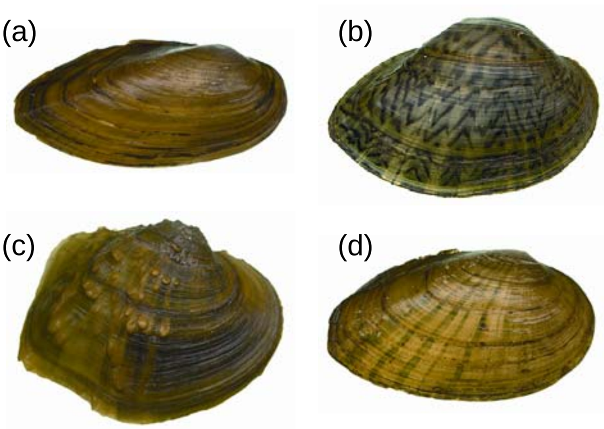
RECOVERY POTENTIAL ASSESSMENT OF EASTERN PONDMUSSEL (*Ligumia nasuta*), FAWNSFOOT (*Truncilla donaciformis*), MAPLELEAF (*Quadrula quadrula*), AND RAINBOW (*Villosa iris*) IN CANADA



(a) Eastern Pondmussel (Ligumia nasuta)*, (b) Fawnsfoot* (Truncilla donaciformis)*, (c) Mapleleaf* (Quadrula quadrula)*, (d) Rainbow* (Villosa iris)
© *Environment Canada*

Figure 1. Distribution of Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow in Canada.

Context:

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Rainbow in April 2006. The assessment resulted in the designation of Rainbow as Endangered. The two population designatable units (DU) of Mapleleaf were also assessed by COSEWIC in April 2006. This resulted in two designations; the Ontario DU was designated as Threatened, while the Manitoba DU was designated as Endangered. The following year, in April 2007, the status of the Eastern Pondmussel was assessed as Endangered. Subsequently, in April 2008, Fawnsfoot was assessed and was determined to be Endangered. These four species are currently being considered for listing on Schedule 1 of the Species at Risk Act (*SARA).*

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to fulfill requirements under the SARA. These requirements include listing decisions, authorizations to carry out activities that would otherwise violate the SARA and development of recovery strategies (DFO 2007). The advice in the RPA may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions of the SARA. This assessment considers the scientific data available with which to assess the recovery potential of Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow in Canada.

SUMMARY

- Eastern Pondmussel is known to be currently distributed in Long Point Bay, Lyn Creek and the St. Clair River delta. It is currently unknown whether reproducing populations are present at Beaver Lake or in the Grand River. It is believed that Eastern Pondmussel has been extirpated from the Great Lakes and their large connecting channels.

- Fawnsfoot currently occupies the Grand, Sydenham and Thames rivers. A single individual has been discovered at both the Saugeen River and the St. Clair River delta. Fawnsfoot is thought to be extirpated from the Great Lakes and their large connecting channels.

- The Canadian distribution of Mapleleaf is divided into two designatable units (DUs): Great Lakes - Western St. Lawrence population (Ontario DU) and the Saskatchewan - Nelson population (Manitoba DU). In Ontario, Mapleleaf are present in the Ausable, Grand, Ruscom, Sydenham, Thames and Welland rivers, as well as Jordan Harbour. A single individual has been recorded from both the Bayfield River and the St. Clair River delta. In Manitoba, Mapleleaf is known to currently occupy the Assiniboine River but the presence of a reproducing population is unknown from all other rivers.

- It is known that Rainbow occupies the Ausable, Bayfield, Grand, Maitland, Moira, Saugeen, Sydenham, Thames and Trent rivers, as well as the St. Clair River delta. It is currently unknown if a Rainbow population is present in the Salmon River.

- Gills of the appropriate host fish are the required habitat for the glochidial life stage of all species.

- Adult Eastern Pondmussel preferred habitat includes both nearshore, sheltered areas of the Great Lakes as well as the slack water of slow-moving rivers.

- Adult Fawnsfoot are generally found in medium- to large-sized rivers at depths ranging from less than 1 m to greater than 5 m.

- The current distribution of adult Mapleleaf in Canada indicates that this species tends to occur in the lower reaches of medium to large rivers. Water flow does not appear to be limiting factor for Mapleleaf as it has been found in both slow- and fast-flowing rivers.

- Although historically Rainbow were present in the nearshore area of the Great Lakes and its connecting channels, Zebra Mussel introduction has restricted this species to small creeks and rivers, and the St. Clair River delta. In river systems it can be found in the middle to upper reaches in or near riffles, and is generally found in areas with moderate to strong current.

- The sensitivity of population growth of freshwater mussels to perturbation can be predicted using life history characteristics.

- Population growth of freshwater mussels is particularly sensitive to the survival of adult and settled juvenile mussels.

- Fawnsfoot population growth is more susceptible to changes in reproductive traits (age at maturity, fecundity and glochidial survival) than are Mapleleaf, Eastern Pondmussel, or Rainbow.

- Uncertainty surrounding life-history estimates is highest for survival of glochidia and early juveniles. Rates of host infestation, and the influence of host density on these rates, are particularly understudied.

- The greatest threat to the survival and persistence of freshwater mussels is attributed to the introduction and establishment of dreissenid mussels and decreases in the quality of available freshwater mussel habitat. In addition, there is evidence that decreases in water quality, specifically increased turbidity and suspended solids, increased nutrient loading, and increased levels of contaminants and toxic substance are also limiting the distribution of freshwater mussels. Additional threats include altered flow regimes and the removal and alteration of habitat. Due to the obligate nature of the mussel reproductive cycle, any threat leading to the separation of mussel and host fish during reproduction can be detrimental to the mussel population. Secondary threats include predation and harvesting, and recreational activities.

- There remain numerous sources of uncertainty related to life history, juvenile habitat requirements, host distribution and abundance, and host-mussel distribution overlap for these freshwater mussels. A thorough understanding of the threats affecting the decline of freshwater mussel populations is also lacking. Numerous modeling parameters specific to these freshwater mussels are currently unknown, such as glochidial survival, juvenile survival, and population growth rates. Little is known of the relationship between the host population density and the frequency of host-mussel encounters.

BACKGROUND

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Rainbow in April 2006. The assessment resulted in the designation of Rainbow as Endangered. The two population designatable units (DU) of Mapleleaf were also assessed by COSEWIC in April 2006. This resulted in two designations; the Ontario DU was designated as Threatened, while the Manitoba DU was designated as Endangered. The following year, in April 2007, the status of the Eastern Pondmussel was assessed as Endangered. Subsequently, in April 2008, Fawnsfoot was assessed and was determined to be Endangered. These four species are currently being considered for listing on Schedule 1 of the *Species at Risk Act (*SARA). When a species is considered for listing the Minister of Fisheries and Oceans Canada (DFO) is required to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including permitting on harm and recovery planning. This RPA focuses on Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow in Canada, and is a summary of a Canadian Science Advisory Secretariat peer-review meeting that occurred on 19-20 October 2010, in Burlington, Ontario. Two research documents, one providing background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (Bouvier and Morris 2010), and a second on recovery potential modelling (Young and Koops 2010) provide an in-depth account of the information summarized below. Proceedings are also made available that document the activities and key discussions of the meeting (DFO 2010). Please note that the complete reference citations have been removed from the following document to minimize the length of the document. Complete references are available at Bouvier and Morris (2010) and Young and Koops (2010).

Species Description and Identification

Eastern Pondmussel

Eastern Pondmussel (*Ligumia nasuta*) is a medium-sized mussel with an average shell length of about 70 mm. Maximum shell size in Canada has been approximated to be 102 mm. The shell is characterized as being thin, narrow and elongate with a distinctive, bluntly-pointed posterior end. Although sexual dimorphism is subtle, females can be distinguished from males by a swelling along the posterior ventral margin. The exterior of the shell varies in colour from yellowish- or greenish-black in juveniles to dark brown or black in adults with a concentration of narrow green rays at the posterior end. The nacre is described as purple, pink or silvery-white.

Fawnsfoot

Fawnsfoot (*Truncilla donaciformis*) is considered a small freshwater mussel with an average adult length in Ontario of approximately 35 mm. The maximum shell size for this species is reported to be 52 mm. The shell shape has been described as moderately thick, oval to triangular with a rounded anterior end and a pointed posterior end. The posterior ridge is described as being dorsally flattened. Shell coloration is yellow to greenish-brown with numerous obvious dark green rays, which are broken forming chevron-shaped markings.

Fawnsfoot is not easily misidentified for most other Canadian freshwater mussel species as its chevron-shaped markings, and relatively small size are unmistakably characteristic of this species. Deertoe (*Truncilla truncata*), the only other member of the genus *Truncilla* found in Ontario, is also characterized by the presence of chevron-shaped markings on the shell, although markings on the Deertoe are noticeably thinner in comparison to those of Fawnsfoot. Fawnsfoot can be identified by its weak posterior ridge and broadly curved ventral margin. In addition adult Deertoe can grow to be approximately twice as large as adult Fawnsfoot.

Mapleleaf

Mapleleaf (*Quadrula quadrula*) is a medium to large freshwater mussel species with an average adult length of 90 mm. In Ontario, Mapleleaf have been recorded up to 135 mm, while adult shell length in Manitoba have been reported up to 121 mm. The shell is described as being moderately inflated, quadrate in outline with a rounded anterior end and a squared or truncated posterior end. A characteristic of Mapleleaf is the presence of two bands of raised nodules radiating in a V-shape from the umbo to the ventral margin. The first row is centrally located, while the second is located on the posterior ridge. A shallow groove separates the two rows of nodules.

The shell color is described as ranging from yellowish green to greenish brown to light brown to dark brown (older individuals occupying the darker extreme of this spectrum). The nacre is generally pearly white with obvious iridescence at the posterior end.

Mapleleaf is most often confused with the only other member of the genus *Quadrula* in Ontario, Pimpleback (*Quadrula pustolusa*); although, these two species are distinguishable by their nodular pattern and shell shape. The nodules on Mapleleaf are generally restricted to two bands, and the shell shape is quadrate; whereas the nodules are more irregularly distributed on Pimpleback and the shell shape is rounded. It should be noted that Pimpleback does not occur in Manitoba waters and Mapleleaf should not be confused with any mussel species present in this province.

Rainbow

Rainbow (*Villosa iris*) is a small-sized freshwater mussel with an average shell length of 55 mm. Adult Rainbow shell lengths have been recorded up to 85 mm in Canada. The shell is described as being elliptical, elongate, laterally-compressed in males to moderately inflated in females. Although sexual dimorphism is subtle, the posterior end of males is described as bluntly pointed, while females are described as rounded.

The shell is characterized as being smooth with well-marked growth rests. The coloration is yellowish green or brown with interrupted dark green rays that are more prominent posteriorly. Bands may be narrow, wide, or may vary in width over the surface of the shell. The nacre is generally white with obvious iridescence posteriorly.

The characteristic small size, interrupted green rays, and narrow elliptical shape of Rainbow enable for easy differentiation of this species from most other Canadian freshwater mussels. Rainbow may be confused with juvenile Mucket (*Actinonaias ligamentina*).

ASSESSMENT

Current Species Distribution

Eastern Pondmussel

Beaver Lake

Three fresh whole shells from Beaver Lake were recorded in 1998. An additional weathered shell was collected from this area in 2006. Although not formally sampled, this site has since been revisited in 2006 and it was noted that Beaver Lake was infested with Zebra (see Figure 2 for Eastern Pondmussel distribution).

Grand River

The first record of Eastern Pondmussel from the Grand River dates back to 1934 when three fresh whole shells were recorded near Dunnville. Subsequent to this record, five fresh whole shells were recorded in 1963 approximately 1 km downstream from the original historic site. More recently, one fresh valve was recorded from McKenzie Creek in 1995. There are no records of live individuals from this river system.

Great Lakes and Connecting Channels

Lake Ontario

In Lake Ontario, the majority of Eastern Pondmussel records originated from the Bay of Quinte watershed, including areas in and around Prince Edward County. These areas included the Moira River, Consecon Lake, East Lake, Hay Bay and Bay of Quinte proper. It was also found in scattered locations along the north shore of Lake Ontario, including the mouth of Pickering Creek, Hanlon’s Point (near Toronto, Ontario) and Hamilton Harbour. The last live record of Eastern Pondmussel in Lake Ontario dates back to 1996 when 14 live individuals were recorded from Consecon Lake. It was noted at time of capture that no Zebra Mussel were present. This site, along with numerous other historic Eastern Pondmussel sites were revisited in 2005, and all areas were found to be infested with Zebra Mussel and not a single live unionid was found. It is believed that Eastern Pondmussel no longer inhabits these formally occupied areas.

Lake Erie

Eastern Pondmussel also flourished throughout Lake Erie, and its connecting channels, with records from the Niagara River, Welland River; along the north shore of Lake Erie from Crystal Beach, Port Colbourne, the mouth of the Grand River, Port Dover, Port Rowan, Long Point Bay and Rondeau Bay; numerous locations from the western basin including Point Pelee, Pelee Island, Colchester, Middle Sister Island, East Sister Island and Holiday Beach. Eastern Pondmussel distribution also included the Detroit River at Windsor and Amherstberg. Many of the historical Eastern Pondmussel sites have been revisited since the Zebra Mussel invasion and no live Eastern Pondmussel specimens, and in many cases no live unionids, were found.

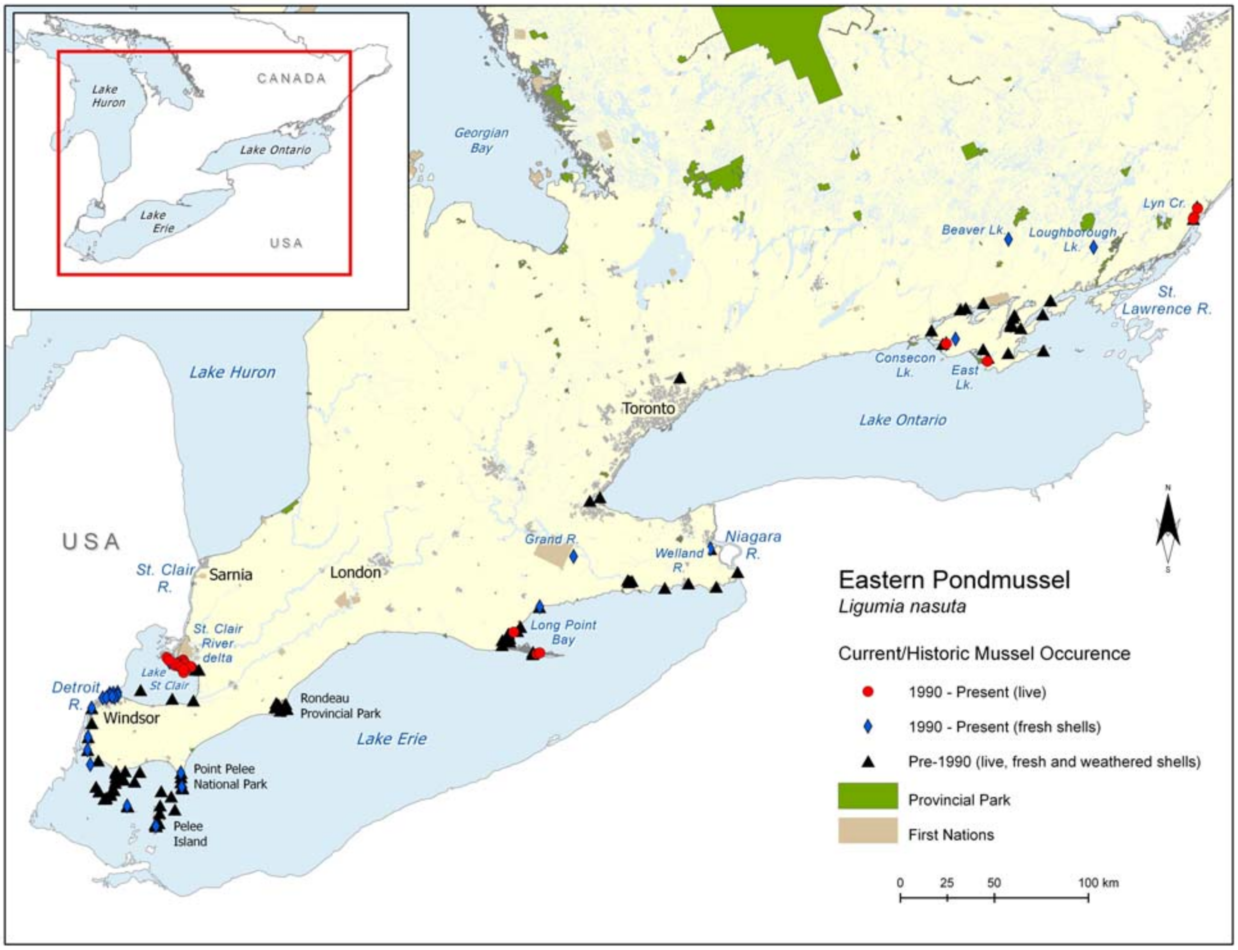


Figure 2. *Current and historic distribution of Eastern Pondmussel in Canada.*

Lake St. Clair

Eastern Pondmussel was historically recorded in the offshore waters of Lake St. Clair and in the Detroit River. Lake St. Clair has been intensively surveyed for unionids since the Zebra Mussel invasion and it is believed that Eastern Pondmussel has been extirpated from the offshore area of Lake St. Clair since 1994. Similarly, unionid surveys of the Detroit River from 1997-98 indicated that Eastern Pondmussel is also no longer present in this system.

Loughborough Lake

One weathered valve (102 mm) and one weathered shell fragment were collected from Loughborough Lake at the Missouri (Co Rd 10) bridge in eastern Ontario in 2009. This location has not been formally sampled and the 2009 record is the only known record from this area, although it was noted at this time that the area was infested with Zebra Mussel.

Lyn Creek

In 2005, two fresh valves and one weathered whole Eastern Pondmussel were found in Golden Creek, a tributary of Lyn Creek (tributary of the upper St. Lawrence River). Lyn Creek was revisited in 2006 and live Eastern Pondmussel were recorded by means of an observational study at seven sites, yielding a total of 42 live individuals. Additional observational studies were completed at new sites, as well as previously visited sites between 2007 and 2009 and noted the presence of live individuals at all but one location. A formal timed-search survey was completed at one site in 2009, and recorded the presence of 10 live Eastern Pondmussel. It is believe that a population of Eastern Pondmussel inhabits an 8 km stretch of Lyn Creek.

Long Point Bay – Cedar Creek and Turkey Point Marsh

Sampling at three sites in Cedar Creek (a small inlet located within the Long Point National Wildlife Area boundaries) in August 2008, resulted in the capture of 21 Eastern Pondmussel. The same area was revisited in September of the same year and an additional 23 individuals were recorded. Turkey Point Marsh (north shore of Long Point Bay) was sampled in the summer of 2008 and four live individuals were recorded at a single site. The presence of live individuals at Cedar Creek and Turkey Point Marsh marks the first time live Eastern Pondmussel have been recorded from Lake Erie since 1979.

Mill Dam (Lake Ontario)

A historic record from 1860 of 15 fresh whole shells exists from Mill Dam (near Markham). There has been no record of any additional individuals in this area since 1860.

St. Clair River Delta

The St. Clair River delta represents the largest remaining Eastern Pondmussel population in Canada. Many of the Eastern Pondmussel records from this location are found within the Walpole Island First Nation territory. Although a fresh whole shell was recorded near the St. Clair River delta in 1965, the first live animal was not recorded until 1999. The St. Clair River delta represents a significant refuge site for Eastern Pondmussel and other native unionids from the Zebra Mussel invasion. It is believed that the shallow depth of the delta as well as its high level of connectivity with the lake proper is discouraging the settlement and survival of Zebra Mussel. Numerous sites were surveyed in the nearshore area of Lake St. Clair from 1999 to 2001 and live mussels were found at many of these sites, including Eastern Pondmussel, which was found at 16 sites. A subsequent study in 2003 and 2005 sampled 15 sites in the Canadian waters of the delta and found live Eastern Pondmussel at 6 of these sites. Since 1999, 310 live Eastern Pondmussel have been sampled from the St. Clair River delta.

Sydenham River

A single Eastern Pondmussel record exists for the Sydenham River from 1991, although there is no information available on whether this record consists of a live individual, or a fresh or weathered shell.

Whitefish Lake (Lake Ontario)

A single weathered Eastern Pondmussel valve was observed from Whitefish Lake in 1995. Whitefish Lake is part of the Lake Ontario portion of the Rideau Canal system. No additional sampling has occurred in this area.

Fawnsfoot

Grand River

There are a total of eight historic Fawnsfoot records from the Grand River, the most recent being 1997 when 11 live individuals were recorded. All Fawnsfoot records are from the extreme lower portion of the Grand River between the mouth of Port Maitland and the Byng Conservation Area at Dunnville. The location of the 1997 records has been since revisited, although a formal sampling event has not occurred, and no additional Fawnsfoot were located (see Figure 3 for Fawnsfoot distribution).

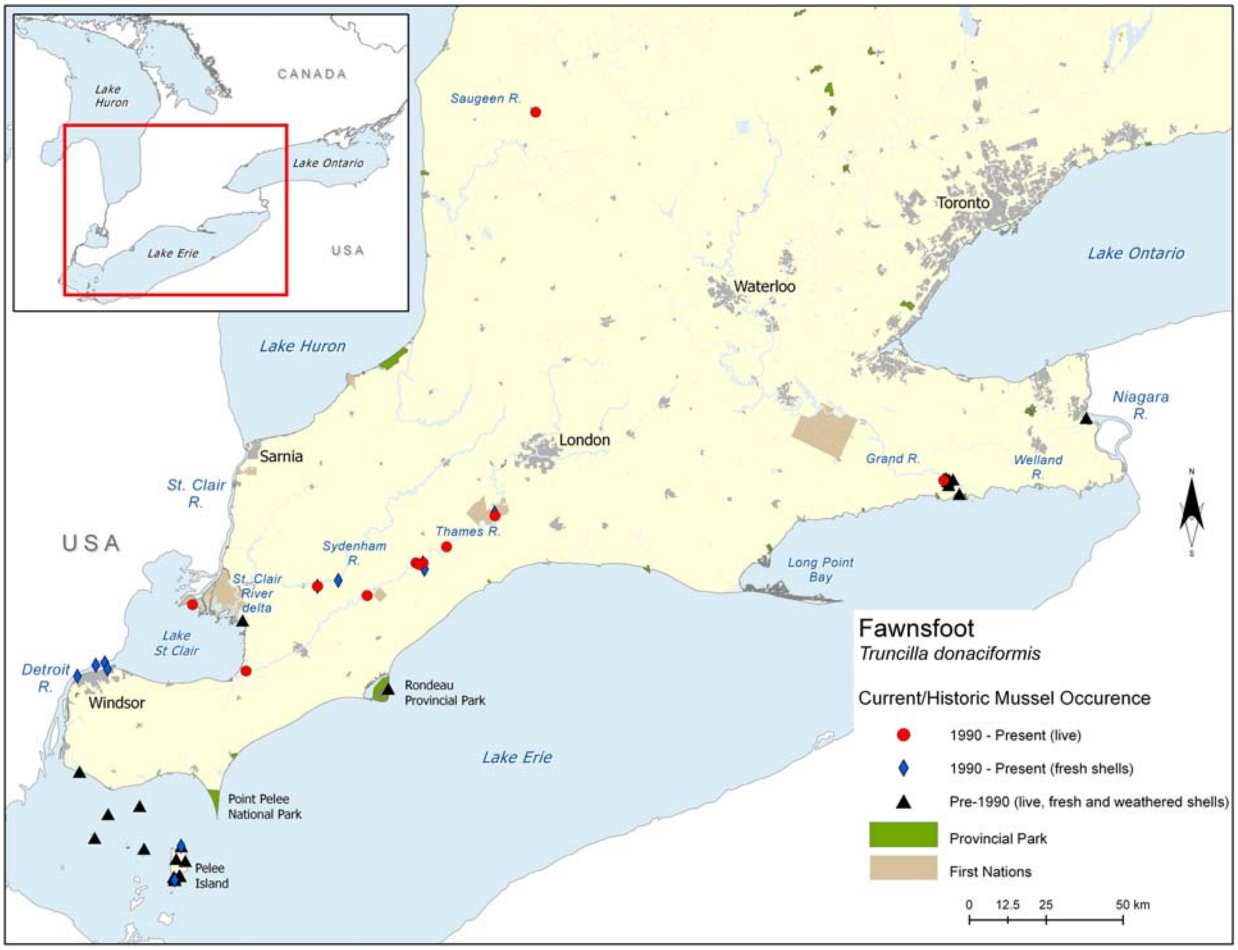


Figure 3. *Current and historic distribution of Fawnsfoot in Canada.*

Great Lakes and Connecting Channels

Although Fawnsfoot has always been rare in any historic sampling event in which it was present, it is believed that this species no longer occurs at any of its formally occupied areas in Lake St. Clair, Lake Erie and the Detroit River. One of the earliest records of Fawnsfoot in Canada was collected from Lake St. Clair in 1934. There is one additional record of Fawnsfoot, consisting of four live individuals, from Lake St. Clair proper which was collected in 1986. This is the last time Fawnsfoot was recorded from the offshore waters of Lake St. Clair. The first collection of Fawnsfoot from Lake Erie dates back to 1951. There are sparse records of both fresh and weathered shells collected from Lake Erie from 1951 to the late 1980s; although the presence of live individuals was very rare throughout this time period. It is believed that

Fawnsfoot had disappeared from the Lake Erie basin by 1961. The first record of Fawnsfoot in the Detroit River is dated 1982, when a single live individual was collected. This record represents the first and only live individual to be collected from this system. Fawnsfoot is now considered to be extirpated from its entire former range in Lake St. Clair, Lake Erie and the Detroit River.

Saugeen River

The first, and only record of Fawnsfoot from the Lake Huron drainage dates to 2005 when a single individual was collected during a benthic invertebrate assessment from Muskrat Creek (a tributary of the Teeswater River) in the Saugeen River watershed. Prior sampling in this system targeting freshwater mussels did not detect the presence of Fawnsfoot. In 2006, subsequent to this discovery, a survey was completed in this watershed. The survey was unsuccessful at detecting any additional Fawnsfoot.

St. Clair River Delta

Substantial sampling for freshwater mussels has been completed in the St. Clair River delta and only a single Fawnsfoot has been recorded in the Canadian portion of the delta. This single individual was found in 2003 at the mouth of Pocket Bay.

Sydenham River

Fawnsfoot was first discovered in the Sydenham River in 1991 when a single fresh whole shell was reported. Subsequent mussel surveys in this river from 1997 to 2003 yielded the capture of 27 live individuals, in addition to five fresh whole shells.

Thames River

The first live Fawnsfoot specimen was not found in the Thames River until 2005, when timed-search surveys and a subsequent quadrat excavation recorded the presence of 23 live individuals. Until 2005 only one single Fawnsfoot valve had been recorded for this system. Two additional quadrat excavation surveys were completed in 2010 and a total of 45 live individuals were recorded. Fawnsfoot is believed to be relatively widespread in the lower portion of the Thames River, and its presence in the extreme lower portion of this system was verified in 2010 when a single live Fawnsfoot was captured during a fish trawling study near the mouth of the river. It is thought that the Thames River Fawnsfoot population may represent the largest remaining population in Canada.

Mapleleaf

The Canadian distribution of Mapleleaf has been separated into two designatable units based on the criteria outlined by COSEWIC[1]. Specifically, reasons for separation include unique haplotypes (i.e., genetic separation) and geographic distance (i.e., separation by distance). The Ontario populations (Figure 4) stem from the Great Lakes-St. Lawrence watershed whereas the Manitoba populations (Figure 5) are considered a part of the Hudson Bay watershed. In addition, both populations occupy distinct eco-geographic regions, in that the Ontario populations occupy the Great Lakes-Western St. Lawrence Ecological Area and the Manitoba populations occupy the Saskatchewan-Nelson Ecological Freshwater Area.

Ontario

Ausable River

Mapleleaf was first detected in the Ausable River in 2002 with the capture of nine live individuals. Subsequent to this discovery, Mapleleaf was recorded at three additional sites in

[1] http://www.cosewic.gc.ca/eng/sct2/sct2_5_e.cfm

2004 (n=9). The original site sampled in 2002 was revisited in 2006 and Mapleleaf was again located, this time in greater numbers (n=19). An additional two sites were sampled in 2008 and 2009, yielding the capture of one and seven live individuals, respectively. These Ausable River records, along with the single individual recorded from Bayfield River, represent the only occurrences of Mapleleaf in the Lake Huron drainage.

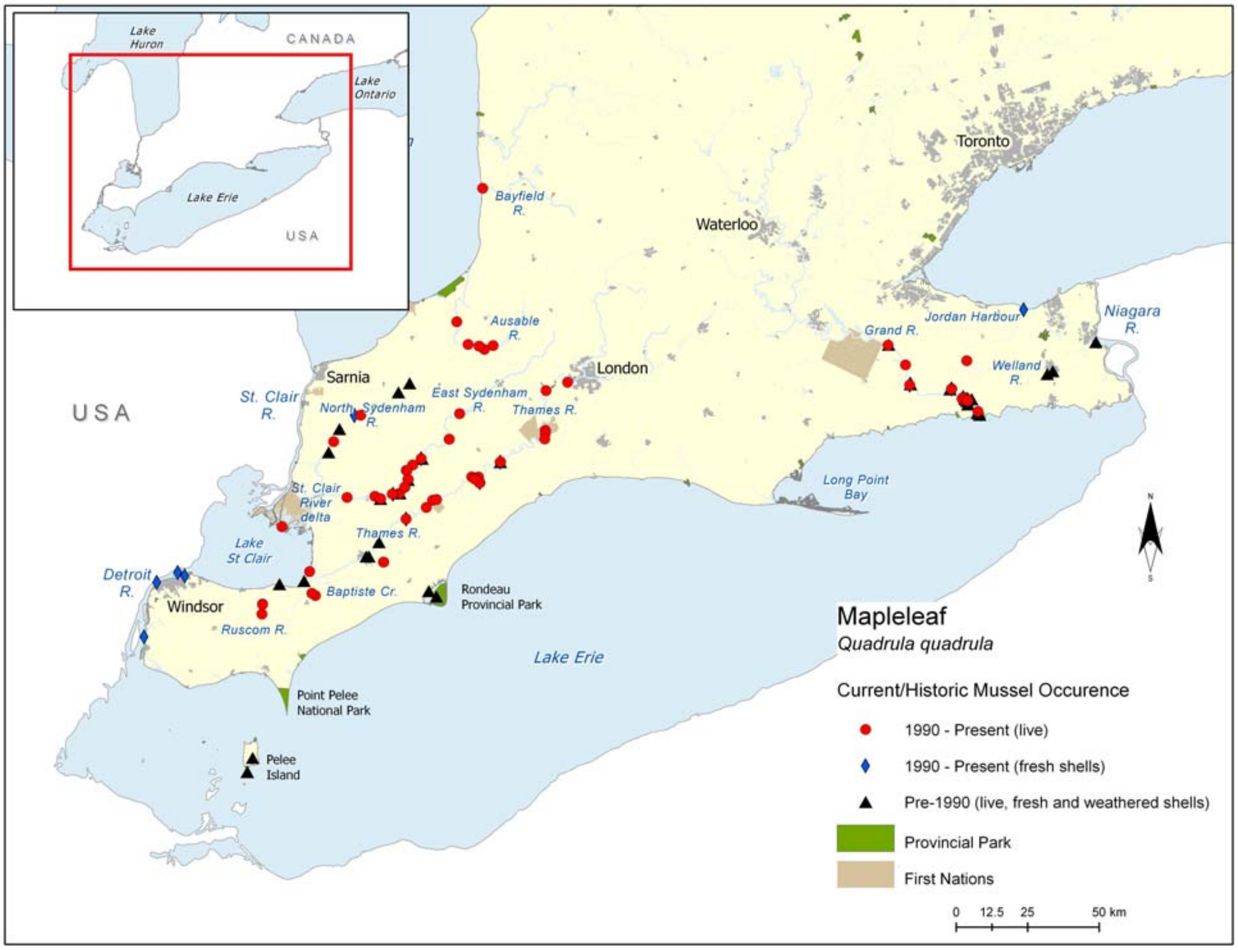


Figure 4. *Current and historic distribution of Mapleleaf in southwestern Ontario.*

Bayfield River

There are no historic records of Mapleleaf from the Bayfield River. A single live Mapleleaf was collected from the Bayfield River in 2007. There has been very limited mussel sampling in the Bayfield River; therefore, it is not possible to determine if a reproducing population of Mapleleaf is present in this system.

Grand River

Historic records dating back as far back as 1885 exist for Mapleleaf in the Grand River. Throughout history Mapleleaf distribution in the Grand River has always occurred in the lower 50 km of this system, ranging from Caledonia to Port Maitland. Numerous sampling events have occurred north of Caledonia and no additional Mapleleaf have been found. It is believed that this 50 km river segment represents the entire distribution of Mapleleaf in the Grand River.

Great Lakes and Connecting Channels

In Ontario Mapleleaf was historically collected from Lake Erie, Lake St. Clair, Detroit River, and Niagara River. Records from Lake Erie indicate that Mapleleaf existed in Rondeau Bay and in the area surrounding Pelee Island. A few historic Mapleleaf records exist from Lake St. Clair although the majority are comprised of shells or single live individual. There are only two Mapleleaf records from the Niagara River that date back to 1934, and three records from the Detroit River. It appears from these scarce records that Mapleleaf was very rare throughout the Great Lakes proper and their connecting channels even prior to the dreissenid invasion. As is the case with most other freshwater mussels, it is believed that Mapleleaf are now extirpated from the Great Lakes and their connecting channels.

Jordan Harbour

Jordan Harbour represents the first known population of Mapleleaf in Lake Ontario. In the summer of 2010 three fresh valves as well as greater than 100 weathered valves were observed on the north east shore of Jordan. No live individuals were recorded during this observational study. There is a need to complete a formal survey of Jordan Harbour as well as suitable habitats in Twenty Mile Creek (which enters Lake Ontario at Jordan Harbour) to determine the size of this Mapleleaf population.

Ruscom River

Ruscom River (a tributary on the south shore of Lake St. Clair) was originally sampled for freshwater mussels in 1999 resulting in the capture of nine live Mapleleaf. It was not possible to determine the status of this population from a single sampling event; therefore, this site was prioritized for sampling in 2010 to determine if a reproducing population was present. Mapleleaf was located in two additional sites during a timed-search survey, yielding a total of 26 live individuals.

St. Clair River Delta

Although Mapleleaf appear to be eradicated from the open water of Lake St. Clair, it has recently been found in both the St. Clair River delta and Ruscom River. Although the St. Clair River delta has been expansively surveyed in the past 10 years, positive detection of Mapleleaf in this area did not occur until 2005 when a single live specimen was recorded from Chematogan Bay during a snorkelling survey.

Sydenham River

The first recorded occurrence of Mapleleaf in the Sydenham River was documented in 1963. Mapleleaf has been noted in this river system from 1960s to present day. The range of Mapleleaf in the Sydenham River occurs from Tupperville to approximately 10 km upstream of Alvinston. Many successful sampling locations along this stretch of the Sydenham River were re-sampled from 1997 to 2009 and continually yielded Mapleleaf captures.

Thames River

Mapleleaf are present in the middle and lower portions of the Thames River. This river has been extensively surveyed since the mid 1990s. Recent quadrat excavation surveys have yielded very high numbers of Mapleleaf, the greatest being 225 Mapleleaf recorded during a single site excavation in 2010. The Mapleleaf population in the lower Thames River is thought to be one of the most stable and abundant Mapleleaf populations in Ontario.

Welland River

The Mapleleaf population of the Welland River was represented historical by two records (neither record included the capture of live individuals). General freshwater mussel surveys were completed in the Welland River in 2008, and although Mapleleaf was not found at either historic site, 25 live individuals were recorded from a site approximately 50 rkm (river kilometer) upstream from the historic location. Additional surveys in this area are required to determine the extent of this newly discovered population.

Manitoba

In Manitoba, Mapleleaf has been recorded from the Assiniboine, Bloodvein, Red and Roseau rivers. Unverified reports of Mapleleaf exist for the Brokenhead, LaSalle, Morris, Rat, Seine, Shell rivers as well as Lake Winnipeg. Unfortunately, very limited information is available for these incomplete records; therefore they can not be considered in the following status accounts.

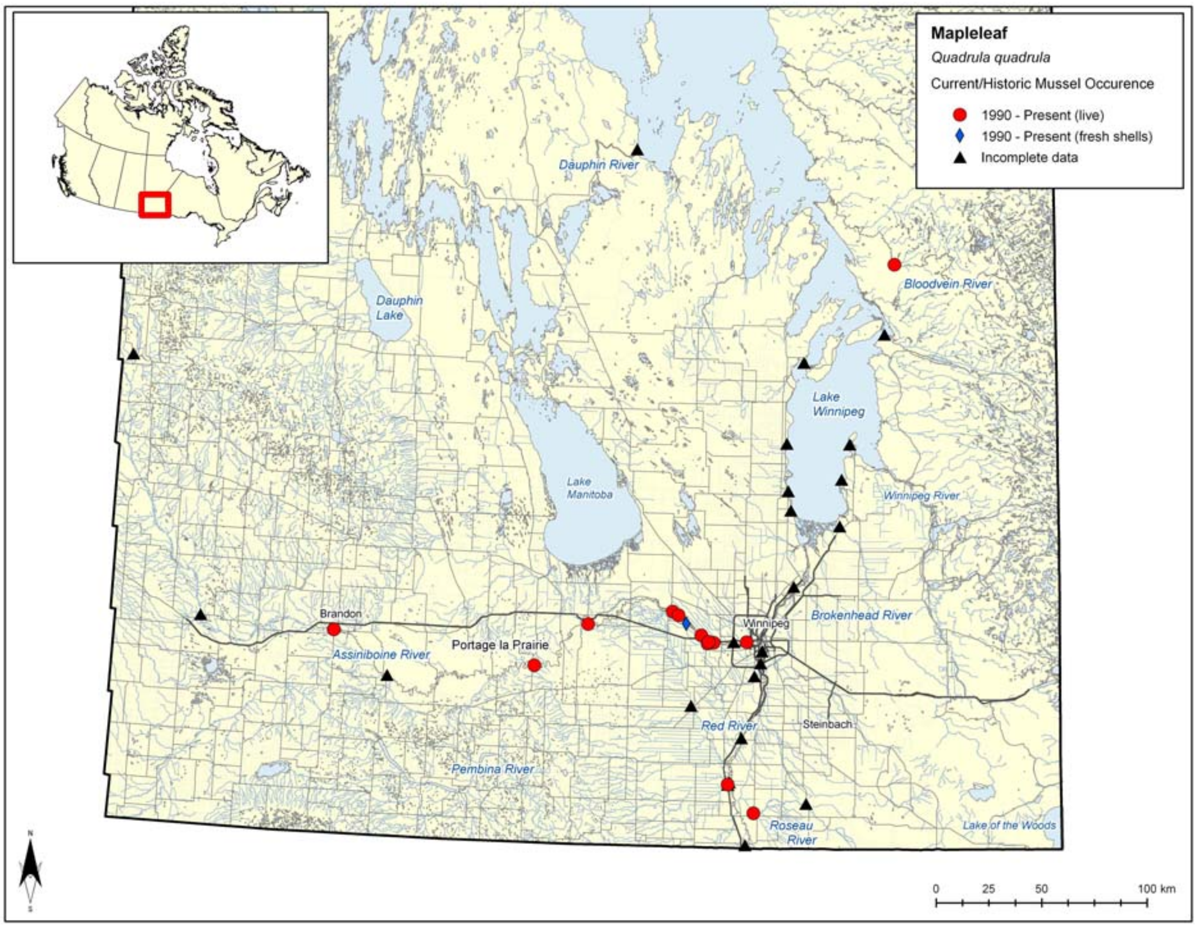


Figure 5. *Current and historic distribution of Mapleleaf in Manitoba [some distribution points digitized from distribution map provided in COSEWIC (2006)].*

Assiniboine River

The largest known population of Mapleleaf in Manitoba occurs in the Assiniboine River. The first record of Mapleleaf in this system stems from mussel surveys completed from 1959 to 1969. Methods used during these surveys included visual search in clear water, observation through a glass-bottomed viewing box, and searching by hand. The method used and the date of capture for Mapleleaf records was not specified. Mapleleaf was again observed during a 1992 scuba diving survey. Additionally, a total of six live individuals were recorded during a graduate student project in 1995. Collections were obtained by employing a raking method and a mini-bullrake. Thus far it was believed that Mapleleaf distribution was restricted to the lower Assiniboine River (below the Portage Diversion). An additional 42 live animals were accounted for during subsequent timed-search surveys. These results extend Mapleleaf distribution to the upper Assiniboine River, past the Portage Diversion, which is considered an impassable barrier to upstream movement of fish and a complete barrier for the upstream dispersal of glochidia-infested hosts. In 2007, as a consequence of a bridge construction project and subsequent mussel survey and relocation, four live Mapleleaf were recorded near the city of Brandon, providing evidence once again that Mapleleaf distribution spans the Assiniboine River both above and below the Portage Diversion. One additional live individual was capture from a location previously sampled for Mapleleaf during a mussel identification workshop in 2009.

Bloodvein River
A single live Mapleleaf has been recorded for the Bloodvein River, which was observed during a canoe expedition in 2005. There are no known historical mussel surveys from this system to verify the presence of a reproducing population.

Red River
Reports indicate that Mapleleaf were present in the Red River from areas such as Fort Gary, St. Jean Baptiste, Aubigny, Emerson and Winnipeg, although information related to sampling date/year, number of individuals captured, or method of capture are not available. Live individuals have not been recorded in the Red River since the historical. It is believed that a viable population of Mapleleaf may persist in the Red River, an assumption based on river geomorphology, Mapleleaf preferred habitat, and the observation of many stranded Mapleleaf during a low water event.

Roseau River
There is very limited information related to the presence of Mapleleaf in the Roseau River. Knowledge of Mapleleaf in this system is limited to a historic account indicating that Mapleleaf were recorded from Tolstoi (number of live individuals is unknown), and the capture of one live individual in 1992 near Dominion City. It is currently unknown if a Mapleleaf population persists in the Roseau River.

Rainbow

Ausable River

Sparse records of Rainbow exist for the Ausable River since 1998 when a single individual was captured. Timed-search surveys and quadrat sampling since 2002 have yielded an additional 54 live animals, with 16 individuals recorded during a single sampling event (see Figure 6 for Rainbow distribution).

Bayfield River

The first occurrence of Rainbow in Bayfield River is represented by a single fresh shell collection from 2005. A formal survey of Bayfield River was complete in 2007 over a two-day period and yielded a total 28 live individuals. This formal survey represents the only known sampling focused on freshwater mussels in the Bayfield River.

Grand River

Although there are quite a few historic records of Rainbow in the Grand River, the overall abundance of this species in this system is quite low. The first recorded occurrence of Rainbow in the Grand River dates back to 1890. Since 1970 there have been a total of 27 live individuals recorded from this system with only 11 live individuals recorded over the past 10 years. However, there have been numerous records of fresh shells over this same period from tributaries of the Grand River, such as Conestogo River and Mallet. Although historic Rainbow records indicate that its distribution extends to the lower reaches of the Grand River, a live Rainbow has not been observed in this section of the Grand River since 1971.

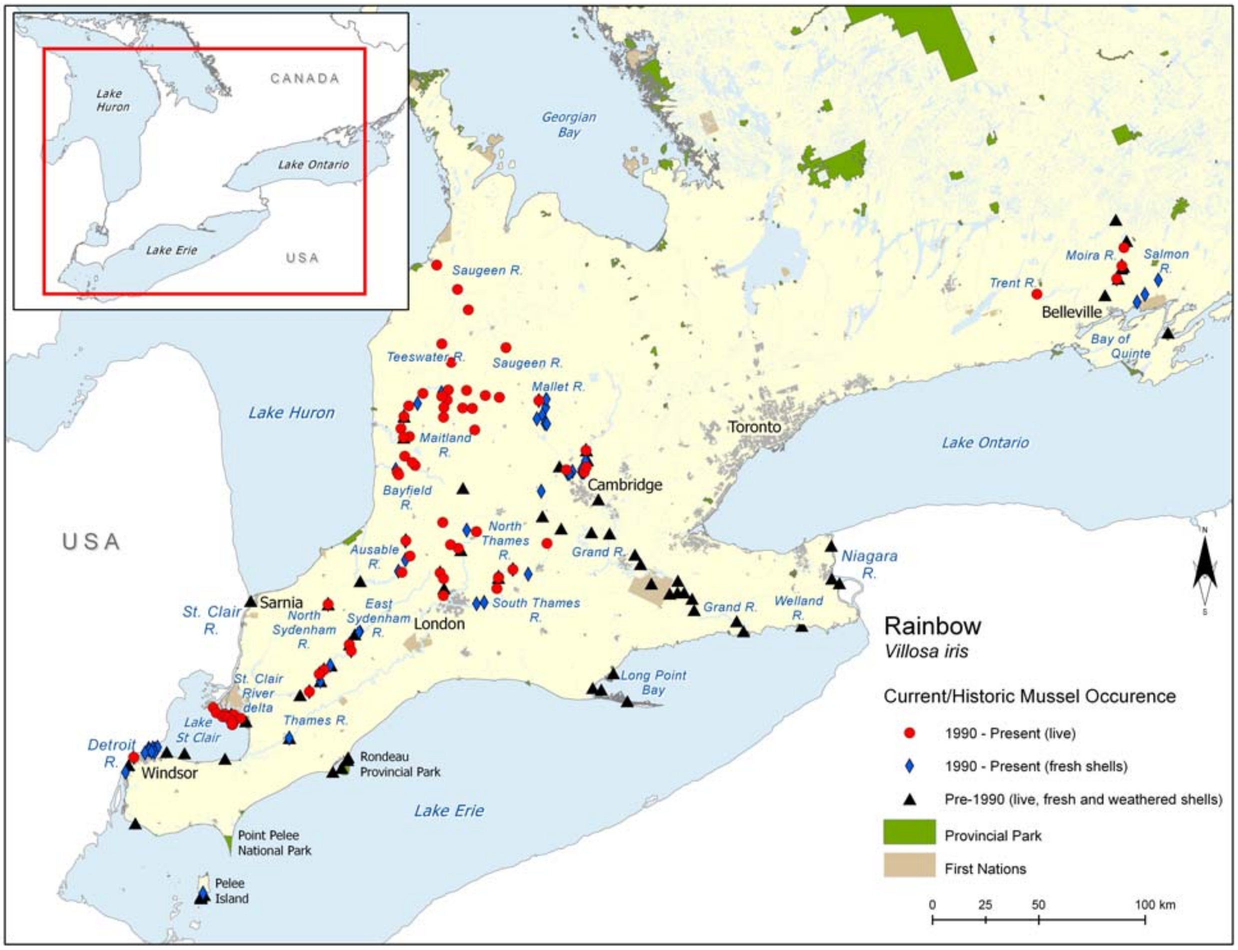


Figure 6. *Current and historic distribution of Rainbow in Canada.*

Great Lakes and Connecting Channels

Historically, Rainbow was found in the nearshore area of Lake Erie (Long Point Bay, Rondeau Bay), Lake Ontario and Lake St. Clair (south shore), as well as throughout the Niagara River, Detroit River and a single location in the St. Clair River. The last occurrence of a live Rainbow from any of these systems was recorded in 1992 when three individuals were sampled from the Detroit River. Surveys have occurred post-dreissenid mussel invasion at all historic Rainbow sites. It is believed that Rainbow, along with the three previously discussed freshwater mussels, is now extirpated from the Great Lakes and its major connecting channels.

Maitland River

Notwithstanding a few historic records from the 1930s, Rainbow had not been recorded from the Maitland River until 1998. Extensive sampling of this system over the past 10 years has yielded greater than 700 live individuals from 19 unique sites. It is believed that the Maitland Rainbow population represents the largest remaining population of this species in Canada.

Moira, Salmon and Trent Rivers

The known distribution of Rainbow in eastern Ontario is limited to three river systems: Moira, Trent and Salmon rivers. It should be noted that there has been very limited historic and current freshwater mussel sampling throughout these three systems. A total of 32 (1996), 2 (1996) and 0 live individuals have been collected from the Moira, Trent and Salmon rivers, respectively. Additional shoreline searches were completed in the Salmon River between 2005-2010 and greater than 100 weathered, and a few fresh shells were observed. Additional quantitative sampling is required throughout eastern Ontario to gain a better understanding of the freshwater mussel community in this area.

Saugeen River

Rainbow was not observed from the Saugeen River until 1993 with the capture of a single live individual. Since this first record, an additional 53 live individuals have been sampled at 10 unique sites, including sites in the main branch, the south Saugeen River and one of the Saugeen River tributaries, the Teeswater River.

St. Clair River Delta

Live Rainbow have sporadically been observed in the St. Clair River delta since 1999, although they are generally found in low numbers, leading one to believe that small isolated populations may exist throughout the delta. Sampling noted that Rainbow were far more common in nearshore waters of the United States than in Canada.

Sydenham River

Infrequent observation of Rainbow in the Sydenham River has occurred since the mid 1960s. Since the first observation of this species in 1963, a total of 22 live individuals have been recorded. Unfortunately, quantitative surveys, and increased sampling effort, completed in 2002-2003 only resulted in the capture of seven live individuals. Rainbow is believed to be rare throughout the Sydenham River.

Thames River

The majority of Rainbow records from the Thames River are restricted to the upper reaches and tributaries of the upper and lower Thames. Timed-search surveys completed in 2004-2005 throughout these areas were successful in locating greater than 90 live individuals.

Population Status

To assess the Population Status each population was ranked in terms of its abundance (Abundance Index) and trajectory (Population Trajectory). The Abundance Index was based on quantitative density estimates and estimates of population size that are currently available. The Population Trajectory was assessed based on the best available knowledge about the current trajectory of the population. Certainty has been associated with the Abundance Index and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=standardized sampling; 3=expert opinion. The Abundance Index and Population Trajectory values were then combined in the Population Status matrix to determine the Population Status for each population. Each Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Extirpated (Table 1). The Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter. Refer to Bouvier and Morris (2010) for the complete methodology on Population Status assessment.

Table 1. *Population Status of all (a) Eastern Pondmussel; (b) Fawnsfoot; (c) Mapleleaf (ON DU); (d) Mapleleaf (MB DU) and (e) Rainbow populations in Canada, resulting from an analysis of both the Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Abundance Index or Population Trajectory). * indicates that the population is represented by a single live individual.*

(a) Eastern Pondmussel

Population	Population Status	Certainty
Beaver Lake	Unknown	3
Grand River	Unknown	3
Great Lakes and connecting channels	Extirpated	2
Long Point Bay	Poor	3
Lyn Creek	Poor	3
St. Clair River delta	Poor	3

(b) Fawnsfoot

Population	Population Status	Certainty
Grand River	Poor	3
Great Lakes and connecting channels	Extirpated	2
Saugeen River*	Poor	3
St. Clair River Delta*	Poor	3
Sydenham River	Poor	3
Thames River	Fair	3

(c) Mapleleaf (ON DU)

Population	Population Status	Certainty
Ausable River	Poor	3
Bayfield River*	Poor	3
Grand River	Fair	3
Great Lakes and connecting channels	Extirpated	2
Ruscom River	Poor	3
St. Clair River Delta*	Poor	3
Sydenham River	Good	3
Thames River	Good	3
Welland River	Poor	3

(d) Mapleleaf (MB DU)

Population	Population Status	Certainty
Assiniboine River	Poor	3
Bloodvein River*	Unknown	3
Roseau River	Unknown	3

(e) Rainbow

Population	Population Status	Certainty
Ausable River	Poor	3
Bayfield River	Poor	3
Grand River	Poor	3
Great Lakes and connecting channels	Extirpated	2
Maitland River	Good	3

Moira River	Poor	3

(e) Rainbow (continued)

Population	Population Status	Certainty
Salmon River	Unknown	3
Saugeen River	Poor	3
St. Clair River delta	Poor	3
Sydenham River	Poor	3
Thames River	Poor	3
Trent River	Poor	3

Habitat Requirements

Glochidium

To fully understand the habitat requirements of freshwater mussels, we must first understand their unique life cycle. During the spawning period, males located upstream release sperm into the water column. Females subsequently utilize their gills to filter the sperm from the water column, and the sperm is deposited in the posterior portion of the female gill, in a specialized region, where the ova are fertilized. The fertilized ova are held until they reach a larval stage. Although some freshwater mussels are obviously sexually dimorphic (mature females characterized by a swelling of the posterior-ventral margin), female Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow only differ slightly in shell shape from their male counterparts, and are often difficult to differentiate.

Brooding Strategy

Freshwater mussels are often categorized in terms of the brooding and glochidial release pattern they employ. Two categories are long-term brooders (bradytictic) and short-term brooders (tachytictic). Eastern Pondmussel, Fawnsfoot and Rainbow are bradyticitic such that they spawn in late summer, brood their glochidia over the winter and subsequently release their glochidia in early spring. Conversely, Mapleleaf are considered tachytictic, spawning early in the season, brooding glochidia for a shorter period of time and releasing their glochidia in the same year. Regardless of brooding strategy, once females release their glochidia they must encyst on the gills of an appropriate fish host.

Fish Host

Three host fishes have been identified for Eastern Pondmussel: Brook Stickleback (*Culaea inconstans*), Pumpkinseed (*Lepomis gibbosus*) and Yellow Perch (*Perca flavescens*). Laboratory fish host experiments suggest that Yellow Perch is the most likely preferred host yielding significantly greater juvenile mussels.

The potential host fish for Fawnsfoot has yet to be tested in a laboratory setting but is believed to be Freshwater Drum (*Aplodinotus grunniens*) and/or Sauger (*Sander canadensis*) Both species have been reported as potential hosts for this species in the United States. Freshwater Drum are known to occur at all locations Fawnsfoot have been recorded with the exception of the one live Fawnsfoot recorded from Muskrat Creek (Saugeen River watershed). It should be noted that there is also no record of Sauger from this area.

Known fish hosts for Mapleleaf include the Flathead Catfish (*Pylodictus olivaris*), which currently does not occur in Canada, and Channel Catfish (*Ictalurus punctatus*). The distribution of Channel Catfish overlaps that of Mapleleaf in both Ontario and Manitoba.

Numerous fish hosts have been identified for Rainbow in the United States, including Striped Shiner (*Luxilus chrysocephalus*), Smallmouth Bass (*Micropterus dolomieu*), Largemouth Bass (*Micropterus salmoides*), Green Sunfish (*Lepomis cyanellus*), Greenside Darter (*Etheostoma blennioides*), Rainbow Darter (*Etheostoma caeruleum*) and Yellow Perch (*Perca flavescens*), which do occur in Canada, and Streamline Chub (*Erimystax dissimilis*) and Bluebreast Darter (*Etheostoma camurum*), which do not occur in Canada. From the above mentioned list of potential hosts, Largemouth Bass has now been verified as a host for Rainbow in Ontario. Mottled Sculpin (*Cottus bairdi*) and Rock Bass (*Ambloplites rupestris*) have also been identified as successful host species in Rainbow glochidia transformation.

Lures

Freshwater mussels use a variety of lures to attract their appropriate fish hosts. Many species of freshwater mussels have evolved complex host attraction strategies to increase the probability of encountering a suitable host. Eastern Pondmussel uses a visual display to attract its fish host. Eastern Pondmussel expose their mantle by slightly gaping their valves, and subsequently ripple white papillae to mimic a swimming amphipod. Once a host fish is attracted to, and attacks this lure the female mussel expels its glochidia, facilitating attachment on the gills of the fish. Similarly, the shape and movement of the mantle of the Rainbow is modified to mimic a crawling crayfish. Mapleleaf utilizes a slightly different strategy to attract a host fish, in that it utilizes conglutinates (packets of glochidia). These conglutinates may have markings similar to that of prey items to mislead potential fish hosts. Unlike Eastern Pondmussel and Rainbow, the mantle of Mapleleaf does not appear to be modified. Very little is known about the display behaviour of Fawnsfoot, although it has been reported that physical manipulation caused a valve-gaping display. With Freshwater Drum (a molluscivorous species) in mind, it has been suggested that consumption of gravid female Fawnsfoot presented a unique route to facilitate the release of glochidia directly inside the mouth of Freshwater Drum. Water would then pass over the gills and provide an opportunity for glochidia to be attached to the gills of the fish host.

Attachment Times

Regardless of the method of exposure and attachment, glochidia will remain encysted until they metamorphose into juveniles. Attachment times have been noted for Eastern Pondmussel to range from 11 to 32 days and appear to be water temperature dependent. For the Mapleleaf, development on the fish host has been noted from 51 to 68 days, with temperature being a key factor in development time. Attachment times are unknown for both Fawnsfoot and Rainbow.

Encystment is an obligate step in the life cycle of Eastern Pondmussel, Rainbow, Mapleleaf and Fawnsfoot, and development will not occur in the absence of this phase. The gills of the appropriate host fish can be considered a habitat requirement for the glochidial life stage of these freshwater mussels.

Juveniles

Subsequent to metamorphoses, juvenile freshwater mussels are released from the gills of the fish host and bury themselves in the substrate until maturity. Time to maturity can vary from one mussel species to another and accurate estimates are not known for most species. The proportion of glochidia that survive to the juvenile stage is estimated to be as low as 0.000001%. A survival tactic to overcome this increased level of mortality is to produce very high numbers of glochidia. It is difficult to classify required habitat for juvenile mussels because they are difficult to detect and because they have a tendency to burrow; although, they are generally found when implementing adult mussel survey methods. Once sexually mature they emerge from the substrate to participate in gamete exchange.

Adult

Eastern Pondmussel

Adult Eastern Pondmussel preferred habitat includes both nearshore, sheltered areas of the Great Lakes as well as the slack water of slow-moving rivers. Substrate preferences include both mud and sand, while depth preferences have been noted to range from 0.3 to 4.5 m. Specifically, in Lake St. Clair, Eastern Pondmussel was found on substrates composed of over 95% sand located at the transition zone between emergent wetland and open waters. In Lyn Creek live Eastern Pondmussel were found in areas described as Zebra Mussel-free streams, in slow moving areas over sand, silt and clay beds.

Fawnsfoot

Adult Fawnsfoot are generally found in medium- to large-sized rivers at depths ranging from less than 1 m to greater than 5 m. Their preferred substrate has been described as sand or mud, although a few recent surveys have recorded Fawnsfoot on rubble- and gravel-dominated substrate.

Mapleleaf

The current distribution of adult Mapleleaf in Canada indicates that this species tends to occur in medium to large rivers. Water flow does not appear to be limiting factor for Mapleleaf as it has been found in both slow- and fast-flowing rivers. Recent surveys have indicated that Mapleleaf preferred substrate is dominated by firmly-packed coarse gravel or rubble, although it can also be found over mud, sand or fine gravel substrates. Water velocity values for successful Mapleleaf capture sites from the Assiniboine River ranged from 0.42 to 0.72 m s^{-1}.

Rainbow

Although Rainbow was once found throughout the nearshore area of the Great Lakes and its connecting channels, Zebra Mussel introduction has restricted this species to small creeks and rivers, and the St. Clair River delta. In river systems it can be found in or near riffles and along the edges of emergent vegetation. It is generally found in areas with moderate to strong current over a mixture of cobble, gravel, or sand.

Residence

Residence is defined in SARA as “dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating”. Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during glochidial, juvenile and adult life stages, Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow do not construct residences during their life cycle.

Threats to Survival and Recovery

In the past 30 years, species diversity and abundance of native freshwater mussels has declined throughout Canada and the United States. It appears that the greatest limiting factors to the stabilization and growth of freshwater mussel populations in Canada are largely attributed to the introduction and establishment of dreissenid mussels and decreases in the quality of available freshwater mussel habitat. The historic vast distribution of freshwater mussels in the Great Lakes and its connecting channels has been devastated by the introduction of dreissenid mussels, and many of the areas once inhabited by freshwater mussels no longer provide suitable habitat.

In addition, there is evidence that decreases in water quality, specifically increased turbidity and suspended solids, increased nutrient loading, and increased levels of contaminants and toxic substance are also limiting the distribution of freshwater mussels. These declines in water quality are the result of activities such as dam construction and impoundments, channel modifications (e.g., channelization, dredging, snagging) and land-use practices (e.g., farming, mining, construction). Impoundments typically result in siltation, stagnation, loss of shallow water habitat, pollutant accumulation and nutrient-poor water, while dams alter flow and temperature regimes and separate mussels from their fish hosts. Channelization, dredging and snagging activities result in the disruption of the riffle-run-pool sequence, as well as the alteration of circulation patterns and substrate composition. Mussels caught in the path of the dredge are destroyed while silt and suspended solids generated by these activities may travel downstream and adversely affect other mussel populations. Sediments stirred up during channelization or dredging activities can result in the re-suspension of contaminants, increased concentrations of inorganic plant nutrients, reduced rates of photosynthesis and increased biochemical oxygen demand. Land-use practices such as farming, logging, mining and construction usually result in the runoff of sediments, pollutants and salt into streams.

Toxic chemicals from both point and non-point sources, especially agriculture, are believed to be one of the major threats to mussel populations today. Substances such as arsenic, cadmium, chlorine, copper, mercury and zinc can be toxic to freshwater mussels because mussels can accumulate these substances from their environment. Due to the obligate nature of the mussel reproductive cycle, any threat leading to the separation of mussel and fish host during reproduction can be detrimental to the mussel population. Direct threats to the host, such as barriers to movement, and recreational activities, such as angling and harvesting pressures, will have cumulative effects on the mussel population.

Threat Level

To assess the Threat Level each threat was ranked in terms of the Threat Likelihood and Threat Impact for all locations where it is believed that a population of Eastern Pondmussel, Fawnsfoot, Mapleleaf or Rainbow may exist [see Bouvier and Morris (2010) for complete details]. The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown. The Threat Likelihood and Threat Impact for each location were subsequently combined in the Threat Level matrix resulting in the final Threat Level for each population (Table 2). Certainty has been classified for Threat Impact and is based on: 1= causative studies; 2=correlative studies; and, 3=expert opinion.

Table 2. *Threat Likelihood and Threat Impact for all locations in Canada where it is believed that a population of Eastern Pondmussel (EPM), Fawnsfoot (FF), Mapleleaf (ML) or Rainbow (RB) may exist. The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown. Certainty is associated with Threat Impact (TI) and is based on the best available data (1= causative studies; 2=correlative studies; and 3=expert opinion). References (Ref) are provided and the complete list of references appears subsequent to the table. Species presence is indicated for each location by means of species code, which appears below the site name. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the site is located. Locations appear based on the geographical location (west to east).*

Manitoba

	Assiniboine River	Red River	Roseau River	Bloodvein River
Threat	**ML**	**ML**	**ML**	**ML**
Exotic species	Medium (3)	High (3)	Medium (3)	Medium (3)
Turbidity and sediment loading	Medium (3)	Medium (3)	Medium (3)	Low (3)
Contaminants and toxic substances	High (3)	High (3)	Medium (3)	Medium (3)
Nutrient loading	Low (3)	Medium (3)	Medium (3)	Low (3)
Altered flow regimes	Medium (3)	Medium (3)	Low (3)	
Habitat removal and alterations	Medium (3)	Medium (3)	Low (3)	Low (3)
Fish hosts (EPM)				
Fish hosts (ML)	Medium (3)	Medium (3)	Medium (3)	Low (3)
Fish hosts (FF)				
Fish hosts (RB)				
Predation and harvesting	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)

Ontario

	Ruscom River	St. Clair River Delta	St. Clair River Delta	Sydenham River
Threat	**ML**	**ML, FF**	**EPM, RB**	**RB**
Exotic species	High (2)	High (2)	High (2)	Medium (2)
Turbidity and sediment loading	Medium (3)	Low (3)	Medium (3)	High (3)
Contaminants and toxic substances	High (3)	High (3)	High (3)	High (3)
Nutrient loading	Medium (3)	Low (3)	Medium (3)	High (3)
Altered flow regimes	Medium (3)			Medium (3)
Habitat removal and alterations	High (3)	Medium (3)	Medium (3)	High (3)
Fish hosts (EPM)		Medium (3)	Medium (3)	
Fish hosts (ML)	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Fish hosts (FF)		Medium (3)	Medium (3)	Medium (3)
Fish hosts (RB)		High (3)	High (3)	High (3)
Predation and harvesting	Unknown (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Unknown (3)	Low (3)	Low (3)	Low (3)

Ontario (continued)

	Sydenham River	Upper Thames River	Lower Thames River	Ausable River
Threat	**ML,FF**	**RB**	**ML,FF**	**RB**
Exotic species	Medium (2)	High (2)	High (2)	Medium (2)
Turbidity and sediment loading	Medium (3)	High (3)	Medium (3)	High (3)
Contaminants and toxic substances	High (3)	High (3)	High (3)	High (3)
Nutrient loading	Medium (3)	High (3)	Medium (3)	High (3)
Altered flow regimes	Medium (3)	High (3)	Medium (3)	Medium (3)
Habitat removal and alterations	High (3)	High (3)	High (3)	Medium (3)
Fish hosts (EPM)				
Fish hosts (ML)	Medium (3)	Medium (3)	Medium (3)	Medium (2)
Fish hosts (FF)	Medium (3)	Medium (3)	Medium (3)	
Fish hosts (RB)	High (3)	High (3)	High (3)	Medium (2)
Predation and harvesting	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)

	Ausable River	Bayfield River	Bayfield River	Maitland River
Threat	**ML**	**RB**	**ML**	**RB**
Exotic species	Medium (2)	Medium (2)	Medium (2)	Medium (2)
Turbidity and sediment loading	Medium (3)	High (3)	Medium (3)	High (3)
Contaminants and toxic substances	High (3)	High (3)	High (3)	High (3)
Nutrient loading	Medium (3)	High (3)	Medium (3)	High (3)
Altered flow regimes	Medium (3)	High (3)	High (3)	Medium (3)
Habitat removal and alterations	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Fish hosts (EPM)				
Fish hosts (ML)	Medium (2)	Medium (3)	Medium (3)	
Fish hosts (FF)				
Fish hosts (RB)	Medium (2)	Medium (3)	Medium (3)	Medium (3)
Predation and harvesting	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)

Ontario (continued)

	Saugeen River	Long Point Bay	Grand River	Grand River
Threat	**RB,FF**	**EPM**	**RB**	**FF,ML**
Exotic species	Medium (2)	High (2)	High (2)	High (2)
Turbidity and sediment loading	High (3)	Medium (3)	High (2)	Medium (2)
Contaminants and toxic substances	High (3)	Medium (3)	High (2)	High (2)
Nutrient loading	High (3)	Medium (3)	High (2)	Medium (2)
Altered flow regimes	Medium (3)		Medium (2)	Medium (2)
Habitat removal and alterations	High (3)	Medium (3)	High (2)	High (2)
Fish hosts (EPM)		Medium (3)		
Fish hosts (ML)				High (3)
Fish hosts (FF)				High (3)
Fish hosts (RB)	High (3)		High (3)	
Predation and harvesting	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)

	Grand River	Jordan Harbour	Welland River	Trent River
Threat	**EPM**	**ML**	**ML**	**RB**
Exotic species	Medium (2)	High (2)	Medium (2)	High (2)
Turbidity and sediment loading	High (2)	Medium (3)	Medium (3)	Medium (3)
Contaminants and toxic substances	High (2)	High (3)	High (3)	High (3)
Nutrient loading	High (2)	Medium (3)	Medium (3)	Medium (3)
Altered flow regimes	Medium (2)		Low (3)	High (3)
Habitat removal and alterations	High (2)	Medium (3)	Medium (3)	High (3)
Fish hosts (EPM)	Medium (3)			
Fish hosts (ML)		Medium (3)	Medium (3)	
Fish hosts (FF)				
Fish hosts (RB)				High (3)
Predation and harvesting	Low (3)	Low (3)	Low (3)	Unknown (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)

Ontario (continued)

	Salmon River	Moira River	Beaver Lake
Threat	**RB**	**RB**	**EPM**
Exotic species	High (2)	High (2)	High (2)
Turbidity and sediment loading	Medium (3)	Medium (3)	Medium (3)
Contaminants and toxic substances	Medium (3)	High (3)	Unknown (3)
Nutrient loading	Medium (3)	Medium (3)	Unknown (3)
Altered flow regimes	Low (3)	Medium (3)	
Habitat removal and alterations	Medium (3)	Medium (3)	Medium (3)
Fish hosts (EPM)			Medium (3)
Fish hosts (ML)			
Fish hosts (FF)			
Fish hosts (RB)	Medium (3)	Medium (3)	
Predation and harvesting	Low (3)	Low (3)	Low (3)
Recreational activities	Unknown (3)	Low (3)	Low (3)

N.B. The Threat Level represents a combination of the current Threat Impact and Threat Likelihood at a location. It does not reflect the potential impact a threat might have on a freshwater mussel population if it was allowed to occur in the future.

Recovery Potential Modelling

Our analysis consisted of four parts: (i) information on vital rates of freshwater mussels from the family Unionidae was compiled, including stage-specific survival and fecundity rates. Representative "low" and "high" estimates were chosen for each vital rate. These estimates were combined in all possible permutations to build population projection matrices, each representing a different life history pattern; (ii) the sensitivity (elasticity) of the population growth rate to changes in each vital rate was determined for all matrices; (iii) using cluster analysis, the matrices were sorted into groups based on elasticity patterns; (iv) classification trees were built and used to predict the elasticity patterns of these four mussel species, given what is known of their life history and vital rates. See Young and Koops (2010) for complete details of the model, parameters, and results.

Sensitivity Patterns

Combining all plausible permutations of high and low values for the 6 vital rates resulted in 48 distinct life history patterns. Overall, the population growth rate of freshwater mussels was most sensitive to juvenile and adult survival (0.48 and 0.56 respectively, averaged over all 48 sets). Cluster analysis revealed 3 distinct groupings of elasticities (Figure 7) with the following distinguishable characteristics:

Group 1: Reproduction dominant: Age at maturity, fecundity and glochidial survival are significantly more sensitive in this group than in the others; juvenile survival, adult survival and age at maturity all rank similarly in importance.

Group 2: Adult survival dominant: Adult survival is on average 1.8 times as important as juvenile survival; this group is the only group in which maximum age is at all relevant.

Group 3: Juvenile survival dominant: Juvenile survival is very important, and is more than twice as sensitive as both adult survival and age at maturity.

Of the 48 matrices considered, 16 belonged to group 1, 24 to group 2, and 8 to group 3. The mean and range of elasticities for each group are summarized in Table 3. Note that the elasticity of age at maturity is negative. This means that a later age at maturity would result in a decreased population growth rate.

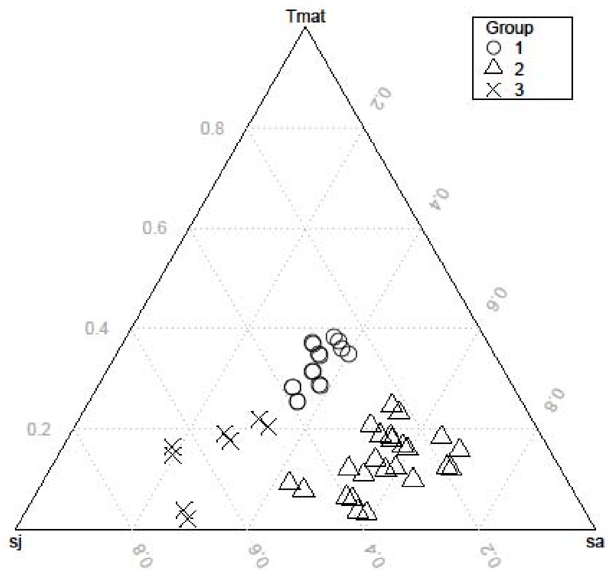


Figure 7. *Triangular plot depicting elasticities of age at maturity (Tmat), adult survival (sa), and juvenile survival (sj) for freshwater unionid mussels. Each point represents a different life history matrix. Elasticities are scaled so that the three values are plotted as proportions. Symbols represent the assigned elasticity pattern group: 1. Reproduction dominant; 2. Adult survival dominant; 3. Juvenile survival dominant.*

Table 3. *Mean and range of elasticities for freshwater mussel vital rates by elasticity pattern group.* s_1*=glochidial survival;* s_j*=juvenile survival;* s_a*=adult survival; f=fecundity;* T_{mat}*=age at maturity;* T_{max}*=maximum age. Bold: group distinguishing rates. * value is significantly higher in this group compared to other groups (pairwise wilcoxon test, p<0.05).*

Group	s_1	s_j	s_a	f	T_{mat}	T_{max}
1: Reproduction dominant	0.25* (0.21, 0.27)	0.49 (0.42, 0.53)	0.56 (0.47, 0.67)	0.25* (0.21, 0.27)	**- 0.52*** (-0.33, -0.67)	0.004 (0, 0.03)
2: Adult survival dominant	0.11 (0.01, 0.18)	0.32 (0.07, 0.66)	**0.59** (0.26, 0.83)	0.11 (0.01, 0.18)	- 0.14 (-0.03, -0.26)	0.01 (0, 0.10)
3: Juvenile survival dominant	0.12	**0.98***	0.46	0.12	- 0.28	0.00004

Classifying Elasticity Based on Life History

Two vital rates (fecundity and age at maturity) had the most influence on elasticity patterns, predicting the correct group with approximately 92% confidence; only 4/48 matrices were classed incorrectly using these two predictors in a classification tree. Adding knowledge of adult and juvenile survival increased the accuracy to 100% (Figure 8). Matrices in the Reproduction dominant elasticity group (group 1) were all characterized by early maturity and high fecundity. High fecundity and late maturity tended to result in an emphasis on juvenile survival (group 3) with two exceptions (both belonging to group 2). Matrices with lower fecundity were all classified as Adult survival dominant (group 2) with two exceptions. If either age at maturity or fecundity are unknown, predicting the elasticity pattern from this model becomes much less accurate (21% and 42% misclassification rate respectively)

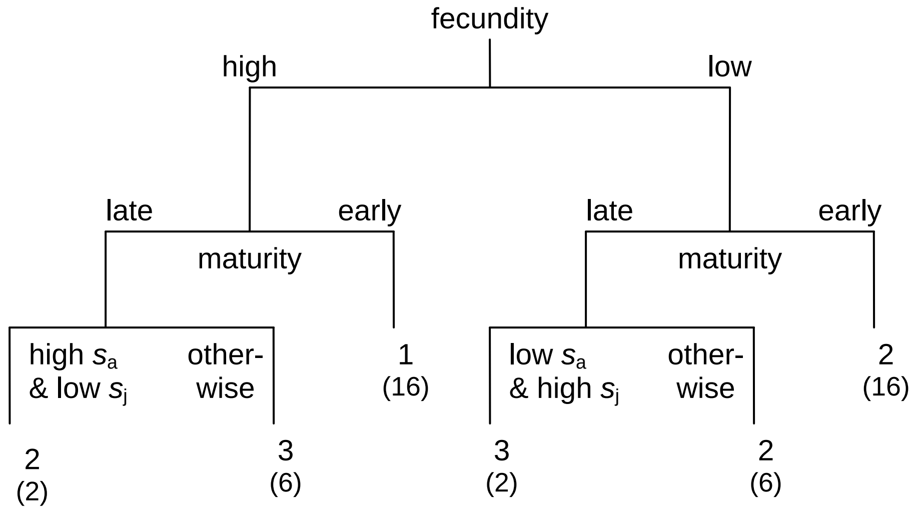


Figure 8. *Decision tree for predicting the elasticity pattern of a species based on its life history and vital rates [See Young and Koops (2010) for vital rate values and Table 3 for summary of elasticity groups]. Elasticity pattern groups: 1 – Reproduction dominant; 2 – Adult survival dominant; 3 – Juvenile survival dominant. In brackets are the numbers of matrices (out of 48) classified into each branch.*

Species Classification

Using limited species-specific information, the four mussels species can be partially classified using the tree in Figure 8. Known vital rates are summarized in Table 4 [see Young and Koops (2010) for sources], along with the most likely elasticity pattern. Also given is the level of certainty, based on how the hypothetical projection matrices with similar life history elements were classified.

Eastern Pondmussel, Mapleleaf, and Rainbow most likely (≥75%) belong to elasticity group 2, but also possibly to group 3. That is, the population growth of these species is likely to be most sensitive to changes in adult survival (group 2), but may also be very sensitive to changes in juvenile survival (group 3). They are relatively insensitive to reproduction related rates (fecundity, glochidial survival, and age at maturity). Fawnsfoot is equally likely to belong to group 1 (if fecundity is high) or group 2 (if fecundity is low). In the latter case, population growth will be most sensitive to juvenile survival, and in the former case it will be more significantly influenced than the other three species by changes in reproduction.

Table 4. *Known vital rate estimates (Est.) and classification (H/L) of each rate as high/low (survival), early/late (maturity) or short/long (lifespan), for four freshwater mussel species. Possible elasticity pattern groups are given with a confidence level based on a cluster analysis of matrices representing 48 different life histories (see text): 1 – Reproduction dominant, 2 – Adult survival dominant, 3 – Juvenile survival dominant.*

	Eastern Pondmussel		Fawnsfoot		Mapleleaf		Rainbow	
Parameter	Est.	H/L	Est.	H/L	Est.	H/L	Est.	H/L
s_1 (glochidial survival)	-	-	-	-	-	-	-	-
s_j (juvenile survival)	-	-	-	-	-	-	-	-
s_a (adult survival)		-	-	-	-	-	0.93	high
f (fecundity)	27000	low	-	-	< 50000	low	-	-
T_{mat} (age maturity)	-	-	-	early	$\geq$ 8	late	$\leq$ 9	late
T_{max} (maximum age)	-	-	$\geq$ 11	short	64	long	48	long
Group (Confidence)	2 (92%) 3 (8%)		1 (50%) 2 (50%)		2 (75%) 3 (25%)		2 (75%) 3 (25%)	

Allowable Harm and Recovery Times

Without complete vital rate information, current population growth rates cannot be estimated. We therefore cannot determine whether the populations in question are increasing or in decline, nor can we give accurate estimates of allowable harm or recovery times. Using the elasticity groupings and vital rate decision trees, however, we can predict which vital rates are likely to be most sensitive to harm and most receptive to recovery. Harm to those vital rates with the highest elasticity is expected to be most detrimental to the population growth rate. Conversely, recovery strategies which increase those same rates are expected to have the most positive impact on population growth. For example, if adult survival has an elasticity of 0.6, then a 10% change (increase or decrease) will result in a 0.1*0.6=6% change in the population growth rate.

In the planning of recovery strategies, the scope for improvement of any given vital rate should be considered in addition to its sensitivity. For instance, glochidial survival was one of the least sensitive vital rates for freshwater mussels, but the scope for improvement in this rate may exceed that of a more sensitive rate. This could be the case if there is existing harm to glochidial survival, such as a physical barrier between mussel and host fish, or if adult or juvenile survival is already very high.

Summary of Science Advice on Allowable Harm

- When population trajectory is declining there is no scope for allowable harm.
- When population trajectory is unknown the scope for allowable harm can only be assessed once population data are collected.
- Scientific research to advance knowledge of population status should be allowed.
- In the absence of population abundance estimates, no harm should be allowed to the survival of adults or settled juveniles for Eastern Pondmussel, Mapleleaf, Rainbow, or Fawnsfoot. In addition, no harm should be allowed to the fecundity or glochidial survival of Fawnsfoot.

Mitigations and Alternatives

Numerous threats affecting mussel populations are related to habitat loss or degradation. DFO – Fish Habitat Management has developed generic mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Ontario Great Lakes Area (Table 5; Coker *et al.* 2010). Additional mitigation and alternative measures related to the introduction of exotic species, disruptions to the mussel-fish host relationship, predation and harvesting, and recreational activities are discussed.

Table 5. *Threats to freshwater mussel populations and the Pathways of Effect associated with each threat. 1 - Vegetation clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site.*

Threats	Pathway(s)
Turbidity and sediment loading	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18
Contaminants and toxic substances	1, 4, 5 ,6 ,7 ,11 ,12 ,13 ,14, 15, 16 ,18
Nutrient loading	1, 4, 7, 8, 11, 12, 13, 14, 15, 16
Altered flow regimes	10, 11, 12, 16, 18
Habitat removal and alteration	1, 2, 3, 4, 5, 7, 8, 10, 11, 13, 14, 15, 16, 18
Fish hosts (barriers to movement)	10, 16, 17

Exotic Species

Exotic species introduction and establishment could have negative effects on freshwater mussel populations.

Mitigation

- Evaluate the likelihood that a waterbody will be invaded by exotic species.
- Watershed monitoring for the presence and abundance of exotic species that may negatively affect freshwater mussel populations, or negatively affect preferred habitat of freshwater mussels.
- Develop and implement plans to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.
- Introduce a public awareness campaign on proper boat cleaning methods when transferring boats from an infested waterway.
- Restrict the use of boats in areas particularly susceptible to Zebra Mussel introduction and infestation (i.e., reservoirs in the Thames and Grand rivers).

Alternatives

- Unauthorized introductions
    - None.
- Authorized introductions
    - Do not carry out introduction where freshwater mussel populations are known to exist.

Fish Hosts

Increased siltation may be limiting the host's ability to visually locate the displaying mussel, impeding the transfer of glochidia from the mussel to the fish host. If decreases in visibility resulting from increased siltation are found to be a limiting factor in reproductive success, mitigation pathways related to increased siltation should be implemented.

In addition, decreases in the number of individual host fish or decreases in the area of overlap between host fish and freshwater mussel may be decreasing the likelihood that a fish-mussel encounter will occur.

Mitigation

- Implement a management plan for the appropriate fish host species. This would increase the host's survival, increasing number of host individuals, creating a healthy host population and subsequently increasing the likelihood that the fish host would encounter a gravid freshwater mussel.
- Immediate release of host fish if caught angling in areas where freshwater mussels of concern are known to occur. Please see distribution maps for each mussel species in the individuals 'Current Status' sections and discussion of verified and potential fish hosts in the 'Habitat Requirements' section.
- Watershed monitoring, risk assessment, and action plan implementation of potential exotics that may affect the fish hosts. The same steps as proposed above for exotic species should be implemented.

Alternatives

- Seasonal or zonal restrictions applied to fish species known to be used as a host to Eastern Pondmussel, Fawnsfoot, Mapleleaf or Rainbow glochidia.

Predation and Harvesting

Muskrat, mink and raccoon may have negative effects on freshwater mussel populations. It should be considered that if this threat was to occur, it would be localized, and have a relatively small impact on the freshwater mussel population. In addition, human harvesting for consumption was also noted as a potential threat to freshwater mussels.

Mitigation

- If predators were identified at a local scale to have an impact on a freshwater mussel population, predator control should be considered.
- A public awareness campaign on the negative effects of freshwater mussel consumption on humans should be introduced.
- Enforcement should be increased in areas where human consumption of freshwater mussels is known to occur.

Alternatives

- None.

Recreational Activities

Recreational activities such as driving all-terrain vehicles (ATVs) through streams, boating, fly-fishing, beach cleaning, canoeing, and kayaking may negatively impact mussel beds

Mitigation

- Introduction of a public awareness campaign on the negative effects of the above-listed recreational activities on freshwater mussels.

Alternatives

- None.

Sources of Uncertainty

Despite concerted efforts to increase our knowledge of Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow populations in Canada, there are still areas of uncertainty related to their life history. Areas of future research should include studies on natural mortality rates, glochidial attachment times, and the threats limiting the survival of freshwater mussels.

Areas of particular uncertainty are related to the juvenile life stage. Very little information is available regarding the preferred habitat of juvenile freshwater mussels and the survival of individuals from the glochidial stage up to, and including, the juvenile life stage. In addition, it is very difficult to obtain gravid females of some species in the field which would provide increased knowledge on fecundity and reproductive capacity. Furthermore, locating gravid females would also allow for fish host experiments on species in which this relationship has yet to be studied. Additional information on vital rates used in the modelling effort would contribute to a more accurate prediction of sensitivity for the four mussel species. Also, little is known about the relationship between the host population density and the frequency of host-mussel encounters. If the population growth rate were measured it could be used to infer a survival rate for glochidia (if all other vital rates are known). Population growth rate is not known for any of the four species considered here.

Additional studies on habitat requirements are imperative to determine critical habitat for all life stages of these freshwater mussels. Additional studies on the preferred habitat of these species may also help to determine possible candidate areas for relocation. Additionally, field work should be completed in all locations where only a few individuals have been located to determine whether or not a reproducing population exists, and if so, to determine the species density at that location. As well, additional quantitative field work should be completed in areas that have yet to be examined. There is a need for additional inventory work which would inform the population status assessment. This type of work is particularly important in Manitoba, eastern Ontario, and the lower portion of many of the major southwestern Ontario rivers where there has been very limited sampling.

Supplementary laboratory experiments, and if feasible field experiments, should be completed to determine fish hosts for all freshwater mussel species currently at risk. For example, the fish host for Fawnsfoot is thought to be Freshwater Drum based on information available from southern populations. Laboratory experiments, using samples from Canadian populations, should be completed to verify the usage of Freshwater Drum as fish host for Fawnsfoot. Also, Channel Catfish has been verified as the fish host for Mapleleaf, and it has been suggested that other members of the catfish family present in Canada [e.g., Brown Bullhead, (*Ameiurus nebulosus*)] may also be acting as a host. The potential relationship between Mapleleaf and other members of the catfish family should be tested. Many of the fish hosts for Rainbow have been verified in the United States. Currently in Canada, only Rock Bass, Largemouth Bass, and Mottled Sculpin have been verified as a successful host during laboratory experiments. Glochidial attachment experiments should be completed for all other potential Rainbow fish hosts. Once a host has been identified for a species, it is important to determine its distribution, abundance and the overall health of the population of the fish host. Knowledge of the fish hosts that these freshwater mussel species at risk use during their obligate glochidial stage may help provide insight on reasons for their decline. It is necessary to determine host distribution and abundance, and to quantify the amount of overlap between the mussel and host fish populations.

Numerous threats have been identified for Eastern Pondmussel, Fawnsfoot, Mapleleaf and Rainbow populations in Canada, although the severity of these threats is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on each population with greater certainty. In the literature, the threat impacts are generally discussed at a broad level (i.e. mussel community level). It is important to further our knowledge on threat likelihood and impact at the species level. Research is currently underway to determine the direct and indirect effects that Round Goby *(Neogobius melanostomus*) may have on native freshwater mussels. This type of species-specific threat research of exotic species on native mussels is needed to better inform decisions on the management of exotic species. Although predation is listed as a potential threat to native mussels, the level of predation by raccoons and other predators is currently unknown. Research is needed to determine the level to which native mussels are preyed on. Once we gain a better understanding on the level of predation, the distribution of predators should be compared to that of mussels of concern to determine the distributional overlap.

SOURCES OF INFORMATION

Bouvier, L.D. and T.J. Morris. 2010. Information in support of a Recovery Potential Assessment of Eastern Pondmussel (*Ligumia nasuta*), Fawnsfoot (*Truncilla donaciformis*), Mapleleaf (*Quadrula quadrula*), and Rainbow (*Villosa iris*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/120. vi + 51 p.

Coker, G.A., D.L. Ming, and N.E. Mandrak 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the species at risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manuscr. Rep. Fish. Aquat. Sci. 2904. vi + 40 p.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2006. COSEWIC assessment and status report on the Mapleleaf mussel, *Quadrula quadrula* (Saskatchewan - Nelson population and Great Lakes - Western St. Lawrence population) in Canada. vii + 58 p.

DFO 2007. Revised protocol for conducting recovery potential assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/39. 11 p.

DFO. 2010. Proceedings of the Fisheries and Oceans Canada Science Advisory Process on the Recovery Potential Assessment of Eastern Pondmussel (*Ligumia nasuta*), Fawnsfoot (*Truncilla donaciformis*), Mapleleaf (*Quadrula quadrula*), and Rainbow (*Villosa iris*); 19-20 October 2010. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2010/049.

Young, J.A.M. and M.A. Koops. 2010. Recovery Potential Modelling of Eastern Pondmussel (*Ligumia nasuta*), Fawnsfoot (*Truncilla donaciformis*), Mapleleaf (*Quadrula quadrula*), and Rainbow (*Villosa iris*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/119. iv + 10 p.

FOR MORE INFORMATION

Contact: Lynn Bouvier
Great Lakes Laboratory for Fisheries and Aquatic Sciences
Fisheries and Oceans Canada
867 Lakeshore Road
Burlington, Ontario
L7R 4A6
Tel: 905-336-4863
Fax: 905-336-6437
E-Mail: Lynn.Bouvier@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, Manitoba
R3T 2N6

Telephone:(204) 983-5131
Fax: (204) 984-2403
E-Mail: xcna-csa-cas@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2011. Recovery Potential Assessment of Eastern Pondmussel (*Ligumia nasuta*), Fawnsfoot (*Truncilla donaciformis*), Mapleleaf (*Quadrula quadrula*), and Rainbow (*Villosa iris*) in Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/073.