# COSEWIC
# Assessment and Status Report

on the

# Fawnsfoot
## *Truncilla donaciformis*

**in Canada**

**ENDANGERED**
**2008**

**COSEWIC**
Committee on the Status
of Endangered Wildlife
in Canada

**COSEPAC**
Comité sur la situation
des espèces en péril
au Canada

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Fawnsfoot — Photo courtesy of the National Water Research Institute.


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COSEWIC
Assessment Summary

**Assessment Summary – April 2008**

**Common name**
Fawnsfoot

**Scientific name**
*Truncilla donaciformis*

**Status**
Endangered

**Reason for designation**
This freshwater mussel is widely distributed in central North America, with the northern portion of its range extending into the Lake Erie, Lake St. Clair and lower Lake Huron drainages of southwestern Ontario. It appears to have always been a rare species in Canada, representing < 5% of the freshwater mussel community in terms of abundance wherever it occurs. Approximately 86% of historical records are in waters that are now infested with zebra mussels and therefore uninhabitable. Zebra mussels, which were accidentally introduced into the Great Lakes, attach to the shells of native freshwater mussels, causing them to suffocate or die from lack of food. The species has declined dramatically and has been lost from four historical locations resulting in a 51% reduction in its range. It is now found in only five widely separated locations, two of which represent single specimens. In two locations, the species' distribution may be limited by the presence of dams that restrict the movements of the frehswater drum, the presumed fish host of the juvenile mussels. Poor water quality resulting from rural and urban influences poses an additional continuing threat.

**Occurrence**
Ontario

**Status history**
Designated Endangered in April 2008. Assessment based on a new report.

**COSEWIC**
**Executive Summary**

**Fawnsfoot**
*Truncilla donaciformis*

## Species information

The Fawnsfoot is a small freshwater mussel with a typical adult length in Ontario of approximately 35 mm and a reported maximum length of 45 mm. The shell is moderately thick, oval to triangular, rounded on the anterior end and bluntly pointed on the posterior. The prominent posterior ridge is rounded and flattened dorsally.
The beaks (the oldest part of the shell) are full, central and slightly elevated above the hinge line. The beaks are marked with 3-8 fine bars; the first bar is concentric and the others are weakly double-looped. The shell is smooth, yellow to greenish with numerous dark green rays often broken into v-shaped or chevron markings.

## Distribution

The global range of the Fawnsfoot is limited to central North America where it is widely distributed, occurring in 23 American states and one Canadian province. In Canada, the Fawnsfoot is known only from the Great Lakes area where it historically occurred in lakes Huron, St. Clair and Erie as well as their connecting channels and the lower reaches of some tributaries. The current distribution is restricted to a single site in the St. Clair delta, a single site in Muskrat Creek of the Saugeen River drainage, a single site in the lower Sydenham River, the lower Thames River below London and the lower Grand River between Dunnville and Port Maitland.

## Habitat

The Fawnsfoot is known to occur in areas of moderate to low flows in medium and large rivers at depths ranging from less than 1 m to greater than 5 m, although they can adapt to low flow environments such as lakes and reservoirs. The Fawnsfoot is usually associated with substrates of sand or mud but can be found in areas with coarser substrate. Remaining populations in Canada are usually found in the lower portions of larger rivers on soft sand or gravel substrates.

## Biology

The Fawnsfoot has separate sexes but males and females do not appear outwardly different. Glochidia (immature juveniles) are obligate parasites on a fish host.

Although not yet confirmed for Canadian populations, the host fishes are believed to be the freshwater drum and sauger, with freshwater drum assumed to be the primary host. The Fawnsfoot is a long-term brooder that reproduces in the spring and maintains glochidia in a pouch in the female's gill overwinter for release the following spring. Juvenile mussels remain burrowed in the substrate for the first 3-5 years of life feeding on bacteria, detritus, and algae obtained from interstitial pore water. Adults can be found at the substrate surface and feed primarily by filtering bacteria, plankton and algae from the water column.

**Population sizes and trends**

The Fawnsfoot has always been a small component of the overall mussel community (< 5%) wherever it occurs, and recent records indicate that this continues to be the case. Of the five extant occurrences, two are represented by single specimens (Lake St. Clair, Muskrat Creek,) while another two (Sydenham River, Grand River) represent multiple individuals but from only a single site. Only the Thames River occurrence represents multiple animals collected at more than one site. The Great Lakes and connecting channel populations, excluding one in the St. Clair delta, have been lost. Populations in the Sydenham and Grand rivers still occupy the known historical range. No assessment can be made of the Muskrat Creek and Thames River populations as no historical information exists.

**Limiting factors and threats**

The major factors shaping the current distribution of the Fawnsfoot in Canada are the establishment of zebra mussels, which has resulted in large portions of historical habitat being rendered unsuitable, and a limited availability of riverine habitat primarily restricted by the distribution of its presumed glochidial host, the freshwater drum. Remaining riverine populations are limited to relatively small sections of the lower reaches of rivers where they are subjected to declining water quality resulting from agricultural and urban influences in the upper portions of the watersheds.

**Special significance of the species**

Freshwater mussels are sensitive indicators of overall ecosystem health and play important roles in structuring aquatic communities. Mussels provide food and habitat for other animals ranging from microscopic bacteria and plankton to large aquatic and terrestrial vertebrates. The presence of mussel beds provides physical stability of substrates and the filtering capacity of the mussels can have profound influences on water quality. The Fawnsfoot is one of only two members of the genus *Truncilla* that occurs in Canada.

## Existing protection or other status designations

The federal *Fisheries Act* represents the single most important piece of legislation currently protecting the Fawnsfoot in Canada. The collection of freshwater mussels requires a permit issued under the authority of the *Fisheries Act*. The last remaining lake population is located in the territorial waters of the Walpole Island First Nation (WIFN). These waters are relatively low-impact areas used primarily for hunting and fishing, and access is regulated through user permits issued by WIFN. Areas where the Fawnsfoot occurs overlap with the distributions of several species at risk protected under the *Species at Risk Act*. The Fawnsfoot may benefit indirectly from protection afforded to these species or actions implemented under the direction of existing recovery strategies.

**COSEWIC HISTORY**

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

**COSEWIC MANDATE**

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

**COSEWIC MEMBERSHIP**

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

**DEFINITIONS**
**(2008)**

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

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

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

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

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

Canada

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

# COSEWIC Status Report

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*Truncilla donaciformis*

**in Canada**

2008

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## SPECIES INFORMATION

### Name and classification

Scientific name: *Truncilla donaciformis* (Lea, 1828)
English common name: Fawnsfoot
French common name: Troncille pied-de-faon

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

| | |
|---|---|
| Kingdom: | Animalia |
| Phylum: | Mollusca |
| Class: | Bivalvia |
| Subclass: | Paleoheterodonta |
| Order: | Unionoida |
| Superfamily: | Unionoidea |
| Family: | Unionidae |
| Subfamily: | Lampsilinae |
| Genus: | *Truncilla* |
| Species | *Truncilla donaciformis* |

### Morphological description

The following description is modified from Metcalfe-Smith *et al*. (2005a), Cicerello and Schuster (2003), Parmalee and Bogan (1998) and Clarke (1981). The Fawnsfoot (Figure 1) is a small freshwater mussel with a typical adult length in Ontario of approximately 35 mm and a reported maximum length of 45 mm. The shell is moderately thick, oval to triangular, rounded on the anterior end and bluntly pointed on the posterior. The prominent posterior ridge is rounded and flattened dorsally.
The beaks are full, central and slightly elevated above the hinge line. Beak sculpture consists of 3-8 fine bars; the first is concentric while the others are weakly double-looped. The shell is smooth, yellow to greenish with numerous dark green rays often broken into v-shaped or chevron markings. The hinge teeth are fully developed with two thin, compressed, divergent, serrated pseudocardinal teeth in the left valve.
The posterior tooth is located directly below the beak and flared upward. The right valve has one flattened, triangular pseudocardinal tooth. The lateral teeth (two in the left valve, one in the right) are thin, straight and long. The Fawnsfoot is easily distinguished from all other Canadian species of freshwater mussels by the large chevron-shaped markings on its shell coupled with its very small size. The Deertoe, *Truncilla truncata*, may also have chevron-shaped markings on its shell but they are finer. The Deertoe also grows about twice as large as the Fawnsfoot and has a sharply angled, rather than rounded, posterior ridge.

Figure 1. Live specimens of the Fawnsfoot (*Truncilla donaciformis*) collected from the Grand River in 1997. Photo courtesy of the National Water Research Institute.

## Genetic description

There is no information available on the genetic structure of North American populations of the Fawnsfoot. However, the remaining Canadian populations (see **Canadian range**) are isolated from one another by large distances (40 – 700 km), and Zanatta *et al*. (2007) have shown that genetic isolation in Canadian populations of freshwater mussels is possible over these spatial scales.

## Designatable units

All Canadian populations are found within the Great Lakes-Upper St Lawrence National Freshwater Biogeographic Zone. There are no known distinctions among populations that warrant consideration for designation below the species level.

# DISTRIBUTION

## Global range

The global range of the Fawnsfoot is limited to central North America where it is widely distributed, occurring in 23 American states and one Canadian province. Largely occurring in the Great Lakes and Mississippi drainages, the Fawnsfoot is also found in the Mobile basin and the Gulf Coastal region (NatureServe 2007). In the United States the Fawnsfoot has been reported from Alabama, Arkansas, Georgia, Iowa, Illinois, Indiana, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Missouri, Massachusetts, Nebraska, New York, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Wisconsin and West Virginia (Figure 2). The New York population is considered possibly extirpated (NatureServe 2007). Despite its widespread distribution, the Fawnsfoot is considered apparently stable or stable in only six jurisdictions (Alabama, Illinois, Kentucky, Mississippi, Oklahoma and Tennessee) and the overall global short-term trend is considered to be rapidly to very rapidly declining (NatureServe 2007).

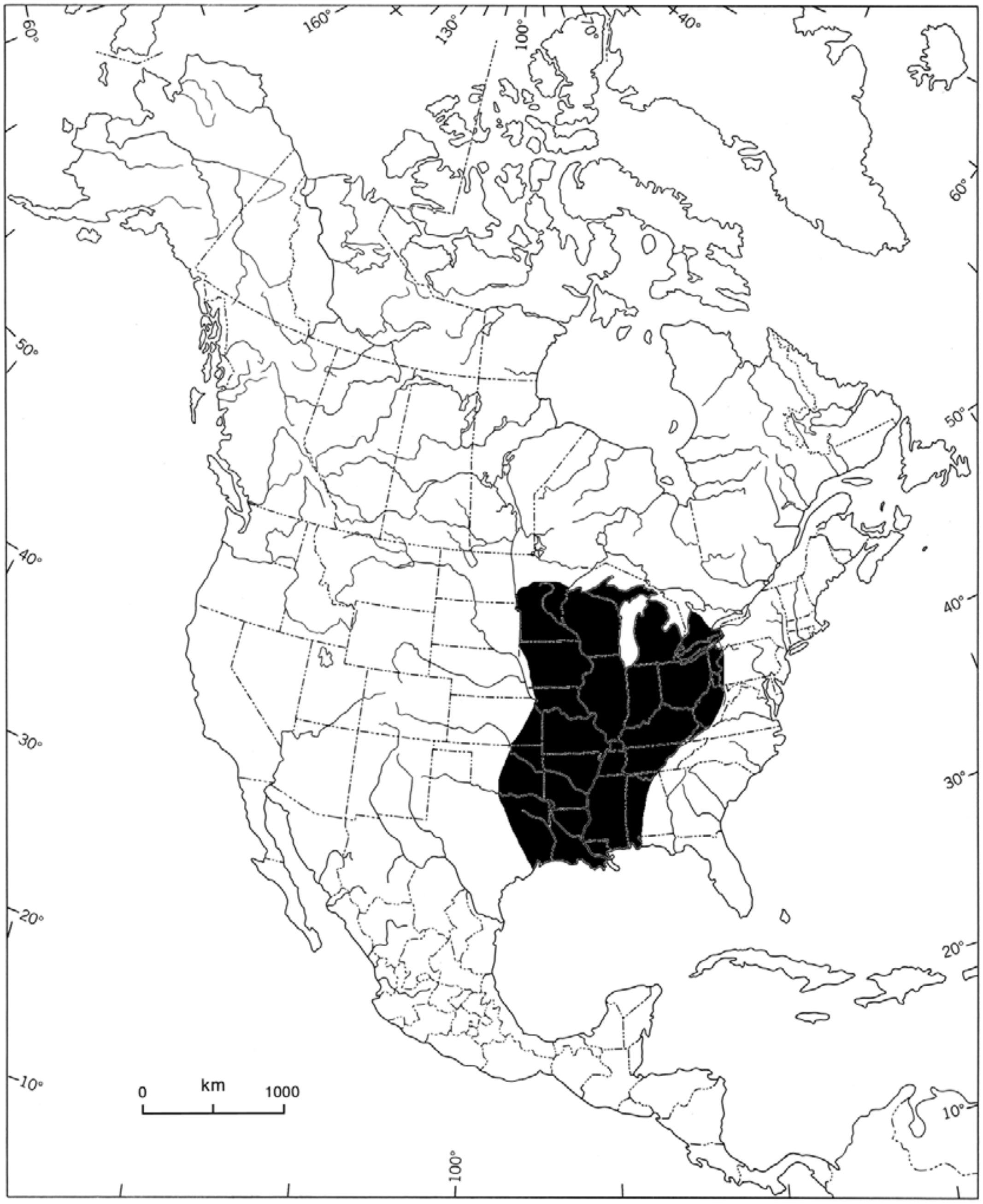


Figure 2. North American distribution of the Fawnsfoot (*Truncilla donaciformis*).

## Canadian range

In Canada, the Fawnsfoot is known only from the Great Lakes drainage of southern Ontario including lower Lake Huron, Lake St. Clair, Lake Erie and the Detroit and Niagara rivers. There are no records of the Fawnsfoot from any other Canadian province or territory (Metcalfe-Smith and Cudmore-Vokey 2004).

The Fawnsfoot has always been a rare species in the faunal record for Canada. Only 58 records exist for this species in the Lower Great Lakes Unionid Database (see **Collections Examined** for details), dating back to 1930 when Wright (1955) detected the species in the western basin of Lake Erie. By 1966, it was known from several locations in the western basin of Lake Erie including Pelee Island and East and Middle Sister Islands. J. P. Oughton and H. van der Schalie reported it from the lower Grand River (Royal Ontario Museum specimen # ROM23), Lake St. Clair (Royal Ontario Museum specimen # ROM43) and the Niagara River (University of Michigan Museum of Zoology specimen # MZUM444) in 1934. The first documented live collection of the Fawnsfoot was made in 1982 when D.W. Schloesser collected it from the Detroit River. The species was first collected from the Sydenham, Thames and Saugeen rivers in 1991, 1997 and 2005 respectively.

The historical distribution (1930-1996) shown in Figure 3 is based on 43 records of which eight are known live collections representing 17 individuals. The current distribution (1997-2007) as shown in Figure 4 is based on 15 records (11 records for live individuals) reporting 56 live animals. The year 1997 has been selected as the starting point for the current records as it marks the beginning of a more intensive, and ongoing, survey effort throughout the range of the Fawnsfoot. The following discussion contains a detailed description of historical and current distribution of the species throughout the Great Lakes basin, beginning with the Lake Huron drainage and moving downstream through the Great Lakes system.

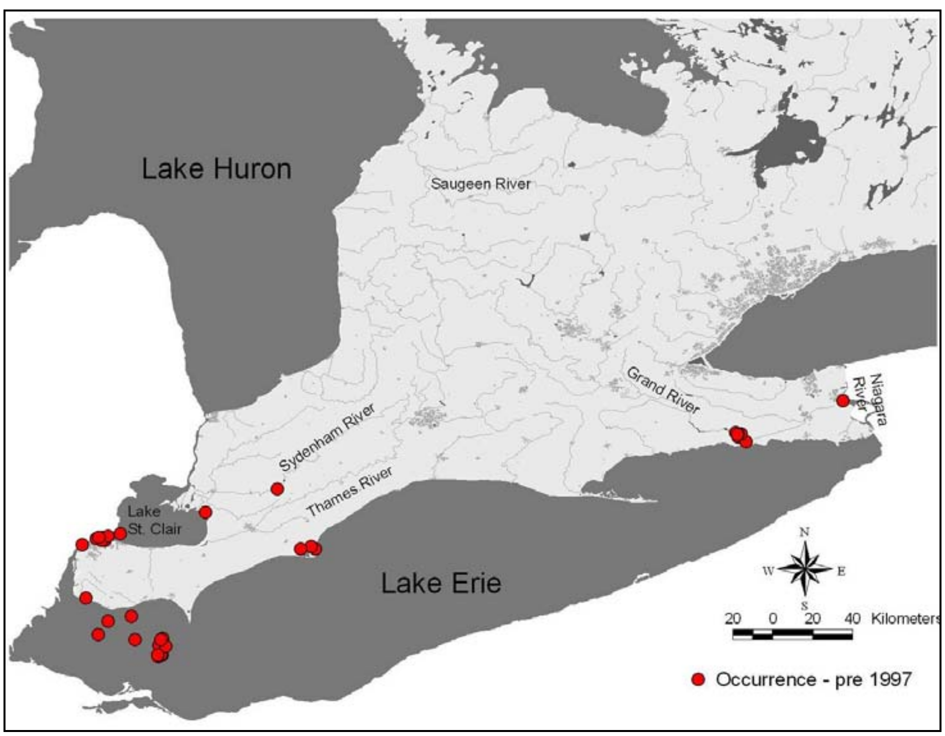


Figure 3. Historical distribution (1930-1996) of the Fawnsfoot (*Truncilla donaciformis*) in Canada. Records obtained from the Lower Great Lakes Unionid Database.

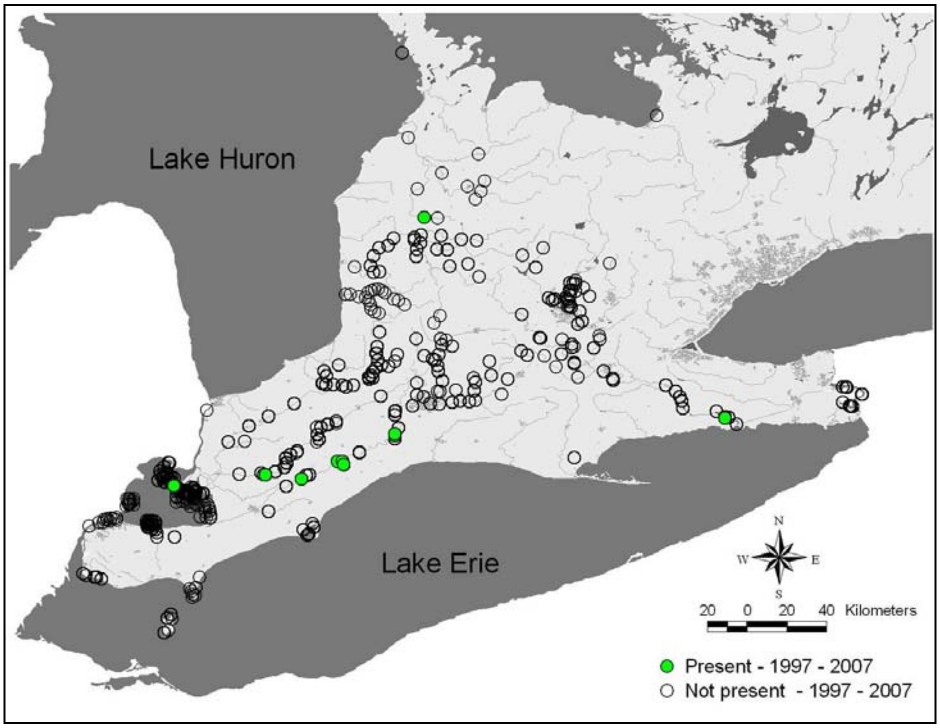


Figure 4. Current distribution (1997-2007) of the Fawnsfoot (*Truncilla donaciformis*) in Canada. Records obtained from the Lower Great Lakes Unionid Database.

The Fawnsfoot had never been recorded from the Lake Huron drainage until a live specimen was collected in 2005. During a benthic invertebrate assessment, a single live animal was collected in a kick net sample from Muskrat Creek on the Teeswater River in the Saugeen River watershed (Logan pers. comm. 2007; specimen verified by the report writer). Prior mussel sampling in this watershed in 1993 and 1994 (5 sites; effort = 1 person-hour per site) had not detected the presence of the Fawnsfoot (Morris and Di Maio 1998-1999). Eight additional sites were surveyed in the Saugeen watershed in 2006 including two sites on the Teeswater River, one just below the confluence with Muskrat Creek (Morris *et al*. 2007). Despite the greater effort expended (4.5 person-hours per site), no specimens of the Fawnsfoot were encountered. Additional sampling in the Bayfield (18 sites in 2007), Maitland (11 sites between 1998 and 2003) and Ausable (6 sites in 1993-1994; 15 sites between 1998 and 2002) rivers of the Lake Huron drainage did not produce any specimens. The Saugeen River record is unique not only in that it represents the only record from the Lake Huron drainage but also because it occurs far up in the watershed, well removed from the mouth of the river, outside the known range of its presumed host(s) (see **Life cycle and reproduction**) and upstream of the first six dams in this river (see Figure 5). All other Canadian Fawnsfoot records are associated with the lake proper or the lower portions of rivers below the first major instream barrier, possibly due to limitations on host dispersal abilities (see **Limiting factors and threats**).

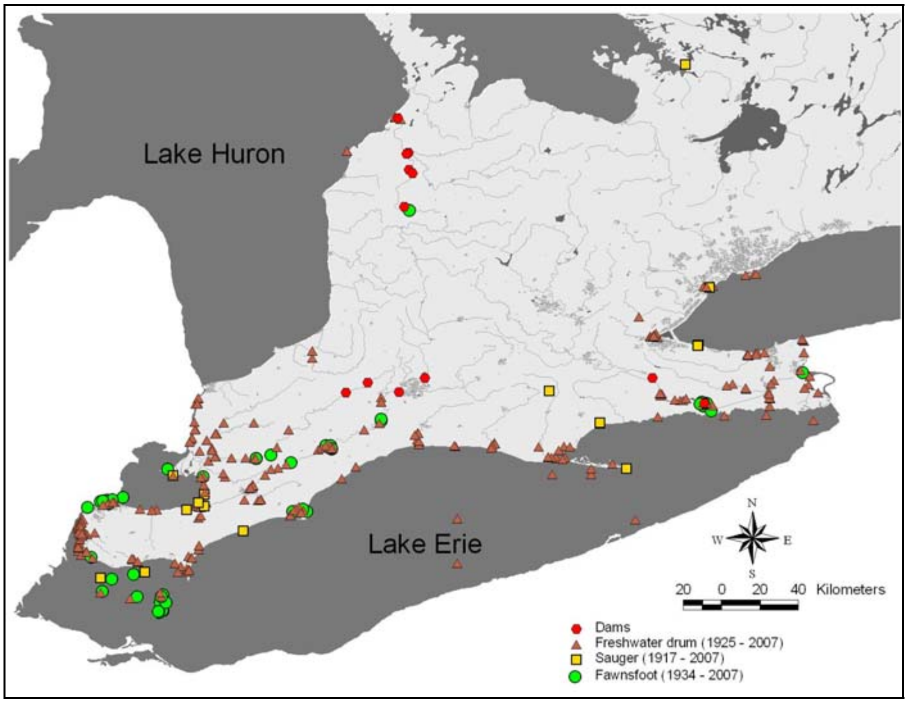


Figure 5. Distribution of the Fawnsfoot in relation to the distribution of the two potential hosts (freshwater drum and sauger) and the locations of dams. Distribution information for the Fawnsfoot is taken from the Lower Great Lakes Unionid Database and the fish distributions are taken from Fisheries and Oceans Canada's fish distribution database. Information on locations of dams has been provided by the local conservation authorities.

The first extensive surveys for unionids in Lake St. Clair were undertaken in 1984 by Nalepa and Gauvin (1988) and in 1986, 1990 and 1992 by Nalepa *et al*. (1996). These efforts identified that the Fawnsfoot represented a small component of the lake's sizable freshwater mussel community. Nalepa and Gauvin (1988) reported only a single individual from one of the 29 sites they sampled while Nalepa *et al*. (1996) reported that the Fawnsfoot represented between 0.35% - 2.4% of the total mussel fauna at the same sites. Recent surveys by Zanatta *et al*. (2002) and Metcalfe-Smith *et al*. (2004) have only produced a single individual.

The Fawnsfoot was first recorded from the Sydenham River of the Lake St. Clair drainage in 1991 when Clarke (1992) reported finding a shell near the town of Croton. Subsequent surveys by Metcalfe-Smith *et al*. (2003) in 1997-1998 (17 sites) and intensive quadrat excavations at 15 sites in 1999-2003 (Metcalfe-Smith *et al*. 2007) have confirmed the presence of the Fawnsfoot near the town of Dawn Mills but not at any other site in this watershed.

There are no historical records for the Fawnsfoot in the Thames River of the Lake St. Clair drainage (Figure 3), possibly because the lower portion of the watershed had not been systematically surveyed during the historical period. However, recent survey efforts by Environment Canada in 1997 (Metcalfe-Smith *et al*., unpublished data) and Fisheries and Oceans Canada in 2004-2005 (48 sites) (Morris and Edwards 2007) have shown that this species is relatively widespread, although at low densities, in the lower portion of the Thames River (see **Abundance**). The Thames River population likely represents the largest remaining known population in Canada.

The Fawnsfoot was first collected from the Detroit River in 1982 when a single animal was found at one of 13 sites sampled by Schloesser *et al*. (1998). This was also the last time the species was recorded from the Canadian waters of the Detroit River although Schloesser *et al*. (1998) continued to find it in the U.S. waters through 1992. No live Fawnsfoot specimens have been found in the Detroit River since the 1992 survey and they, along with all other unionids, are now considered extirpated from the river (Schloesser *et al*. 2006).

Wright's (1955) surveys of the Lake Erie benthos in 1930 produced some of the earliest Fawnsfoot specimens from the Great Lakes. Nalepa *et al*. (1991) summarized the decline of unionids in the western basin of Lake Erie during the 1951-1982 period and showed that the Fawnsfoot, while always rare (2.4 – 2.6% of the mussel community), apparently disappeared from the basin by 1961.

Metcalfe-Smith *et al.* (2000b) provide a summary of the historical and current data available regarding the freshwater mussel fauna of the Grand River of the Lake Erie drainage. They provide information for over 900 records from the Grand River between 1885 and 1998. Only eight of these records, dating between 1934 and 1997, are for the Fawnsfoot. All Fawnsfoot records are from the area defined by Metcalfe-Smith *et al*. (2000) as the Lower River and are in fact from the extreme lower portion between the mouth at Port Maitland and the Byng Conservation Area at Dunnville approximately 8 km upstream from the mouth. The most recent record for the Fawnsfoot from the Grand River is for the collection of 11 live individuals and many fresh dead valves from an area just below the dam in Dunnville in 1997 (Metcalfe-Smith *et al*. 2000b). This site was revisited, although not formally sampled, in 2005 by the report writer. No Fawnsfoot specimens were found, although shells of 10 other species were observed.

One of the first records for the Fawnsfoot in Canada was from the Niagara River in 1934. The only other record for the species from the Niagara River watershed is from 2002 when a single live specimen was collected from Lyons Creek in a kick net sample not directed at detecting unionids (Logan pers. comm. 2007). Although a voucher specimen was apparently collected, it was not verified and has since been misplaced. The report writer was not able to confirm this record. Thus, this occurrence must be regarded as suspect until a specimen can be properly confirmed and it is not considered further in this report. Limited mussel sampling has been conducted in the Niagara River in recent years. Riveredge Associates surveyed 15 sites for mussels in the area of Grand Island in 2001 and 2002 and found live specimens of six species, none of which was the Fawnsfoot (New York Power Authority 2003).

Extent of occurrence (EO) was calculated in ArcView GIS 3.3 using the maximum convex polygon constructed around historical and current distributions represented in Figures 3 and 4. Assuming the Muskrat Creek population has always been present but went undetected until 2005, a possibility given the low densities and low sampling effort in this watershed, the historical EO is 51,238 $km^2$. In contrast, the current EO is 24,952 $km^2$ and represents a reduction of 51%. The current area of occupancy (AO) is estimated to be 128 $km^2$ but has declined over the last twenty years as populations have been lost from the offshore waters of Lake St. Clair, the Detroit River and Lake Erie. AO does not appear to have changed in the Sydenham and Grand rivers, while new populations have been recently discovered in the Thames (1997) and Saugeen (2005) rivers (see **Fluctuations and trends**). For all populations except the Thames River, AO was calculated by applying a 2×2 km grid over each occurrence. For the Thames River population, AO was calculated by assuming a continuous distribution between the furthest upstream and downstream records in the river and applying a 1×1 km grid over this entire stretch of river (Filion pers. comm. 2007). The AO for each of the five extant populations was calculated as follows: 4 $km^2$ for each of the St. Clair delta, Muskrat Creek, Sydenham River and Grand River populations and 112 $km^2$ for the Thames River population.

## HABITAT

### Habitat requirements

The Fawnsfoot is known to occur in areas of moderate to low flows in medium and large rivers at depths ranging from less than 1 m to greater than 5 m, although it can adapt to low flow environments such as lakes and reservoirs (Clark 1981; Parmalee and Bogan 1998). The Fawnsfoot is usually associated with substrates of sand or mud (Clark 1981; Parmalee and Bogan 1998), but can be found in areas with coarser substrate (Howells *et al.* 1996). Remaining populations in Canada are usually found in the lower portions of larger rivers on fine sand or gravel substrates.

### Habitat trends

The most significant change in habitat for the Fawnsfoot is associated with the invasion of the dreissenid mussels (*Dreissena polymorpha* and *D*. *bugensis*) in the mid-1980s. Dreissenid mussels compete with native unionids for space and food and, by attaching directly to native mussel shells, impair the ability of the native mussels to feed, respire and move normally (see **Limiting factors and threats**). Within about a decade of the first invasion, native unionids had been almost completely eradicated from Lake St. Clair, Lake Erie and the Detroit and Niagara rivers (Schloesser and Nalepa 1994; Nalepa *et al*. 1996; Schloesser *et al*. 2006). Over 80% of historical Fawnsfoot records in the Lower Great Lakes Unionid Database were from areas that have been negatively impacted by dreissenid mussels and represent areas where unionids are now considered essentially extirpated. Despite these catastrophic effects, there are still areas where dreissenid mussels occur in sufficiently low densities to allow coexistence with unionids, such as the St. Clair delta (Zanatta *et al*. 2002). Recent work by Strayer and Malcom (2007) suggests the potential for continued coexistence in areas where the impacts of dreissenids are more related to competition for food (e.g., the Hudson River in New York) than to biofouling.

Habitat trends for riverine populations are difficult to assess as there are very few historical records available. The following discussion summarizes general conditions for unionids in these watersheds.

The Sydenham River flows through an area of prime agricultural land in southwestern Ontario. Over 85% of the land in the watershed is in agricultural use, with 60% of land in tile drainage (Dextrase *et al.* 2003). Large areas of the river have little to no riparian vegetation as only 12% of the original forest cover remains. Strayer and Fetterman (1999) identified high sediment and nutrient loads and toxic chemicals from non-point sources, especially agricultural activities, as the primary threat to riverine mussels. Agricultural lands, particularly those with little riparian vegetation and large amounts of tile drain, allow large inputs of sediments to the watercourse. In the case of tile drained land, the sediment is often of a very fine grain that can clog the gill structures of mussels and result in decreased feeding and respiration rates and reductions in growth efficiency. The Sydenham River has had high nutrient levels with total phosphorus levels consistently exceeding provincial water quality levels over the last 30 years, while chloride levels have shown recent increases due to the increased use of road salt (Dextrase *et al.* 2003). Human population pressure within the watershed is low as the total population is less than 90,000 with roughly half occurring in urban settings. Although the watershed is not highly populated, the lower portion of the river is subject to commercial shipping activities that tend to fluctuate in response to economic conditions.

The lower Thames River watershed in the area where the Fawnsfoot occurs is subjected to intense agricultural pressure. Eighty-eight percent of the land in the lower watershed is in agricultural use and less than 5% of the historical forest cover still remains (Taylor *et al*. 2004). Despite these land-use pressures, the lower Thames River remains one of the largest free-flowing river systems in southern Ontario. No major barriers or dams exist for approximately 200 km from the mouth of the river upstream to the city of London, the largest urban centre in the watershed with a population of approximately 330,000. The city of London has undergone a 10-fold population expansion in the last century. Although this city is located upstream of both the known historical and current ranges of the Fawnsfoot, the impacts of such a large urban centre (e.g., wastewater treatment outflows) and its expansion are likely to be observed downstream in the areas where the species occurs.

Mussel communities in the Grand River are among the best studied in Canada and there is abundant evidence to indicate that these communities have undergone a significant decline and subsequent recovery over the last 35 years (Kidd 1973; Mackie 1996; Metcalfe-Smith *et al*. 2000b). When Kidd (1973) sampled the river (115 sites between 1970-72) he reported only 17 of the 31 species historically known from the river. He attributed much of this loss to impaired water quality related to agricultural activity and habitat fragmentation resulting from dam construction. Mackie (1996) indicated that anthropogenic stressors, particularly below urban centres, were likely driving the species declines. Metcalfe-Smith *et al*. (2000b) surveyed 94 sites over a four-year period and found 25 species, representing a 50% increase in species richness compared with Kidd's (1973) results from 25 years earlier. Morris (2006b) reports that the Grand River is now believed to be home to one of the two largest populations of the Endangered Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada. When Mackie (1996) surveyed 70 sites ten years earlier, no live Wavyrayed Lampmussels were found. Metcalfe-Smith *et al*. (2000b) relate much of the improvement in mussel communities of the Grand River to improved water quality and the addition of fish ladders promoting fish movement (allowing dispersal through host activity) and reconnection of formerly fragmented habitat.

### Habitat protection/ownership

The *Fisheries Act* represents an important tool for habitat protection for aquatic species. Under the federal *Fisheries Act* mussels are considered shellfish, falling under the definition of 'fish', and their habitat is, therefore, protected from harmful alteration, disruption or destruction unless authorized by the Minister of Fisheries and Oceans, or his/her delegate. The Ontario *Lakes and Rivers Improvement Act* prohibits the impoundment or diversion of a watercourse if siltation will result, while the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs is designed to reduce erosion on agricultural lands. Stream-side development in Ontario is managed through floodplain regulations enforced by local conservation authorities. A majority of the land adjacent to the rivers where the Fawnsfoot is found is privately owned; however, the river bottom is generally owned by the Crown.
The uppermost portion of the Thames River population occurs adjacent to the Munsee-Delaware First Nations whereas the upstream extent of the Grand River population extends to the Byng Conservation Area owned by the Grand River Conservation Authority. The only remaining lake population is found in the St. Clair delta in waters within the boundaries of the Walpole Island First Nation.

## BIOLOGY

Freshwater mussels like the Fawnsfoot are long-lived (Heller (1991) reports lifespans for the Lampsilinae of approximately 20 years), relatively sedentary filter-feeders. They have a complex reproductive cycle involving a period of obligate parasitism on a vertebrate host. Juvenile mussels are believed to burrow completely below the substrate surface where they will spend the first 3-5 years of their life (Balfour and Smock 1995; Schwalb and Pusch 2007). During this time they are likely feeding on a combination of detritus, algae and bacteria obtained from the interstitial pore water or through pedal feeding (Gatenby *et al*. 1997). Adult mussels are found at the substrate surface during the summer months, but are known to burrow below the surface during the winter months likely in response to dropping water temperatures or changing flow regimes (Schwalb and Pusch 2007). Adults feed by siphoning algae from the water column but may also engage in some pedal feeding (Nichols *et al*. 2005). The following discussion is based on a survey of the available literature and the personal observations of the report writer.

### Life cycle and reproduction

The reproductive biology of the Fawnsfoot is believed to follow the general reproductive biology of most mussels. During spawning, male mussels release sperm into the water and females living downstream filter it out of the water with their gills. Female mussels brood their young from the egg to the larval stage in specialized regions of their gills known as marsupia. Immature juveniles, known as glochidia, develop in the gill marsupia and are released by the female into the water column to undergo a period of parasitism on a suitable host fish species. Further development to the juvenile stage can not continue without a period of encystment on a vertebrate host. During encystment the immature juvenile will feed from the body fluids of the host and undergo significant differentiation, although virtually no growth occurs during this time (Haag pers. comm. 2007). Natural glochidial mortality is difficult to estimate but assumed to be extremely high. The duration of encystment is unknown for the Fawnsfoot. After releasing from the host, the juveniles settle to the river bottom and begin life as free-living mussels. Juvenile mussels remain burrowed in the sediment for several years until sexual maturity is reached at which point they migrate to the substrate surface and begin the cycle again (Watters *et al*. 2001). Age at maturity is unknown for the Fawnsfoot, but the average age of maturity for unionids is 6-12 years (McMahon 1991).

The Fawnsfoot is dioecious (i.e., has separate sexes) but males and females do not appear different externally. The spawning season for the Fawnsfoot is not well known but Parmalee and Bogan (1998) reported that this species is probably bradytictic (i.e., glochidia overwinter on the female). Clarke (1981) reported that females are gravid (i.e., brooding their young) from spring through summer, but no studies have been conducted on Canadian populations. Glochidia are very small at approximately 60 µm in length and height and lack hooks (Utterback 1915-16), suggesting they are gill parasites.

Clarke (1981) states that the most likely host for the Fawnsfoot in Canada is freshwater drum (*Aplodinotus grunniens*) although sauger (*Sander canadensis*) has also been reported as a host (Surber 1913; Wilson 1916). Neither species has yet been examined as a potential host for Canadian populations. Although the Great Lakes distributions for both fish species overlay well with the current and historical Fawnsfoot distribution (Figure 5), freshwater drum is a more abundant species in Ontario. Within the area bounded by the distribution of the Fawnsfoot, Fisheries and Oceans Canada’s fish distribution database contains 533 records for freshwater drum and only 29 records for sauger, supporting Clarke’s assertion that freshwater drum is the more likely host for Canadian populations. Freshwater drum and/or sauger have been collected from all areas in southern Ontario where the Fawnsfoot has also been collected with the exception of Muskrat Creek in the Saugeen River watershed (Figure 5). Although Fisheries and Oceans Canada’s fish database contains 4681 fish records from this area, there are no records for either freshwater drum or sauger from the entire Saugeen watershed.

Many species of freshwater mussels have evolved complex host attraction strategies to increase the probability of encountering a suitable host (Zanatta and Murphy 2006). These strategies range from the formation and release of conglutinates (bundles of glochidia bound in mucous) and the development of complex lures to extreme cases of host capture in the genus *Epioblasma*. Little is known of the reproductive behaviours of the Fawnsfoot; however, the closely related Deertoe (*Truncilla truncata*) is reported to use a valve-gaping display in response to physical manipulation (Zanatta and Murphy 2006).

When stimulated, the female mussel gapes and exposes the bright white swollen marsupia containing the glochidia. Adult freshwater drum, particularly those that inhabit rivers, are known to be molluscivorous (Scott and Crossman 1973). Predation on gravid female mussels may present a unique route to facilitate the host-parasite relationship. During consumption the glochidia will be released into the mouth of the host then passed out through the gills where they may be able to attach and encyst.

### Predation

Predation by terrestrial mammals such as muskrats (*Ondatra zibethicus*) and raccoons (*Procyon lotor*) has been shown to be an important limiting factor for some populations of freshwater mussels (Neves and Odom 1989). Muskrats are both size and species-specific predators and although they will consume the Fawnsfoot, Tyrrell and Hornbach (1998) report that it was selected against in the St. Croix River likely because of its small size and deep burrowing behaviour. Metcalfe-Smith and McGoldrick (2003) reported observing raccoon predation on mussels in Ontario waters. Human-related activities, such as the adoption of conservation tillage practices, have resulted in surges in predator populations which may increase the importance of predation-related threats in the future (Metcalfe-Smith and McGoldrick 2003). This anecdotal observation needs verification in order to quantify the effects of human-related activities on predator populations.

As discussed in the previous section (**Life cycle and reproduction**) predation by molluscivorous fishes such as the freshwater drum may facilitate the complex life cycle.

### Physiology

No specific studies on the physiology of the Fawnsfoot could be located. In general, freshwater mussels of the family Unionidae are good indicators of overall ecosystem health and are particularly sensitive to heavy metals (Keller and Zam 1990), ammonia (Goudreau *et al*. 1993; Mummert *et al*. 2003), acidity (Huebner and Pynnonen 1992) and salinity (Liquori and Insler 1985, as cited in USFWS 1994).

### Dispersal/migration

There are no specific studies on movement of the Fawnsfoot. In general, adult mussels 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; Villella *et al*. 2004). Small-scale movements on the order of centimetres/week have been reported by Amyot and Downing (1998) for *Elliptio complanata*; however, the primary means for large-scale dispersal, upstream movement, and the movement into novel habitats is limited to the encysted glochidial stage on the host fish. Both suggested hosts for the Fawnsfoot, freshwater drum and sauger, are capable of large-scale dispersal. Funk (1957) reported annual movement of freshwater drum in Missouri of up to 300 km although most fish dispersed less than 20 km. Pegg *et al*. (1997) reported that radio-tagged sauger in the Lower Tennessee River moved 67 km on average, while some travelled up to 276 km over a period of approximately 6 months.

### Interspecific interactions

Immature Fawnsfoot are obligate parasites on vertebrate hosts. These hosts are believed to be freshwater drum and sauger. Freshwater mussels of the Great Lakes region have been severely impacted by negative interactions with the introduced dreissenid mussels *D. polymorpha* and *D. bugensis* (see **Fluctuations and trends** and **Limiting factors and threats**).

### Adaptability

The Fawnsfoot is reported to have fairly broad habitat tolerances (see **Habitat requirements**) both in terms of flow and substrate preferences suggesting they may be able to tolerate some environmental changes. However, the sedentary nature of adult freshwater mussels, general sensitivity to water quality (see **Limiting factors and threats**) and host dependency may offset these broader habitat tolerances. At this time there have been no studies to specifically address the adaptability of the Fawnsfoot and no known attempts to artificially rear this species (Brady pers. comm.2007).

## POPULATION SIZES AND TRENDS

### Search effort

Historical surveys

Based on records from the Lower Great lakes Unionid Database, the Fawnsfoot was historically (1930-1996) found in Lake Erie, Lake St. Clair and the Detroit, Niagara, Sydenham and Grand rivers. Approximately two-thirds of the 43 historical records are from museum specimens that have no information on search effort associated with them. Information on sampling methods and search effort *is* available for the remaining records, which were taken from surveys published in the literature. Table 1 provides a summary of this information. Surveys conducted on the Saugeen and Thames rivers are included in Table 1 because the Fawnsfoot was recently recorded from these rivers. A variety of quantitative and semi-quantitative sampling techniques were used in the historical surveys.

Recent Surveys

The Lower Great Lakes Unionid Database contains 15 recent (1997-2007) records for the Fawnsfoot from the Grand, Thames and Sydenham rivers, Muskrat Creek in the Saugeen River watershed, and Lake St. Clair. All but one of these records is accompanied by information on sampling methodology and search effort. The remaining record, from Muskrat Creek, is from a survey targeting other benthic invertebrates. Southwestern Ontario, which encompasses the range of the Fawnsfoot, has been extensively surveyed for freshwater mussels over the past ten years. Surveys have been conducted at approximately 300 different sites in 11 systems. Table 2 provides a summary of the sampling methods and search effort used in these surveys. It should be noted that different sampling techniques may provide different types of data. Semi-quantitative methods (timed-search surveys while wading, snorkelling or using SCUBA gear) provide data on the presence/absence of species and their relative abundance. Quantitative methods, i.e., methods that sample a defined area of the substrate surface using quadrats, grabs, circular plots or line transects, provide additional data on mussel densities. The above-described methods detect only those mussels visible at the sediment surface, all of which would be adults. Quadrat surveys with excavation, i.e., where the substrate in each quadrat is searched to a depth of about 10 cm, have been used at ~ 10% of the sites surveyed to date. This very time-consuming technique detects both adult mussels occurring at the sediment surface and juvenile mussels that tend to burrow deeply in the substrate (see **Biology**). The latter method can therefore provide additional data on recruitment.

**Table 1. Summary of historical (1930-1996) mussel sampling effort within the range of the Fawnsfoot.**

| Water body | # of sites | Year | Effort | Notes | Source |
|---|---|---|---|---|---|
| Lake St. Clair | 29 | 1986, 1990, 1992, 1994 | 10 x 0.5 $m^2$ quadrats per site per year | | Nalepa *et al*. 1996 |
| | 2 | 1990, 1992 | 20 x 1 $m^2$ quadrats | includes 2 of Nalepa *et al*.'s (1996) sites | Gillis and Mackie 1994 |
| Detroit River | 13 | 1982-83 | SCUBA searches over 500 $m^2$ area over 60 minute period. Additional 15-30 min if live unionids detected. | | Schloesser *et al*. 1998 |
| | 17 | 1992 | SCUBA searches over 500 $m^2$ area over 60 minute period. Additional 15-30 min if live unionids detected. | | Schloesser *et al*. 1998 |
| | 9 | 1994 | SCUBA searches over 500 $m^2$ area over 60 minute period. Additional 15-30 min if live unionids detected. | | Schloesser *et al*. 1998 |
| Lake Erie | 40 | 1930 | drag-dredge? | | Wright 1955 |
| | ? | 1951-52 | 204 samples taken from an unknown number of sites using a 42 x 16 cm drag-dredge | | Wood 1963 |
| | 15 | 1973-74 | 29 samples taken from 15 sites using a 42 x 16 cm drag-dredge | | Wood and Fink 1984 |
| | 17 | 1961, 1972, 1982 | 3-5 benthic grabs per site with either a Ponar or Peterson sampler. | | Nalepa *et al*. 1991 |
| | 17 | 1991 | 3 x 0.05 $m^2$ Ponar grabs and 5 min tow with 0.46 x 0.26 cm epibenthic sled | | Schloesser and Nalepa 1994 |
| Saugeen River | 6 | 1993-94 | 1 person-hour while wading | | Morris and Di Maio 1998-1999 |
| Sydenham River | 12 | 1971 | 0.7-> 4 person-hours while wading | | Clarke 1972 |
| | 22 | 1985 | minimum 1 person-hour while wading | includes 12 of Clarke's (1972) sites | Mackie and Topping 1988 |
| Sydenham River (cont'd) | 16 | 1991 | 0.4-8.0 person-hours while wading | most productive of Clarke's (1972) sites | Clarke 1992 |

(*con't on p. 18*)

(*con't from p. 17*)

| Water body | # of sites | Year | Effort | Notes | Source |
|---|---|---|---|---|---|
| Thames River | 1 | 1983 | 240 x 0.5 $m^2$ quadrats | | Salmon and Green 1983 |
| | ? | 1993 | 1 person-hour | | Bowles 1994 |
| | 16 | 1994 | 1 person-hour while wading | | Morris and Di Maio 1998-1999 |
| | 16 | 1995 | 1 person-hour while wading | includes site of Salmon and Green (1983) and overlap with Bowles (1994) | Morris 1996 |
| Grand River | 115 | 1970-72 | no precise effort reported per site description of methods reported | | Kidd 1973 |
| | 70 | 1995 | 1.5 person-hours while wading and extra 1.5 person-hours when stream order greater than 4 (using SCUBA) | extra effort directed at surveying deeper areas | Mackie 1996 |

**Table 2. Summary of current (1997-2007) mussel sampling effort within the range of the Fawnsfoot.**

| Water body | # of sites | Year | Effort | Notes | Source |
|---|---|---|---|---|---|
| Lake St. Clair | 3 | 1998 | 10 transects at 3 depths (1, 2.5 and 4 m) with 5 x 1 $m^2$ quadrats and 20 Ekman grabs in each transect | | Zanatta *et al*. 2002 |
| | 60 | 1999 | sites < 2.0 m deep employed 0.75 person-hours of snorkelling effort and if mussels present an additional 0.75 person-hours was spent; sites > 2.0 m deep employed 0.5 person-hours of SCUBA effort | includes 10 locations surveyed in 1998 | Zanatta *et al*. 2002 |
| | 10 | 2000 | 1.5 person-hours of snorkelling | includes 10 sites from previous years | Zanatta *et al*. 2002 |
| | 9 | 2001 | 5-21 x 65 $m^2$ circular plots surveyed using snorkellers | includes 4 previously sampled sites | Zanatta *et al*. 2002 |
| | 18 | 2003 | 10 x 195 $m^2$ circular plots surveyed using snorkellers | 9 sites in Canadian waters of delta, 9 sites in U.S. waters | Metcalfe-Smith *et al*. 2004 |
| | 10 | 2003 | 1 person-hour of snorkelling | 2 sites in Canadian waters of delta, 8 sites in U.S. waters | Metcalfe-Smith *et al*. 2004 |
| | 4 | 2005 | 3-4 person-hours of snorkelling | | Metcalfe-Smith *et al*. 2005c |
| Detroit River | 1 | 1997 | 4 x 120 $m^2$ line transects | | Schloesser *et al*. 2006 |
| | 4 | 1998 | 500 $m^2$ area searched for 60 minutes using SCUBA; second 500 $m^2$ area searched for 25 minutes | sites where live unionids were observed in 1992 and 1994 | Schloesser *et al*. 2006 |
| | 1 | 1998 | 10 x 1$m^2$ quadrats within a 10 m x 10 m grid | | Schloesser *et al*. 2006 |
| Lake Erie | 6 | 2001 | approximately 2 person-hours of snorkelling | | D. Zanatta and D. Woolnough unpublished data |
| | 12 | 2005 | 1.5 person-hours of snorkelling | | D. McGoldrick unpublished data |
| | 5 | 2005 | beach search for shells | | D. McGoldrick unpublished data |

(*con't on p. 19*)

(*con't from p. 18*)

| Water body | # of sites | Year | Effort | Notes | Source |
|---|---|---|---|---|---|
| Niagara River | 22 | 2001-2002 | 0.5 person-hours of snorkelling plus 0.5 person-hours if mussels found during first effort | U.S. waters near Grand Island | New York Power Authority 2003 |
| Saugeen River | 8 | 2006 | 4.5 person hours while wading | timed-search sampling technique used in this and other inland rivers is described in Metcalfe-Smith *et al*. 2000a | Morris *et al*. 2007 |
| Maitland River | 11 | 1998, 2003 | 4.5 person hours while wadsing | | McGoldrick and Metcalfe-Smith 2004 |
| Bayfield River | 18 | 2007 | 4.5 person hours while wading | | Morris unpublished data |
| Ausable River | 21 | 1993-94, 1998-02 | 4.5 person hours while wading | | |
| | 7 | 2006 | 69-75 x 1 $m^2$ quadrats with excavation | | Staton pers. comm. 2007 |
| Sydenham River | 17 | 1997-98 | 4.5 person hours while wading | | Metcalfe-Smith *et al*. 2003 |
| | 15 | 1999-03 | 60-80 x 1 $m^2$ quadrats with excavation | includes 12 sites surveyed in 1997-98 | Metcalfe-Smith *et al*. 2007 |
| Thames River | 48 | | 4.5 person hours while wading | | Morris and Edwards 2007 and unpublished data |
| | 5 | 2004-05 | 60-80 x 1 $m^2$ quadrats with excavation | sites included in Morris and Edwards 2007 | Morris unpublished data |
| Grand River | 24 | | 4.5 person hours while wading | | Metcalfe-Smith *et al*. 2000b |
| | 4 | 2007 | 48-65 x 1 m2 quadrats with excavation | all sites included in Metcalfe-Smith *et al*. 2000b | Morris unpublished data |

## Abundance

To the best of our knowledge, the Fawnsfoot no longer occurs in the Detroit River (Schloesser *et al*. 2006), Lake Erie (Schloesser and Nalepa 1994; D. McGoldrick, Environment Canada, unpublished data) or the Niagara River (New York Power Authority 2003). Extant occurrences are restricted to the St. Clair River delta area of Lake St. Clair, the Saugeen River (Muskrat Creek), the lower Sydenham River, the lower Thames River, and the lower Grand River.

### Lake St. Clair

Relative abundance of the Fawnsfoot in the delta area of Lake St. Clair can be estimated from the work of Zanatta *et al*. (2002) and Metcalfe-Smith *et al*. (2004). It is clear from these studies that the Fawnsfoot currently represents a very small component of the mussel fauna in this region of the lake. Zanatta *et al*. (2002) found 1356 live unionids at 33 different sites between 1998 and 2001 and did not find a single Fawnsfoot. Similarly Metcalfe-Smith *et al*. (2004) found 1778 live unionids at 18 sites in the delta and only reported a single live Fawnsfoot for a total relative abundance of 0.00024% of the unionid community. Focusing only on the Canadian waters of the delta where the single specimen was located still yields a relative abundance of only 0.12% of the total unionid community. Metcalfe-Smith *et al*. (2004) calculated a density of $6.86 \times 10^{-5}/m^2$ (one Fawnsfoot found in 14,577 $m^2$ searched) for the entire delta. The one animal was collected from three circle plots of 650 $m^2$ each, yielding a site-specific density of $0.000513/m^2$ (SE = 0.000513). It is not possible to estimate the size of the Fawnsfoot population in the delta based on information from a single individual.

Inland Rivers

Thirty-six hours of sampling at eight stations in the Saugeen River watershed in 2006 produced 1064 mussels of eight species but no Fawnsfoot specimens, either live or dead (Morris *et al*. 2007). The only record of the Fawnsfoot from this watershed or the entire Canadian portion of the Lake Huron watershed is from a benthic sample collected from Muskrat Creek upstream of Teeswater. It is not possible to estimate abundance in the Saugeen River with the available information.

The Fawnsfoot was only found at one of the 22 sites sampled in the Sydenham River between 1997 and 2003 (Metcalfe-Smith *et al*. 2007). Seven individuals were collected from the 78 1 $m^2$ quadrats excavated at this site, yielding a density estimate of $0.089/m^2$ (SE = 0.0348). It is not possible to estimate the population size in the Sydenham River as the species was only found at a single site. Although the sample size is small (n = 20 and includes individuals collected during timed-searches as well as those collected during the quadrat excavations), the size frequency distribution presented for the Sydenham River (Figure 6) provides evidence of recruitment and representation from multiple size classes.

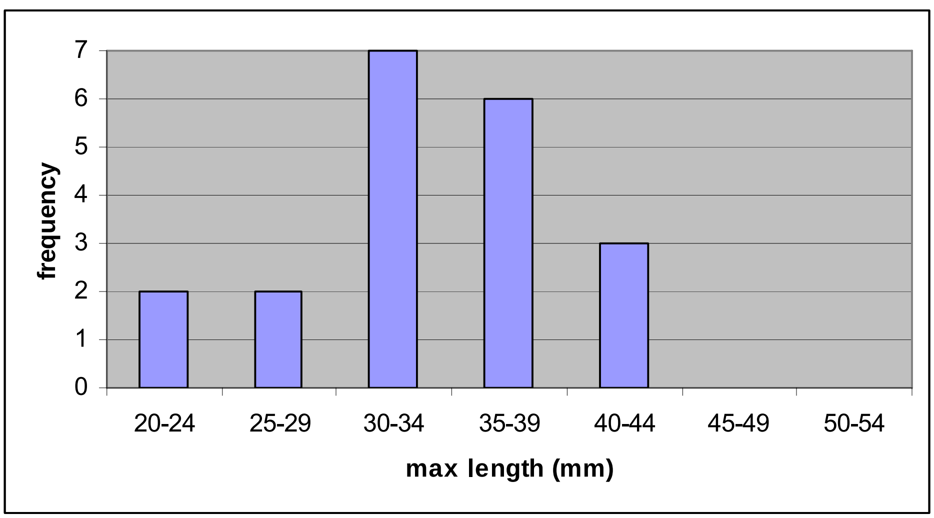


Figure 6. Size distribution of the Fawnsfoot collected from the Sydenham River using timed-search methods in 1998 (n = 13) and quadrat excavations in 1999 (n = 7) (J. Metcalfe-Smith, Environment Canada, unpublished data).

A total of 23 live specimens of the Fawnsfoot were collected from seven of 48 sites sampled in the Thames River between 1997 and 2005. All seven sites were located contiguously over a 112 km stretch of the lower Thames River between London and Chatham. One site within the range of the Fawnsfoot was chosen for detailed quadrat excavation work. Three Fawnsfoot specimens were recorded during these excavations giving a density estimate for the Thames River of 0.043/$m^2$ (SE = 0.0237). At sites where this species was found it ranged from 0.55 – 4.0% of the total mussel community. Figure 7 represents the size distribution for the 23 animals collected in the Thames River. Despite the small sample size there is again evidence for multiple size classes suggesting reproduction over several years (Figure 7).

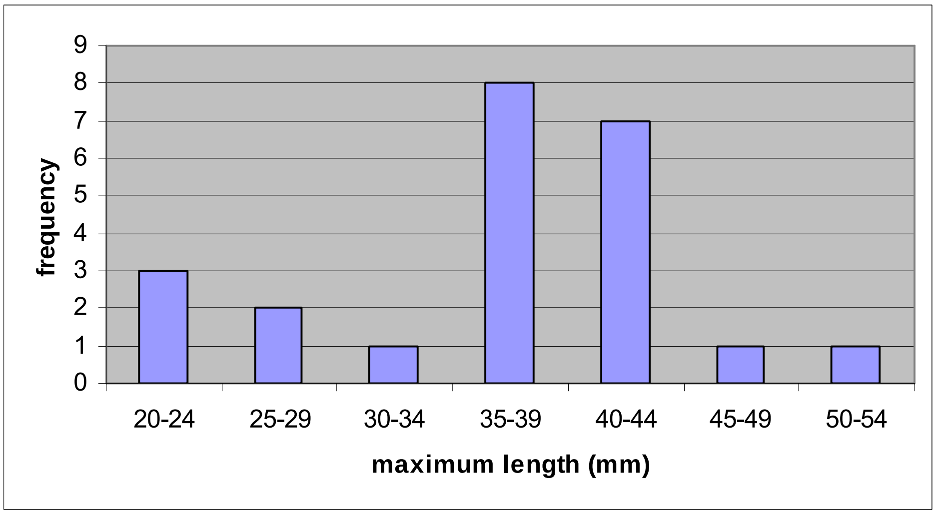


Figure 7. Size distribution of the Fawnsfoot collected from the Thames River using timed-search methods (n = 20) and quadrat excavation (n = 3) (T. Morris, Fisheries and Oceans Canada, unpublished data).

Metcalfe-Smith *et al*. (2000b) surveyed 24 sites in the Grand River for mussels in 1997-1998, and found the Fawnsfoot at only one of these sites. At this one site, immediately below the dam in Dunnville, 11 individuals were collected representing 21.1% of all live mussels at the site. The Fawnsfoot was not collected during quadrat sampling at four sites in the Grand River in 2007, making an estimate of population abundance impossible. The size distribution of specimens from the Grand River (Figure 8) indicates a much smaller range of sizes in this river in comparison with the Sydenham and Thames rivers. It is not clear whether the truncated size distribution is indicative of limited reproduction or simply a consequence of the small sample size.

### Fluctuations and trends

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

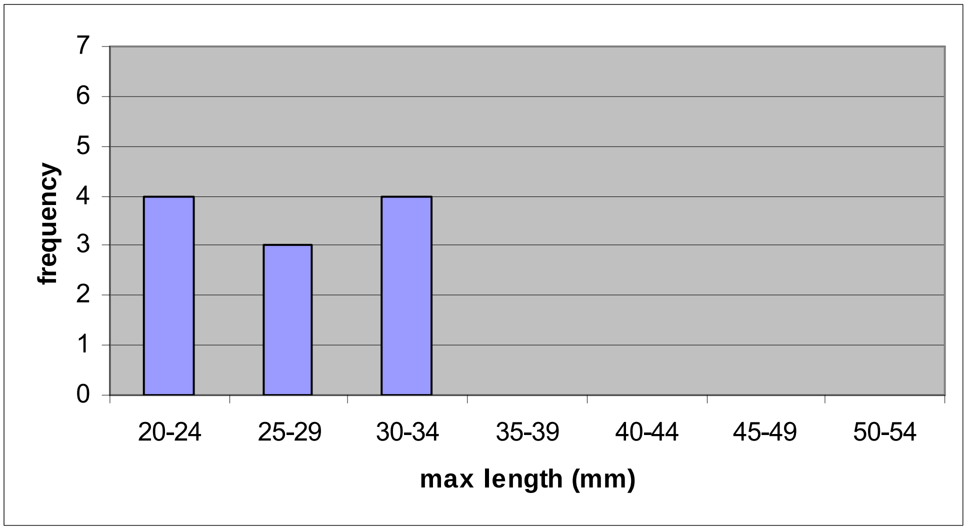


Figure 8. Size distribution of the Fawnsfoot collected from the Grand River using timed-search methods in 1997 (n = 11) (J. Metcalfe-Smith, Environment Canada, unpublished data).

The Fawnsfoot appears to be extirpated from the offshore waters of lakes St. Clair and Erie and the Detroit and Niagara rivers as a result of the invasion of dreissenid mussels. Even prior to this invasion, the Fawnsfoot was never a large part of the native mussel fauna. In Lake St. Clair, Nalepa *et al*. (1996) report that the Fawnsfoot represented 0.35% (1 of 281 animals), 2.4% (6 of 248 animals) and 1.0% (1 of 99 animals) of the total mussel fauna captured in 1986, 1990 and 1992 respectively. By the time Zanatta *et al*. (2002) sampled 95 sites between 1998 and 2001, no Fawnsfoot were among the 2356 live animals detected. The only record of the Fawnsfoot from Lake St. Clair in the last 15 years was the single live animal collected by Metcalfe-Smith *et al*. (2004) from the delta area in 2003.

Similarly, in the western basin of Lake Erie, Nalepa *et al*. (1991) reported that the Fawnsfoot represented 2.4% of the fauna in 1951-52 and 2.6% in 1961. Specific numbers of unionids captured were not reported by Nalepa *et al.* (1991); however, they did report a total average density of 10/m$^2$ in 1961. The Fawnsfoot has not been reported from Lake Erie since 1961.

Schloesser *et al*. (1998) summarized mussel survey efforts in the Detroit River between 1982 and 1994. Along the southeastern (Canadian) shore the Fawnsfoot represented 0.23% (1 of 422 animals) of the mussel fauna in 1982-83 and was not detected alive after that. Along the northwestern (American) shore the species was more abundant but still only represented 4.24% (7 of 165 animals) in 1982-83 and 0.31% (5 of 1592 animals) in 1992, with no animals detected in 1994. Additional survey effort since 1994 has produced no records and all freshwater mussels are now believed to be extirpated from the Detroit River (Schloesser *et al*. 2006).

The only historical record for the Fawnsfoot in the Sydenham River consists of a single specimen collected by Clarke from a site near Croton in 1991. Metcalfe-Smith *et al*. (2003) found the Fawnsfoot in almost the same location in 1998-1999. This site is the only place in the Sydenham River where the species has ever been recorded despite considerable recent sampling effort. This location has been revisited annually since 2005 as part of the Ontario Freshwater Mussel Identification Workshop and the report writer has observed live Fawnsfoot on each occasion. There are no data to estimate trends in abundance for riverine populations; however, there is no evidence of a change in the range of the Fawnsfoot in the Sydenham River.

The Fawnsfoot was first reported from the Thames River in 1997 as a single fresh valve from the area of Big Bend (Metcalfe-Smith *et al*., unpublished data). Morris and Edwards (2007) revisited this site in 2005 and found one weathered and four fresh shells in 4.5 person hours. An additional three live specimens were recorded during quadrat excavations at this site. The Fawnsfoot was recorded at six other sites over a 112 km reach of the lower Thames River making this likely the largest and healthiest remaining population in Canada. The lack of any time series makes evaluation of trends or fluctuations in this population impossible.

Historically the Fawnsfoot was known from six records in the lower Grand River between Dunnville and Port Maitland. Five of these records are identified as being in the Dunnville area where recent efforts have produced the only live specimens for the watershed. Kidd reported finding 10 shells but no live animals in this area in 1972, while Metcalfe-Smith *et al*. (2000b) found 11 live animals in 1997-98. There are no data to estimate trends in abundance for riverine populations; however, there is no evidence of a change in the range of the Fawnsfoot in the Grand River.

It is not possible to assess fluctuations or trends in Fawnsfoot numbers in Muskrat Creek of the Saugeen River drainage as this record consists only of a single animal collected on a single occasion. Fawnsfoot populations in the Lake St. Clair-Lake Erie corridor have undergone substantial declines over the last 20-40 years. Only one live specimen has been found in Lake St. Clair in the past 15 years and none have been found in the Detroit River. Fawnsfoot populations appear to have crashed earlier in the western basin of Lake Erie, with no specimens recorded since 1961. There are insufficient data available to estimate trends in abundance for the inland rivers, although there is no indication of a range reduction in any river.

### Rescue effect

All Canadian populations of the Fawnsfoot are isolated from one another and from American populations by large areas of unsuitable habitat, making the likelihood of re-establishment of extirpated populations by immigration small. The two potential hosts of the Fawnsfoot, freshwater drum and sauger, are capable of the large-scale movements required to connect these populations. However, movements of this magnitude are typically associated with spring spawning behaviour in these fishes (Funk 1957; Pegg *et al*. 1997) and would likely occur at a time when they are not bearing glochidia. Furthermore, Fawnsfoot populations in adjacent U.S. states that could act as sources are not considered stable. In the four U.S. states of the Lake Huron-Lake St. Clair-Lake Erie corridor, populations in two are considered at greater conservation risk than in Ontario (New York – SH, possibly extirpated; Pennsylvania – S1, critically imperiled) while one is considered on par (Ohio – S2, Imperiled). The Fawnsfoot has not been ranked in Michigan.

## LIMITING FACTORS AND THREATS

The single most significant factor in the recent declines of the Fawnsfoot is the introduction in the late 1980s and subsequent spread of dreissenid mussels (*D. bugensis* and *D. polymorpha*). The attachment of dreissenid mussels to the shells of native mussels can interfere with normal metabolic functions, and impede feeding, respiration, reproduction and locomotion (Mackie 1991; Haag *et al*. 1993; Baker and Hornbach 1997). Eighty-six percent of the historical records in the Lower Great Lakes Unionid Database for the Fawnsfoot in Canada are from areas that have been heavily impacted by dreissenids. Many of the areas are now completely devoid of unionids (Western Lake Erie - Schloesser and Nalepa 1994; Lake St. Clair - Nalepa *et al*. 1996; Detroit River - Schloesser *et al*. 2006). With the exception of the Saugeen River (Muskrat Creek) and Sydenham River, all known remaining Fawnsfoot populations occur in areas where dreissenid mussels are established. Morris and Edwards (2007) surveyed 37 sites in the Thames River in 2004-2005 and found live dreissenid mussels and/or evidence of attachment to unionids (live animals or byssal threads attached to the unionid shells) at nearly every site between Fanshawe Reservoir in the city of London and the mouth. Although no dreissenids were observed attached to individual Fawnsfoot, this area overlaps completely with its known distribution in the Thames River. Likewise, dreissenid mussels are present in the St. Clair River delta (Metcalfe-Smith *et al*. 2005b) and Grand River up to the Dunnville dam (pers. obs. Morris, 2005).

Damming of rivers has been shown to detrimentally affect mussels in many ways. Reservoirs alter downstream flow patterns, completely disrupting the natural hydrograph, and have been shown to change the natural thermal profiles of the watercourse (Vaughn and Taylor 1999). Impoundments also act as physical barriers to host movement making large areas of potential habitat completely unavailable to some mussel species. Watters (1996) observed that the distributions of two mussel species (*Leptodea fragilis* and *Potamilus alatus*) in Indiana, Ohio and West Virginia were limited by the presence of small dams that acted to restrict movement of their host, the freshwater drum. Tiemann *et al*. (2007) have also shown that the Fawnsfoot is one of five species in the Fox River system of Illinois that appears to have an upstream distribution limited by the presence of a low-head dam. Freshwater drum, the reported glochidial host of the Fawnsfoot, is a species adapted to shallow lacustrine waters that uses the lower portions of rivers for spawning (Scott and Crossman 1973). What limits the upstream distribution of the freshwater drum in southern Ontario rivers is not known. However, Watters (1996) suggests that the limiting factor in some U.S. rivers may be the presence of dams. He supports this notion by reporting that freshwater drum were once present in unimpounded river reaches in the Ohio River but disappeared after dams were constructed.

There are no historical data for southern Ontario that could be used to directly evaluate the impact of dam construction on fish and mussel populations, although the distributions presented in Figure 5 for the freshwater drum, sauger and Fawnsfoot show some relation to the placement of dams. In the Grand River, the Fawnsfoot has only been collected up to the dam in Dunnsville even though freshwater drum are able to pass this dam and have been found almost as far as the next dam in Caledonia which they are unable to pass (MacDougall pers. comm. 2007) (Figure 5). The Thames River is a unique river in southern Ontario as it is unregulated for nearly 200 km from the mouth to the first dam at Springbank Park in the city of London. This dam represents a barrier to fish passage from mid-May until early November (Reid and Mandrak 2006). Both the Fawnsfoot and the freshwater drum have distributions that extend nearly as far as this dam but there are no records of either species beyond the dam (Figure 5). A second dam above the city of London represents a permanent barrier to fish passage. The first major barrier on the Sydenham River is located well above the distribution of both species. In the Saugeen River, freshwater drum are not found above Denny's Dam; however, the only Fawnsfoot collected from this watershed was collected well above the dam. There are at least five additional barriers to fish passage between Denny's Dam and Muskrat Creek (Nichols pers. comm. 2007) (Figure 5). It is highly unlikely that the Fawnsfoot collected from Muskrat Creek arrived at the site while encysted on a freshwater drum or sauger.

Evidence suggests that freshwater mussels are sensitive to PCBs, DDT, Malathion and Rotenone, all of which can inhibit respiration and accumulate in mussel tissue (USFWS 1994). The glochidial stage appears to be particularly sensitive to heavy metals (Keller and Zam 1990), acidity (Huebner and Pynnonen 1992) and salinity (Liquori and Insler, as cited in USFWS 1994). It has recently been reported that juvenile freshwater mussels are among the most sensitive aquatic organisms to un-ionized ammonia toxicity, typically showing adverse responses at levels well below those used as guidelines for aquatic safety in U.S. waterways (Newton 2003; Newton *et al*. 2003). High inputs of silt from agricultural lands may adversely affect mussels by clogging gill structures and negatively impacting feeding, respiration and reproduction (Strayer and Fetterman 1996). The primary land use in the Sydenham River basin is agriculture. Dextrase *et al*. (2003) report suspended solids levels as high as 900 mg/L leading to the conclusion that siltation and turbidity are the predominant threat to species at risk in this watershed. In the Grand River, clearing of riparian vegetation and allowing livestock to access the river has resulted in poor water quality with increased sediment loads (WQB 1989a). Agricultural activity is expected to increase in the Grand River basin over the next 25 years leading to a predicted increase in sediment, pesticide, fertilizer, and manure runoff. Water quality in the Thames River basin has historically suffered greatly from agricultural activities. Tile drainage, wastewater drains, manure storage and spreading, and insufficient soil conservation have all contributed to poor water quality within the Thames basin (Taylor *et al*. 2004). Phosphorus and nitrogen loadings have increased steadily and some of the highest inputs of livestock waste for the entire Great Lakes basin have been reported for the Thames River watershed (WQB 1989b). Mean ammonia concentrations in all sub-basins of the Thames River exceed the federal freshwater aquatic life guidelines (Taylor *et al*. 2004). Given the general sensitivity of freshwater mussels, particularly glochidia and juveniles, to aquatic pollutants, the levels of pollution observed in these watersheds may be negatively impacting the remaining riverine populations of the Fawnsfoot.

Natural levels of predation by species identified earlier (see **Predation**) are not likely to adversely impact healthy populations of the Fawnsfoot; however, if the range of the mussel continues to shrink then these influences may become disproportionately large.

In summary, the major factors shaping the current distribution of the Fawnsfoot in Canada are the establishment of dreissenid mussels, which has resulted in large portions of historical habitat being rendered unsuitable, and a limited availability of riverine habitat primarily restricted by the distribution of its presumed glochidial host, the freshwater drum. Except for a small population in the St. Clair delta, remaining Fawnsfoot populations are limited to relatively small sections of the lower reaches of rivers where they are subjected to declining water quality resulting from agricultural and urban influences in the upper portions of the watersheds.

## SPECIAL SIGNIFICANCE OF THE SPECIES

Freshwater mussels in general play an integral role in the functioning of aquatic ecosystems. Vaughn and Hakenkamp (2001) summarized much of the literature relating to the role of unionids and identified numerous water column processes (size-selective filter-feeding; species-specific phytoplankton selection; nutrient cycling; control of phosphorus abundance) and sediment processes (deposit feeding decreasing sediment organic matter; biodeposition of feces and pseudofeces; epizoic invertebrates and epiphytic algae colonizing shells; benthic invertebrate densities positively correlating with mussel density) mediated by the presence of mussel beds. Welker and Walz (1998) have demonstrated that freshwater mussels are capable of limiting plankton in European rivers, while Neves and Odom (1989) reported that mussels also play a role in the transfer of energy to the terrestrial environment through predation by muskrats and raccoons. However, given that the Fawnsfoot appears to have always been a minor component of the freshwater mussel community in Canada, its relative contribution to these processes is likely minor.

The Fawnsfoot is one of four species of the genus *Truncilla*, only two of which occur in Canada.

## EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Fawnsfoot is considered globally secure (G5) and is listed as nationally secure (N5) in the United States but nationally imperiled (N2) in Canada (NatureServe 2007). This species is not currently listed under Canada’s *Species at Risk Act* or the *Endangered Species Act* of the United States. It is also not on the IUCN’s Red List.

The national general status assessment of freshwater mussels in Canada (Metcalfe-Smith and Cudmore-Vokey 2004) assigned a national rank of 2 (May be at Risk) to the Fawnsfoot that corresponds with a sub-national rank in Ontario of Imperiled (S2) (NHIC 2007). The Fawnsfoot is considered vulnerable to possibly extirpated in 12 U.S. jurisdictions, secure or apparently secure in six and not ranked in an additional five (Table3).

**Table 3. Subnational conservation rankings for the Fawnsfoot in American jurisdictions. Tied rankings have been assigned the higher conservation rank. All information taken from NatureServe (2007).**

| Conservation rank | Description | Jurisdiction |
|---|---|---|
| SH | Possibly extirpated | New York |
| S1 | Critically imperiled | Georgia, Pennsylvania, Texas, West Virginia, Wisconsin |
| S2 | Imperiled | Kansas, Ohio, South Dakota |
| S3 | Vulnerable | Arkansas, Indiana, Louisiana |
| S4 | Apparently secure | Alabama, Illinois, Kentucky, Mississippi |
| S5 | Secure | Oklahoma, Tennessee |
| SNR | Not ranked | Iowa, Michigan, Minnesota, Missouri, Nebraska |

The federal *Fisheries Act* represents the single most important piece of legislation currently protecting the Fawnsfoot in Canada. As shellfish, freshwater mussels are considered ‘fish’ under the *Fisheries Act* and receive the same protections granted to vertebrate fish. The collection of freshwater mussels requires a collection permit issued under authority of the *Fisheries Act*. In Ontario, this permit is issued by the Ontario Ministry of Natural Resources. Other indirect protections are realized through the habitat protections identified earlier (**Habitat protection/ownership**).

The last remaining lake population of this mussel is located in the territorial waters of the Walpole Island First Nation. These waters are relatively low-impact areas used primarily for hunting and fishing. Access to these areas is regulated through user permits issued by WIFN.

Areas where the Fawnsfoot occurs overlap with the distributions of several mussel species protected under Canada’s *Species at Risk Act*. The Fawnsfoot may benefit indirectly from protection afforded to these species or by actions implemented (e.g., research, stewardship and outreach) under the direction of recovery strategies for the Round Hickorynut and Kidneyshell (Morris 2006a), Northern Riffleshell, Snuffbox, Round Pigtoe, Mudpuppy Mussel and Rayed Bean (Morris and Burridge 2006) and Wavyrayed Lampmussel (Morris 2006b).

## TECHNICAL SUMMARY

***Truncilla donaciformis***
Fawnsfoot — Troncille pied-de-faon
Range of Occurrence in Canada :ON

**Demographic Information**

| | |
|---|---|
| Generation time (average age of parents in the population) | estimated 6-12 yrs |
| *Population trend and dynamics* | |
| Estimated percentage of reduction in total number of mature individuals over the last 3 generations. | Unknown |
| Projected percentage of reduction in total number of mature individuals over the next 10 years. | Unknown |
| Observed percentage reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future. | Unknown |
| Are the causes of the decline clearly reversible? | No |
| Are the causes of the decline clearly understood? | Yes |
| Are the causes of the decline clearly ceased? | No |
| Observed trend in number of populations | Decline |
| Are there extreme fluctuations in number of mature individuals? | No |
| Are there extreme fluctuations in number of populations? | No |

**Number of mature individuals in each population**

| **Population** | **N Mature Individuals** |
|---|---|
| Lake St. Clair | Unknown |
| Muskrat Creek | Unknown |
| Sydenham River | Unknown |
| Thames River | Unknown |
| Grand River | Unknown |

**Extent and Area Information**

| | |
|---|---|
| Estimated extent of occurrence (km²)<br>Area contained within a convex polygon drawn to include all confirmed occurrences. | Historical - 51,238;<br>Current - 24,952 km² |
| Observed trend in extent of occurrence<br>Decline by 51% | Decline |
| Are there extreme fluctuations in extent of occurrence? | No |
| Estimated area of occupancy (km²)<br>St. Clair delta – 4 $km^2$; Muskrat Creek – 4 $km^2$; Sydenham River – 4 $km^2$; Thames River – 112 $km^2$; Grand River – 4 $km^2$ | 128km² |
| Observed trend in area of occupancy | Decline |
| Are there extreme fluctuations in area of occupancy? | No |
| Is the total population severely fragmented?<br>Found in 5 widely separated locations. | Yes |
| Number of current locations<br>2 of the 5 locations are based on single specimens. | 5 |

| | |
|---|---|
| Trend in number of locations | Decline |
| Are there extreme fluctuations in number of locations? | No |
| Observed trend in area of habitat<br>Area, extent and quality of habitat have all declined. | Decline |

**Quantitative Analysis**

| | |
|---|---|
| Not available. | |

**Threats (actual or imminent, to populations or habitats)**

| |
|---|
| Dreissenid mussels have rendered much of the historical habitat in Lake St. Clair, the Detroit River and Lake Erie unavailable and pose a continuing threat to remaining populations in the St. Clair delta, Thames River and Grand River.<br><br>River fragmentation resulting from instream barriers and dams may restrict the upstream movement of the host species (believed to be freshwater drum), thereby limiting the available habitat.<br><br>Poor water quality resulting from rural and urban influences in the watersheds poses a threat as mussels in general are known to be sensitive to many aquatic pollutants. |

**Rescue Effect (immigration from an outside source)**

| | |
|---|---|
| Status of outside population(s)?<br>USA: No federal or state designations have been made although the Fawnsfoot is considered declining across its North American range and is ranked S3 or higher in 11 U.S. jurisdictions. | |
| Is immigration known or possible? | No |
| Would immigrants be adapted to survive in Canada? | Unknown |
| Is there sufficient habitat for immigrants in Canada? | No |
| Is rescue from outside populations likely? | No |

**Current Status**

| |
|---|
| COSEWIC: Endangered, April 2008 |

**Status and Reasons for Designation**

| | |
|---|---|
| **Status**: Endangered | **Alpha-numeric code**: A2ce; B2ab(i,ii,iii,iv,v) |
| **Reasons for Designation:**<br>This freshwater mussel is widely distributed in central North America, with the northern portion of its range extending into the Lake Erie, Lake St. Clair and lower Lake Huron drainages of southwestern Ontario. It appears to have always been a rare species in Canada, representing < 5% of the freshwater mussel community in terms of abundance wherever it occurs. Approximately 86% of historical records are in waters that are now infested with zebra mussels and therefore uninhabitable. Zebra mussels, which were accidentally introduced into the Great Lakes, attach to the shells of native freshwater mussels, causing them to suffocate or die from lack of food. The species has declined dramatically and has been lost from four historical locations resulting in a 51% reduction in its range. It is now found in only five widely separated locations, two of which represent single specimens. In two locations, the species' distribution may be limited by the presence of dams that restrict the movements of the frehswater drum, the presumed fish host of the juvenile mussels. Poor water quality resulting from rural and urban influences poses an additional continuing threat. | |

**Applicability of Criteria**

| |
|---|
| **Criterion A**: (Decline in Total Number of Mature Individuals):<br>Meets Endangered A2ce: A(2) Estimated population size reduction of >50% over the past 3 generations (~30 years, given that the average age of maturity for unionids is 6-12 years), where the main cause (impacts of zebra mussels, which began in 1986) may not have ceased and may not be reversible based on: (c) a decline in EO of ~ 51% from 51,238 $km^2$ historically to 24,952 $km^2$ at present and a decline in the quality/availability of habitat, and (e) the effects of introduced taxa (zebra mussels). |
| **Criterion B**: (Small Distribution Range and Decline or Fluctuation):<br>Meets Endangered B2ab(i,ii,iii,iv,v): B(2) AO < 500 $km^2$ (AO ~ 128 $km^2$) and:<br>(a) severely fragmented and known from < or = 5 locations (known from 5 widely separated locations), and (b)(i,ii,iii,iv,v) continuing decline projected in EO, AO, area, extent and quality of habitat, number of locations or populations and number of mature individuals (2 locations are based on single specimens; 3 locations, including the largest remaining population, are in areas where zebra mussels are established and represent a continuing threat). |
| **Criterion C**: (Small and Declining Number of Mature Individuals):<br>Does not apply because the number of mature individuals is unknown. |
| **Criterion D**: (Very Small Population or Restricted Distribution):<br>Meets D2 for Threatened: Known from only 5 locations, 2 of which are based on single specimens, 3 of which (including the largest remaining population) are in areas where zebra mussels are established and represent a continuing threat, and 2 of which may be limited in distribution by the presence of dams that restrict the movements of the presumed fish host. |
| **Criterion E**: (Quantitative Analysis):<br>Does not apply (no data available). |

## ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED


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## BIOGRAPHICAL SUMMARY OF REPORT WRITER

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

## COLLECTIONS EXAMINED

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

In 1996, all available historical and recent data on the occurrences of freshwater mussel species throughout the lower Great Lakes drainage basin were compiled into a computerized, GIS-linked database referred to as the Lower Great Lakes Unionid Database. The database is housed at Fisheries and Oceans Canada's Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario. Original data sources included the primary literature, natural history museums, federal, provincial, and municipal government agencies (and some American agencies), conservation authorities, Remedial Action Plans for the Great Lakes Areas of Concern, university theses and environmental consulting firms. Mussel collections held by six natural history museums in the Great Lakes region (Canadian Museum of Nature, Ohio State University Museum of Zoology, Royal Ontario Museum, University of Michigan Museum of Zoology, Rochester Museum and Science Center, and Buffalo Museum of Science) were the primary sources of information, accounting for over two-thirds of the initial data acquired. Janice Metcalfe-Smith personally examined the collections held by the Royal Ontario Museum, University of Michigan Museum of Zoology and Buffalo Museum of Science, as well as smaller collections held by the Ontario Ministry of Natural Resources. The database continues to be updated with new field data and now contains approximately 8200 records of unionids from Lake Ontario, Lake Erie, Lake St. Clair and their drainage basins as well as several of the major tributaries to lower Lake Huron. The majority of records in the database are now from recent (post-1996) field collections made by Fisheries and Oceans Canada, Environment Canada, provincial agencies, universities and conservation authorities. This database is the source for all information on Canadian populations of the Fawnsfoot discussed in this report.

The report writer has personally verified live specimens (Sydenham River, Thames River), shell vouchers (Muskrat Creek, Grand River) or digital vouchers (Lake St. Clair) from all populations described in this report.