PROPOSED

Species at Risk Act
Recovery Strategy Series

Recovery Strategy and Action Plan for the Mapleleaf (*Quadrula quadrula*) in Canada (Great Lakes – Western St. Lawrence Population)

Mapleleaf

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For copies of the recovery strategy and action plan, or for additional information on species at risk, including COSEWIC Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the SARA Public Registry.

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Preface

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

This document has been prepared to meet the requirements under SARA of both a recovery strategy and an action plan. As such, it provides both the strategic direction for the recovery of the species, including the population and distribution objectives for the species, as well as the more detailed recovery measures to support this strategic direction, outlining what is required to achieve the objectives. SARA requires that an action plan also include an evaluation of the socio-economic costs of the action plan and the benefits to be derived from its implementation. It is important to note that the setting of population and distribution objectives and the identification of critical habitat are science-based exercises and socio-economic factors were not considered in their development. The socio-economic evaluation only applies to the more detailed recovery measures. The recovery strategy and action plan are considered part of a series of documents that are linked and should be taken into consideration together, along with the COSEWIC status report.

The Minister of Fisheries and Oceans Canada is the competent minister under SARA for the Mapleleaf (Great Lakes – Western St. Lawrence population) and has prepared this recovery strategy and action plan, as per section 37 and 47 of SARA. It has been prepared in cooperation with the Government of Ontario, Environment and Climate Change Canada, Central Michigan University, University of Guelph, Bishop Mills Natural History Centre, St. Clair Region Conservation Authority, Ausable-Bayfield Conservation Authority, Upper Thames River Conservation Authority, Lower Thames Valley Conservation Authority, Grand River Conservation Authority and Niagara Peninsula Conservation Authority.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and action plan and will not be achieved by Fisheries and Oceans Canada, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this strategy and action plan for the benefit of the Mapleleaf (Great Lakes – Western St. Lawrence population) and Canadian society as a whole.

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

Acknowledgments

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Executive summary

The Mapleleaf is a medium-sized (up to 12 cm) member of the freshwater bivalve family Unionidae. The shell is approximately square in outline, relatively thick and displays colour variations ranging from yellowish green to light brown in juveniles, and greenish brown to dark brown in older individuals. Typically, two rows of raised nodules extending in a v-shape from the point of shell union (umbo or beak) to shell edge (ventral margin) distinguish the outer shell surface of this bivalve species, while the interior (nacre) of the shell is white.

There are two designatable units (DUs) of Mapleleaf in Canada: the Great Lakes – Western St. Lawrence DU in Ontario and the Saskatchewan – Nelson DU in Manitoba. In 2006, the Mapleleaf (Great Lakes-Western St. Lawrence DU) was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and was listed on Schedule 1 of the *Species at Risk Act* (SARA) in 2013. The COSEWIC designation was based on the species' restricted distribution as well as past and continuing declines. The Saskatchewan – Nelson DU has been designated as Endangered by COSEWIC and was also listed under SARA in 2013. A separate recovery strategy is being developed for the Saskatchewan – Nelson DU.

The principal threats identified for the Mapleleaf (Great Lakes – Western St. Lawrence DU) (Mapleleaf from this point forward) include activities that degrade water quality and habitat, most prominently, run-off and discharge from agricultural, municipal and industrial activities, which often contain metals and nutrients and often result in increased siltation rates. In Ontario, invading dreissenid mussels (Zebra Mussel and Quagga Mussel), which began their spread in the mid 1980s, have resulted in profound changes in unionid community structure and continue to be a major threat for existing populations as they outcompete native mussels for habitat and food resources.

The population and distribution objectives for the Mapleleaf in Ontario are to return or maintain self-sustaining populations in the following locations where live animals currently exist: Ausable River, Sydenham River (including the North Sydenham River and Bear Creek), Thames River (including McGregor and Baptiste creeks), Ruscom River, Grand River, Welland River, Twenty Mile Creek/Jordan Harbour and Sixteen Mile Creek. The populations at these locations could be considered recovered when they demonstrate active signs of reproduction and recruitment throughout their known distribution at each location, such that populations are stable or increasing; in addition, risk from threats at these locations would need to be reduced to 'low'.

Using available data, critical habitat has been identified at this time for the Mapleleaf in the following locations: Ausable River, Sydenham River (including the North Sydenham River and Bear Creek), Thames River (including McGregor and Baptiste creeks), Ruscom River, Grand River, Welland River, Jordan Harbour/Twenty Mile Creek and Sixteen Mile Creek. Additional areas of potential critical habitat for this species in Lake St. Clair may be considered in collaboration with Walpole Island First Nation if supported by the results of further surveys. A schedule of studies has been developed that outlines the necessary steps to obtain the information to further refine these critical habitat descriptions. Until critical habitat has been fully identified, the recovery team recommends that currently occupied habitats are in need of conservation.

Recovery approaches have been organized into three broad categories: (1) Research and Monitoring; (2) Management and Coordination; and, (3) Communication and Outreach. These

approaches are best accomplished through cooperation with existing ecosystem recovery teams and research efforts. Most of these will prove beneficial to all aquatic species at risk and eliminate duplication of effort.

The action plan portion of this document provides the detailed recovery planning in support of the strategic direction set out in the recovery strategy section of the document. The plan outlines what needs to be done to achieve the population and distribution objectives, including the measures to be taken to address the threats and monitor the recovery of the species, as well as the measures to protect critical habitat. Socio-economic impacts of implementing the action plan are also evaluated.

Recovery feasibility summary

Recovery of the Mapleleaf is believed to be both biologically and technically feasible. The following feasibility criteria[1] have been met for the species:

1. *Individuals of the Mapleleaf that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.*

   Yes. Reproducing populations currently exist within the Ontario range of the species (e.g., Ausable, Sydenham, Thames and Grand rivers) and could be used for translocations or artificial propagation if necessary.

2. *Sufficient suitable habitat is available to support this species or could be made available through habitat management or restoration.*

   Yes. Suitable habitat is present at several locations with extant populations. At locations with extirpated or declining populations, suitable habitat may be made available through current and proposed restoration efforts.

3. *The primary threats to the species or its habitats (including threats outside Canada) can be avoided or mitigated.*

   Yes. Significant threats such as sedimentation, and nutrient and contaminant loading can be mitigated through proposed recovery techniques; throughout much of the Mapleleaf range, recovery efforts are already underway. While action has been taken to limit the expansion of dreissenid mussels, recovery of Mapleleaf populations to historical levels in heavily infested areas (i.e., Great Lakes and connecting waterways) is not possible; however, the establishment of managed refuge sites is being investigated within such locations.

4. *Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.*

   Yes. Techniques to reduce identified threats (e.g., Best Management Practices to reduce sedimentation) and restore habitats are well known and proven to be effective. The effort expended to achieve recovery will not be uniform across all populations with much greater effort required to improve habitat at locations with reduced populations.

[1] Draft Policy on the Feasibility of Recovery, *Species at Risk Act* Policy. January 2005.

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1. COSEWIC[2] species assessment information

Date of assessment: April 2006
Common name (population): Mapleleaf (Great Lakes – Western St. Lawrence population)
Scientific name: *Quadrula quadrula*
COSEWIC status: Threatened
Reason for designation: This heavy shelled mussel that is shaped like a maple leaf, has a very small area of occupancy in watersheds dominated by agriculture with past and continuing declines due to habitat loss and degradation. Although the mussel has been lost from the Great Lakes and connecting channels due to zebra mussels, the number of mature individuals appear to be very large in two of the watersheds and three of five watersheds have recovery teams in place for aquatic species at risk. Zebra mussels continue to be a potential threat in watersheds that have numerous impoundments.
Canadian occurrence: Ontario
COSEWIC status history: Designated Threatened in April 2006. Assessment based on a new status report.

2. Species status information

Global status: The Mapleleaf (*Quadrula quadrula* Rafinesque, 1820) is globally listed as G5 (demonstrably widespread, abundant, and secure). In the U.S., it is considered N5 (secure) but there are states where this species is listed as imperiled to critically imperiled (NatureServe 2012) (Table 1). In Canada, the Mapleaf is considered N3 (nationally vulnerable) and occurs only in Ontario and Manitoba (NatureServe 2012) (Table 1). In both provinces, an analysis of the historical records indicates a decline in the overall distribution of the species.

Canadian status: In Canada, the Mapleleaf has a national ranking of N3, and is designated as S2 (imperiled) in Ontario and is unranked in Manitoba (NatureServe 2012). It was designated as Endangered in Manitoba and Threatened in Ontario in 2006 by COSEWIC (COSEWIC 2006). In Manitoba it is listed as Endangered under the federal *Species at Risk Act* (SARA). In Ontario, it is listed as Threatened under both SARA and Ontario's *Endangered Species Act*, 2007.

Percent of global distribution and abundance in Canada: The Mapleleaf has been lost from approximately 49% of its former range in Ontario. Specifically, its extent of occurrence is approximately 13 000 km^2 and its area of occupancy is approximately 35.2 km^2 (Sydenham, Thames, Grand, and Ausable rivers). In Manitoba, its extent of occurrence is 11 500 km^2 and its area of occupancy is approximately 36.3 km^2 (Assiniboine and Bloodvein rivers)(COSEWIC 2006).

[2] COSEWIC (Committee on the Status of Endangered Wildlife in Canada)

Table 1. Global, national and sub-national ranks for the Mapleleaf (NatureServe 2012).

Rank	Jurisdiction rank*
Global (G)	G5 (last reviewed 19 April. 2007)
National (N)	
Canada	N3
U.S.	N5
Subnational (S)	
Canada	Manitoba (SNR), Ontario (S2)
U.S.	Alabama (S5), Arkansas (S5), Illinois (S5), Indiana (S4), Iowa (SNR), Kansas (S4), Kentucky (S4S5), Louisiana (S5), Michigan (SNR), Minnesota (SNR), Mississippi (S5), Missouri (S4), Nebraska (SNR), New York (SH), North Dakota (S3), Ohio (S5), Oklahoma (S5), Pennsylvania (S1S2), South Dakota (S2), Tennessee (S5), Texas (SNR), West Virginia (S2), Wisconsin (S2S3)

* For an explanation of G, N and S-ranks, please refer to NatureServe (2012).

3. Species information

3.1 Species description

The Mapleleaf is a medium-sized (up to 12 cm) member of the freshwater bivalve family Unionidae. The shell is approximately square in outline, relatively thick and displays colour variations ranging from yellowish green to light brown in juveniles and greenish brown to dark brown in older individuals. Typically, two rows of raised nodules extending in a v-shape from the point of shell union (umbo or beak) to shell edge (ventral margin) distinguish the outer shell surface of this bivalve species, while the interior (nacre) of the shell is white. The sex of the Mapleleaf cannot be determined based on external examination (i.e., it is not obviously sexually dimorphic; Morris and Bouvier 2011). More detailed information can be found in COSEWIC (2006a).

3.2 Population and distribution

Global range: The global range of the Mapleleaf extends throughout the Ohio-Mississippi River drainages from Louisiana to Texas and up to the Red River drainage in Manitoba and the Great Lakes drainage in Ontario (Figure 1). In the U.S., the distribution ranges from Texas in the southwest to Alabama in the southeast, while the northern distribution ranges from the Great Lakes drainage in Minnesota and Wisconsin to New York and extends into the Red River drainage in Minnesota and North Dakota (NatureServe 2012) (Figure 1).

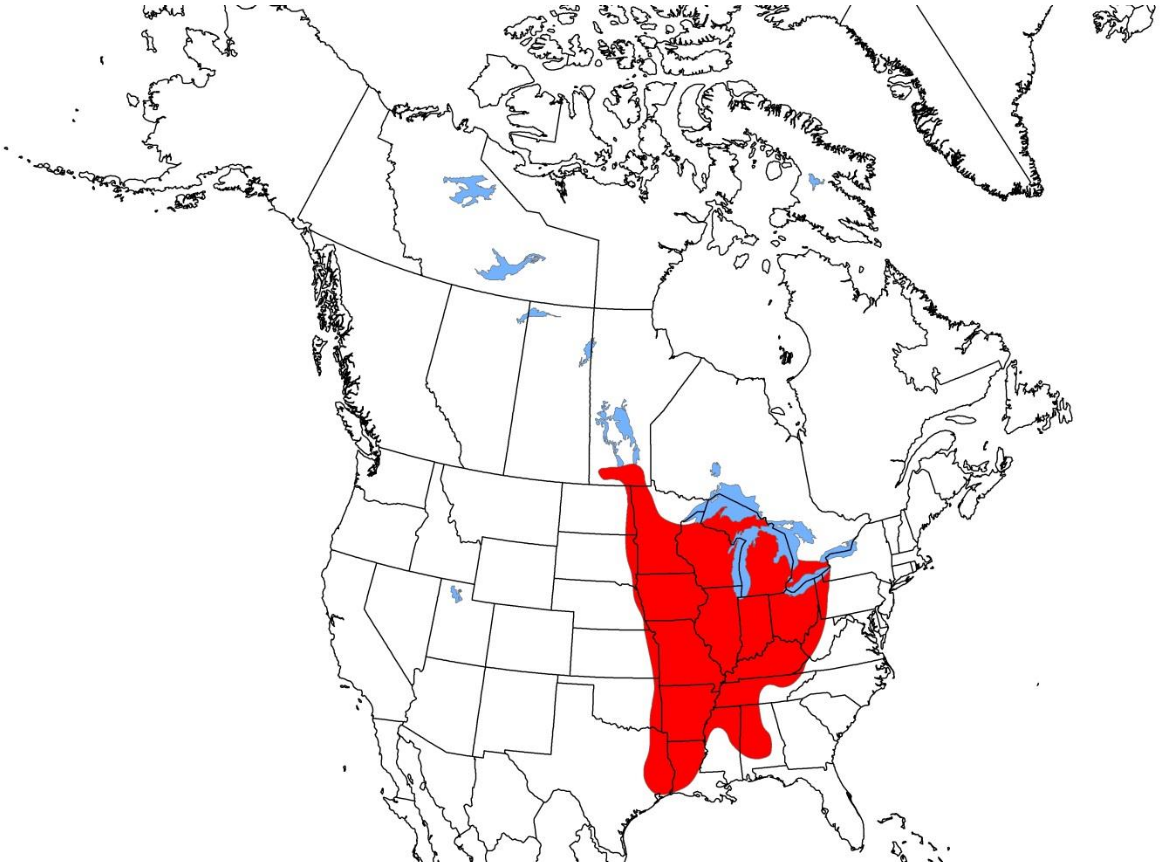

Figure 1. North American distribution of the Mapleleaf (*Quadrula quadrula*) (modified from Royal Ontario Museum [ROM]).

Canadian range: The Canadian distribution of Mapleleaf has been separated into two designatable units (DUs): the Great Lakes - Western St. Lawrence populations (Ontario) (Figure 2) and the Saskatchewan – Nelson populations (Manitoba). This separation is based on genetic and geographic separations (COSEWIC 2006). In Manitoba, populations occur in the Assiniboine (lower reaches) and Bloodvein rivers, while Ontario populations appear mainly restricted to a few rivers (Ausable, Sydenham, Thames, Ruscom, Grand, Welland, Twenty Mile Creek and Sixteen Mile Creek) draining into lakes Huron, St. Clair, Erie and Ontario. In both provinces, an analysis of the historical records indicates a decline in the overall distribution of the species (COSEWIC 2006).

Canadian population size: To date, it appears that there are at least eight remaining populations of Mapleleaf in Ontario and two remaining in Manitoba. In Ontario, the overall population has been estimated at 5.5 million (COSEWIC 2006), with the largest population in the Thames, followed by the Grand and Sydenham rivers (Bouvier and Morris 2011). The largest population in Manitoba is found within the Assiniboine River and has been estimated at between 1-4 million individuals.

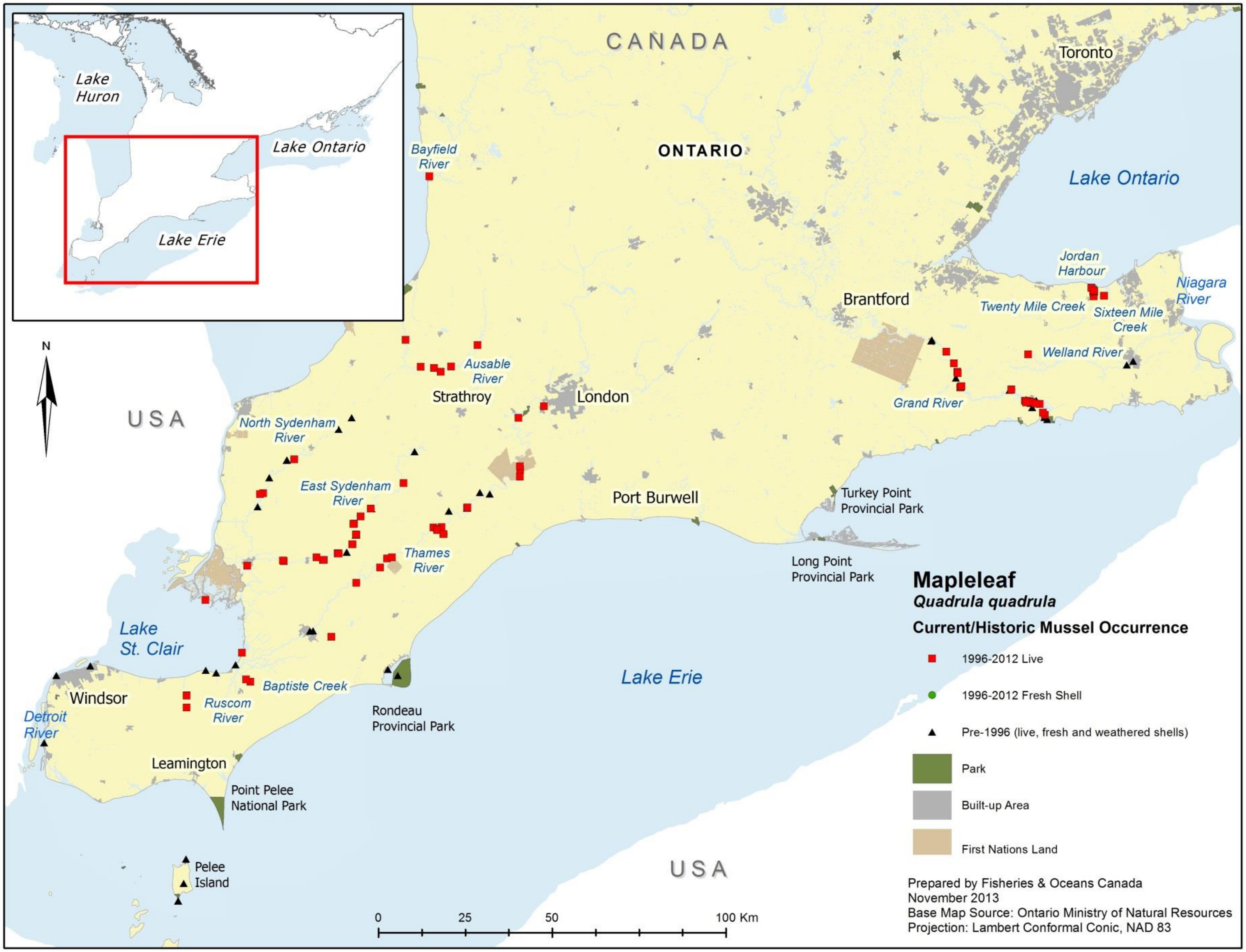

Figure 2. Distribution of Mapleleaf in Ontario, Great Lakes – Western St. Lawrence population.

The following descriptions of the known occurrence of Mapleleaf in Ontario were modified from Bouvier and Morris (2011).

Ausable River: The first record of Mapleleaf in the Ausable River is from 2002 when nine live specimens were captured. Subsequent sampling at additional sites in 2004 yielded another nine specimens. In 2006, the 2002 site was revisited and 19 live Mapleleaf were observed (Ausable-Bayfield Conservation Authority [ABCA]) unpubl. data). Additional sampling in 2008, 2009 and 2011 resulted in the capture of one, seven and ten live animals, respectively (ABCA, unpubl. data). These records, along with a single record from the Bayfield River, represent the only occurrences of Mapleleaf in the Lake Huron drainage.

Bayfield River: No historic records exist for the Mapleleaf in the Bayfield River. The species was first detected at this location in 2007 when a single Mapleleaf was collected. Limited sampling for freshwater mussels has occurred in the Bayfield River and therefore at this time it is not known whether a reproducing Mapleleaf population is present.

Grand River: Records of Mapleleaf in the Grand River date back to 1885, with all known records occurring in the lower 50 km of the river, between Caledonia and Port Maitland. Intensive sampling has occurred north of Caledonia; however, no Mapleleaf have been detected. It is believed that the entire distribution of Mapleleaf in the Grand River is found in this lower stretch of river.

Great Lakes and connecting channels: In Ontario, historic records of Mapleleaf occur within Lake Erie, Lake St. Clair, the Detroit River and the Niagara River. In Lake Erie, Mapleleaf were found in Rondeau Bay and the area around Pelee Island. Records from Lake St. Clair are mainly comprised of shells or single individuals. Only two records exist for the Niagara River, from 1934, while there are only three records from the Detroit River. From these scarce records, it can be assumed that the Mapleleaf was fairly rare throughout the Great Lakes and connecting channels prior to the dreissenid mussel (Zebra Mussel [*Dreissena polymorpha*] and Quagga Mussel [*D. bugensis*]) invasion. With the exception of the St. Clair River delta, the species is now believed to be extirpated from the *Canadian* waters of the Great Lakes and connecting channels; within U.S. waters however, several populations were detected within drowned river mouths along the coasts of Lake Erie and Lake St Clair in 2012 with over 200 live Mapleleaf encountered (D. Zanatta, pers. comm, University of Michigan).

Twenty Mile Creek/Jordan Harbour: The first recorded population of Mapleleaf within the Lake Ontario watershed was discovered in Jordan Harbour, where Twenty Mile Creek enters Lake Ontario. In 2010, three fresh valves and more than 100 weathered shells were observed on the northeast shore of Jordan Harbour (T. Theysmeyer, Royal Botanical Garden, pers. obs.); however, no live specimens were observed. Further surveys in 2012 did detect the species live at several sites in the lower Twenty Mile Creek system near Jordan Station (Brumpton *et al.* 2013), however further sampling is required to determine the size of this population.

Sixteen Mile Creek: The first recorded population of Mapleleaf within the lower Sixteen Mile Creek was reported in June 2013 when six live animals were found at a total of two sites (S. Reid, pers. comm, OMNRF). Sampling methods used included visual, tactile and clam raking. Live animals were found upstream of coastal wetlands where no zebra mussels were observed in the turbid waters.

Ruscom River: In 1999, a freshwater mussel survey was conducted on the Ruscom River (a tributary on the south shore of Lake St. Clair), which yielded nine live Mapleleaf. As it was not possible to determine the size and status of this population based on a single sampling event, the site was revisited in 2010 and 26 live Mapleleaf were located at an additional two sites.

St. Clair River delta: The St. Clair River delta has been surveyed extensively over the last ten years, but Mapleleaf was not recorded until 2005, when a single live animal was recorded from Chematogan Bay during a snorkelling survey.

Sydenham River: Mapleleaf was first recorded in the Sydenham River in 1963 and has been found regularly in subsequent surveys until present day. The species' range in this system occurs from Wallaceburg to just upstream of Alvinston in the East Sydenham as well as the upper regions of the North Sydenham River in Bear Creek downstream of Petrolia. Many Mapleleaf locations have been sampled throughout the East Sydenham River from 1997 to 2012 and continue to yield live Mapleleaf.

Thames River: The Thames River has been sampled extensively since the mid-'90s and although a few records of Mapleleaf exist in the upper Thames River, the species is predominantly present in the middle and lower portions of the river (including two tributaries – McGregor and Baptiste creeks). A large number of live Mapleleaf (e.g., 225 from a single excavation) were detected during recent quadrat excavations in 2010 (Fisheries and Oceans Canada [DFO], unpubl. data). The Mapleleaf population in the lower Thames River is thought to be one of the most stable and abundant in Ontario.

Welland River: Two historic records exist for the Mapleleaf in the Welland River, neither of which represented a live individual. In 2008, freshwater mussel surveys were conducted in the Welland River and 25 live individuals were recorded at a site approximately 50 river kilometers upstream of the historic location, although no specimens were detected at the historic location (Morris *et al.* 2012). Further surveys of the Welland River are required to determine the extent of this population.

Using data available up to 2010, Bouvier and Morris (2011) derived population estimates for all current Mapleleaf populations in Ontario (Table 2). The Great Lakes and connecting channels were not included in their estimates as the Mapleleaf is believed to be extirpated from these areas. Refer to Bouvier and Morris (2011) for details on the methodology.

Table 2. Population estimates for all current Mapleleaf populations in Ontario.
*indicates the population is represented by a single live individual; **indicates that density estimates are only available from a single site, and therefore Standard Error (SE) is not available; NA – information is not available. (Table reproduced from Bouvier and Morris 2011)

Population	Average total unionid density (#/m^2) (SE)	Mapleleaf density (#/m^2) (SE)	Mapleleaf area of occupancy (m^2)	Mapleleaf estimated population size
Ausable River	2.065 (± 1.945)	0.135 (± 0.121)	712 637	9977 – 183 005
Bayfield River*	NA	NA	80 287	NA
Grand River	2.253**	0.030**	10 827 716	324 831
Jordan Harbour (Twenty Mile Creek)	NA	NA	492 747	NA
Ruscom River	NA	NA	56 719	NA
St. Clair River delta*	NA	NA	755 799	NA
Sydenham River	5.826 (± 1.587)	0.210 (± 0.058)	5 800 645	883 191 – 1 553 783

Population	Average total unionid density (#/m^2) (SE)	Mapleleaf density (#/m^2) (SE)	Mapleleaf area of occupancy (m^2)	Mapleleaf estimated population size
Thames River	5.045 (± 0.748)	0.508 (± 0.187)	11 733 405	3 765 144 – 8 144 262
Welland River	NA	NA	6394	NA

The population trend for the Mapleleaf is believed to be declining as it has been lost from approximately 49% of its former range in Ontario (COSEWIC 2006).

Populations of Mapleleaf were ranked by Bouvier and Morris (2011), with respect to abundance and trajectory. Population abundance and trajectory were then combined to determine the population status for populations known to exist prior to 2011 (Table 3). A certainty level was also assigned to the population status, which reflected the lowest level of certainty associated with either population abundance or trajectory. Refer to Bouvier and Morris (2011) for further details on the methodology.

Table 3. Abundance index, population trajectory, and population status of the Mapleleaf.
*indicates population represented by a single live individual. Certainty associated with abundance index or population trajectory is listed as: 1=quantitative analysis; 2=standardized sampling; 3=expert opinion; certainty for population status reflects the lowest level of certainty associated with either abundance index or population trajectory. (Table modified from Bouvier and Morris 2011)

Population	Abundance index	Certainty	Population trajectory	Certainty	Population status	Certainty
Ausable River	Medium	2	Unknown	3	Poor	3
Bayfield River*	Low	3	Unknown	3	Poor	3
Grand River	High	2	Unknown	3	Fair	3
Great Lakes and connecting channels[1]	Extirpated	2	-	-	Extirpated	2
Ruscom River	Medium	2	Unknown	3	Poor	3
St. Clair River delta*	Low	1	Unknown	3	Poor	3
Sydenham River	High	1	Stable	3	Good	3
Thames River	High	1	Stable	3	Good	3
Welland River	Low	2	Unknown	3	Poor	3

[1] Surveys in 2012 of potential coastal mussel refuges in U.S. waters of Lake Erie and Lake St. Clair indicated the presence of live Mapleleaf in several locations (D. Zanatta, pers. comm, University of Michigan); similar survey work is required in Canadian waters to further investigate the potential for remnant populations within the lower Great Lakes.

3.3 Needs of the Mapleleaf

Habitat and biological needs

Spawning: The reproductive biology of the Mapleleaf is similar to that of most unionid mussels (adapted from Clarke 1981 and Kat 1984). During spawning, males release sperm into the water and females living downstream filter the sperm out of the water with their gills. Once the ova are fertilized, they are held until they reach a larval stage called the glochidium. The female mussel then releases the glochidia, which must attach to an appropriate host fish.

The length of the brooding season for the Mapleleaf has been reported to vary with location, ranging from late spring to early summer in Canada (Clarke 1981). Mapleleaf is considered a short-term brooder (tachytictic), brooding and releasing its glochidia in the same year (COSEWIC 2006).

Many species of freshwater mussels have evolved complex host attraction strategies to increase the probability of encountering a suitable host (Zanatta and Murphy 2006). Mapleleaf uses conglutinates (packets of glochidia) (COSEWIC 2006). These conglutinates may have markings similar to that of prey items to mislead potential host fishes.

Encysted glochidia stage: The life cycle of unionid mussels includes a larval stage that is an obligate parasite (glochidium). Most common hosts appear to be fish species, but little information on the specificity of host requirements for the Mapleleaf exists. The Channel Catfish (*Ictalurus punctatus*) has been implicated as a host fish (Schwebach *et al.* 2002) for Canadian populations; its distribution overlaps that of Mapleleaf in both Ontario and Manitoba (Bouvier and Morris 2011).

Glochidia will remain encysted until they metamorphose into juveniles. Attachment times for the Mapleleaf have been noted from 51 to 68 days, with temperature being a key factor in development time (Schwebach *et al.* 2002).

Unionids cannot complete their life cycle without access to the appropriate glochidial host. If host fish populations disappear or decline in abundance to levels below that which can sustain a mussel population, recruitment will no longer occur and the mussel species may become functionally extinct (Bogan 1993).

Juvenile: After metamorphosis, juveniles release themselves from the host and fall to the substrate to begin life as free-living mussels. Unionid juvenile stages generally reside buried within sediment substrates for a number of years, behaviour that most likely applies to the Mapleleaf. Juveniles residing within the sediment likely consume interstitial organic material, such as bacteria and algae (e.g., Yeager et al. 1994). They remain buried until they are sexually mature, at which point they move to the surface for the dispersal/intake of gametes (Watters *et al.* 2001).

Adult: In Canada, the Mapleleaf is most commonly encountered in shallow lakes, deep river impoundments, and medium to large rivers and embayments with slow to moderate flow characteristics on firmly packed coarse gravel, sand and clay/mud mixtures (Clarke 1981; Parmalee and Bogan 1988; Watson 2000; Baitz et al. 2008). Flow does not seem to be a limiting characteristic as Mapleleaf has been found in both slow- and fast-flowing water (Bouvier and Morris 2011). The Mapleleaf has also been found in mud, sand, or fine gravel substrates (DFO, unpubl. data); during recent work in the Grand River at Cayuga, Mapleleaf were found in: 0-40% boulders, 30-50% cobble, 5-55% gravel all with some mud. (Mackie et al. 2011). In the Ausable River, Mapleleaf were found exclusively at the survey station with the slowest flow characteristics (Baitz et al. 2008). Temperature tolerance is unknown but must range from near freezing to upwards of 27°C, the temperature ranges recorded in occupied Canadian rivers.

Adult Mapleleaf have very limited dispersal abilities. Although adult movement can be directed upstream or downstream, studies have found a net downstream movement through time

(Balfour and Smock 1995). The primary means for large-scale dispersal, upstream movement, and the invasion of new habitat or evasion of deteriorating habitat, is limited to the encysted glochidial stage on the host fish.

Nutritional requirements of unionid mussels are poorly understood and species-specific studies on Mapleleaf food requirements are unavailable. Extrapolation from feeding studies of other freshwater mussels suggest that Mapleleaf are likely to ingest both suspended (e.g., Nichols and Garling 2000) and deposited (e.g., Raikow and Hamilton 2001) particulate organic matter, with possible selection of phytoplankton and bacteria.

Ecological role: The impact of the loss of unionid mussels from streams and rivers is difficult to predict, but these animals can be important components of food web dynamics, linking and influencing multiple trophic levels (e.g., Vaughn et al. 2004; Vaughn and Spooner 2006). Vaughn et al. (2008) catalogued some of the food web and trophic influences of freshwater mussel communities on other ecosystem components. Mussels can provide habitat for other organisms by creating physical structure, and dense mussel beds can stabilize streambed substrates during periods of high flow. Unionid species influence food availability directly and indirectly through bio-deposition of organic matter and nutrient excretion. For example, the metabolic waste products of unionids can be assimilated by algae, while their pseudofeces (material which has been removed from the water column but not metabolized; Nalepa et al. 1991) are decomposed by benthic microorganism and consumed by portions of the benthic fauna. Rare species, including other unionid species, have been shown to benefit energetically from living in species-rich communities, namely the multispecies assemblages that healthy mussel communities form (Spooner 2007).

Limiting factors: Factors involving reproduction and dispersal may be the most significant limiting factors for the Mapleleaf. Availability of host fish(es) suitable for glochidial attachment may inhibit unionid population growth and dispersal, and the time frame for glochidia attachment to host fish may be very limited. Effectively, large-scale dispersal is limited to the encysted glochidial stage on the host fish. Predation by fishes, mammals and birds can threaten mussel populations and in some cases may be impacting Mapleleaf populations.

4. Threats

4.1 Threat assessment

Table 4, adapted from Bouvier and Morris (2011), provides a summary of threats to Mapleleaf populations in Ontario. Known and suspected threats were ranked with respect to threat likelihood and threat impact for each population. The threat likelihood and threat impact were then combined to produce an overall threat status. A certainty level was also assigned to the overall threat status, which reflected the lowest level of certainty associated with either threat likelihood or threat impact. See Bouvier and Morris (2011) for further details. Additional information is provided in the threat descriptions which follow the table.

Table 4. Threat levels for the Mapleleaf in Ontario.

Threat Level (High, Medium, Low or Unknown) was produced from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Level, which relates to the level of certainty associated with Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and 3=expert opinion. Gray cells indicate that the threat is not applicable to the location due to the nature of the aquatic system. Clear cells do not necessarily represent a lack of a relationship between a location and a threat; rather, they indicate that either the Threat Likelihood or Threat Impact was Unknown. (Table modified from Bouvier and Morris 2011)

Threat	Ruscom River	St. Clair River Delta	Sydenham River	Lower Thames River	Ausable River	Bayfield River	Grand River	Jordan Harbour	Welland River
Exotic species	High (2)	High (2)	Medium (2)	High (2)	Medium (2)	Medium (2)	High (2)	High (2)	Medium (2)
Turbidity and sediment loading	Medium (3)	Low (3)	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (2)	Medium (3)	Medium (3)
Contaminants and toxic substances	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	High (2)	High (3)	High (3)
Nutrient loading	Medium (3)	Low (3)	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (2)	Medium (3)	Medium (3)
Altered flow regimes	Medium (3)		Medium (3)	Medium (3)	Medium (3)	High (3)	Medium (2)		Low (3)
Habitat removal and alterations	High (3)	Medium (3)	High (3)	High (3)	Medium (3)	Medium (3)	High (2)	Medium (3)	Medium (3)
Disruption of fish hosts	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (2)	Medium (3)	High (3)	Medium (3)	Medium (3)
Predation and harvesting	Unknown (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Unknown (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)

N.B. The Threat Level represents a combination of the **current** Threat Impact (i.e., not potential impact) and Threat Likelihood at a location.

4.2 Description of threats

The following brief descriptions emphasize the principal threats currently acting on Mapleleaf populations throughout Ontario. Much of the information has been summarized from Bouvier and Morris (2011).

Exotic species: Invasive dreissenid mussels have had a profound impact on native freshwater mussel communities in Canada (e.g., Ricciardi et al. 1998). Direct attachment by Zebra and Quagga mussels on unionids can lead to interference of feeding, locomotion, respiration, and excretion (e.g., Haag et al. 1993; Schloesser et al. 1996). The apparent loss of the Mapleleaf from the Canadian waters of lakes Erie and St. Clair and the Niagara and Detroit rivers is believed to be directly related to the invasion of dreissenid mussels within these systems, starting in the mid to late 1980s (COSEWIC 2006). Dreissenid mussels also threaten and limit the distribution of freshwater mussels in the St. Clair River delta (Metcalfe-Smith et al. 2007a).

Dreissenid mussels rely on passive dispersal of their larvae, and are therefore generally unable to move upstream, unlike unionid mussels which employ fish hosts to facilitate upstream dispersal (Mackie 1991). For this reason, dreissenid mussels pose an important threat to the lacustrine habitat of native freshwater mussels. However, Zebra Mussel could also pose a threat to riverine mussel populations, if it were to become established in reservoirs (Bouvier and Morris 2011). Zebra Mussel have been reported in two reservoirs on the Thames River (UTRCA 2003), and throughout the lower Thames River from Fanshawe Reservoir to the mouth of the river (Morris and Edwards 2007). Freshwater mussel populations in the Grand River are highly susceptible to Zebra Mussel, as the Grand River is heavily impounded. Infestation by Zebra Mussel of the Luther, Belwood, Guelph, or Conestogo reservoirs could have a significant impact on the freshwater mussel populations (Metcalfe-Smith et al. 2000b). However, it should be noted that there is some evidence to suggest that Mapleleaf in the lower Grand River exposed to Zebra Mussels (near Port Maitland) appear to survive infestation as demonstrated by the presence of live individuals covered in byssal threads (S. Staton, DFO, pers. comm.). Further research in a coastal wetland of Lake Erie has suggested that large molluscivorous fishes (e.g., Common Carp, Freshwater Drum and Channel Catfish) can be effective predators of Zebra Mussel attached directly to Mapleleaf (Bowers and de Szalay 2007).

Additionally, the Common Carp (*Cyprinus carpio*) and the Round Goby (*Neogobius melanostomus*) may pose a threat to some populations by increasing turbidity and reducing host fish species, respectively. Other potentially deleterious relationships to invasive species require further investigation.

Turbidity and sediment loading: Increased rates of siltation can result in impairment of oxygen intake, feeding and reproductive functions as well as physical smothering, of which the young are particularly at risk. Vulnerability to siltation varies among unionids; susceptibility of the Mapleleaf is unknown.

Agricultural practices that may result in increased siltation rates include allowing livestock access to streams, which can result in streambank 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 smother mussels.

Over 85% of the Sydenham River watershed is agricultural land (Dextrase *et al.* 2003). Suspended solids have been reported as high as 900 mg/L in the Sydenham River (Dextrase et al. 2003), a level that would negatively impact freshwater mussel populations (Bouvier and

Morris 2011). Over 88% of land in the lower Thames River is used for agricultural purposes (Taylor et al. 2004). The lower Thames River is considered to be highly turbid (COSEWIC 2006). Increased agricultural pressure (from 68% in 1976 to 75% in 1998) has affected water quality in the Grand River, resulting in increased turbidity and sediment loads; however, it is the species found in the lower Grand River, such as Mapleleaf, that are mainly affected (COSEWIC 2006; Bouvier and Morris 2011). The presence of a low head dam near the mouth of the river at Dunnville is also known to contribute to degraded (e.g., high nutrient levels and low oxygen), highly turbid conditions within the lower 30 km reach of the Grand River where the Mapleleaf is found (MacDougall and Ryan 2012). The St. Clair River delta is considered to be less affected by this threat, as it is afforded some protections by the Walpole Island First Nation Territory (e.g. access restrictions).

The Ausable River watershed has been drastically altered and it is estimated that by 1983, 85% of the land in this watershed had been converted from forest and lowland vegetation to agricultural land, and that 70% of the land is now in tile drainage (Nelson et al. 2003).

Contaminants and toxic substances: Freshwater mussels are among the most sensitive aquatic organisms to environmental contaminants (e.g., Goudreau et al. 1993; Mummert et al. 2003). As benthic filter-feeders, mussels are exposed to any contaminants found in both the dissolved phase (i.e. in the water column) and those associated with the sediment (both suspended and settled). Juvenile freshwater mussels remain buried in the sediment for the first few years of life where they feed exclusively on particles in the interstitial water. Such behaviour may increase their exposure to sediment-bound contaminants during this sensitive early life stage (Yeager et al. 1994) which could have implications for the survival of species that are especially sensitive to toxic chemicals.

Contaminants can enter Mapleleaf habitat in a variety of ways, including, but not limited to, agricultural and road run-off, and industrial and storm sewer discharges. A wide variety of contaminants may enter mussel habitat including pesticides, road salts, hydrocarbons, and heavy metals. Recent studies on the impacts of pesticides on juvenile mussels and glochidia indicate that the Unionidae are relatively sensitive to pesticides (e.g., Bringolf et al. 2007). Unionids appear to be especially susceptible to ammonia and copper, particularly the glochidial and juvenile stages (e.g., Mummert et al. 2003; Gillis et al. 2008); potassium is also a concern (see Morris et al. 2008) as well as salinity (Gillis 2011).

Gillis (2011) has shown that glochidia of the Wavyrayed Lampmussel (*Lampsilis fasciola*) were acutely sensitive to sodium chloride. Assuming that the salt sensitivity of the Mapleleaf is comparable to that of the Wavyrayed Lampmussel, chloride from road salt is a substantial threat to the early life stages; the range of both species is limited to southern Ontario, Canada's most road-dense and thus heavily salted region. While natural water does buffer the toxic effects of chloride to the glochidia, chloride levels in mussel habitat have been reported at levels (>1300 mg/L) that are toxic to the Wavyrayed Lampmussel (Gillis 2011). Although federal water quality guidelines for the protection of aquatic life have been set at 120 mg/L for chronic exposure to chloride, this guideline may not be sufficiently protective of glochidia of some species at risk mussels in southern Ontario (CCME 2011). Further work by Todd and Kaltenecker (2012) suggest that long-term road salt use is contributing to increases in baseline chloride concentrations in at risk mussel habitats in southern Ontario that may affect recruitment of at-risk mussel populations; Mapleleaf are found in many of these habitats.

Many forms of pollution resulting from human encroachment, such as residential and urban development, into Mapleleaf habitat may be present (e.g., run-off of lawn fertilizers and pesticides, road salts, and heavy metals from industrial sources) (e.g., Pip 1995, 2006). Exposure to municipal wastewater effluent can negatively affect unionid health (e.g., Gagné et al. 2004; Gagnon et al. 2006). 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 as significant effects on freshwater fish communities have been demonstrated (Kidd et al. 2007); in the Grand River, recent work by Tetreault et al. (2011) have documented feminization of some fishes.

Freshwater mussels in the Grand River are subjected to anthropogenic stressors, such as sewage pollution, below the urban centres (Mackie 1996). The Grand River watershed has a population of approximately 780 000 people and is expected to increase by nearly 40% over the next 20 years (COSEWIC 2006). As such, wastewater discharge is a major input in these urban areas and is expected to increase with increasing population. A recent study that assessed the cumulative impacts of urban runoff and municipal wastewater effluent on freshwater mussels in the Grand River concluded that chronic exposure to multiple contaminants (e.g. ammonia, chloride and metals such as copper, lead, and zinc) contributed to the decline of mussel populations in this watershed (Gillis 2012); the author also confirmed this negative impact through a follow up (unpublished) study which revealed the existence of a ‘dead zone’ immediately downstream of one wastewater treatment plant outfall near Kitchener where no live mussels were detected for several kilometers (P. Gillis, Environment and Climate Change Canada, pers. comm). The negative impacts of wastewater treatment plants on mussel populations has also been reported in other regions (Goudreau et al. 1993).

In the Thames River watershed, mean ammonia concentrations exceed federal guidelines in all sub-basins (Morris et al. 2008), while mean concentrations of copper exceed guidelines in several sub-basins (Metcalfe-Smith et al. 2000a).

In the Welland River watershed, recent research has indicated the presence of highly elevated levels of per- and poly-fluorinated compounds (e.g. PFOS) in biota within Lake Niapenco in the upper watershed with the source of the contamination attributed to the Hamilton airport upstream (de Solla et al. 2011). This contamination by fluorinated compounds is of concern for Mapleleaf (as well as other freshwater mussels) found further downstream in the Welland River as recent laboratory results have indicated that the brooding glochidia of some mussel species are highly sensitive to such contaminants and are among the most sensitive organisms tested to date (Hazelton et al. 2012).

Nutrient loading: The primary concern of nutrient loadings in Mapleleaf habitat relates to eutrophication effects, namely algal blooms that can result in oxygen depletion and algal toxins. Additionally, freshwater mussels, particularly juvenile stages, may be sensitive to ammonia (e.g., Newton et al. 2003; Newton and Bartsch 2007). A negative correlation was found between concentrations of phosphorus and nitrogen and Wavyrayed Lampmussel (*Lampsilis fasciola*) abundance in a variety of southwestern Ontario streams (Morris et al. 2008).

The potential for run-off of fertilizer must be considered where agriculture is present. Accidental spills that have the potential to reduce dissolved oxygen (DO) can negatively influence unionid populations (Tetzloff 2001). The Thames River exhibits some of the highest phosphorus and nitrogen loadings found in the Great Lakes basin (WQB 1989). In particular, the lower Thames River is heavily impacted by agricultural activities. Phosphorus levels exceeding the provincial water quality objectives are often found in the Sydenham River (Dextrase et al. 2003), and concentrations of total phosphorus associated with agricultural runoff in the east branch are increasing, affecting the Mapleleaf (COSEWIC 2006). In the Ausable River, total phosphorus levels are often above the provincial water quality objective and nitrate levels also exceed guidelines (COSEWIC 2006).

Altered flow regimes: Many biotic and abiotic effects of impounded rivers can influence unionid mussel communities, including the potential elimination of host fish(es) from upper reaches of river systems, alteration of flow and thermal characteristics, and the potential to create reservoirs with retention times suitable for the colonization of invasive species, such as dreissenid mussels. High flow conditions may result in dislodgement of adults and disruption of larval forms, while low flow can lead to low DO, silt accumulation, elevated temperatures and, at the extreme, desiccation. Freshwater mussels are particularly vulnerable to reductions in water depth as they are frequently found in very shallow water (10–20 cm) (Metcalfe-Smith et al. 2007b). A significant negative correlation between mean annual stream flow and growth of a variety of freshwater mussel species has been demonstrated (Rypel et al. 2008), indicating the profound role impoundments and artificial flow manipulation may have on freshwater mussel assemblages.

There are a total of 173 water control structures (e.g., dams and weirs) in the upper Thames River watershed and 65 in the lower Thames watershed below the city of London (COSEWIC 2006). However, the lower Thames River is one of the largest free-flowing river systems in southern Ontario, with no major barriers or dams for approximately 200 km from the mouth of the river upstream to the first dam at Springbank Park in the city of London (COSEWIC 2008); although only seasonal, this dam has not been in operation for the past several years. Within the lower Grand River, the low head dam near the mouth of the river at Dunnville has a profound effect on flow and habitat conditions including sediment transport and connectivity to Lake Erie (MacDougall and Ryan 2012). Recent genetic research also suggests that the dam has resulted in genetic isolation for Mapleleaf occurring upstream within the impounded reaches of the lower Grand (D. Zanatta, University of Michigan, unpublished data).

Habitat removal and alterations: Destruction of habitat through dredging, ditching, and other forms of channelization, including measures that result in flow reduction, and practices that result in the diversion of cool or cold water into Mapleleaf habitat, may impact this species (e.g., through interference with reproductive timing). River channel modifications, such as dredging, can result in the direct destruction of mussel habitat and lead to siltation and sand accumulation of local and downstream mussel beds. The construction of impoundments can lead to the fragmentation of habitat, altered water levels, habitat conversion, and the clearing of riparian zones, resulting in the loss of cover, increased rates of siltation and thermal shifts. These are all factors that can be deleterious to the survival of Mapleleaf in areas under development.

Disruption of fish hosts: Any factors that directly or indirectly affect host fish abundances and distributions will impact Mapleleaf distributions. Unionids cannot complete their life cycle without access to the appropriate glochidial host. If host fish populations disappear or decline in abundance to levels below that which can sustain a mussel population, recruitment will no longer occur and the mussel species may become functionally extinct (functionally extinct in this case is defined as a population that is no longer viable, as a crucial part of their life cycle [in this case the host fish] has been removed) (Bogan 1993).

The likely host fish for the Mapleleaf in Canada (based on research in the U.S.) is the Channel Catfish, which is considered to be a common species in Ontario (COSEWIC 2006). Therefore, the fish-mussel host interaction is not thought to be limiting the presence of Mapleleaf throughout its range in Ontario (Bouvier and Morris 2011). Although the Flathead Catfish also acts as a host for Mapleleaf in the U.S., this species does not occur in Canada.

Predation and harvesting: Freshwater mussels are known to be food sources for a variety of mammals and fishes (Fuller 1974). There have been several studies of Muskrat predation on freshwater mussels (Neves and Odom 1989; Tyrrell and Hornbach 1998), but these studies were not conducted in areas that support populations of Mapleleaf. There is little information on the direct impact of predation on Canadian freshwater mussels; however, it is thought that the impact would be quite low (Bouvier and Morris 2011).

Harvesting mussels for human consumption could be a potential concern; however, to date, there are no reports of the harvest of Mapleleaf for human consumption (Bouvier and Morris 2011). Poaching of unionid mussels is suspected but unknown in its intensity or occurrence.

Recreational activities: Recreational activities that may impact mussel beds include (Bouvier and Morris 2011):

- Driving all-terrain vehicles (ATVs) through river beds – this has been identified as a threat in the Thames and Sydenham rivers.
- Propellers on recreational boats and jet skis – propeller channels have been noted through the mussel beds in the St. Clair River delta.
- Paddling action disturbance (kayaks, etc.) of the mussel bed.

5. Population and distribution objectives

The long-term recovery goal (>20 years) for the Mapleleaf in Ontario is to assist the recovery of the species by:

1. Protecting existing populations to prevent further declines;
2. Restoring degraded populations to healthy, self-sustaining levels by improving the extent and quality of habitat (where feasible)

The population and distribution objectives (to support the recovery goal) for the Mapleleaf in Ontario are to return or maintain self-sustaining populations in the following locations where live animals currently exist:

1. Ausable River
2. Sydenham River (including the North Sydenham River and Bear Creek)
3. Thames River (including McGregor and Baptiste creeks)
4. Ruscom River
5. Grand River
6. Welland River
7. Twenty Mile Creek/Jordan Harbour
8. Sixteen Mile Creek

The population and distribution objectives would be met when the populations at these locations demonstrate active signs of reproduction and recruitment throughout their known distribution at each location (further details will be informed through the implementation of a monitoring program – see Table 5, 5a). In addition, 'recovered' populations would need to be stable or increasing and demonstrably secure with low risk from known threats.

The Great Lakes and connecting channels are currently excluded from the recovery goal as these areas have been devastated by dreissenid mussels and no longer provide suitable conditions for freshwater mussels (DFO 2011b). However, with recent surveys detecting the presence of live Mapleleaf from drowned river mouths along the U.S. coast of Lake Erie and Lake St. Clair, more survey work is required to determine if remnant populations may persist within Canadian waters of these lakes. More quantifiable objectives (that may include consideration of extirpated populations where suitable habitats may be present) will be developed once necessary surveys and studies have been completed (refer to Section 7.5 Schedule of studies to identify critical habitat).

Rationale: Little is known about the Mapleleaf in Ontario and much research and monitoring is required before the population and distribution objectives can be refined. Population demographics (extent, abundance, trajectories and targets) are known for some populations but not others. With only a single live animal detected in the Bayfield River and St. Clair delta, these locations in particular require further work to clarify their possible role in the recovery of the species within Ontario.

6. Broad strategies and recovery actions

Recommended scale for recovery: Currently, a single-species recovery strategy (and action plan) is best suited for the Mapleleaf in Ontario. Although its range and distribution overlaps with other SARA-listed mussel species in some watersheds, it also occurs in watersheds where other mussel species at risk do not occur (e.g., Welland River, Twenty Mile Creek, Sixteen Mile Creek and Ruscom River). The remaining Mapleleaf populations in Ontario are found within the range of existing multi-species and ecosystem-based recovery strategies or action plans (see Section 6.1 Actions already completed or currently underway). It is expected that the Mapleleaf will receive substantial benefit from these complementary recovery initiatives.

6.1 Actions already completed or currently underway

Single and multi-species recovery strategies have been drafted previously for several freshwater mussel species whose distributions partly overlap with the Mapleleaf. Recovery teams for these species are currently engaged in the implementation of recovery actions within these watersheds that will benefit the Mapleleaf and include:

- Recovery Strategy for the Northern Riffleshell, Snuffbox, Round Pigtoe, Mudpuppy Mussel and Rayed Bean in Canada (DFO 2012a)
- Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) in Canada (DFO 2012b)
- Recovery Strategy for the Wavy-rayed Lampmussel (*Lampsilis fasciola*) in Canada (Morris 2006)

Ecosystem-based recovery strategies that overlap with the Mapleleaf include:

- *Sydenham River Action Plan:* This action plan is a multi-species, ecosystem-based plan that addresses the needs of seven freshwater mussels as well as two species of fishes – the Eastern Sand Darter (*Ammocrypta pellucida*) and Northern Madtom (*Noturus stigmosus*) (DFO 2013). The plan builds on the recovery program established ten years earlier by the Sydenham River Recovery Team (Dextrase et al. 2003); it targets stewardship actions for maximum effectiveness in threat mitigation at the landscape level to recover multiple aquatic species at risk that share similar threats and habitat. A network of monitoring sites for mussel species at risk was established in 2003 (see Metcalfe-Smith et al. 2007b).
- *Ausable River ecosystem recovery strategy* (Ausable River Recovery Team 2006): Stewardship efforts are ongoing and a monitoring program to track the recovery of endangered freshwater mussels in the Ausable River has been established (Baitz et al. 2008).
- *Thames River ecosystem recovery strategy*: The goal of the strategy is to develop "a recovery plan that improves the status of all aquatic species at risk in the Thames River through an ecosystem approach that sustains and enhances all native aquatic communities" (Thames River Recovery Team 2005). This recovery strategy addresses 25 COSEWIC-designated species, including seven mussels, 12 fishes, and six reptiles. Following the lead of the Sydenham Recovery Team, mussel monitoring stations have been established in the Thames River as well.
- *Grand River fish species at risk recovery strategy* (Portt et al. 2007): While this recovery strategy deals specifically with fish species, many of the same threats apply to the Mapleleaf, such as the impacts of sediment and nutrient loadings and invasive species.
- *Walpole Island ecosystem recovery strategy*: The Walpole Island Ecosystem Recovery Strategy Team was established in 2001 to develop an ecosystem-based recovery

strategy for the area containing the St. Clair River delta, with the goal of outlining steps to maintain or rehabilitate the ecosystem and species at risk (Walpole Island Heritage Centre 2002). Although the strategy is initially focusing on terrestrial ecosystems there are future plans to include aquatic components of the ecosystem.

Conservation authorities (e.g., Lower Thames Valley, Upper Thames River, St. Clair Region, Ausable-Bayfield and Grand River) continue to play a vital role in stewardship and public education programs that have resulted in increased awareness of species at risk and improvements to habitat and water quality throughout the Mapleleaf range in Ontario.

6.2 Recovery and action planning

Three broad strategies were recommended to address threats to the species and habitat as well as to meet the population and distribution objectives: 1) Research and Monitoring; 2) Management and Coordination; and, 3) Communication and Outreach. Approaches are identified for each of the broad strategies. These approaches or activities are further divided into numbered recovery measures with priority ranking (high, medium, low); identification of the threat(s) addressed; and, associated timeline (Tables 5 and 6). Table 5 identifies the measures to be undertaken by DFO to support the recovery of the Mapleleaf; Table 6 identifies the measures to be undertaken collaboratively between DFO and its partners, other agencies, organizations or individuals. Implementation of these measures will be dependent on a collaborative approach, in which DFO is a partner in recovery efforts, but cannot implement the measures alone. More detailed narrative for some recovery measures is included after the tables (Section 6.3). It should be noted that many of the activities identified in Tables 5 and 6 meet the requirements of SARA, subsection 49(1)(d) - i.e. research and management activities needed to meet the population and distribution objectives as well as measures to monitor the recovery of the species and its long term viability.

Implementation of these measures will be accomplished in coordination with relevant ecosystem-based recovery teams, First Nations and other organizations. Of the broad strategies, higher priority will be given to the research and monitoring measures, as these data will be used to inform the other two strategies (i.e., management and coordination, and communication and outreach).

Table 5. Measures for the recovery of Mapleleaf to be undertaken by Fisheries and Oceans Canada

#	Recovery measures	Priority	Threats addressed	Timeline
Broad strategy: research and monitoring				
	Approach: research and monitoring - inventory			
1(a)	Conduct further surveys within the historical distribution of the Mapleleaf to determine extent, abundance and demographics of known populations in Ontario.	High	All	2015-2017
1(b)	Conduct surveys of rivers where uncertainty of Mapleleaf persistence exists (e.g. Bayfield River).	Medium	All	2015-2017
	Approach: research - habitat requirements			
2	Determine habitat requirements of all life stages of the Mapleleaf.	High	All	2016-2018
	Approach: monitoring - host fish populations			
3(a)	Identify/confirm functional host fish species for Mapleleaf.	Medium	Disruption of fish hosts	2015-2017
3(b)	Determine the distribution and abundance of the identified host fish(es).	Medium	Disruption of fish hosts	2017-2018
	Approach: monitoring - populations and habitat			
4(a)	Establish long-term quantitative surveys to monitor changes in the distribution and abundance of extant populations of Mapleleaf populations and exotic species (e.g., dreissenid mussels).	High	Exotic species	2017-2019
4(b)	Establish stations to monitor changes to the habitat of Mapleleaf. This monitoring will complement and be integrated into the long-term monitoring program.	High	All habitat threats[3]	2017-2019
	Approach: research and threat evaluation – habitat requirements			
5(a)	Evaluate threats to habitat for all extant populations to guide local stewardship programs to improve conditions within critical habitat and other	High	All habitat threats	2015-2017

[3] Habitat threats include: turbidity and sediment loading, contaminants and toxic substances, nutrient loading and altered flow regimes.

#	Recovery measures	Priority	Threats addressed	Timeline
	occupied habitats..			
5(b)	Determine the sensitivity of early life stages of Mapleleaf to environmental contaminants that populations may be exposed to.	High	Contaminants and toxic substances	2017-2018
Broad strategy: management and coordination				
	Approach: coordination of activities			
6	Promote and enhance expertise in freshwater mussel identification, biology, ecology and conservation.	Medium	All	On-going
7	Work with ecosystem recovery teams and other relevant groups (e.g. conservation authorities, stewardship groups and First Nations) to aid in the implementation of recovery actions.	High	All	On-going
Broad strategy: communication and outreach				
	Approach: communication and outreach			
12	Encourage public support and participation in mussel recovery by developing awareness materials and programs. Will encourage participation in local stewardship programs to improve and protect habitat for Mapleleaf.	Medium	All	2015-2018
13	Mussel identification workshop that incorporates identification, biology, ecology, threats, and conservation of freshwater mussel species in Ontario over a two-day workshop.	High	All	On-going

Table 6. Measures for the recovery of Mapleleaf to be undertaken collaboratively between Fisheries and Oceans Canada and its partners

#	Recovery Measures	Priority	Threats addressed	Timeline (short, medium or long term)	Potential Partnerships
Broad strategy: management and coordination					
	Approach: co-ordination of activities				
8	Implement local stewardship programs to improve habitat conditions and reduce threats within critical habitat and other occupied habitats. Priorities and mitigation approaches to be informed through threat evaluation research.	High	All	Long term	Conservation Authorities*
9(a)	Work with municipal planning authorities so that they consider the protection of critical habitat for Mapleleaf within official plans.	High	All	Medium – Long term	Municipal and County Planning Departments, Conservation Ontario
9(b)	Support the development and implementation of legislation and policies at all levels of government that will aid in the protection and recovery of existing populations. Facilitate distribution and habitat information to planning agencies, public land managers, permitting organizations and others involved in decision making.	Low	All	Long term	All levels of government
Broad strategy: communication and outreach					
	Approach: communication and outreach				
10	Development of an overall communications plan to increase awareness and support for the protection and recovery of the Mapleleaf. This communications plan will provide direction and coordination for all communications and outreach activities related to the species.	Medium	All	Medium	Conservation Authorities*
11	Increase awareness within the angling community about the role of hosts for the Mapleleaf to reduce the possible risks of harvesting fish hosts during the encystment phase.	Low	Disruption of fish hosts	Medium – long term	Conservation Authorities*, angling groups

*Conservation Authorities may include one or more of the following organizations that cover watersheds where Mapleleaf currently occur: Ausable-Bayfield Conservation Authority, St. Clair Region Conservation Authority, Lower Thames Valley Conservation Authority, Upper Thames River Conservation Authority Essex Region Conservation Authority, Grand River Conservation Authority and Niagara Region Conservation Authority.

6.3 Narrative to support the recovery planning and implementation tables

1 (a-b): Further surveys are required to confirm the current distribution and abundance of the Mapleleaf in Ontario. Additional sampling effort is also required to determine if remnant populations may persist in river mouths and coastal wetland habitats of lakes Erie and St. Clair (as populations were detected in 2012 in U.S. waters). Sampling methods to determine density and demographic information need to be quantitative (i.e. include the excavation of defined quadrats) and could be informed by the work of Metcalfe-Smith *et al.* (2007b). A thorough understanding of all extant populations is necessary for the refinement of critical habitat as well as to inform effective recovery actions.

2: Research to better understand the differences in habitat for all life stages of the Mapleleaf will help further refine the identification of critical habitat. The identification of critical habitat is a legal requirement under SARA and will facilitate protection of Mapleleaf populations.

3 (a-b): To determine if the Mapleleaf is host limited, it is necessary to first confirm the functional host fish(es) (currently thought to be Channel Catfish). Once the host(s) of the Mapleleaf in Ontario have been identified, it is necessary to determine the distribution, abundance, and health of the host species.

4 (a-b): A network of monitoring stations should be established throughout the current range of the Mapleleaf similar to that developed for freshwater mussels within the Sydenham River for riverine habitats (Metcalfe-Smith *et al.* 2007b); some monitoring stations using these methods have more recently been established in the Ausable, Grand and Thames Rivers. Mussel monitoring methods need to be developed that can be adapted to lake and wetland habitats where Mapleleaf are also found (e.g., Jordan Harbour, lower Grand River within impounded reaches). The results of the monitoring program will allow for assessment of the progress made towards achieving the population and distribution objectives. As for other at-risk mussel species, monitoring sites should be established in a manner so as to permit:

- Quantitative tracking of changes in mussel abundance and demographics (size, age, sex), or that of their hosts;
- Detailed analysis of habitat use and the ability to track changes in the use or availability; and,
- The ability to detect and track exotic species – additional monitoring stations should be set up in areas where there is a likely source location for establishment of dreissenid mussels (e.g., reservoirs) to permit early detection.

5 (a): Although some preliminary work has been done on evaluating threats for some populations (refer to Section 4), little is known regarding threats to other populations (for example for recently discovered populations within the Welland River and Twenty Mile Creek/Jordan Harbour). More comprehensive threat evaluations for all extant populations will help inform stewardship programs to ensure the most efficient and effective use of limited resources while promoting an ‘ecosystem approach’ when warranted.

5(b): Some initial research has been completed on selected contaminants for early life stages of freshwater mussels – including chloride, ammonia and copper. However further work is required that is specific to the Mapleleaf (e.g. PFOS contamination is known from the upper Welland River and may be impacting downstream populations).

6: Expertise in freshwater mussel identification, distribution, life history, and genetics is limited to a small number of biologists in Ontario. This capacity could be increased by training personnel (both within government as well as non-government organizations and First Nations groups with a conservation focus) and encouraging graduate and post-graduate research directed towards the conservation of freshwater mussels. Such efforts would enhance partnering opportunities to implement recovery measures for freshwater mussels.

7-8: Many of the threats affecting Mapleleaf populations are similar to those that affect other fish and mussel species at risk. Therefore, efforts to remediate these threats should be done in close connection with ecosystem recovery teams (e.g., for Ausable, Sydenham, Thames and Grand Rivers) and other relevant groups to eliminate duplication of efforts. Once threats have been evaluated for extant populations, the results will inform local stewardship programs for threat mitigation. As with other mussels, measures to improve habitat for the Mapleleaf include stewardship actions involving Best Management Practices (BMPs) for agricultural properties (Agriculture Canada and OMAFRA 1992-2011) and residential properties (School of Environmental Design and Rural Development 2007) within watersheds where critical habitat has been identified.

10: A communications plan to increase awareness and support for the protection and recovery of the Mapleleaf will provide overall direction for all outreach activities (i.e. measures 11-13).

12-13: Increasing freshwater mussel knowledge and identification can be assisted though the development of awareness material, such as the *Photo Field Guide to the Freshwater Mussels of Ontario* (Metcalfe-Smith et al. 2005) and the recently completed identification “app” - *Canadian Freshwater Mussel Guide* now available for free download from iTunes. In addition, an annual, hands-on mussel identification workshop is offered by DFO to government, agency, non-government organizations, Aboriginal peoples and the public. Increased public knowledge and understanding of the importance of the Mapleleaf, and mussels in general, will play a key role in the recovery of this species.

7. Critical habitat

7.1 General identification of critical habitat for the Mapleleaf

The identification of critical habitat for Threatened and Endangered species (on Schedule 1) is a requirement of SARA. Once identified, SARA includes provisions to prevent the destruction of critical habitat. Critical habitat is defined under section 2(1) of SARA as:

> "…*the habitat necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species*". [s. 2(1)]

SARA defines habitat for aquatic species at risk as:

> *"… spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced."* [s. 2(1)]

Critical habitat for the Mapleleaf has been identified to the extent possible, using the best information currently available. The critical habitat identified in this recovery strategy describes the geospatial areas that contain the habitat necessary for the survival or recovery of the species. The current areas identified may be insufficient to achieve the population and distribution objectives for the species. As such, a schedule of studies has been included to further refine the description of critical habitat (in terms of its biophysical functions/features/attributes as well as its spatial extent) to support its protection.

7.2 Information and methods used to identify critical habitat

Using the best available information, critical habitat has been identified using a 'bounding box' approach for extant populations of Mapleleaf in the Ausable, Sydenham, Thames, Ruscom, Grand and Welland rivers as well as Jordan Harbour/Twenty Mile Creek and Sixteen Mile Creek; additional areas of potential critical habitat within the St. Clair River delta region will be considered in collaboration with Walpole Island First Nation.

This approach requires the use of essential functions, features and attributes for each life stage of this species to identify patches of critical habitat within the 'bounding box', which is defined by occupancy data for the species. Life stage habitat information was summarized in chart form using available data and studies referred to in Sections 3.3 (Needs of the Mapleleaf). The 'bounding box' approach was the most appropriate, given the limited information available for this species and the lack of detailed habitat mapping for these areas. This approach and the methods used to identify reaches of critical habitat are consistent with the approaches recommended by DFO (2011a) for freshwater mussels.

Within the rivers currently occupied by Mapleleaf, an ecological classification system was used in the identification of critical habitat. The OMNRF's Aquatic Landscape Inventory System (ALIS version 1) (Stanfield and Kuyvenhoven 2005) was used as the base unit for defining reaches within riverine systems. The ALIS system employs a valley classification approach to define river segments with similar habitat and continuity on the basis of hydrography, surficial geology, slope, position, upstream drainage area, climate, landcover and the presence of instream barriers, all of which are believed to have a controlling effect on the biotic and physical processes within the catchment. Therefore, if the species has been found in one part of the ecological classification, it would be reasonable to expect that it would be present in other spatially contiguous areas of the same valley segment. Within all identified river segments (i.e., valley segments), the width of the habitat zone is defined as the area from the mid-channel point to bankfull width on both the left and right banks. Critical habitat for the Mapleleaf was therefore identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present; segments or reaches were excluded only when supported by robust data indicating the species absence and/or unsuitable habitat conditions. Current occupancy for this species was defined by recent records of live individuals (and/or fresh shells) from 1996 onward; this is the point in time when systematic surveys of freshwater mussel communities in southern Ontario began. Unoccupied ALIS segments with suitable habitats were also included when limited sampling had occurred (i.e., the species was assumed to be present).

7.3 Identification of critical habitat: biophysical function, features and their attributes

Table 7 summarizes the limited available knowledge of the functions, features and attributes for each life stage of the Mapleleaf (refer to section 3.3 Needs of the Mapleleaf for full references). Areas within which critical habitat is found must be capable of supporting one or more of these habitat functions. *Note that not all attributes in Table 7 must be present for a feature to be identified as critical habitat.* If the features, as described in Table 7, are present and capable of supporting the associated functions, the feature is considered critical habitat for the species, even though some of the associated attributes might be outside of the range indicated in the table. All attributes may be used to help inform management decisions for the recovery and/or protection of habitat.

Table 7. Essential functions, features, and attributes of critical habitat for each life stage of the Mapleleaf

Life stage	Function	Feature(s)	Attribute(s)*

Spawning and fertilization (time period unknown)
 	
Glochidia present in females from late spring to summer (short-term brooder).
	Reproduction	Wetlands and reaches of medium to large rivers and streams with slow to fast flow characteristics and substrates suitable for burrowing (excluding areas of bedrock and hardpan clay)
		(includes 'bankfull channel'[4])
			• Attributes assumed to be same as for adults (see below)
			• Flow typically present (distribution of sperm)
			• Contaminants levels below the following thresholds:
			  • Long term chloride levels < 120 mg/L – (CCME 2011)
			  • Mean concentrations of < 0.3 mg/L total ammonia as N at pH 8; for protection of all life stages of freshwater mussels (Augspurger et al. 2003)
			• Copper levels < 3 µg/L (CCME 2005) should protect sensitive glochidia (Gillis et al. 2008).

Encysted glochidial stage (reported to be 51–68 days) on host fish until drop off (early summer – late summer)	Development on host for encystment	Same as above with host fish(es) present	• Attributes assumed to be same as below (as these conditions support both fish hosts and adults). • Presence of host fishes (e.g., Channel Catfish). • Dissolved Oxygen (DO) levels sufficient to support host (DO > 47% saturation at temperatures from 0-25C; PWQO [1994] for protection of warm-water species). • Summertime water temperatures reach ~27°C (range unknown) for successful development.
Adult/Juvenile	Feeding Cover	Wetlands and reaches of medium to large rivers and streams with slow to fast flow characteristics and substrates suitable for burrowing (excluding areas of bedrock and hardpan clay) (includes 'bankfull channel')	• Typically slow to fast flow (in sufficient volume to prevent stranding and predation). • Substrates of coarse gravel, sand and clay/mud mixtures (Clark 1981; also over mud, sand, or fine gravel substrates (DFO, unpubl. data). • Supply of food (plankton: bacteria, algae, organic detritus, protozoans). • Dreissenids absent or in low abundance. • Maintenance of an "environmental thermal regime" [5] (gamete production and development).

* Note that not all attributes must be present for a feature to be identified as critical habitat.

[4] From the top of the riverbank on one side of the channel to the top of the riverbank on the other.
[5] Maintenance of an 'environmental thermal regime' requires that water temperatures are maintained within the limits of natural variability (daily or seasonal) such that lifecycle processes are completed without impacting the fitness of the organism.

Studies to further refine knowledge on the essential functions, features and attributes for various life stages of the Mapleleaf are described in Section 7.5 (Schedule of studies to identify critical habitat).

7.4 Identification of critical habitat: geospatial

Using the best available information, critical habitat has been identified for Mapleleaf populations in the following waterbodies:

1. Ausable River
2. Sydenham River
3. Thames River (including McGregor and Baptiste creeks)
4. Ruscom River
5. Grand River
6. Welland River
7. Jordan Harbour/Twenty Mile Creek
8. Sixteen Mile Creek

The areas delineated on the following maps (Figures 3-9) represent the extent of critical habitat that can be identified at this time. Note that the areas delineated include the entire 'bankfull' channel (e.g., from the top of the riverbank on one side of the channel to the top of the riverbank on the other); this supports long-term channel forming discharges important in maintaining in-stream habitat conditions required by freshwater mussels. *By using the 'bounding box' approach, critical habitat is not comprised of all areas within the identified boundaries, but only those areas where the specified essential biophysical features/attributes occur* (refer to Table 7). *Note that permanent anthropogenic structures that may be present within the delineated areas (e.g., marinas, navigation channels) are specifically excluded; it is understood that maintenance or replacement of these features may be required at times.* Brief explanations for the areas within which critical habitat is identified are provided for each of the waterbodies below.

Table 8, below, provides the geographic coordinates that situate the boundaries within which critical habitat is found for the Mapleleaf; these points are indicated on Figures 3-9.

Table 8. Coordinates locating the boundaries within which critical habitat is found for the Mapleleaf*.

	Coordinates† locating areas of critical habitat					
Location	**Point 1**	**Point 2**	**Point 3**	**Point 4**	**Point 5**	**Point 6**
Ausable River	81° 49' 5.599" W 43° 11' 13.915" N	81° 31' 17.253" W 43° 17' 45.606" N				
Sydenham River (including East and North)	81° 42' 12.309" W 42° 54' 14.978" N	81° 44' 0.289" W 42° 51' 35.425" N	81° 52' 1.573" W 42° 51' 35.535" N	81° 59' 56.182" W 42° 39' 12.599" N	82° 24' 38.800" W 42° 33' 36.788" N	82° 8' 13.617" W 42° 52' 47.700" N
Thames River	81° 19' 25.597" W 42° 57' 37.190" N	82° 1' 33.521" W 42° 31' 27.053" N				
McGregor Creek	81° 59' 11.077" W 42° 26' 37.826" N	82° 7' 49.746" W 42° 23' 34.944" N				
Baptiste Creek	82° 26' 36.418" W 42° 18' 20.955" N	82° 22' 30.444" W 42° 14' 33.384" N				
Ruscom River	82° 37' 42.843" W 42° 16' 15.942" N	82° 37' 44.693" W 42° 12' 23.755" N				
Grand River	79° 57' 43.053" W 43° 4' 26.316" N	79° 34' 40.903" W 42° 51' 21.477" N				
Welland River	79° 37' 46.408" W 43° 1' 25.455" N	79° 34' 10.326" W 42° 59' 58.040" N				
Jordan Harbour /Twenty Mile Creek	79° 22' 24.263" W 43° 11' 7.063" N	79° 22' 46.921" W 43° 8' 1.578" N				
Sixteen Mile Creek	79° 20' 1.317" W 43° 9' 35.325" N	79° 20' 0.553" W 43° 8' 8.046" N				

*Riverine habitats are delineated to the midpoint of channel of the uppermost stream segment(s) and lowermost stream segment.
†All coordinates obtained using map datum NAD 83

Ausable River: The area within which critical habitat is found for the Mapleleaf in the Ausable River is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 3). This critical habitat description includes the entire 'bankfull' channel and represents a stretch of river approximately 65 km long. The downstream boundary within which critical habitat can be found ends approximately 1 km upstream of Parkhill Drive (County Road 18). The upstream boundary ends approximately 2 km downstream of Ailsa Craig.

Sydenham River (including North Sydenham River and Bear Creek): The area within which critical habitat is found for the Mapleleaf in the East Sydenham River is currently identified as the reach of river represented as a single ALIS segment with the species present (Figure 4). Also connected with this segment are the lower reaches (< 3 km) of the following tributaries: Fansher, Brown and Spring creeks. This critical habitat description includes the entire 'bankfull' channel. These areas represent a total river reach of approximately 150 km. The downstream extent of critical habitat ends at the confluence of the East Sydenham River with the Chenal Ecarte. The upstream extent of critical habitat in the East Sydenham River is the bridge at Murphy Drive (approximately 15 km northeast of Alvinston).

The area within which critical habitat is found for the Mapleleaf in the North Sydenham River watershed is currently identified as the reach of river represented that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 4). This critical habitat description includes the entire 'bankfull' channel and includes the North Sydenham River (from the confluence with the East Sydenham River) upstream through reaches of Bear Creek to the dam just east of Petrolia. These areas represent a total river reach of approximately 200 km. Note that although no live Mapleleaf have been recorded from the main branch of the North Sydenham River (live animals have only been reported from Bear Creek), the species is assumed to be present here as habitat conditions are similar to those in the adjacent East Sydenham River where the species is abundant.

Thames River (including McGregor and Baptiste creeks): The area within which critical habitat is found for the Mapleleaf in the Thames River is currently identified as the reach that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 5a). This critical habitat description includes the entire 'bankfull' channel and includes a stretch of river approximately 100 km long, from the City of London to a point approximately 5 km southwest of Thamesville.

The area within which critical habitat is found in McGregor Creek is currently identified as the reach that includes a single ALIS segment with the species present (Figure 5b). This critical habitat description includes the entire 'bankfull' channel and includes a stretch of river approximately 12 km long, from about 1.5 km upstream from Chatham to a point approximately 15 km northeast of Chatham.

The area within which critical habitat is found in Baptiste Creek is currently identified as the reach that includes a single ALIS segment with the species present (Figure 5c). This critical habitat description includes the entire 'bankfull' channel and includes a stretch of river approximately 10 km long, from the confluence with Tilbury Creek to a point about 4 km south east of Tilbury.

Ruscom River: The area within which critical habitat is found in the Ruscom River is currently identified as the reach that includes a single ALIS segment with the species present (Figure 6). This critical habitat description includes the entire 'bankfull' channel and includes a stretch of river approximately 8 km long, beginning at the town of St. Joachim.

Grand River: The area within which critical habitat is found for the Mapleleaf in the Grand River is currently identified as the reach that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 7). This critical habitat description includes the entire 'bankfull' channel and includes a stretch of the lower river approximately 50 km long, from the mouth of the river at Port Maitland upstream to the dam in Caledonia.

Welland River: The area within which critical habitat is found in the Welland River is currently identified as the reach that includes a single ALIS segment with the species present (Figure 8). This critical habitat description includes the entire 'bankfull' channel and includes a stretch of river beginning from a point approximately 7 km west of Wellandport and ending at a point approximately 10 km upstream.

Jordan Harbour/Twenty Mile Creek: The area within which critical habitat is found in the Twenty Mile Creek is currently identified as the reach that includes a portion of a single ALIS segment with the species present (Figure 9). This critical habitat description includes the entire 'bankfull' channel and includes all contiguous waters of Jordan Harbour (up to the entrance to Lake Ontario) as well as the lower Twenty Mile Creek upstream to the first barrier at Ball's Falls Conservation Area (a distance of approximately 5 km).

Sixteen Mile Creek: The area within which critical habitat is found in the Sixteen Mile Creek is currently identified as the reach that includes a portion of a single ALIS segment with the species present (Figure 9). This critical habitat description includes the entire 'bankfull' channel and includes all contiguous waters of the lower Sixteen Mile Creek from the entrance to the Sixteen Mile Pond upstream to the first barrier at the Niagara Escarpment (a distance of approximately 3.5 km).

Note: Areas of critical habitat identified at these locations may overlap with critical habitat identified for other co-occurring species at risk (e.g., Northern Riffleshell [*Epioblasma torulosa rangiana*], Snuffbox [*Epioblasma triquetra*], Rayed Bean [*Villosa fabalis*], Mudpuppy Mussel [*Simpsonaias ambigua*], Round Pigtoe [*Pleurobema sintoxia*] and Eastern Sand Darter); however, the specific habitat requirements within these areas may vary by species.

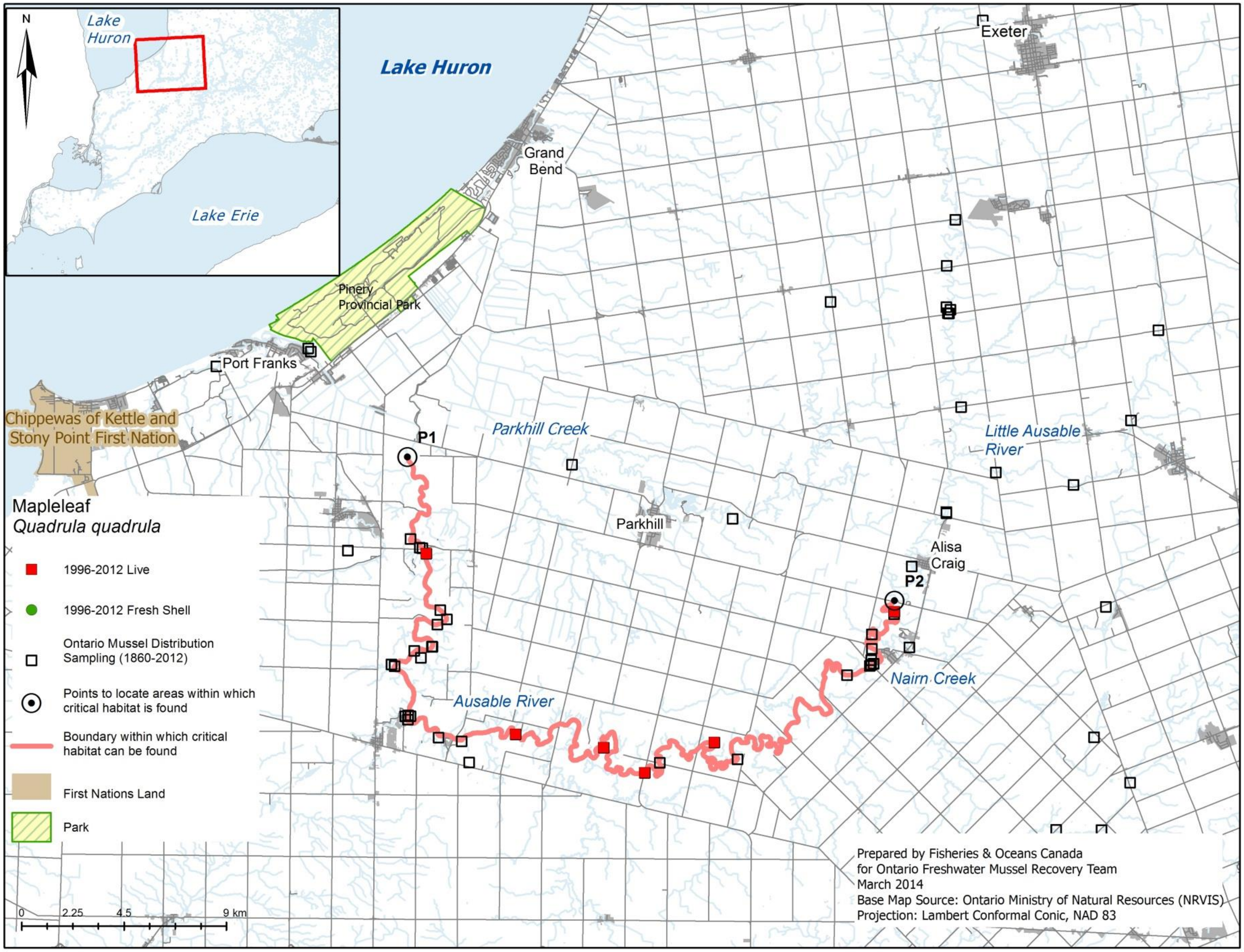

Figure 3. Area within which critical habitat is found for the Mapleleaf in the Ausable River.

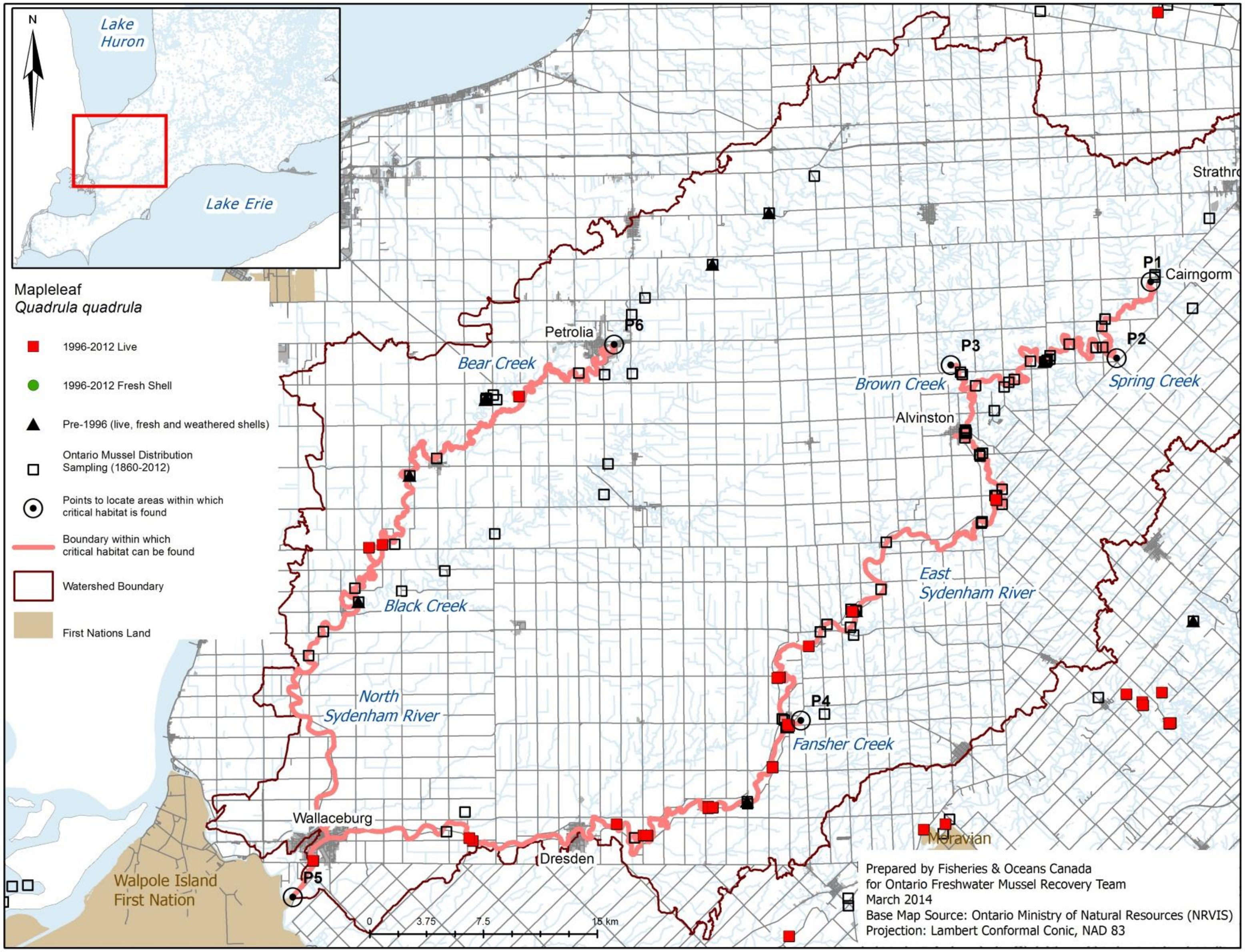

Figure 4. Area within which critical habitat is found for the Mapleleaf in the East Sydenham River and the North Sydenham River (including Bear Creek).

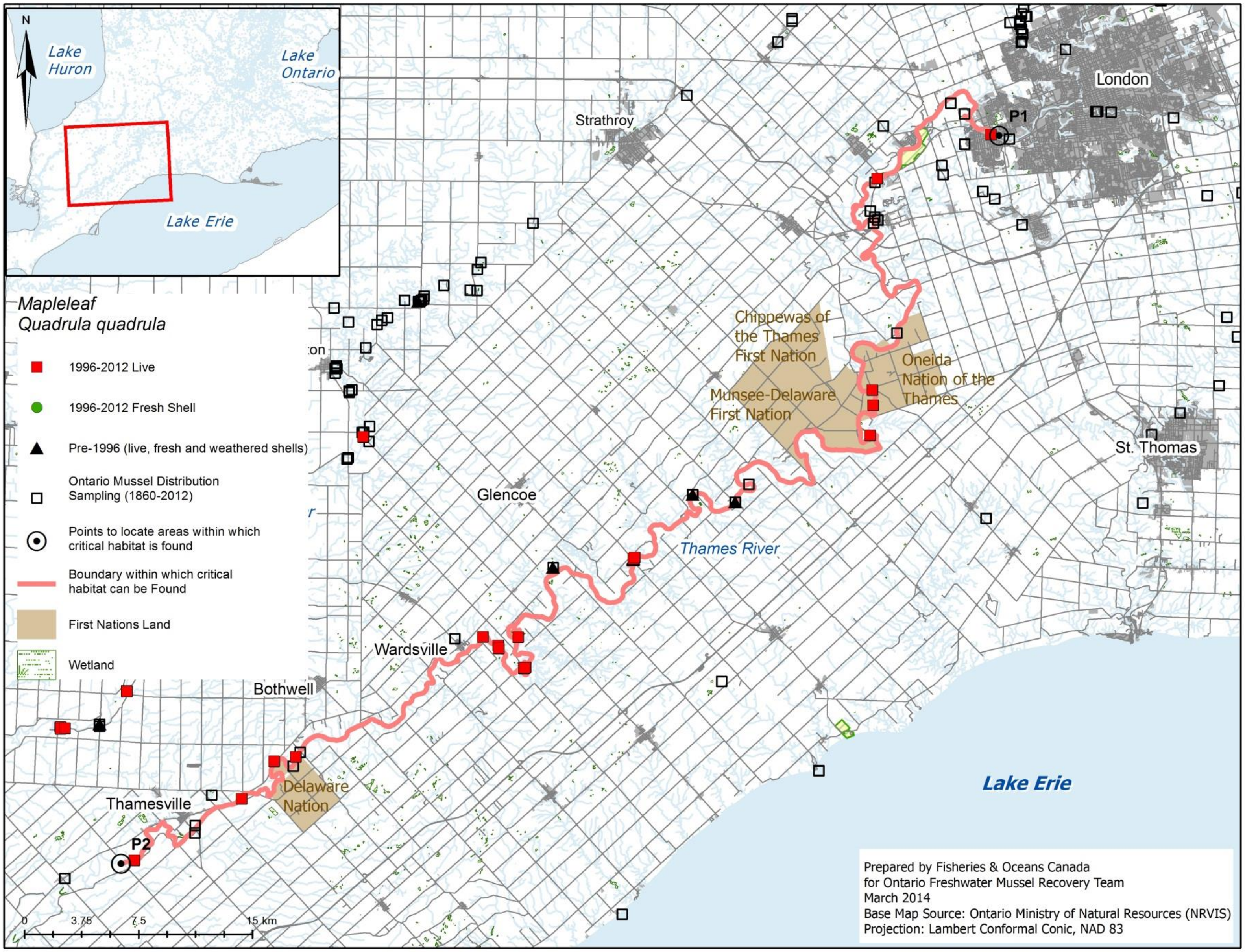

Figure 5 (a). Area within which critical habitat is found for the Mapleleaf in the Thames River.

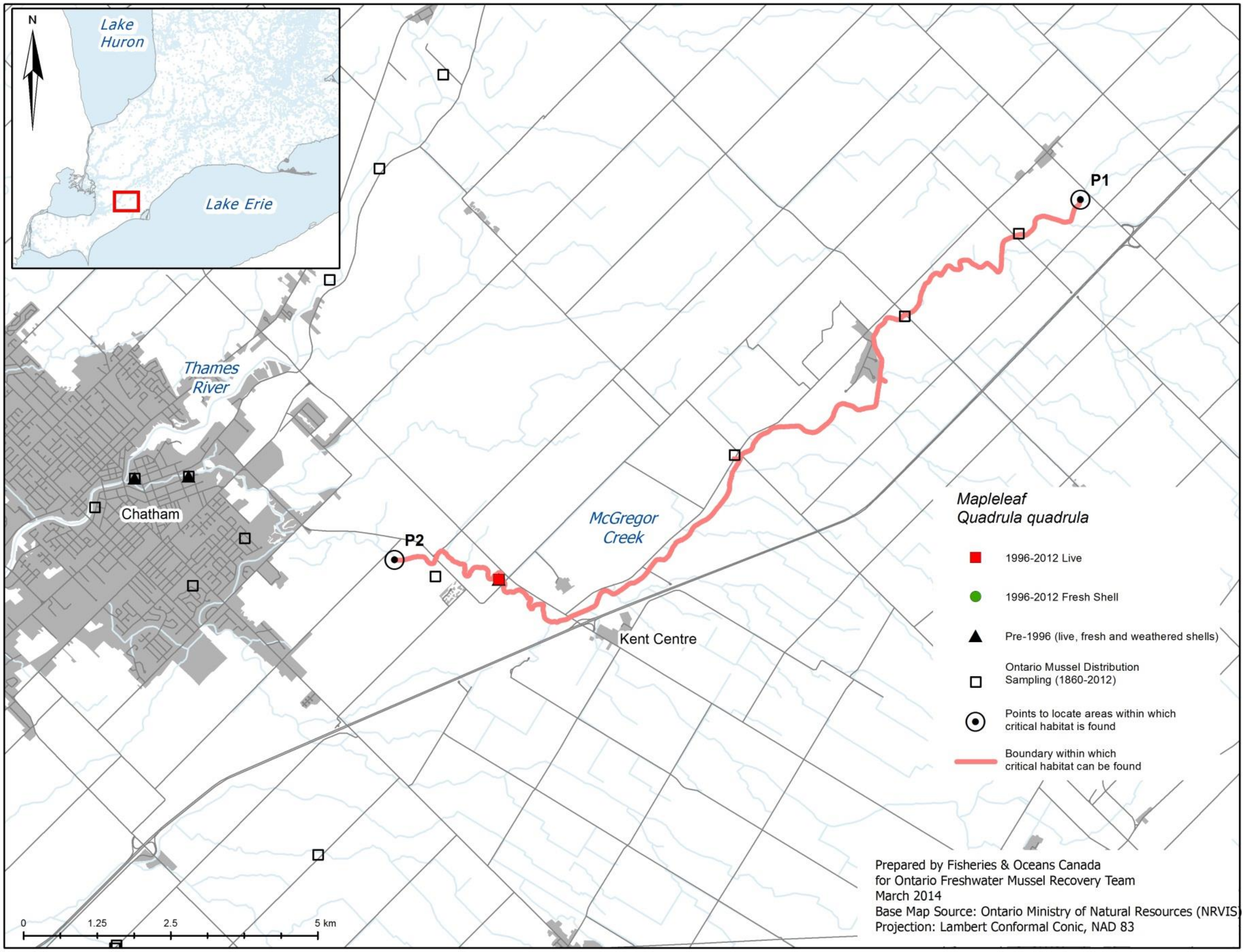

Figure 5 (b). Area within which critical habitat is found for the Mapleleaf in McGregor Creek (Thames River).

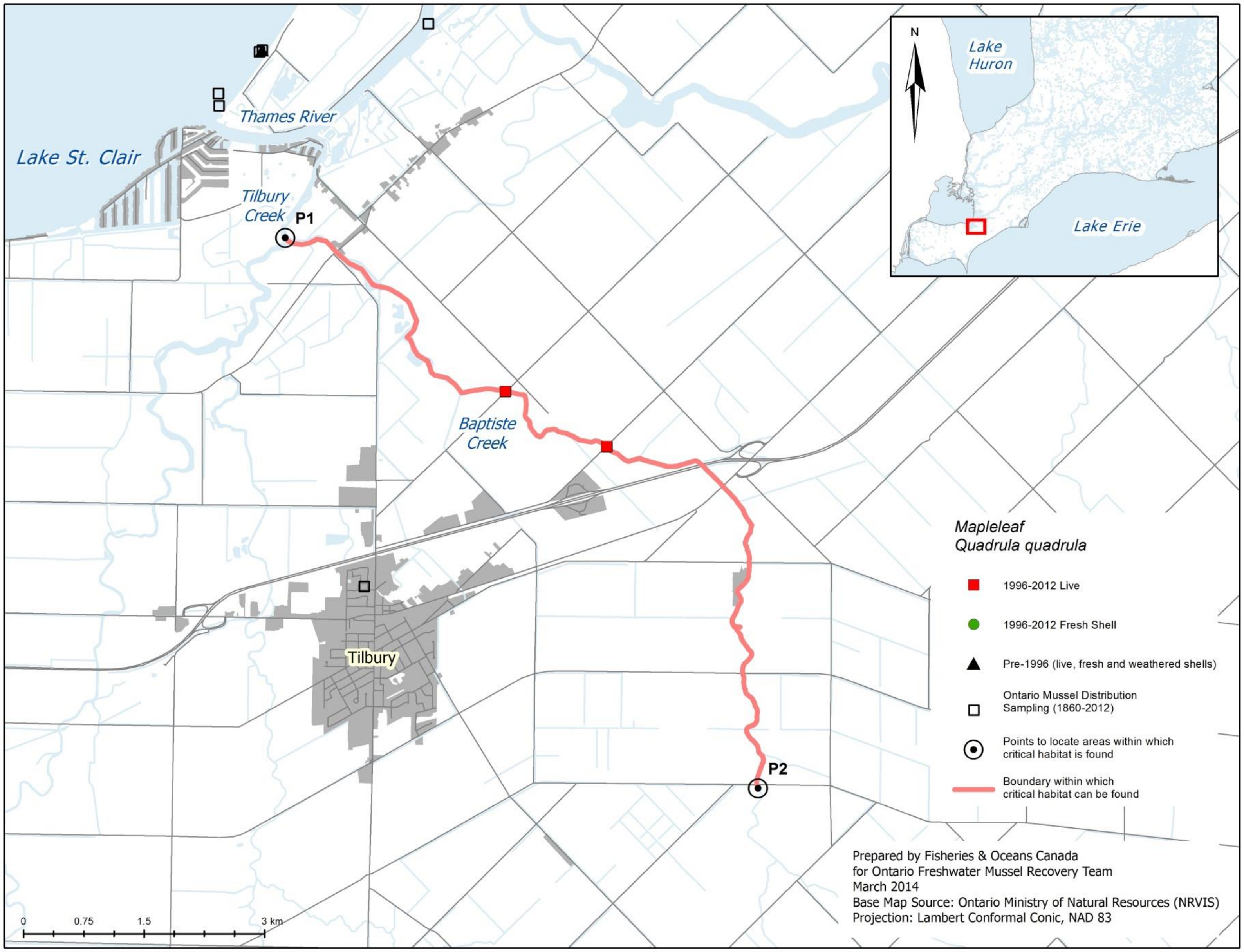

Figure 5 (c). Area within which critical habitat is found for the Mapleleaf in Baptiste Creek (Thames River).

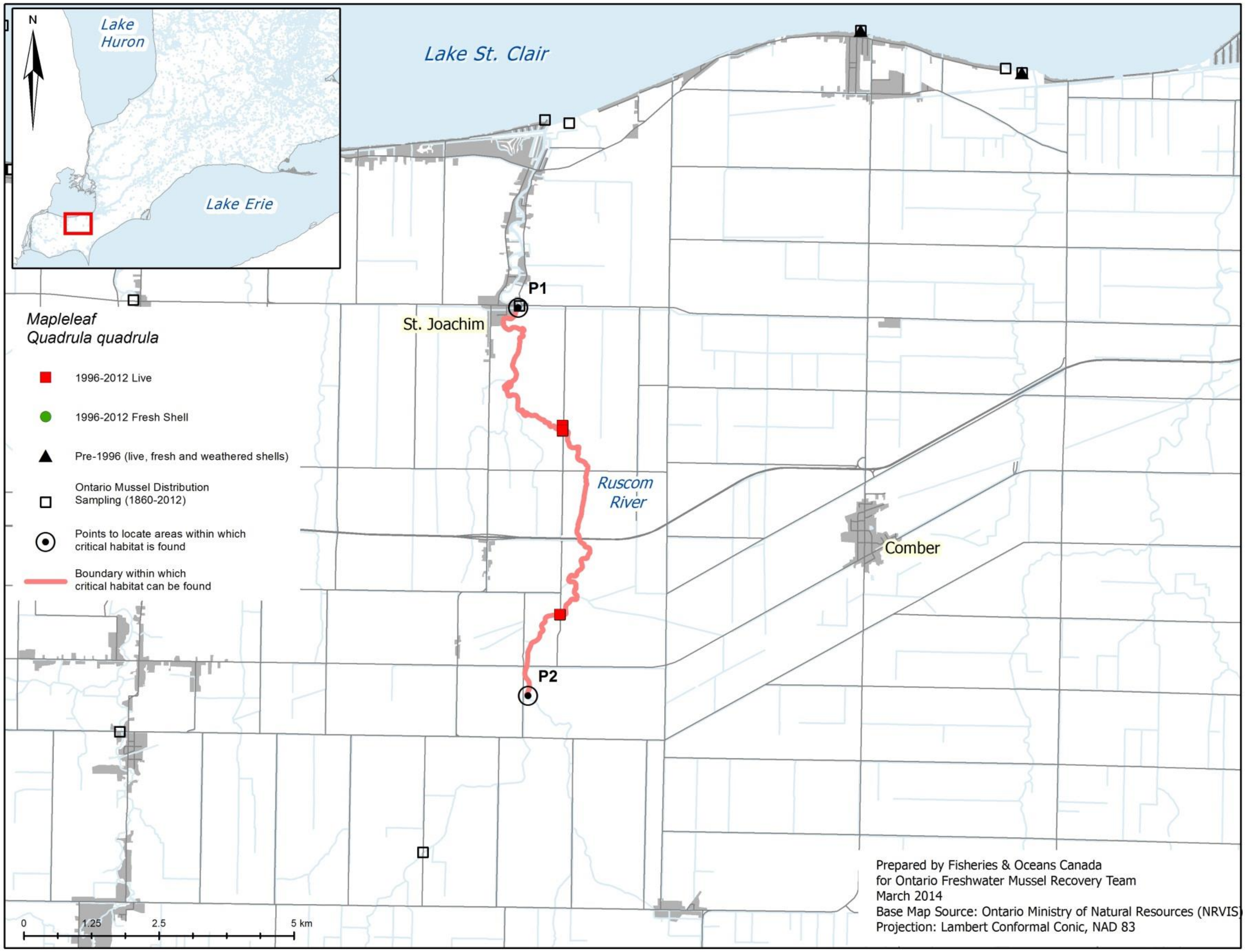

Figure 6. Area within which critical habitat is found for the Mapleleaf in the Ruscom River.

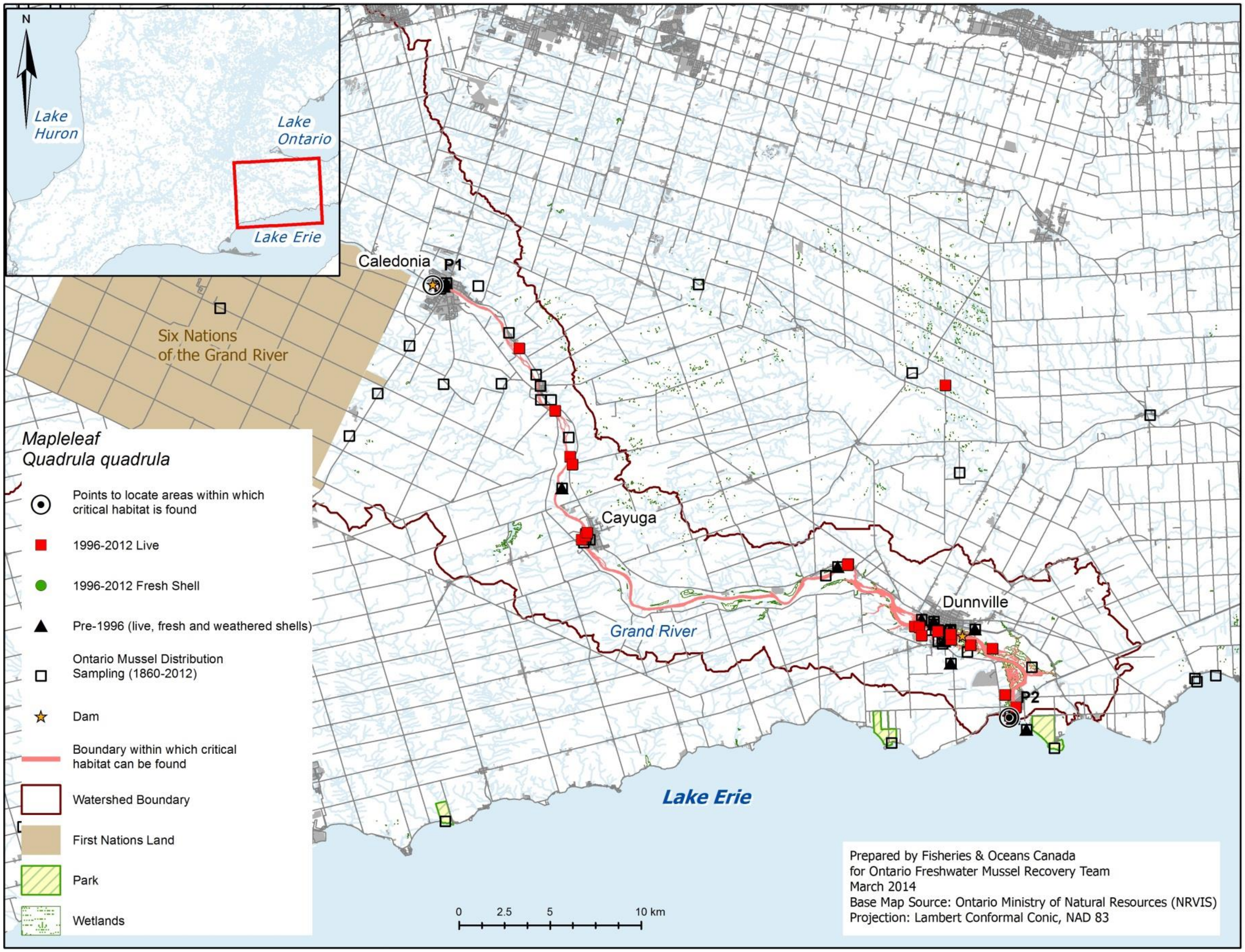

Figure 7. Area within which critical habitat is found for the Mapleleaf in the Grand River.

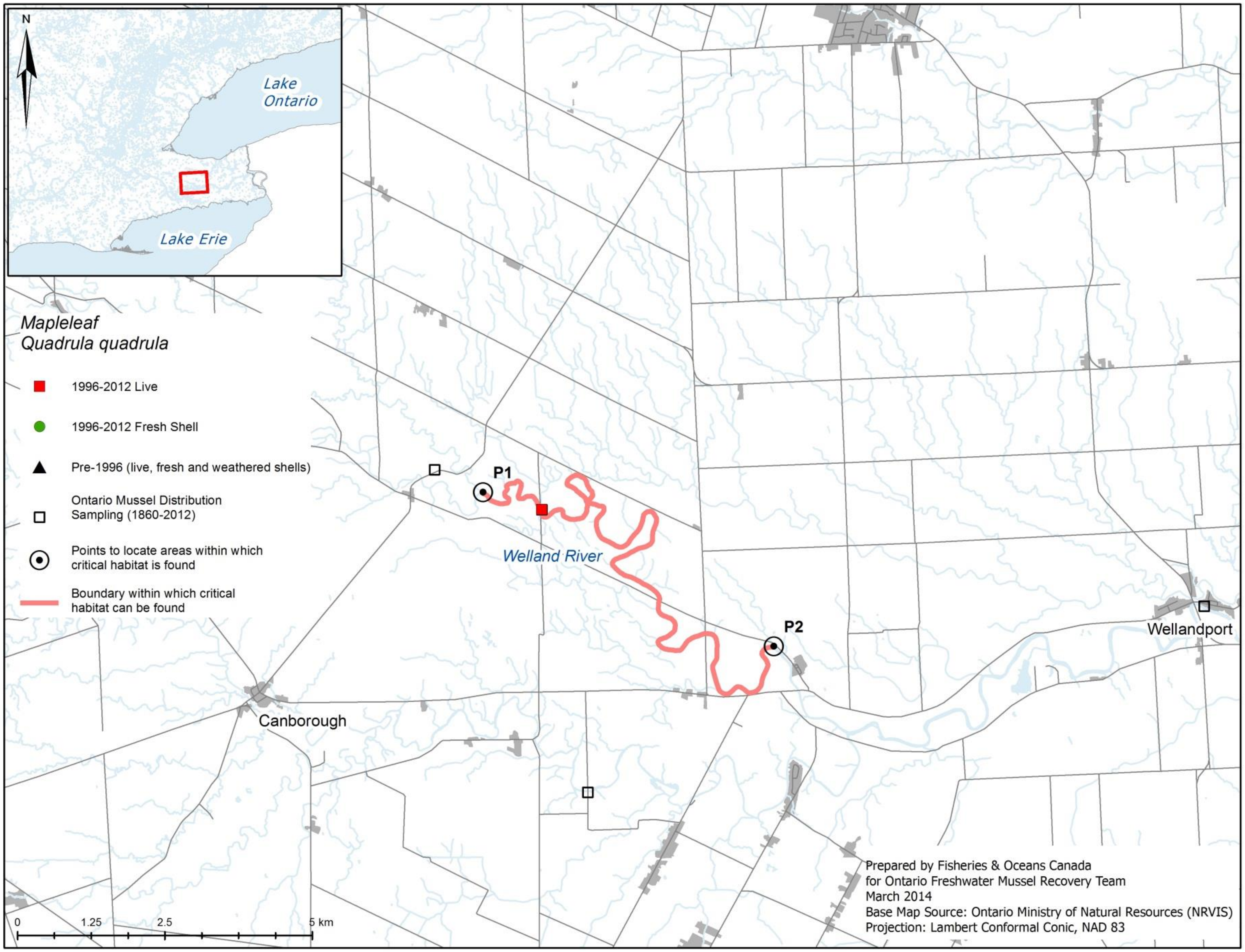

Figure 8. Area within which critical habitat is found for the Mapleleaf in the Welland River.

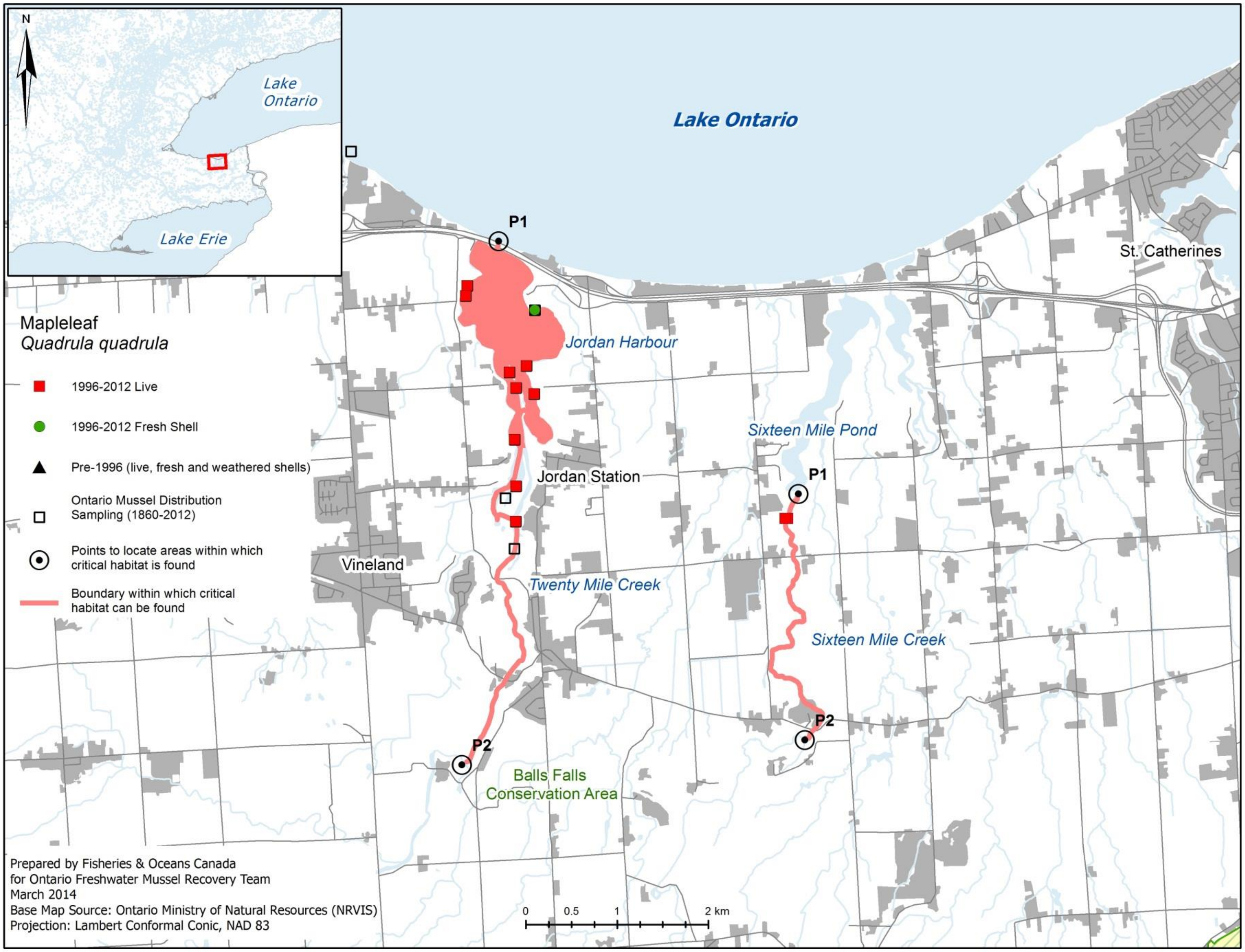

Figure 9. Area within which critical habitat is found for the Mapleleaf in Jordan Harbour, Twenty Mile Creek and Sixteen Mile Creek.

The identification of critical habitat within the Ausable, Sydenham, Thames, Grand, Ruscom and Welland rivers as well as Jordan Harbour/Twenty Mile Creek and Sixteen Mile Creek, will ensure that currently occupied habitat is protected, until such time as critical habitat is further refined according to the schedule of studies laid out in Section 7.5 (Schedule of studies to identify critical habitat). The schedule of studies outlines activities necessary to refine the current critical habitat descriptions at confirmed extant locations as well as address locations with limited information (e.g., Bayfield River, Jordan Harbour, Sixteen Mile Creek). Critical habitat descriptions will be refined as additional information becomes available to support the population and distribution objectives.

7.5 Schedule of studies to identify critical habitat

This recovery strategy includes an identification of critical habitat to the extent possible, based on the best available information. Further studies are required to refine critical habitat identified for the Mapleleaf and to support the population and distribution objectives for this species. The activities listed in Table 9 are not exhaustive and it is likely that the process of investigating these actions will lead to the discovery of further knowledge gaps that need to be addressed.

Table 9. Schedule of studies to identify critical habitat.

Description of activity	Outcome/Rationale	Timeline*
Conduct mussel population surveys in areas of known and potential occurrence.	Will define current Mapleleaf distribution and aid in refining population and distribution objectives as well as critical habitat.	2015–2017
Assess and characterize habitat conditions in currently occupied areas and determine if unique conditions are required for any particular life stage.	Refine features and attributes of critical habitat.	2015–2018
Determine/confirm the functional host fish species (Channel Catfish distribution and others possible).	Confirm/determine host for the glochidial phase.	2015–2018
Conduct host fish surveys (and associated habitat data) within the range of the Mapleleaf where current data do not exist.	Will determine range and abundance of the suitable host fish(es).	2016–2018
Based on collected information, review population and distribution objectives. Determine amount and configuration and description of critical habitat required to achieve these objectives if adequate information exists.	Refinement of recovery objectives as well as critical habitat description required to meet these objectives	ongoing

* Timelines are subject to change in response to demands on resources and/or personnel and as new priorities arise.

7.6 Examples of activities likely to result in the destruction of critical habitat

Under SARA, critical habitat for aquatic species not found in an area described in subsection 58(2) of the *Act* must be legally protected within 180 days of the final recovery strategy or action plan in which it is identified being posted on the Species at Risk Public Registry. For the critical habitat of the Mapleleaf, it is anticipated that this will be accomplished through a SARA Critical Habitat Order made under subsections 58(4) and (5), which will trigger the prohibition in subsection 58(1) against the destruction of the identified critical habitat.

The Mapleleaf, like most mussel species, is sensitive to a wide variety of stressors. Therefore, the activities described in Table 10 are neither exhaustive nor exclusive and have been guided by the threats described in Section 4 (Threats). The absence of a specific human activity does not preclude the department's ability to regulate it pursuant to SARA. Furthermore, the inclusion of an activity does not necessarily result in its prohibition. The prohibition against the destruction of critical habitat is engaged if a critical habitat protection order is made. Also, activities that impact critical habitat but do not result in its destruction are not prohibited. Since habitat use is often temporal in nature, every activity is assessed on a case-by-case basis and site-specific mitigation measures are applied where they are reliable and available. In every case, where information is available, thresholds and limits are associated with attributes to better inform management and regulatory decision-making. However, in many cases the knowledge of a species and its critical habitat may be lacking. In particular, information associated with a species' or habitat's thresholds of tolerance to disturbance from human activities is lacking and must be acquired.

Table 10. Examples of human activities likely to result in the destruction of critical habitat for the Mapleleaf. The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features, and attributes of critical habitat.

Activity	Effect pathway	Function affected	Feature affected	Attribute affected
Siltation and turbidity: Work in or around water with improper sediment and erosion control (e.g., installation of bridges, pipelines, culverts), overland runoff from ploughed fields, run-off from urban and residential development, use of industrial equipment, cleaning or maintenance of bridges or other structures without proper mitigation.	Improper sediment and erosion control or mitigation can cause increased turbidity and sediment deposition, changing preferred substrates and impairment of feeding and reproductive functions	Reproduction Feeding Cover Development on host for encystment	Wetlands and reaches of medium to large rivers and streams with slow to fast flow characteristics and substrates suitable for burrowing (excluding areas of bedrock and hardpan clay) (includes 'bankfull channel') Presence of host fish(es)	• Summertime water temperatures • Substrates of coarse gravel, sand and clay/mud • Presence of host species • Food supply • Maintenance of an environmental thermal regime
Unfettered livestock access to waterbodies.	When livestock have unfettered access to waterbodies damage to shorelines, banks and watercourse bottoms can cause increased erosion and sedimentation, affecting turbidity and water temperatures.			
Removal or cultivation of riparian vegetation.	Agricultural lands, particularly those with little riparian vegetation and without tile drainage, allow large inputs of sediments to the watercourse.			

(cont'd)

Table 10 (cont'd). Examples of human activities likely to result in the destruction of critical habitat for Mapleleaf. The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features, and attributes of critical habitat.

Activity	Effect pathway	Function affected	Feature affected	Attribute affected
Nutrient loading: Over-application of fertilizer and improper nutrient management (e.g., organic debris management, wastewater management, animal waste, septic systems, and municipal sewage).	Improper nutrient management can cause nutrient loading of nearby waterbodies. Elevated nutrient levels (phosphorus and nitrogen) can cause increased turbidity causing harmful algal blooms, changing water temperatures, and reduced DO levels. Mussel survival rates are closely related to DO levels. Low DO may cause mortality of warm water fish hosts, thereby disrupting mussel reproductive cycles. Recent evidence has shown that juvenile mussels are among the most sensitive aquatic organisms to ammonia toxicity.	Reproduction Feeding Nursery Cover	Wetlands and reaches of medium to large rivers and streams with slow to fast flow characteristics and substrates suitable for burrowing (excluding areas of bedrock and hardpan clay) (includes 'bankfull channel') Presence of host fish(es)	• Summertime water temperatures • Presence of host fish species • Food supply • Low contaminants levels – ammonia • Dissolved oxygen (DO) levels sufficient to support host • Maintenance of an environmental thermal regime
Altered flow regimes: Water-level management (e.g., through dam operation) or water extraction activities (e.g., for irrigation), that causes dewatering of habitat or excessive flow rates; large increases in impervious surfaces from urban and residential development.	High flow conditions (and 'flashier' flows) can cause dislodgement and passive transport of mussels from areas of suitable habitat into areas of lesser or marginal habitat. Low flows can result in depressed DO levels, desiccation, elevated temperatures and stranding. Host fish may also be impacted, thereby disrupting reproduction. Altered flow patterns can affect habitat availability (e.g., by 'dewatering' habitats) in creeks and rivers, sediment deposition (e.g., changing preferred substrates), and water temperatures.	Same as above	Same as above	• Adequate flow • Summertime water temperatures • Food supply • DO levels sufficient to support host • Presence of host fish species • Substrates of coarse gravel, sand and clay/mud • Maintenance of an environmental thermal regime

Table 10 (cont'd). Examples of human activities likely to result in the destruction of critical habitat for Mapleleaf. The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features, and attributes of critical habitat.

Activity	Effect pathway	Function affected	Feature affected	Attribute affected
Disruption of host fish(es): Excessive removal of host fish(es) (through either commercial or recreational harvest) or indirect means (e.g., damming activities may prevent fish movement).	Any activities that affect the host species' abundance, movements, or behaviour during the period of encystment or release may disrupt the reproductive cycle of these mussels.	Development on host for encystment	Same as above	• Presence of host fish species
Contaminants and toxic substances: Over application or misuse of herbicides and pesticides. Release of urban and industrial pollution into habitat (including the impact of stormwater runoff from existing and new developments). Introduction of high levels of chloride through activities such as excessive salting of roads in winter.	Introduction of toxic compounds (e.g., high chloride levels from stormwater runoff) into habitat used by these species can change water chemistry affecting habitat and host fish(es) availability or use, especially during sensitive life stages (glochidia, juvenile). Chloride levels have shown recent inclines due to an increased use of road salt. High chloride levels can cause direct mortality of sensitive glochidia.	Reproduction Cover Development on host for encystment	Same as above	• Presence of host fish species • Contaminants levels – chloride, ammonia, and copper
Habitat removal and alterations: • Dredging • Grading • Excavation Placement of material or structures in water (e.g., groynes, piers, infilling, partial infills, jetties.)	Changes in bathymetry, shoreline and channel morphology caused by dredging and near-shore grading and excavation can move mussels, alter preferred substrates, change water depths, change flow patterns potentially affecting turbidity, nutrient levels and water temperatures. Placing material or structures in water reduces habitat availability (e.g., the footprint of the infill or structure is lost). Placing of fill can cover organisms and preferred substrates for mussels and their host fish(es).	Reproduction Cover Feeding Development on host for encystment	Same as above	• Summertime water temperatures • Substrates of coarse gravel, sand and clay/mud • Presence of host fish species • Food supply • Adequate water flow

(cont'd)

Table 10 (cont'd). Examples of human activities likely to result in the destruction of critical habitat for Mapleleaf. The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features, and attributes of critical habitat.

Activity	Effect pathway	Function affected	Feature affected	Attribute affected
Physical habitat loss/modification: Construction of dams and/or barriers	Dams/barriers can result in direct loss of habitat or fragmentation, which can limit the reproductive capabilities of mussels by eliminating or decreasing the number of hosts available.	Reproduction Cover Feeding Development on host for encystment	Same as above	• Summertime water temperatures • Substrates of coarse gravel, sand and clay/mud • Presence of host fish species • Food supply • Adequate water flow
Recreational activities: Excessive baitfish collection (either recreational or commercial); baitfish releases. Use of motor vehicles in the river.	Can affect (direct or indirectly) the number and health of available host fishes. Spread aquatic invasive species (boats, bait buckets). Disrupt substrate, dislodge and/or damage mussels.	Reproduction Cover Feeding Development on host for encystment	Same as above	• Presence of host fish species • Substrates of coarse gravel, sand and clay/mud • Dreissenids absent or in low abundance

In the future, threshold values for some stressors may be informed through further research. For some of the above activities, BMPs may be enough to mitigate threats to the species and its habitat; however, in some cases, it's not known if BMPs are adequate to protect critical habitat and further research is required.

7.7 Proposed measures to protect critical habitat

Under SARA, critical habitat for aquatic species not found in an area described in subsection 58(2) of the *Act* must be legally protected within 180 days of the final recovery strategy or action plan in which it is identified being posted on the Species at Risk Public Registry. For the critical habitat of the Mapleleaf, it is anticipated that this will be accomplished through a SARA Critical Habitat Order made under subsections 58(4) and (5), which will trigger the prohibition in subsection 58(1) against the destruction of the identified critical habitat.

8. Relevant habitat legislation

Under SARA, there are general prohibitions against killing, harming, taking, possessing, capturing, and collecting the Mapleleaf. Once identified, SARA includes provisions to prevent the destruction of critical habitat.

Provincially, protection is also afforded under the *Planning Act*. Planning authorities are required to be "consistent with" the provincial Policy Statement under Section 3 of Ontario's *Planning Act*, which prohibits development and site alteration in the habitat of Endangered or Threatened species. In addition, the Mapleleaf is listed as Threatened under Ontario's *Endangered Species Act*, *2007* (ESA). Under the ESA, individuals are currently protected from harm and harassment, and the species has received general habitat protection since June 30, 2013. Stream-side development in Ontario is managed through flood plain regulations enforced by local conservation authorities.

9. Socio-economic evaluation of the action plan

The *Species At Risk Act* requires that the action plan component of the recovery document[6] include an evaluation of the socio-economic costs of the action plan and the benefits to be derived from its implementation (SARA 49(1)(e)). This evaluation addresses only the incremental socio-economic costs of implementing this action plan from a national perspective as well as the social and environmental benefits that would occur if the action plan were implemented in its entirety, recognizing that not all aspects of its implementation are under the jurisdiction of the federal government. Its intent is to inform the public and to guide decision making on implementation of the action plan by partners.

The protection and recovery of species at risk can result in both benefits and costs. The Act recognizes that "*wildlife, in all its forms, has value in and of itself and is valued by Canadians for aesthetic, cultural, spiritual, recreational, educational, historical, economic, medical, ecological and scientific reasons*" (SARA). Self-sustaining and healthy ecosystems with their various elements in place, including species at risk, contribute positively to the livelihoods and

[6] The "action plan component of the recovery document" will simply be referred to as "action plan" from this point forward.

the quality of life of all Canadians. A review of the literature confirms that Canadians value the preservation and conservation of species in and of themselves. Actions taken to preserve a species, such as habitat protection and restoration, are also valued. In addition, the more an action contributes to the recovery of a species, the higher the value the public places on such actions (Loomis and White 1996; DFO 2008). Furthermore, the conservation of species at risk is an important component of the Government of Canada's commitment to conserving biological diversity under the *International Convention on Biological Diversity*. The Government of Canada has also made a commitment to protect and recover species at risk through the *Accord for the Protection of Species at Risk*. The specific costs and benefits associated with this action plan are described below. The evaluation describes, to the extent possible, the benefits that may accrue, as well as the costs that governments, industry and/or Canadians may incur due to activities identified in this action plan.

It is important to note that the socio-economic evaluation only applies to the detailed recovery measures. The setting of population and distribution objectives and the identification of critical habitat are science-based exercises and socio-economic factors were not considered in their development.

This evaluation does not address the socio-economic impacts of protecting critical habitat for the Mapleleaf. Under SARA, DFO must ensure that critical habitat identified in a recovery strategy or action plan is legally protected within 180 days of the final posting of the recovery document. Where a Critical Habitat Order will be used for critical habitat protection, the development of the Order will follow a regulatory process in compliance with the Cabinet Directive on Regulatory Management (CDRM), including an analysis of any potential incremental impacts of the Ministerial Order that will be included in the Regulatory Impact Analysis Statement. As a consequence, no additional analysis of the critical habitat protection has been undertaken for the assessment of costs and benefits of the action plan.

Policy Baseline

The policy baseline consists of the protection under the *Species at Risk Act* for the Mapleleaf (the species was listed under SARA in 2013), along with continued protection under Ontario's *Endangered Species Act, 2007.* Other legislation that may provide direct or indirect habitat protection for the Mapleleaf include the federal *Fisheries Act* and existing provincial legislation[7]. The policy baseline also includes any recovery actions[8] that were implemented prior[9] to and after the Mapleleaf was listed under SARA. These recovery actions included various projects[10] funded by the federal government and province of Ontario.

Socio-economic Benefits of Implementing this Action Plan

Some of the benefits of recovery actions required to return or maintain self-sustaining populations of the Mapleleaf outlined in this action plan are difficult to quantify but would generally be positive. Generally freshwater mussels are ecologically important as a food source

[7] Examples of other provincial legislation that provide habitat protection include, but may not be limited to, considerations under Section 3 of Ontario's *Planning Act* which prohibits development and site alteration in the significant habitat of endangered species and protection under the *Lakes and Rivers Improvement Act* in Ontario.

[8] Where recovery actions for several freshwater mussel species whose distributions partly overlap with the Mapleleaf have been implemented.

[9] Recovery actions that will benefit the Mapleleaf have been implemented under the *Recovery Strategy for the Northern Riffleshell, Snuffbox, Round Pigtoe, Mudpuppy Mussel and Rayed Bean in Canada*, the *Recovery Strategy for the Round Hickorynut and the Kidneyshell in Canada*, and the *Recovery Strategy for the Wavy-rayed Lampmussel in Canada*. Ecosystem-based recovery strategies that will benefit the Mapleleaf include the *Sydenham River Action Plan*, *Thames River ecosystem recovery strategy*, *Ausable River ecosystem recovery strategy* and the *Grand River fish species at risk recovery strategy*.

[10] Projects included fish host research.

for many aquatic and terrestrial animals; they indirectly provide ecosystem services by improving water quality by filtering contaminants, sediments, and nutrients from waterways; and because mussels are sensitive to toxic chemicals, they serve as an early warning system to alert us of water quality problems. These ecosystem benefits would be maintained as a result of implementing the recovery actions proposed in the action plan.

Some of the unquantifiable non-market benefits mentioned in the second paragraph of this evaluation would be enjoyed by the Canadian public as a result of implementing the recovery actions contained in the action plan. The implementation of local stewardship programs to improve habitat conditions and reduce threats within critical habitat will help to improve riverine habitat and help lead to healthier watersheds through improved water quality.

The socio-economic benefits of implementing the recovery actions contained in the action plan are anticipated to be low.

Socio-economic Costs of Implementing this Action Plan

The majority of the recovery activities identified in this action plan are short-term (2015-2019), medium term or ongoing. Most of these activities focus on research, monitoring, engagement, education, and management to reduce threats and to inform and promote species recovery. Some of the actions are one-time projects (e.g., research and monitoring), likely funded from existing federal government resources. Implementation of local stewardship actions would be supported by programs such as the Species at Risk Habitat Stewardship Program. In addition, most programs require a level of direct or in-kind support costs from applicants as matching funds[11]. The costs (direct and in-kind) associated with these short-term actions are estimated to be low[12] and spread over the next five years[13].

Costs would be incurred by the federal government to implement the activities listed in the action plan. In-kind costs such as volunteer time, providing expertise and equipment would be incurred as a result of implementing activities listed in the action plan. Costs (including in-kind support) could be incurred by the province of Ontario and conservation authorities.

Long-term recovery activities will be developed through a cooperative approach following discussions between other agencies, levels of government, stewardship groups and stakeholders allowing for consideration of costs and benefits during the process.

[11] For example, matching funds for the Species at Risk Habitat Stewardship Program can come from landowners and/or provincial funding programs. This helps leverage additional support for recovery actions.

[12] Low costs are defined as less than $1 million annually, as per the Treasury Board of Canada definition.

[13] Future expenditures cannot be determined in great detail as it is expected these activities would continue to be funded through existing government funding, including the Species at Risk Habitat Stewardship Program, where support is determined on a priority basis and based on availability of resources.

Distributional Impacts
Governments and conservation authorities will incur the majority of costs of implementing the action plan.

The Canadian public will benefit from the implementation of the action plan through expected non-market and ecosystem benefits associated with recovery and protection of the species and its habitat. Recovery actions that improve riverine habitat will help lead to healthier watersheds with benefits such as improved water quality.

10. Measuring progress

The overall success of implementing the recommended recovery approaches will be evaluated primarily through routine population (distribution and abundance) and habitat (quality and quantity) surveys and monitoring (refer to implementation schedule – table 5, recovery measures #1 and #4). During the next five years, focus will be placed on completing recovery actions identified as “high priority” for the Mapleleaf. Reporting on *implementation* of the action plan components, under s. 55 of SARA, will be done by assessing progress towards achieving the broad strategies/approaches outlined in this document. Reporting on the ecological and socio-economic impacts of the action plan, under s. 55 of SARA, will be done by assessing the results of monitoring the recovery of the species and its long term viability, and by assessing the implementation of the action plan.

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Crystal Allan	Grand River Conservation Authority
Muriel Andreae	St. Clair Region Conservation Authority
Dave Balint	Fisheries and Oceans Canada
Amy Boyko	Fisheries and Oceans Canada
Mike Nelson	Essex Region Conservation Authority
Alan Dextrase	Ontario Ministry of Natural Resources and Forestry
Scott Gibson	Ontario Ministry of Natural Resources and Forestry
Dr. Patricia Gillis	Environment and Climate Change Canada
Lee-Ann Hamilton	Niagara Peninsula Conservation Authority
Kari Jean	Ausable Bayfield Conservation Authority
Dr. Gerry Mackie	University of Guelph
Daryl McGoldrick	Environment and Climate Change Canada
Kelly McNichols	Fisheries and Oceans Canada
Dr. Todd Morris (Co-Chair)	Fisheries and Oceans Canada
Dr. Scott Reid	Ontario Ministry of Natural Resources and Forestry
Dr. Frederick Schueler	Bishop Mills Natural History Centre
Dr. Astrid Schwalb	University of Waterloo
John Schwindt	Upper Thames River Conservation Authority
Shawn Staton (Co-Chair)	Fisheries and Oceans Canada
Valerie Towsley	Lower Thames River Conservation Authority
Mari Veliz	Ausable Bayfield Conservation Authority
Dr. Daelyn Woolnough	Central Michigan University
Dr. Dave Zanatta	Central Michigan University

Appendix A: Effects on the environment and other species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or achievement of any of the Federal Sustainable Development Strategy's[14] (FSDS) goals and targets.

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

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

[14] www.ec.gc.ca/dd-sd/default.asp?lang=En&n=F93CD795-1