 1991; Bringolf *et al.* 2007a; Bringolf *et al.* 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). Toxic chemicals from both point and non-point sources, particularly agriculture, are believed to be one of the major threats to mussel populations today (Strayer and Fetterman 1999). Roads and urban areas can also contribute significant contaminants to waterways, including oil and grease, heavy metals, and chlorides.

In addition, 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 possible endocrine and reproductive effects from these chemicals on aquatic biota; related work with unionids is in its infancy (see Cope *et al.* 2008), but there is reason for concern. 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 using Flutedshell (*Lasmigona costata*), Eastern Elliptio and Giant Floater (*Pyganodon grandis*) are underway in the Grand, St. Lawrence and north Saskatchewan rivers to assess biomarkers of stress and immune status of field-deployed mussels upstream and downstream of municipal wastewater effluent outfall—results are pending (Gillis pers. comm. 2011).

Medium-Impact Threats

<u>Invasive and other problematic species and genes (8.1 Invasive non-native/alien species)</u>

For populations of Threehorn Wartyback occurring in the Great Lakes, the most significant threat is associated with the invasion of the dreissenid mussels in the mid-1980s. Zebra and Quagga mussels attach to a unionid mussel's shell and interfere with feeding, respiration, reproduction, excretion and locomotion (Haag *et al.* 1993; Baker and Hornbach 1997). Within a decade of the first invasion, native unionids had been almost completely eradicated from Lake St. Clair, Lake Erie and the Detroit River (Schloesser and Nalepa 1994; Nalepa *et al.* 1996; Schloesser *et al.* 2006). Although dreissenids have caused significant changes to the ecosystem in the Great Lakes, it has been suggested that their threat is not as pronounced as it was a decade ago and some macroinvertebrate species (other then mussels) appear to be showing signs of recovery (Crail *et al.* 2011; Strayer *et al.* 2011).

Predation by molluscivorous fishes, such as the invasive Round Goby, may influence survival of native mussel populations (Ray and Corkum 1997; Poos *et al.* 2010). Recent research has shown that Round Goby in the Sydenham River are preying on juvenile mussels of other species (Poos pers. comm. 2011). In addition, Round Goby have been implicated in the declines (via predation on eggs and juveniles, competition for food and habitat, and interference competition for nests) of native benthic fishes such as Logperch (*Percina caprodes*), Mottled Sculpin (*Cottus bairdii*), Johnny Darter (*Etheostoma nigrum*), Trout-perch (*Percopsis omiscomaycus*), Channel Darter (*P. copelandi*), Fantail Darter (*E. flabellare*), and Greenside Darter (*E. blennioides*) (French and Jude 2001; Thomas and Haas 2004; Baker 2005; Reid and Mandrak 2008). Although there are no specific studies that show Round Gobies negatively affect Common Shiner or Longnose Dace, they do change the ecosystem where they occur, which could lead to disruptions in the Threehorn Wartyback reproductive cycle.

Another exotic species that may currently be exerting negative effects throughout the Threehorn Wartyback's distribution is the Common Carp. This species is abundant throughout the watershed and is likely to be adversely affecting sensitive species. Although they can potentially consume juvenile mussels and dislodge adult mussels, their uprooting of plants and feeding on sediment-associated fauna can significantly increase turbidity, which is likely a far greater impact (Dextrase *et al.* 2003).

Predation by terrestrial mammals such as Muskrat and Raccoon has been shown to be an important limiting factor for some populations of freshwater mussels (Neves and Odom 1989). Owen *et al.* (2011) reported that Muskrat preferred the Threehorn Wartyback in the lower Licking River (Kentucky, USA) as they exhibit selective predation in relation to size (preferred 20-90 mm in length) and shape (cuboidal). Metcalfe-Smith and McGoldrick (2003) reported observing Raccoon predation on mussels in Ontario waters. These observations need verification in order to quantify such effects.

<u>Human intrusions and disturbance (6.1 Recreational activities)</u>

Recreational activities, such as the driving of all-terrain vehicles (ATVs) through rivers negatively impacts mussel beds by crushing individuals, churning substrate and disturbing host populations. Groups of ATVs have been observed driving in the river through sensitive mussel habitat in several southern Ontario rivers. Other recreational activities (e.g., boating, fishing) likely have minor overall impacts on mussel beds though localized impacts (e.g., boat access points) could be high.

Low-Impact Threats

<u>Residential and commercial development (1.1 Housing and urban areas)</u>

Any instream works associated with human development that have a substantial footprint, contributing to the physical loss or modification (including those that affect changes in host fishes) of Threehorn Wartyback habitat is a threat to extant populations. These include activities such as dock construction, marina operation and maintenance, shoreline hardening and infilling. Although there is no quantitative information available regarding the number of Threehorn Wartyback affected by residential and commercial development activities in Canada, removal or alteration of preferred habitat, for either the mussel or its host, could have a direct effect on the recovery or survival of the Threehorn Wartyback.

<u>Transportation and service corridors (4.3 Shipping lanes)</u>

River channel modifications such as dredging for shipping purposes can result in the direct destruction of mussel habitat and lead to siltation and sand accumulation of local and downstream mussel beds. In addition, it can lead to removal of mussels (found in the spoil) and the redistribution of these individuals (Aldridge 2000) into sub-optimal habitat.

Navigation in the mouths of some of these rivers that are commercialized (e.g., Grand River) can also impact aquatic populations (Nielsen *et al.* 1986; Aldridge *et al.* 1987). The effects of navigation and their impact on mussels, particularly the Threehorn Wartyback, have not been studied in Canada; however, Aldridge *et al.* (1987) completed a lab experiment on the effects of intermittent suspended solids and turbulence exposure on three species of mussels in Mississippi. They found that frequent exposure to turbulence and high levels of suspended solids significantly altered mussel physiological energetics by lowering food clearance rates, oxygen uptake, and nitrogenous excretion rates, as well as changes to alternate catabolic substrates, which often indicate environmental stress (Aldridge *et al.* 1987). Miller and Payne (1995), on the other hand, conducted a study on how navigation affects mussel beds in Ohio and found that the changes in velocity that occurred were too small and the duration too short to have any negative effect on the mussel bed.

<u>Pollution (9.2 Industrial and military effluents)</u>

Oil spills may also pose a threat to Threehorn Wartyback populations in these rivers. Oil spills can limit oxygen exchange, interfere with respiration, blanket substrate, cause toxic effects if consumed (Crunkilton and Duchrow 1990), as well as change fish communities—all of which can affect the survival of mussels. In July 2010, an accident caused an oil pipeline to release over 800 000 gallons of crude oil into a tributary of the Kalamazoo River in Michigan, greatly affecting the organisms in the area (Murray and Korpalski 2010). Oil transmission trunk lines run through the Grand and Thames rivers and some of their tributaries. If a spill occurs in the Grand River it could devastate the Threehorn Wartyback population because they are located just downstream of the trunk line. If a spill were to occur in the Thames River, it is unlikely that the Threehorn Wartyback population would be significantly affected as the trunk lines occur in the headwaters of these rivers and the Threehorn Wartyback populations occur in the lower portions of these rivers (Natural Resources Canada 2011).

<u>Human intrusions and disturbance (6.3 Work and other activities)</u>

Other activities that may have some impact on Threehorn Wartyback populations include the collection of individuals for scientific research. Impacts may include dislodgement of mussels and handling effects (e.g., growth rates; Haag and Commens-Carson 2008). The impact of these threats is considered low and the benefits obtained through research and an increased knowledge of the species likely outweigh any potential harm when performed by qualified individuals using approved methods.

Biological resource use (5.4 Fishing and harvesting aquatic resources)

In addition to predation, harvesting freshwater mussels for human consumption has been highlighted as a potential concern. To date, there has only been a single recorded occurrence of shells that were found at a site where human consumption was apparent and this occurred in the upper Grand River (Bouvier and Morris 2010). Although in this instance the Wavyrayed Lampmussel (*Lampsilis fasciola*) was the focus, this may be a problem in the future for other species including the Threehorn Wartyback.

Large commercial mussel harvests occurred on both the lower Grand and Thames rivers from the late 1800s through the 1950s as shells were collected for the production of buttons. Though little information appears available regarding the size of these harvests, Detweiler (1918) and Stewart (1992) report annual collection rates between 100 and 265 tons. Using average sizes of today's individuals, these collection rates equate to 250,000 - 500,000 individuals. Although it is not known if the Threehorn Wartyback was targeted in the Thames River harvests, it was likely targeted in the Grand River (Detweiler 1918). Though the fishery no longer occurs it is likely that the current status of these populations has been heavily affected by these historic harvests.

Number of locations

The number of locations was determined following IUCN guidelines by first selecting the most serious plausible threat that affects all of the taxon's distribution; where the most serious plausible threat does not affect all of the taxon's distribution, other threats can be used to define and count locations in those areas not affected by the most serious plausible threat. If there are two or more serious plausible threats, the number of locations should be based on the threat that results in the smallest number of locations. In the case of the Threehorn Wartyback, using the high impact of pollution (from sediment and nutrient loading, contaminants and toxic substances) relating primarily to urban development resulted in as many as five locations: the Sydenham and Thames River, both of which empty pollutants into Lake St. Clair, are two locations, while the Grand River, Lake Erie, and Rondeau Bay are the three other locations (Table 2). Using medium-impact threats of invasive and problematic species (Table 2), including the Zebra and Quagga mussels, which invade in the downstream direction, and Round Gobi, which can invade in the upstream direction, results in three locations, (1) Lake St. Clair with its two tributaries, Sydenham and Thames rivers, (2) Grand River, and (3) Lake Erie including Rondeau Bay.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The federal *Fisheries Act* historically represented the single most important piece of legislation protecting the Threehorn Wartyback and its habitat in Canada. However, recent changes to the *Fisheries Act* have significantly altered protection for this species and it is unclear at this time if the *Fisheries Act* will continue to provide protection for this species. Three significant changes are: All explicit references to fish habitat have been removed; "harmful alteration, disruption, or destruction of fish habitat" has been replaced by "serious harm to fish"; general prohibitions against harm to fish habitat have been replaced by those that apply now only to fish that are important to a "commercial, recreational, or Aboriginal fishery". The collection of freshwater mussels requires a collection permit issued by the Ontario Ministry of Natural Resources under authority of the *Fish and Wildlife Conservation Act.* Other indirect protections are realized through the habitat protections identified below in **Habitat Protection and Ownership**.

Areas where Threehorn Wartyback populations occur overlap (estimate 50% to 75%) with the distributions of several mussel species protected under Canada's *Species at Risk Act* and the Ontario *Endangered Species Act, 2007*. The Threehorn Wartyback may benefit indirectly from protection afforded to these species or by actions implemented (e.g., research, stewardship and outreach) under the direction of recovery strategies for the Round Hickorynut (*Obovaria subrotunda*) and Kidneyshell (*Ptychobranchus fasciolaris*) (Morris 2006a), Northern Riffleshell (*Epioblasma torulosa rangiana*), Snuffbox (*Epioblasma triquetra*), Round Pigtoe (*Pleurobema sintoxia*), Salamander Mussel (*Simpsonaias ambigua*) and Rayed Bean (*Villosa fabalis*) (Morris and Burridge 2006) and Wavyrayed Lampmussel (Morris 2006b).

Non-Legal Status and Ranks

The Threehorn Wartyback is considered globally secure (G5; last assessed 2007) and is listed as nationally secure (N5) in the United States but critically Imperilled (N1) in Canada (NatureServe 2011). It is not on the IUCN's (International Union for Conservation of Nature) Red List. The national general status assessment of freshwater mussels in Canada (Metcalfe-Smith and Cudmore-Vokey 2004) assigned a national rank of 2 (May be at Risk) to the Threehorn Wartyback and it has a sub-national rank in Ontario of Critically Imperilled (S1;NHIC 2011). In the United States, the Threehorn Wartyback is considered possibly extirpated in one jurisdiction, critically imperilled or imperilled in four, vulnerable in four, apparently secure or secure in nine. It has not been ranked in three jurisdictions (Table 3).

Table 3. Subnational conservation rankings for the Threehorn Wartyback in North American jurisdictions. All information is from NatureServe (2011).

Conservation Rank	Description	Jurisdiction
S1	Critically imperilled	Ontario
SH	Possibly extirpated	Pennsylvania
S1	Critically imperilled	Iowa, South Dakota
S2	Imperilled	Ohio, West Virginia
S3	Vulnerable	Indiana, Kansas, Oklahoma, Wisconsin
S4	Apparently secure	Arkansas, Georgia, Illinois, Kentucky (S4-S5), Missouri
S5	Secure	Alabama, Louisiana, Mississippi, Tennessee
SNR	Not ranked	Michigan, Minnesota, Texas

Habitat Protection and Ownership

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

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 (OME 2011); (3) *Ontario Water Resource 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 (OME 2011); 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 (OME 2011).

A majority of the land adjacent to the rivers where the Threehorn Wartyback is found is privately owned; however, the river bottom is generally owned by the provincial Crown. The uppermost portion of the Thames River population occurs adjacent to the Munsee-Delaware First Nations. Some of the occurrences in the Grand River extend to the Byng Conservation Area owned by the Grand River Conservation Authority.

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COLLECTIONS EXAMINED

The following description of the creation of the Lower Great Lakes Unionid Database was modified from (COSEWIC 2006).

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 8200 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 Canada, provincial agencies, universities and conservation authorities. This database is the source for all information on Canadian populations of the Threehorn 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	Obliquaria reflexa							
Element ID		**Elcode**						
							Suggested Number of Locations	
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**				**3**	
	Threat Impact		**high range**	**low range**			count non-ranges	count inc. ranges
	A	Very High	0	0			0	0
	B	High	0	0			0	0
	C	Medium	0	0			0	0
	D	Low	0	0			0	0
		Calculated Overall Threat Impact:					Total	0
		Assigned Overall Threat Impact:						
		Impact Adjustment Reasons:						
		Overall Threat Comments						

Threat		**Impact (calculated)**		**Scope**	**Severity**	**Timing**	**Comments**	**Number of Locations**		
								Lowest	**Most Likely**	**Highest**
1	Residential & commercial development									
1.1	Housing & urban areas	D	Low	Small	Extreme	High	instream works, docks etc.			
1.2	Commercial & industrial areas									
1.3	Tourism & recreation areas							1	1	5
2	Agriculture & aquaculture									
2.1	Annual & perennial non-timber crops									
2.2	Wood & pulp plantations									
2.3	Livestock farming & ranching									
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									
4.1	Roads & railroads									
4.2	Utility & service lines									

Threat		Impact (calculated)		Scope	Severity	Timing	Comments	Number of Locations		
								Lowest	Most Likely	Highest
4.3	Shipping lanes	D	Low	Small	Extreme	High	dredging harbours etc. (Wallaceburg)			
4.4	Flight paths									
5	Biological resource use									
5.1	Hunting & collecting terrestrial animals									
5.2	Gathering terrestrial plants									
5.3	Logging & wood harvesting									
5.4	Fishing & harvesting aquatic resources	D	Low	Small	Slight	Moderate	known for wrl in upper grand but not for this species or in this area	many	many	many
6	Human intrusions & disturbance									
6.1	Recreational activities	C	Medium	Large	Moderate	High	ATV in Syd with potential for other rivers.	many	many	many
6.2	War, civil unrest & military exercises									
6.3	Work & other activities	D	Low	Small	Slight	High	species research			
7	Natural system modifications									
7.1	Fire & fire suppression									
7.2	Dams & water management/use									
7.3	Other ecosystem modifications									
8	Invasive & other problematic species & genes									
8.1	Invasive non-native/alien species	C	Medium	Pervasive	Moderate	High		1	1	3
8.2	Problematic native species									
8.3	Introduced genetic material									
9	Pollution									
9.1	Household sewage & urban waste water	B	High	Pervasive	Serious	High		3	3	3
9.2	Industrial & military effluents	D	Low	Small	Extreme	Low	check with Daelyn on michigan oil spill; other potential road spills - chlorine, road salt, fuel etc.	3	3	3

Threat		Impact (calculated)		Scope	Severity	Timing	Comments	Number of Locations		
								Lowest	Most Likely	Highest
9.3	Agricultural & forestry effluents	B	High	Pervasive	Serious	High		3	3	3
9.4	Garbage & solid waste									
9.5	Air-borne pollutants									
9.6	Excess energy									
10	Geological events									
10.1	Volcanoes									
10.2	Earthquakes/tsunamis									
10.3	Avalanches/landslides									
11	Climate change & severe weather									
11.1	Habitat shifting & alteration							1	1	5
11.2	Droughts									
11.3	Temperature extremes									
11.4	Storms & flooding									

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008).