Carney et al 2005

COSEWIC Status Report

on

the Mapleleaf mussel
Quadrula quadrula

prepared for

COMMITTEE ON THE STATUS OF ENDANGERED WILDLIFE IN CANADA

by

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EXECUTIVE SUMMARY

Species information

The mapleleaf, *Quadrula quadrula*, (Rafinesque, 1820) is a freshwater bivalve belonging in the family Unionidae. The shell is thick, quadrate in outline and ranges in colour from yellowish green through light brown to dark brown. Typically the species can be recognized by 2 rows of raised nodules extending in a v-shape from the umbo to the ventral margin. There are occasional deviations from this nodule pattern. Canadian specimens reach 125 mm in length, 100 mm in height and 50 mm in width. Interior of the shell is white with heavy hinge teeth.

Distribution

The type locality is the Ohio River. In the United States this species occurs throughout the Ohio-Mississippi drainages ranging from Texas to Alabama in the south to Minnesota and Pennsylvania in the north. Its distribution extends into the Great Lakes drainage in Minnesota and Wisconsin to New York and into the Red River drainage in Minnesota and North Dakota. In Canada this species is limited in Manitoba to the Red River and some tributaries, most notably the lower Assiniboine River, and in southern Ontario to larger rivers draining into Lake St. Clair and Lake Erie.

Habitat

Quadrula quadrula occurs in a variety of habitats ranging from medium to large rivers with slow to moderate current, lakes and reservoirs in mud, sand, or gravel substrates. In Manitoba *Q. quadrula* is most typically recovered from medium to large rivers in firmly packed coarse gravel and sand to firmly packed clay /mud substrate.

Biology

Quadrula quadrula is dioecious with little or no difference in shell morphology of the two sexes. Larvae, called glochidia, are brooded in the gills by the female and are parasitic on catfish species. Known fish hosts are the flathead catfish which does not occur in Canada, and the channel catfish which does occur in Canada. Development on the fish host requires approximately 50-60 days. During this time the larval mussel transforms to a juvenile, then drops off the fish host and grows to adult size and maturity. Like other freshwater mussels, *Q. quadrula* feeds on algae and bacteria filtered from the water column and substrate. *Quadrula quadrula* is a long-lived species with individuals from Manitoba living up to 64 and averaging 22 years of age.

Population sizes and trends

Although actual population sizes are estimated to range between 1-4 million in Manitoba, and approximately 5.5 million in Ontario, population densities are generally very low and appear to be in decline. Populations in Manitoba occur only in the Red River and the lower reaches of the Assiniboine and Roseau Rivers. Comparison with

historical records of distribution indicates overall that the freshwater mussel fauna in Manitoba is in decline. Where *Quadrula quadrula* does occur it is never abundant with many fresh empty valves indicating high levels of recent mortalities.

In Ontario *Quadrula quadrula* populations are restricted to a few rivers draining into Lake Erie and Lake St. Clair. Reports indicate that the mussel fauna in this region also is in decline with many species considered extirpated from areas they once occupied. Comparison with historical records indicates a reduction in the distribution of this species in Ontario. Recent studies indicate that *Q. quadrula* is considered to be rare in locations where it does occur and may be in decline, although it does appear to be increasing its distribution within the Sydenham River.

Limiting factors and threats

Like almost all North American freshwater mussels this species is threatened by habitat loss and degradation and the effects of invasive species, particularly the zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*) in Ontario. In both Manitoba and Ontario *Quadrula quadrula* occurs in areas that are heavily populated by people and that are affected by industrial and municipal pollution and agricultural runoff.

Special significance of the species

There are 20 recognized species in the genus *Quadrula* of which 1 species is considered extinct and 4 species are considered endangered in the United States. *Quadrula quadrula* and *Quadrula pustulosa* are the only species of the genus that extend into Canada, but only *Q. quadrula* occurrs in both Manitoba and southwestern Ontario. Canadian populations of *Q. quadrula* occur in the Great Lakes/St. Lawrence watershed (Ontario) and the Hudson Bay watershed (Manitoba). These are continental watersheds that are separate from this specie's main distribution in the Mississippi drainage. These Canadian populations may represent unique genetic and ecological entities important in conserving the diversity of the species.

Existing protection

The Mapleleaf is not specifically protected in Canada. *Quadrula quadrula* is considered to be stable in some states and critically imperiled in others, but in the majority of jurisdictions the species is unranked or ranks are under review.

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SPECIES INFORMATION

Name and classification

Scientific name: *Quadrula quadrula* (Rafinesque, 1820)
English common name: Mapleleaf
French common name: Mulette feuille d'érable

The current authority for the classification and scientific nomenclature of freshwater mussels in North America is Turgeon *et al.* (1998). The classification currently accepted is:

Phylum Mollusca
Class Bivalvia
Subclass Palaeoheterodonta
Order Unionoida
Superfamily Unionoidea
Family Unionidae
Subfamily Ambleminae
Genus *Quadrula*
Species *quadrula*

A complete list of synonymies and the nomenclatural history for *Quadrula quadrula* is provided by Parmalee and Bogan (1998).

Morphological description

The mapleleaf (*Quadrula quadrula*) is a medium to large freshwater mussel species that can be recognized by 2 bands of nodules radiating in a V-shape from the umbo to the ventral margin (Fig. 1). One band is located centrally and the other is located on the posterior ridge. The rows are separated by a shallow groove. The accompanying species description has been adapted from Clarke (1981), Cummings and Mayer (1992), Parmalee and Bogan (1998), Graf and Ó'Foighil (2000), Cicerello and Schuster (2003), Haag and Staton (2003) and Hay *et al.* (2003). Morphology of Canadian specimens consistent with the range of variation reported from American specimens. Conchological morphology of sexes alike. Shell is thick, moderately inflated, quadrate in outline. Anterior end rounded, posterior end squared or truncated. Umbos are small and slightly raised above the hinge line. Umbo sculptured; double loops or zigzags that radiate to ventral margin as 2 rows of raised nodules. Nodules on the umbo are small and crowded, generally eroded on older specimens. Nodules distal to umbo may be elongated or rounded. Nodules radiating from umbo separated by a wide, shallow sulcus or furrow. One row is centrally located, the other posterior. Occasional variations in nodule patterns range from small nodules scattered over shell surface to absent (Neel 1941). Periostracum variable, ranging from yellowish green to light brown in young individuals, older individuals ranging from greenish brown through dark brown.

Annual growth lines on the shell surface are obvious and well defined, especially in younger individuals; can be crowded and difficult to distinguish at the shell margin of older individuals.

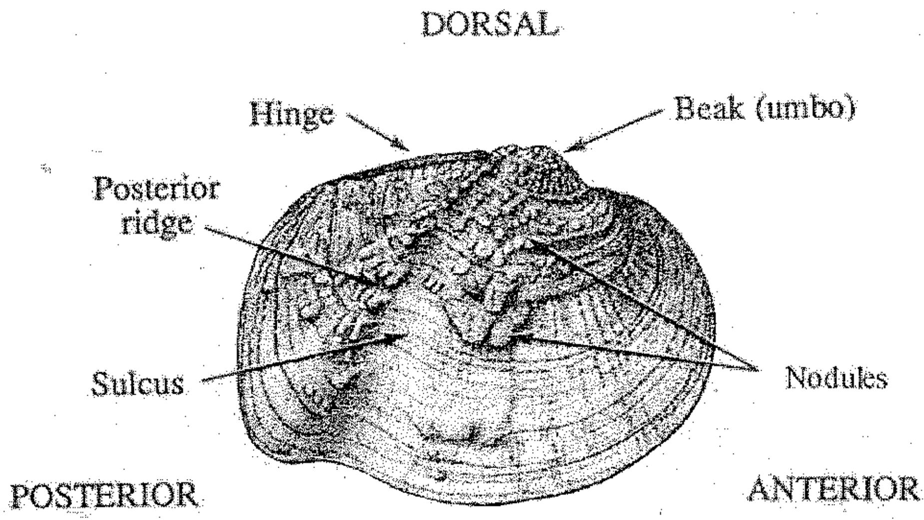

Figure 1. Diagrammatic line drawing showing *Quadrula quadrula* external shell morphology (after Cummings and Mayer 1992, permission pending).

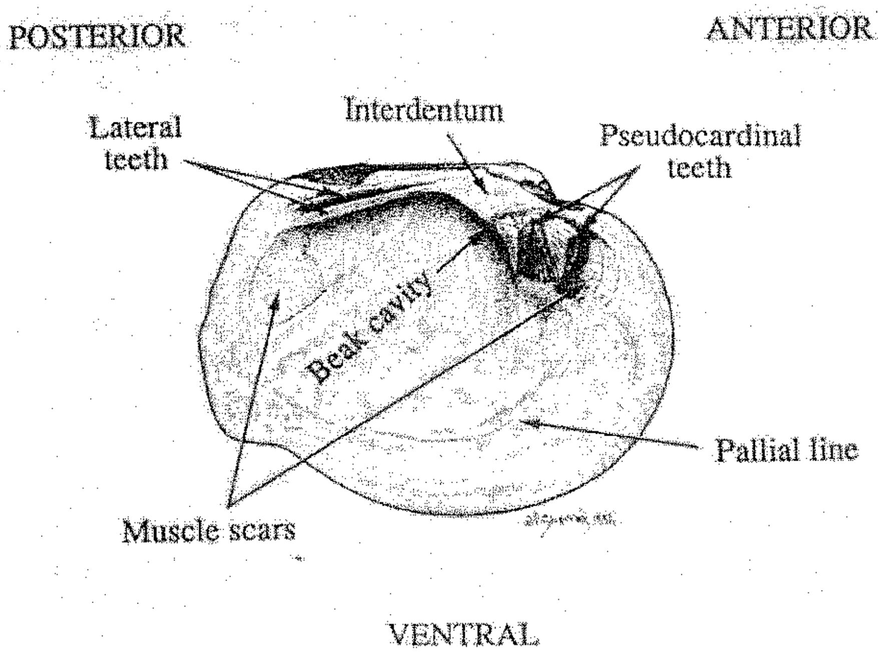

Figure 2. Diagrammatic line drawing showing *Quadrula quadrula* left valve internal shell morphology (after Cummings and Mayer 1992, permission pending).

Pseudocardinal teeth are well developed, vertically elongated and serrated; two in the left valve, one in the right (Fig. 2). Pseudocardinal tooth in the right valve heavy, thick and triangular. Pseudocardinal teeth in left valve rough, solid and sometimes joined dorsally. Two lateral teeth in the left valve; erect, fairly long and straight, may be serrated. Single lateral tooth in the right valve: high, long and straight, may be serrated. Interdentum is wide. Beak (umbo) cavity is deep but open. Nacre is white and iridescent posteriorly.

Parmalee and Bogan (1998) report mature *Quadrula quadrula* reaching 120 mm in length. In Canada Clarke (1981) reports Q. *quadrula* reaching 125 mm in length, 100 mm in height and 50 mm in width. In Manitoba, individuals have been recorded up to 121 mm in length, 88 mm in height and 52 mm in width (Carney 2003a).

In Ontario *Quadrula quadrula* is most similar to *Quadrula pustulosa*. The two can be distinguished as follows. *Quadrula quadrula* has nodules restricted to two bands whereas they are scattered and more uniformly distributed on Q. *pustulosa*. *Quadrula quadrula* is quadrate in outline whereas Q. *pustulosa* is rounded in outline. There are no other mussels in Canada with which Q. *quadrula* can be confused.

The following description of soft-tissue morphology is derived from Lydeard *et al.* (1996) and Graf and Ó'Foighil (2000). *Quadrula quadrula* uses all four gill demibranchs as marsupia. Interlamellae of gill demibranchs connected by complete septa. Marsupial water tubes undivided, not tripartite. No swelling of marsupial interlamellar septa into water tubes. Margin of gravid marsupium sharp. Ventral margin of marsupium does not extend beyond non-marsupial portion of gill. Mantle ventral to incurrent siphon simple, not modified with papillae or lure-like elaborations.

Genetic description

Genetic approaches to freshwater mussel systematics is a growing area of research and many of the reported conclusions depend on the species included, the geographic scale from which specimens are collected, the type of genetic data examined and how those data are analyzed. Genetic approaches include allozyme electrophoresis (Davis *et al.* 1981; Berg *et al.* 1998), analysis of restriction fragment length polymorphisms (RFLP) (White *et al.* 1996), and analyses of gene sequence data from the nuclear and mitochondrial genomes (Lydeard *et al.* 1996; Graf and Ó'Foighil 2000; Serb *et al.* 2003). Gene sequences investigated have been derived from NADH dehydrogenase (NDI) gene, cytochrome *c* oxidase subunit I (COI) gene, 16S rRNA, and 28S rDNA and have been used to address questions pertaining to character evolution, species identification, phylogeography and systematic relationships across a range of taxonomic scales.

Genetic information specific to *Quadrula quadrula* are scattered and have been used to address questions relating to higher level Unionidae phylogenetic relationships, or questions including the evolution of specific traits such as reproductive characters (e.g. Davis and Fuller 1981; Lydeard *et al.* 1996; Graf and Ó'Foighil 2000). For example, Serb *et al.* (2003) used the mitochondrial ND1 gene to assess the molecular systematics of the genus *Quadrula*. Their results indicated the genus was monophyletic only if *Tritogonia verrucosa*, '*Fusconaia*' *succissa* and '*Quincuncina*' *infucata* were included in the genus. They also revealed that *Q. quadrula* is not monophyletic but may form a species group that includes *Q. rumphiana, Q. apiculata* and *Q. nobilis* (Serb *et al.* 2003). However, they were able to demonstrate repeated geographic structuring especially in the *quadrula* species group and predicted that phylogeographic studies would result in populations being differentiated by drainage. A study by Krebs *et al.* (2003) using a fragment of the mitochondrial 16S rRNA gene supported the idea that *Q. quadrula* may not be monophyletic. They (Krebs *et al.* 2003) found that an individual *Q. quadrula* from the Lake Erie drainage was more similar to *Q. apiculata* than to a *Q. quadrula* from a southern location. Krebs *et al.* (2003) also reported that *Q. quadrula* had a higher degree of molecular variation than the other unionid species they investigated.

These gene sequence data are generally not presented in a way that allows assessments of population genetic structure, population variation and gene flow between and among populations. There are however some allozyme data available specific to these questions for *Quadrula quadrula.*

Davis (1984) and Johnson *et al.* (1998a, b, c) using allozyme electrophoresis described genetic variation in populations of *Quadrula quadrula* from Wisconsin and Arkansas, respectively. They described similar alleles per locus (1.6) and mean polymorphism (0.35-0.36) for these populations (Table 1). Mean heterozygosity was almost double in the Wisconsin populations relative to the Arkansas populations. The data are in contrast to those reported by Berg *et al.* (1998) who investigated allozyme variation in *Q. quadrula* populations from Ohio and the lower Mississippi and found much higher values for mean polymorphism, mean heterozygosity and alleles per locus than reported by Davis (1984) and Johnson *et al.* (1998a, b, c) (Table 1). Berg *et al.* (1998) also reported much lower values for F_{st} and Nei's genetic distance than reported by Johnson *et al.* (1998a, b). The genetic distance data indicate there is very little genetic variation among the *Q. quadrula* populations examined by Berg *et al.* (1998) despite being separated by up to 2000 km of river. Berg *et al.* (1998) suggested this may be a consequence of high gene flow resulting from using a highly vagile host for the glochidia.

Recent data have become available analyzing Cytochrome Oxidase I gene region of the mitochondrial genome of *Quadrula quadrula* populations from regions in the United States and from Manitoba and Ontario (Levine, email comm.) (Figure 3). Preliminary analysis of these data reveals that the Manitoba and Ontario populations share the majority of their haplotypes with some populations in the United States, suggesting the Canadian populations are subsets derived from the American populations. Both the Manitoba and Ontario populations appear to have low genetic diversity. However, both populations respectively have haplotypes that are unique and not shared with any other region. This indicates there is unique genetic information in each of the Manitoba and Ontario populations.

It is clear that data derived from allozymes and data derived from gene sequences are not always in agreement. Allozymes suggest little genetic variability in *Quadrula quadrula* whereas gene sequence data indicate high variability, possibly more than one species and phylogeographic structuring. In many cases the number of individuals sampled is very small (e.g. n = 1; Krebs *et al.* 2003) and the geographic coverage is limited. The majority of available data are from the Mississippi drainage (but see Krebs *et al.* 2003) with few data from the Great Lakes/St. Lawrence drainage or from the Red River/Hudson Bay drainage. Clearly there is a pressing need for a more comprehensive continental coverage of the genetic structure of these taxa that includes larger sample sizes.

Table 1. Genetic data for some North American populations of *Quadrula quadrula*.

Author	Mean Polymorphism	Mean Heterozygosity (H)	Alleles per locus	F_{st}	Nei's Genetic Distance
Davis (1984) (Wisconsin)	0.357	0.112	1.6	n/a	n/a
Berg *et al.* (1998) (Ohio & Mississippi)	0.614	0.24	2.1	0.031	0.009
Johnson *et al.* (1998a, b) (Arkansas)	0.360	0.058	1.6	0.108	0.333

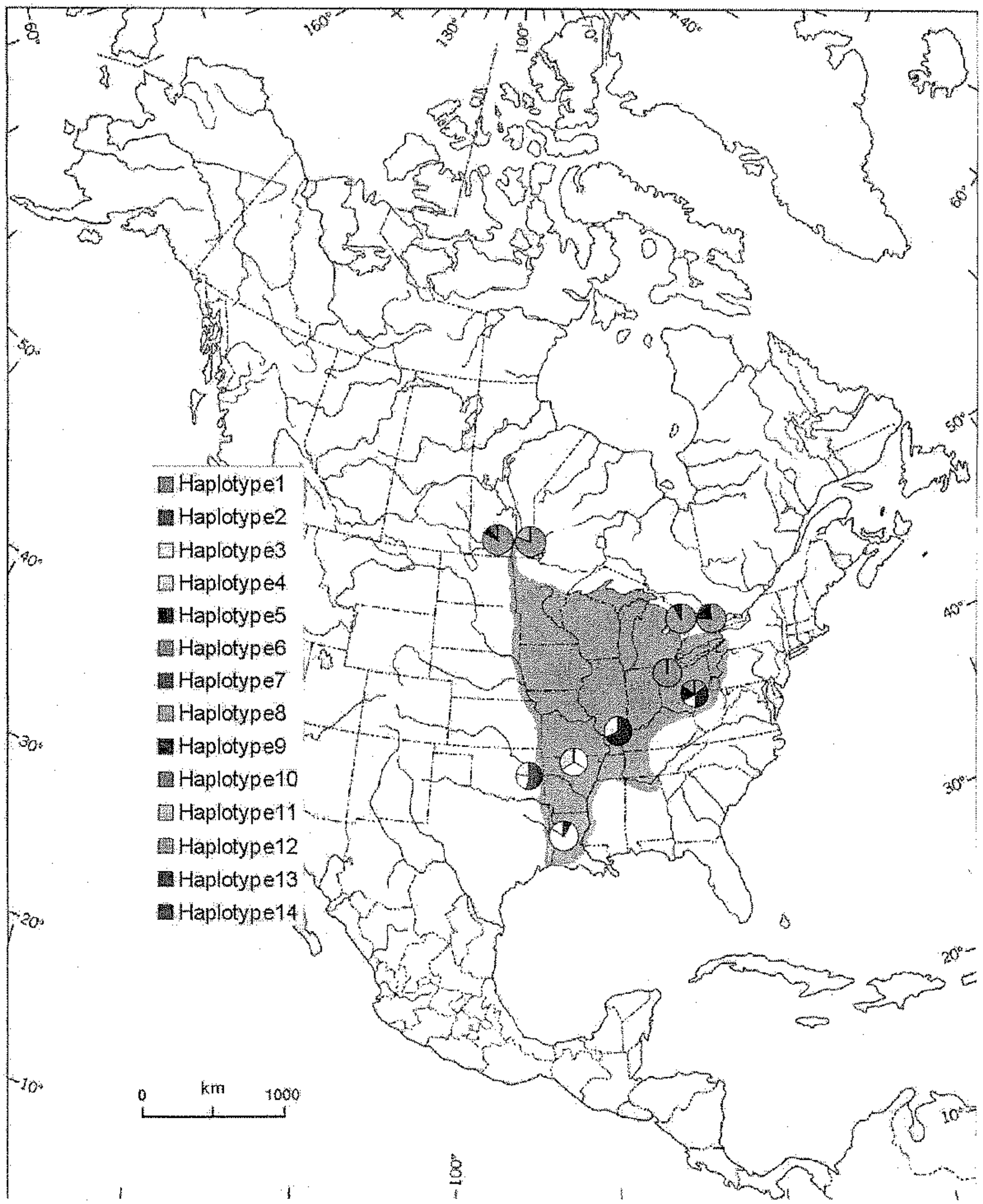

Figure 3. Haplotype distributions for *Quadrula quadrula* populations determined from the cytochrome oxidase I gene of the mitochondrial genome. Shaded area indicates the North American distribution of *Q. quadrula* (derived from Parmalee and Bogan 1998).

Designatable units

COSEWIC recognizes units below the species level based on taxonomically recognized subspecies or varieties; genetic distinctiveness; separation of units by range disjunction; and presence in biogeographically different ecoregions. The populations of *Quadrula quadrula* in Ontario and Manitoba merit distinction as separate designatable units according to the criteria outlined by COSEWIC. First, they can be recognized as being genetically distinct. Despite being low in genetic diversity and the majority of individuals sharing a haplotype common throughout North American populations, each population has haplotypes unique to each population. Manitoba populations have 3 distinct haplotypes and Ontario populations have 2 distinct haplotypes. Second, they are units separated by a major range disjunction. The Manitoba populations are part of the Hudson Bay watershed and the Ontario populations are part of the Great Lakes-St. Lawrence watershed. As aquatic organisms they are limited to dispersal only within these continental scale watersheds. Effectively this means they are disjunct from each other and from other North American *Q. quadrula* populations in the Ohio-Mississippi watershed in the United States and dispersal among these watersheds is not possible. Third, they occupy biogeographically distinct different eco-geographic regions. The Manitoba populations occupy the Saskatchewan-Nelson National Ecological Freshwater Area whereas the Ontario populations Great Lakes-Western St. Lawrence Ecological Area. As such, these populations meet 3 of the 4 criteria outlined by COSEWIC for recognition as distinct designatable units.

DISTRIBUTION

Global range

Quadrula quadrula is distributed throughout the Ohio-Mississippi River drainages extending southeast to Louisiana, southwest to eastern Texas and northwest to Minnesota (Clarke 1981; Parmalee and Bogan 1998). Present in the Red River drainage in North Dakota, Minnesota and Manitoba (Clarke 1981; Cvancara 1983). In the Great Lakes drainage it has been recorded from the Lake Erie and Lake St. Clair drainages. In the United States *Q. quadrula* has been reported from the states of Alabama, Arkansas, Iowa, Illinois, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Missouri, Mississippi, North Dakota, Nebraska, New York, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Wisconsin and West Virginia (Parmalee and Bogan 1998; www.natureserve.org. accessed 26 November 2004).

Canadian range

In Canada, *Quadrula quadrula* has been reported only from Manitoba and Ontario (Fig. 4). In Manitoba *Q. quadrula* has been recorded from the Assiniboine River, Red River and the Roseau River. In Ontario *Q. quadrula* has been reported from Lake St.

Clair and western Lake Erie and tributaries including the Sydenham, Ausable, Grand, Maitland, Thames Rivers and others.

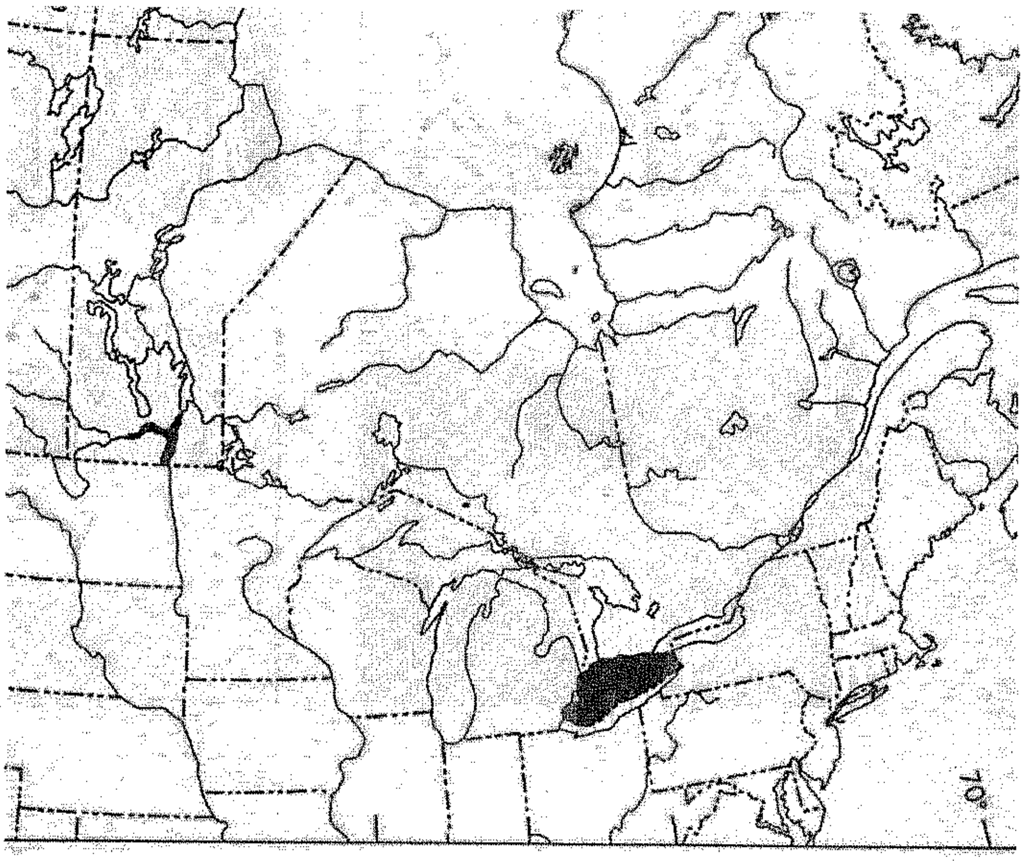

Figure 4. Distribution of *Quadrula quadrula* in Manitoba and Ontario.

Distribution of the Mapleleaf in Ontario

The National Water Research Institute's Lower Great Lakes Unionid Database was used to identify occurrence records for *Quadrula quadrula* in Ontario. The database is continually updated with the results of new surveys by Janice Metcalfe-Smith and her team as well as surveys elsewhere in Ontario by other organizations such as the Department of Fisheries & Oceans' Great Lakes Laboratory for Fisheries and Aquatic Sciences and the Eastern Ontario Biodiversity Museum. At the time of writing the database consisted of approximately 8200 records for 40 species collected from nearly 2500 sites throughout the Lake Ontario, Lake Erie, Lake St. Clair and lower Lake Huron drainage basins since 1860. For a detailed description of the database and its historical data sources, see Metcalfe-Smith *et al.* (1998a).

The Mapleleaf was historically collected from the Detroit, Sydenham, Thames, Grand, Welland and Niagara Rivers as well as Lake Erie and Lake St. Clair. The earliest known records of the species in each of these waterbodies was as follows: between the 1880s and 1930s by various surveyors for the Detroit River (Schloesser et al. submitted), 1963 by H.D. Athearn for the Sydenham River near Shetland, 1894 by J. Macoun for the Thames River near Chatham, 1885 by J. Macoun for the Grand River near Cayuga, 1983 by D.J. Berg for the Welland River in Welland, 1934 by J.P. Oughton for the Niagara River, 1894 by J. Macoun for Lake Erie at Rondeau Bay, and 1965 by C.B. Stein for Lake St. Clair near the mouth of the Thames River. Figure 5 shows the historical distribution of the Mapleleaf in Ontario based on 78 records collected between 1885 and 1994. The current distribution of the species is shown in Figure 6 and is based on 43 records (live animals and shells) collected between 1995 and 2004. Live specimens were most recently collected from the Ausable River, lower Lake Huron drainage, in August, 2004.

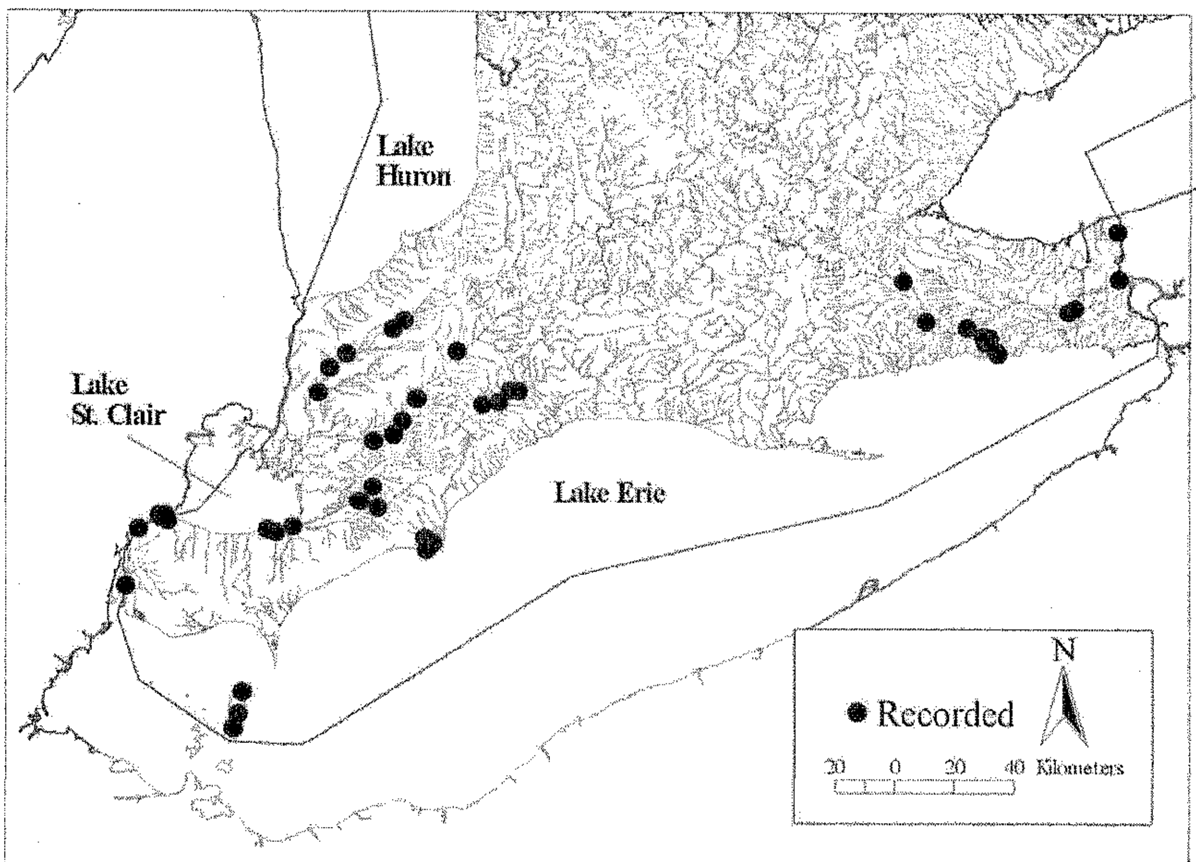

Figure 5. Historical distributions of *Quadrula quadrula* in Ontario based on records and

surveys prior to 1995 reported in the Lower Great Lakes Unionid database.

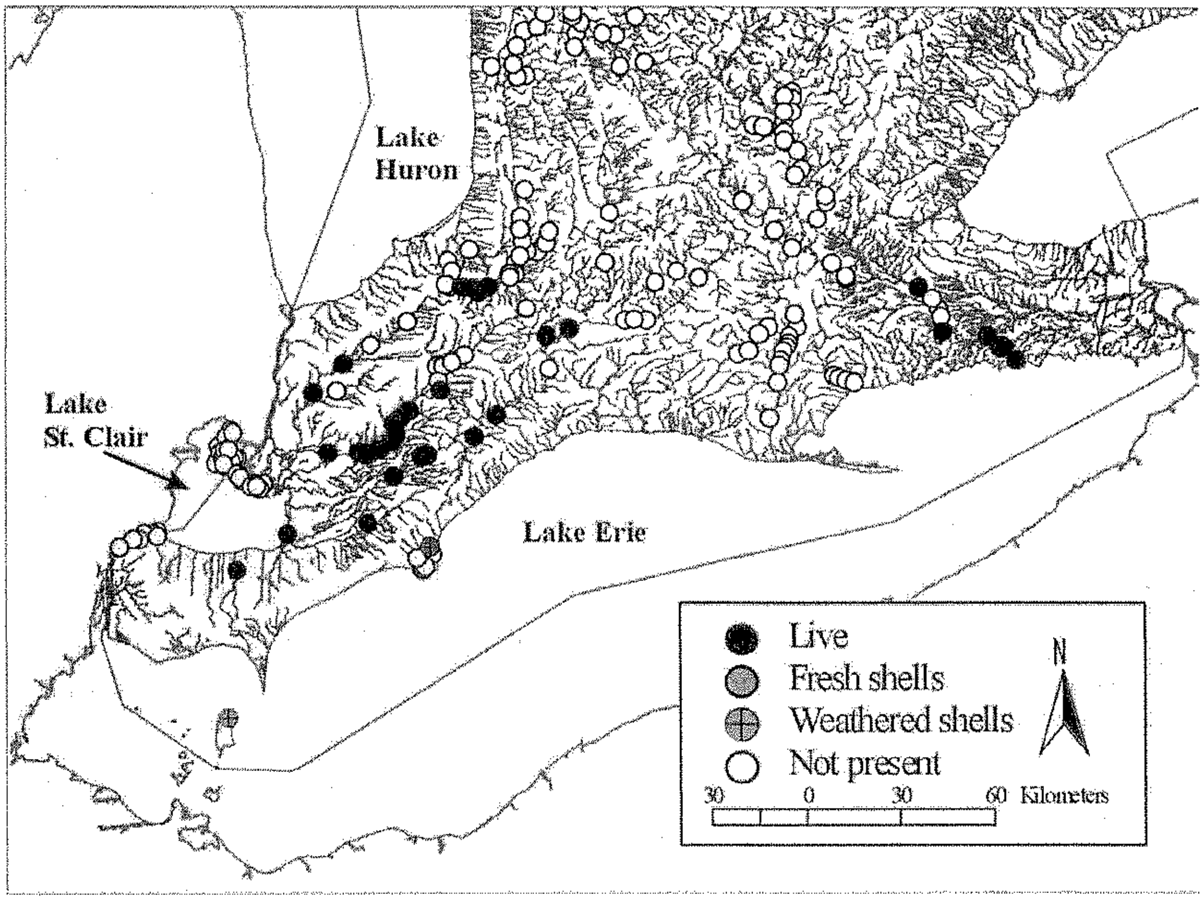

Figure 6. Current distributions of *Quadrula quadrula* in Ontario based on records and surveys from 1995-2003 reported in the Lower Great Lakes Unionid database.

Populations of *Quadrula quadrula* and other species of freshwater mussels in the Canadian and U.S. waters of the lower Great Lakes and connecting channels have been almost entirely lost due to the impacts of dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*). Small isolated populations can still be found in some nearshore areas where densities of dreissenids have remained low (e.g., Nichols and Wilcox 1997; Zanatta *et al.* 2002). In the Detroit River, less than 10% of the unionid population and only 13 of 24 species present prior to the dreissenid invasion survived to 1994 (Schloesser *et al.* 1998). Only 5 live mussels were found during follow-up surveys at several sites in 1998 (Schloesser *et al.* submitted) and none were *Q. quadrula*. Nalepa *et al.* (1996) surveyed 29 sites in the offshore waters of Lake St. Clair in 1986, 1990, 1992 and 1994. *Quadrula quadrula* was found alive at one site in U.S. waters in both 1986 and 1990 but not during later surveys. Gillis and Mackie (1994) surveyed an area off the mouth of the Puce River on the southwestern shore of Lake St. Clair between 1990 and 1992. The number of species found declined from 11 in 1990 to 4 in 1991 and no live mussels were found in 1992. They did not find any *Q. quadrula* during their surveys. Zanatta *et al.* (2002) surveyed 95 sites in nearshore areas around Lake St. Clair between 1999 and 2001 and found one *Q. quadrula* at a site near the mouth of the Thames River in 1999. Metcalfe-Smith *et al.* (2004) surveyed 28 sites in Canadian and U.S. waters of the Lake St. Clair delta in 2003 and did not find any live *Q. quadrula. Quadrula quadrula* was reported from Rondeau Bay on the north shore of Lake Erie in 1894 and 1961, but only old weathered shells were found during a survey in 2001 (D.T. Zanatta, unpublished data). There are records for *Q. quadrula* from Pelee Island in 1962, 1978 and 1985 and shells were collected in 1992. Although there have been no further surveys around Pelee Island, 19 sites around the nearby Bass Islands (U.S. waters) were surveyed in 1998 and no live unionids were found (Ecological Specialists 1999). One site on South Bass Island had supported 27 live species of mussels in 1960. There are two historical records for *Q. quadrula* from the Niagara River. Thirteen sites were surveyed in 2001 for the New York Power Authority. Old shells of 16 species were found and one site had living animals of 3 species; unfortunately, the consultant who did the survey was unable to disclose the names of the species found alive (K. Schneider, Stuyvesant Falls, NY, pers. comm., November 2002). There are no recent data available for the Welland River.

According to Metcalfe-Smith *et al.* (2003), the Mapleleaf has been encountered more frequently in the Sydenham River during recent surveys than in the past. It was found at 56% of 16 sites surveyed in 1997-1999 vs. 30% of 23 sites surveyed in the same reaches between 1929 and 1991. Intensive survey work on the Sydenham River has continued and by the end of 2004 a total of 18 sites had been sampled semi-quantitatively and 15 sites quantitatively (13 sites were sampled using both techniques). New data have extended the known range of *Quadrula quadrula* further downstream in the east branch of the river, but the range of this species may have contracted in the north branch (Metcalfe-Smith and Zanatta 2003; Metcalfe-Smith *et al.*, unpublished data).

There are only scattered historical records available for mussels in the Thames River. However, the Mapleleaf was reported from several locations in the middle and lower reaches in 1894, 1934, 1963, 1973, 1985 and 1991-92. The river has been extensively surveyed in recent years. Morris (1996) surveyed 30 sites in 1994, focusing on the smaller tributaries, and found *Quadrula quadrula* at one site on McGregor Creek in Chatham. Metcalfe-Smith *et al.* (1998b, 1999) surveyed 16 sites, mainly on the main stem, in 1997-98 and observed the species at 7 sites in the lower part of the watershed. Finally, Morris surveyed 25 sites in the Upper Thames River above Delaware in 2004 and did not find the Mapleleaf at any site (T.J. Morris, Department of Fisheries and Oceans, Burlington, ON, unpublished data). The available data do not indicate any change over time in the distribution of the Mapleleaf in the Thames River.

The Grand River is one of the best-studied watersheds for mussels in Ontario, with nearly 1000 records available from 1885-2004. Collections have been made in nearly every decade. Major surveys were conducted in 1970-72 (68 sites, Kidd 1973) and in 1995 and 1997-98 (94 sites, Metcalfe-Smith *et al.* 2000a). There have been no changes over time in the distribution of the Mapleleaf in the Grand River; it has always occurred in the lower 50 km of the river between Caledonia and Port Maitland.

Detweiler (1918) surveyed the Ausable River in 1916 primarily for thick-shelled species that could be used in the pearl button industry. There are also records from 1929 and 1950 for a site near Hungry Hollow in the lower portion of the watershed and Morris and Di Maio (1998-1999) surveyed 6 sites on the river in 1993-94. The Mapleleaf was not among the 14 species found during these surveys. Metcalfe-Smith *et al.* (unpublished data) surveyed 25 sites throughout the river from 1998-2004 and found 23 species of mussels alive including *Quadrula quadrula* which was restricted to 4 sites in a short stretch of the lower main stem of the river. It is unlikely that the Mapleleaf ever occurred in the lower Lake Huron drainage north of the Ausable River. It was not among 7 species found by Morris and Di Maio (1998-1999) during surveys of 6 sites on the Saugeen River in 1993-94 nor was it among 11 species found by Metcalfe-Smith *et al.* (unpublished data) during surveys of 21 sites on the Maitland River in 1998-2004.

Overall, *Quadrula quadrula* has been lost from approximately 49% of its former range (in terms of extent of occurrence) in Ontario, with virtually all of this loss occurring in the Great Lakes and connecting channels. The current extent of occurrence (EO) is approximately 12,500 km^2 as compared with 24,500 km^2 historically. The current area of occupancy (AO) is approximately 35.2 km^2 (Table 2).

Table 2. Current Area of Occupancy (AO) for all known populations of *Quadrula quadrula* in Ontario.

River	Length of occupied reach (km)	Mean width of reach (m)	Area of Occupancy (km^2)
Ausable	17	17	0.29
North Sydenham	25	6.5	0.16
East Sydenham	60	20	1.20
Thames	110	80	8.80
Grand	55	450	24.75
TOTAL AO			35.2

Distribution of the Mapleleaf in Manitoba

There are few historical records for *Quadrula quadrula* in Manitoba. Clarke (1973) summarized the history of malacological research in the Canadian Interior Basin as well as results from investigations into Mollusc distributions undertaken from 1959-1969. During this time, surveys within Manitoba were conducted for 7 years. A total of 103 stations were examined and approximately 15,310 specimens representing 13 species were collected. Sampling methods included visual search in clear water, by using a glass bottomed viewing box, and feeling by hand. This indicates collecting was done close to shore in water that would not exceed waist deep (approximately 1m). Pip (pers. comm., 2000), from 1961 to present, was investigating freshwater molluscs in Manitoba and recorded the presence of freshwater mussels at a variety of sites along the Assiniboine River, tributaries of the Red River and Lake Winnipeg. These 2 sources, with the contribution of a single study by Scaife and Janusz (1992), provide the bulk of information for the historical distribution of *Quadrula quadrula* in Manitoba.

Results summarized by Clarke (1973) indicate that, within the Hudson Bay drainage, *Quadrula quadrula* was distributed within the Red River and lower reaches of larger tributaries of the Red River such as the Assiniboine and Roseau rivers in Manitoba (Figure 7), Red Lake River in Minnesota and the Pembina and Sheyenne rivers in North Dakota. Within the boundaries of Manitoba, Clarke (1973) records *Q. quadrula* from the Red River at St. Jean Baptiste and Aubigny and reports additional historical records from the Red River at Fort Garry, Winnipeg and Emerson. *Quadrula quadrula* was also collected from the Assiniboine River in and near Winnipeg and from the Roseau River near Tolstoi. Data recorded by Pip (pers. comm.) extend the distribution to the length of the Assiniboine River from Lake of the Prairies to Winnipeg and from sites on the Shell, Rat, Morris, Seine and LaSalle Rivers and from Lake Winnipeg. With the exception of the lower Assiniboine near Winnipeg, these are locations from which *Q. quadrula* has not previously, or subsequently, been observed (Clarke 1973, Watson *et al.* 1998, Carney 2003a, unpublished data), The study reported by Scaife and Janusz (1992) in the Assiniboine River near Winnipeg, recorded *Q. quadrula* well within the distribution established by both Clarke (1973) and Pip (pers. comm.). Taken in concert, it seems reasonable to conclude that the historical distribution of this species was limited to the Red River and the lower reaches of its tributaries, the Assiniboine River, and Lake Winnipeg.

Recent investigations into the freshwater mussel fauna of Manitoba indicate a decline in the distribution of *Quadrula quadrula*. Watson *et al.* (1998) and Carney (2003) report *Q. quadrula* from the lower Assiniboine River, in the stretch below the Portage Diversion, a large water control dam located at Portage la Prairie that diverts water from the Assiniboine River north to Lake Manitoba. Watson *et al.* (1998) surveyed 18 sites on 157 km of the Assiniboine River between Portage la Prairie and Winnipeg and recovered *Q. quadrula* from 4 sites. Watson *et al.* (1998) searched an additional 167 sites on 15 rivers draining into the Assiniboine River and encountered no evidence of *Q. quadrula* at any of these sites. Carney (2003, 2004a, b) surveyed 67 sites on 10 rivers and recovered live *Q. quadrula* from only some sites on the lower Assiniboine River. In addition, Carney (2003) collected a single, small individual approximately 50 km upstream of the Portage Diversion. This represents the only recent documented case of *Q. quadrula* upstream of the Portage Diversion. Extensive subsequent surveys from the Portage Diversion upstream to the Shellmouth Reservoir have not encountered any other individuals of this species (Carney unpublished data). In 1992 live *Q. quadrula* were recovered from the Roseau River (Carney, unpublished data), but not in the surveys conducted in 2003-2004. Carney (2004a) encountered no live *Q. quadrula* from the same sites along the Red River investigated by Clarke (1973) although there was ample evidence of fresh-dead individuals stranded due to low water levels in 2003. In 2004 Carney and Watkins (unpublished data) investigated sites along the Red River south of Winnipeg, including those reported by Clarke (1973), and found no live *Q. quadrula*. They did find half a dozen highly weathered empty valves. Recent surveys by Pip (pers. comm.) throughout Lake Winnipeg have found no evidence of *Q. quadrula*.

These data collectively indicate that the present distribution of *Quadrula quadrula* is limited to confirmed populations scattered throughout the lower Assiniboine River. Populations in the Assiniboine appear to occur as assemblages of a few widely separated individuals separated by long stretches of river bottom composed of drifting sand that is completely unsuitable habitat. It is likely that populations persist in the Red River based on the historical record, river size and current lack of extensive search effort. It is unknown if populations persist in the Roseau. Recent investigations have not recovered evidence of this species in this river at sites where it has been reported. However, the limited amount of search effort on this river, and low mussel densities cannot preclude the presence of *Q. quadrula* in the Roseau River.

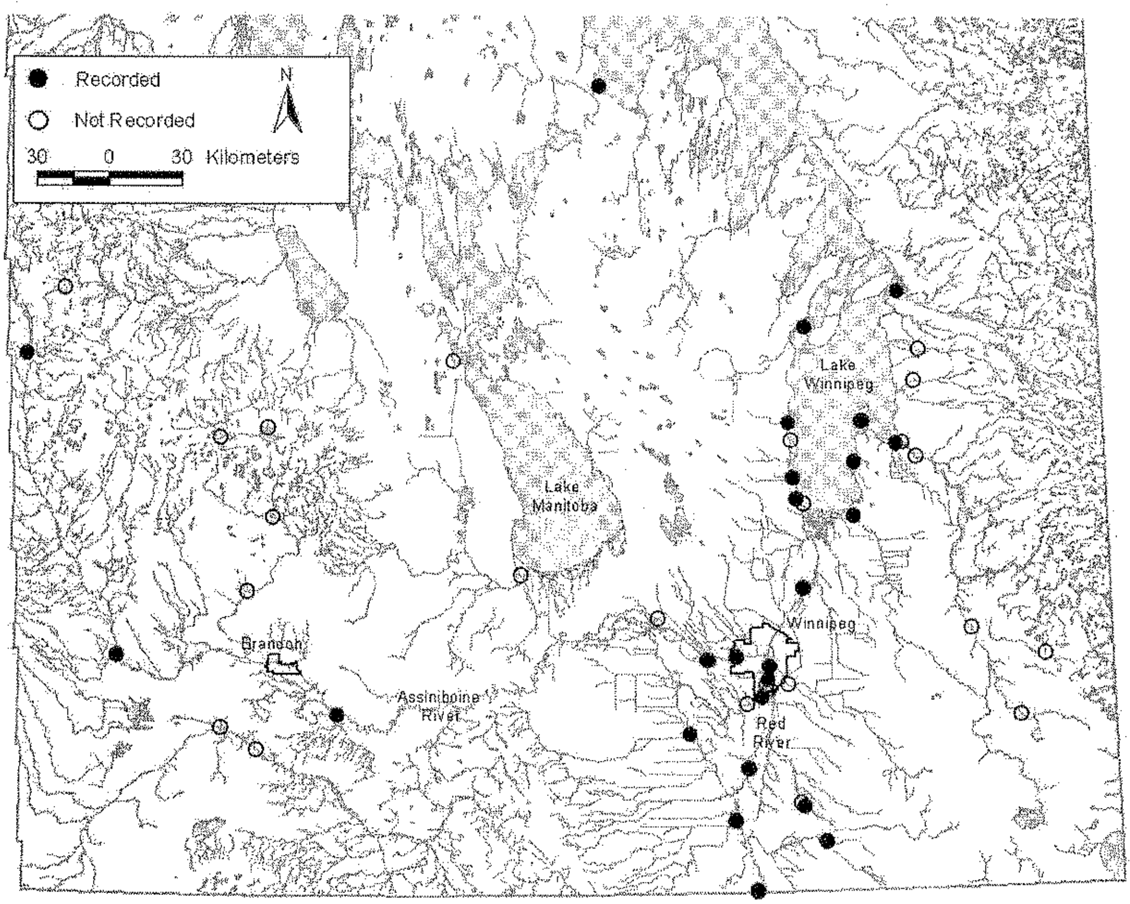

Figure 7. Historical distributions of *Quadrula quadrula* in Manitoba based on records

and surveys prior to 1992 reported by Clarke (1973) and Pip (pers. comm.).

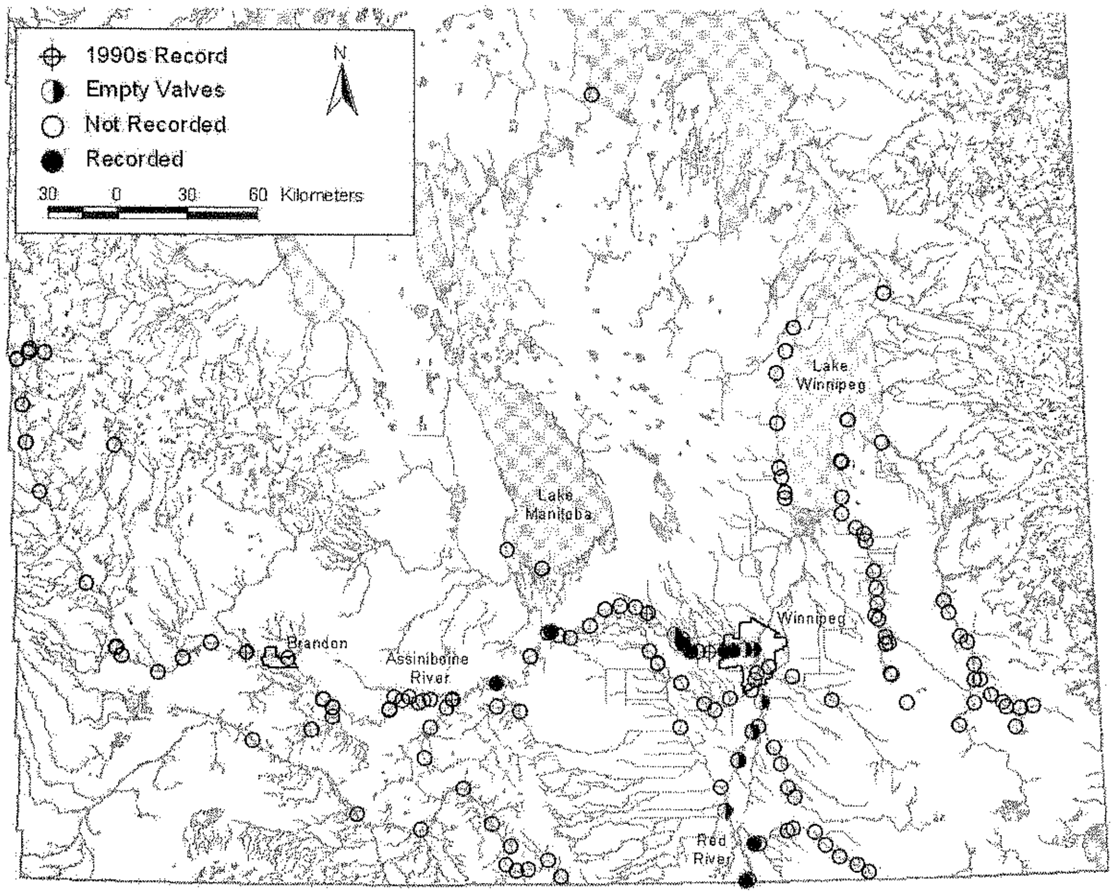

Figure 8. Current distributions of *Quadrula quadrula* in Manitoba based on surveys from 1992-2004 reported by Scaife and Janusz (1992), Watson et al. (1998), Carney (unpublished, 2003a, 2004, b), Pip (pers. comm.) and Watkins (unpublished). Symbol for 1990s record indicates sites where *Q. quadrula* were recorded between 1995 and 1999 but not in surveys in 2002 and 2003.

The current distribution has declined by comparison to that recorded historically (Clarke 1973; Pip pers. comm.). The current extent of occurrence is approximately 11,500 km^2. The current area of occupancy is estimated to be 29.14 km^2 (Table 3). This should be considered an upper boundary because it assumes there are still populations in the Roseau and that the single individual collected above the Portage Diversion was not vagrant, and that the Red River still harbours populations.

Table 3. Current Area of Occupancy (AO) for all known populations of *Quadrula quadrula* in Manitoba.

River	Length of occupied reach (km)	Mean width of reach (m)	Area of Occupancy (km^2)
Assiniboine (above Portage diversion)	50	50	2.5
Assiniboine (below Portage diversion)	150	50	7.5
Red	242	75	18.15
Roseau	99	10	0.99
TOTAL AO			29.14

HABITAT

Habitat requirements

Quadrula quadrula is found in a variety of habitats, including medium to large rivers with slow to moderate current, big river embayments, shallow lakes and in deep river impoundments. It has been recorded from mud, sand, and gravel substrates. Preferred substrates have been reported as sand and fine gravel (Parmalee and Bogan 1998) to mud and sand (Clarke 1981). This variability likely reflects the adaptability of this species to particular habitats and a variety of substrates. In Manitoba *Q. quadrula* is most typically recovered from medium to large rivers in firmly packed coarse gravel and sand to a substrate of firmly packed clay /mud. *Quadrula quadrula* is usually recovered at the surface of the substrate in the "tombstone" position with its posterior margins exposed to the water current and the anterior firmly embedded in the substrate.

Habitat trends in Ontario

The invasion of the Great Lakes by the zebra mussel began in 1986 and resulted in the near extirpation of native mussels from Lake Erie, Lake St. Clair and the Detroit and Niagara Rivers by the mid-1990s. Only isolated communities with reduced species richness and low abundance still survive in several bays and marshes along the U.S. shore of Lake Erie and in the delta area of Lake St. Clair. As the Mapleleaf has always been rare in these waters, the loss of habitat is less significant for this species than for many other unionids.

Mussel communities in the Grand River declined dramatically from a historical total of 31 species to only 17 by the early 1970s. Kidd (1973) blamed this decline on pollution, siltation and the presence of dams. He found few mussels living below dams or in reservoirs and noted that none of the dams had fishways. He also found that dissolved oxygen concentrations were low and turbidity was high in the lower reaches of the river, most likely due to agricultural runoff. Sewage pollution was probably the major cause of the decline of mussels in this river. At the time of Kidd's surveys, only 7 of the river's 22 sewage treatment plants (STPs) had had secondary treatment for 10 years, 7 others had upgraded from no treatment to secondary treatment during that time and the remaining 8 were in the process of installing treatment facilities for the first time. Twenty-five years later, Metcalfe-Smith *et al.* (2000a) found that the mussel communities of the river had rebounded – most likely in response to significant improvements in water quality. Unfortunately, this trend is unlikely to continue. The population of the watershed doubled from 375,000 to 787,000 between 1971 and 1996 and is expected to grow by another 300,000 over the next 25 years (GRCA 1997). The percentage of the minimum daily flow consisting of treated effluent from STPs ranged from 1% to 22% in 1993 and the capacity of the river to receive additional wastewater at reasonable cost is in question. The proportion of the Grand River basin in agricultural use increased from 68% in 1976 to 75% by 1998 (GRCA 1998). Row crop farming has increased, and along with it the potential for greater soil erosion and runoff of pesticides and fertilizers. Livestock production has changed, becoming more concentrated and specialized, and focusing on pigs and sheep rather than cattle. There has also been a change in manure handling from solid to liquid, and inadequate management of these liquid wastes has become a problem in some areas. Cumulative impacts of these stresses will be greatest in the lower reaches of the river where the Mapleleaf occurs.

Habitat trends in the Sydenham River are summarized from Staton *et al.* (2003). Prior to European settlement, the Sydenham River watershed was 70% forest and 30% swamp. By 1983, 81% of the land area was in intensive agriculture (mainly corn and soybean crops), with only 12% forest and <1% swamp. Sixty percent of the watershed is tile drained. Total phosphorus (TP) levels have consistently exceeded the provincial water quality objective (PWQO) over the past 30 years. Concentrations of TP and total Kjeldahl nitrogen continue to increase in the species-rich East branch and most of the P is associated with particulate material that probably originates from agricultural runoff. Chloride levels have been relatively low but are slowly increasing – a widespread pattern that is attributed to the increased use of road salt. Sediment loadings from overland runoff and tile drains are high and the north branch of the river is particularly turbid. Wooded riparian zones, which are important for bank stabilization and interception of nutrients and sediments from overland runoff, are very limited. The population of the Sydenham River watershed is small (74,000), with 50% rural and 50% living in towns and villages. Despite a modest rate of population growth, all municipalities have upgraded their sewage treatment facilities over the past 30 years. Leakage of nutrients and contaminants from rural septic systems is a significant and ongoing problem, especially in the north branch.

Agriculture is the dominant form of land use in the Thames River watershed, with 78% of the land area in the upper Thames and 88% in the lower Thames in agricultural use (Taylor *et al.* 2004). Forested areas have been reduced to 12% of the land area in the upper Thames and 5% in the lower Thames. Eight percent of the watershed is classified as urban, with concentrations in the cities of London (population 350,000), Stratford and Woodstock in the upper watershed and Chatham in the lower watershed. As the land was cleared, flooding became a serious problem. Three large dams and reservoirs were constructed in the upper watershed between 1952 and 1965. Numerous private dams and weirs have been installed since the 1980s and there are now 173 structures in the upper and 65 in the lower watershed. The extent of tile drainage is not known. Water quality data collected since the 1960s show that concentrations of phosphorus and heavy metals are declining while nitrate and chloride levels are on the rise. The upper Thames is moderately turbid while the lower Thames, where the Mapleleaf mainly occurs, is highly turbid. Soil conservation remains a serious issue in the watershed.

Mussel habitat in the Ausable River has been dramatically altered over time. Prior to European settlement, 80% of the basin was covered in forest, 19% was in lowland vegetation and 1% was marsh. By 1983, 85% of the land area was in agriculture (70% in row crops), and only 13% remained in small unconnected woodlots (Nelson *et al.* 2003). Over 70% of the basin is now in tile drainage. The natural course of the lower portion of the river was destroyed in the late 1800s, when it was diverted in two places to alleviate flooding. The Ausable River has been described as "event responsive", meaning there are large increases in flow during runoff event following storms. The nearby Sydenham, Thames and Maitland Rivers are more stable in this regard. There are 21 dams in the system causing sediment retention upstream and scouring downstream. Water quality data collected since 1965 show that TP levels are consistently above the PWQO and have decreased only marginally over the past 35 years. Nitrate levels currently exceed federal guidelines for the prevention of eutrophication and the protection of aquatic life and are slowly rising. Mean total suspended solid concentrations in the lower Ausable River, which supports a small population of *Quadrula quadrula*, exceed levels required for good fisheries.

Habitat trends in Manitoba

The Red River and Assiniboine River drainages flow through what once was tall-grass to mixed-grass prairie. This is one of the most altered biomes on the planet with less than 1% remaining (Meffe and Carroll 1997). European colonization, breaking of the land with the plow and contemporary industrial scale agriculture have all contributed to the demise of this biome. The majority of the land within these watersheds is now agricultural being tilled for grain and oilseed crops, being used for grazing, or urban/industrial. A recent development is the growing hog industry with high density hog barns being established throughout the watershed. The effect on the rivers that flow through this landscape cannot be under estimated. The major current concern is non-point source nutrient enrichment from agricultural runoff (Manitoba Conservation 2000). A second issue is damage to river banks resulting from uncontrolled access of cattle herds to the river. Industrial water removal and usage is also a concern with regard to water quality. The most recent issue relating to water quality in Manitoba relates to industrial hog barns. These are operations raising hundreds to thousands of hogs per site annually. The waste produced is of particular concern either due to the potential for catastrophic spills from storage tanks or from runoff after the waste has been applied to the land as a "natural fertilizer".

The major concern with respect to habitat in Manitoba is water quality. Jones and Armstrong (2001) analysed existing data on water quality in Manitoba and reported a significant increase in total nitrogen (TN) and total phosphorous (TP) in the Red River and Assiniboine drainage in the past 30 years. These increases ranged from 29% to 62% for phosphorous in the Red and Assiniboine rivers, respectively, and from 54% to 57% for total nitrogen in the Red and Assiniboine rivers, respectively. These 2 nutrients are major contributors to nutrient enrichment and loading of waterways that can result in cultural eutrophication and degradation of water quality. The Jones and Armstrong (2001) study was followed up by Bourne *et al.* (2002) who focused on the Red and Assiniboine watersheds. The data were reported as total nitrogen and phosphorous expressed as tones per year due to extreme variation in nutrient loads at weekly, seasonally and yearly time scales. They (Bourne *et al.* 2002) found that nutrient enrichment was substantial and primarily resulted from non-point sources, in particular agricultural runoff. Bourne *et al.* (2002) reported that from 1994-2001 the Assiniboine River on average carried 3,682 tonnes per year of total nitrogen and 637 tonnes per year of total phosphorous near its outflow into the Red River. During this same time period, the Red River on average carried 15,301 tonnes per year total nitrogen and 4,269 tonnes per year total phosphorous. The result of this nutrient input has been the increasing eutrophication of Lake Winnipeg such that basin wide algae blooms are visible from space (http://www.cbc.ca/manitoba/features/lakewinnipeg/special.html).

There is an accumulating body of evidence that freshwater mussels are sensitive to ammonia at levels below what is acceptable by the U.S. Environmental Protection Agency (Augspurger *et al.* 2003, Bartsch *et al.* 2003, Mummert *et al.* 2003). The juvenile stage appears most vulnerable to this exposure, which can result in adult populations persisting, but no recruitment. This could lead to the illusion of a healthy population based on the persistence of adult populations. None of the aforementioned studies specifically tested *Quadrula quadrula*, or any members of that genus. However, tests revealed juvenile sensitivity to low ammonia concentrations across a variety of species (Augspurger *et al.* 2003) that may be extended to *Q. quadrula*. The increasing trajectory of N loading in Manitoba streams coupled with the apparent absence of recruitment into the existing *Q. quadrula* populations is therefore of concern.

Habitat protection/ownership

Ontario

Land ownership along the reaches of the Sydenham, Thames, Ausable and Grand Rivers where *Quadrula quadrula* occurs is mainly private and in agricultural use. Only two small properties in the Sydenham River watershed, the 7 ha Shetland Conservation Area and the 20 ha Mosa Township forest, are publicly owned and somewhat protected (M. Andreae, pers. comm. 1998). There are 21 natural areas totalling 6200 ha in the Thames River watershed, but only one – the 16 ha Big Bend Conservation Area – is located in the same reach as the Mapleleaf (Thames River Background Study Research Team 1998). Also in this reach are four Indian Reserves (Delaware of Moraviantown, Munsee Delaware, Oneida of the Thames and Chippewa of the Thames) that occupy over 6700 ha of land along ~ 45 km of the river. The Ausable Bayfield Conservation Authority owns a number of properties totalling 1830 ha throughout the basin (Snell and Cecile Environmental Research 1995). Less than 3% of the land in the Grand River watershed is publicly owned (GRCA 1998). There are 11 conservation areas, only one of which (Byng Island) is located within the Mapleleaf's range in the river. It should be noted that recovery strategies and action plans are being developed/implemented for the Sydenham, Thames and Ausable River aquatic ecosystems to protect and recover aquatic and semi-aquatic Species At Risk including fishes, mussels, turtles and snakes. Many landowners are participating in riparian rehabilitation projects and improved land use practices that will ultimately benefit all aquatic species.

Manitoba

Land ownership on the Assiniboine, Red and Roseau Rivers was determined using GIS from 1:500,000 base maps for the water layer. Land along these rivers is predominately privately owned and in agricultural use. Approximately 19% of the Red River could be considered urban, passing through Winnipeg and Selkirk. With the exception of small towns, the remainder is agricultural. There are no protected lands along the Red River. The Roseau River flows through no protected lands or designated areas. Approximately 7% is Crown land, 9% is Indian Reserve land and the remaining 84% is patented land used mostly for agriculture. If we consider the entire length of the Assiniboine River within Manitoba (approximately 1000 km) then 84% of the surrounding land is privately held and agricultural, 6% is urban and approximately 10% flows through either a park or a Wildlife Management Area (WMA). Approximately 60% of these parks or WMA's are designated as protected meaning mining, logging, hydro-electric development and other activities that affect wildlife habitat are prohibited. The non-protected parks and WMA's are designated crown lands without a regulation or order in council specifying that land is to be protected. It should be noted that about half of these designated lands, whether protected or not, lie on one bank of the river, with the opposite bank being privately held. However, if we consider just the stretch of the Assiniboine downstream from the Portage Diversion to the confluence with the Red River, there is only 7% flowing through protected land (Beaudry Provincial Park). The remainder is 80% agricultural and 13% is urban, flowing through Winnipeg.

BIOLOGY

General

Freshwater mussels in the family Unionidae have a complex life cycle that includes a larval stage called a glochdium (pl. glochidia) that is an obligate parasite, most commonly on a fish host. One species (*Simpsonaias ambigua*) has been reported using a mudpuppy as host (Howard 1951) and another (*Strophitus undulatus*) to be able to develop to maturity without any host (Lefevre and Curtis 1910).

The life history of *Quadrula quadrula* reflects the general pattern of unionid mussels. During the spawning period, the male releases sperm into the water through the excurrent siphon. Sperm are carried by the water current, taken in by the female through the incurrent siphon and gills filter the sperm out of the water. In the female, ova are released and held in a specialized area of the gill called the marsupium (pl. marsupia). The sperm that has been filtered from the water is carried into the marsupium where the ova are fertilized. Fertilized ova develop into glochidia and are brooded in the marsupium. There are 2 patterns of brooding and glochidial release. long term (bradytictic) and short term (tachytictic) and the pattern of release may be related to temperature (Watters and O'Dee 1998). *Quadrula quadrula* is considered to be a tachytictic species that spawns early in the season, broods glochidia for a short time before release (Parmalee and Bogan 1998). Fully developed glochidia have 2 valves that may be rounded to ovate, axe-head shaped, or triangular in shape, and may or may not have hooks for host attachment, depending on the species. *Quadrula quadrula* glochidia are ovate, lack hooks and measure approximately 80 μm in length and height (Clarke 1981). Glochidia may be released singly or in packets called conglutinates or even super conglutinates that may be metres in length. Conglutinates and super conglutinates may have markings that mimic potential prey items of potential fish hosts. *Quadrula quadrula* releases glochidia in small, lanceolate, white-coloured conglutinates. The female mantle is modified to act as a lure for potential fish hosts in some species but the mantle of *Q. quadrula* is not modified in any visible way. The number of potential fish hosts varies from few to many depending on the mussel species. Howard and Anson (1922) identified the flathead catfish (*Pylodictis olivaris*) and Schwebach *et al.* (2002) identified the channel catfish (*Ictalurus punctatus*) as hosts for *Q. quadrula* glochidia which attach to the gills. Other mussel species glochidia attach to the fins or skin, with the site depending on the mussel species and adaptations of the glochidia for attachment. If glochidia do not attach to an appropriate host they will die. In rare cases, some species have been reported as not requiring a host for life cycle completion. Glochidia attach to the host and become encysted. Glochidia obtain nourishment from the host allowing them to transform to juveniles which are recognized by development of the foot. The amount of time for transformation is variable both within and among mussel species and may be temperature and host dependent. Once transformed, the juvenile mussel breaks out of the capsule and drops to the substrate and will begin to grow and develop as a free-living mussel. The percentage of glochidia successfully reaching maturity is extremely low due to high mortalities associated with reaching a suitable host, dropping onto suitable habitat and the sensitivity of juvenile stages to environmental conditions.

Life cycle and reproduction

Quadrula quadrula is dioecious. Males and females cannot be distinguished based on external morphology.

Quadrula quadrula is considered to be a short term brooder (tachytictic). Reports on the length of the brooding season appear to vary with the location ranging from May to August in the United States (Parmalee and Bogan 1998) and late spring to early summer in Canada (Clarke 1981) and may be temperature dependent. In Manitoba, *Q. quadrula* brooding glochidia have not been observed, and ova have never been observed in the marsupium later than mid-June (Carney 2003a, personal observation). This would seem to suggest that in Manitoba at least there may not be successful reproduction every year and that there is a very limited time during which glochidia are available for host infestation.

Quadrula quadrula releases glochidia in lanceolate conglutinates that are approximately 10mm in length and 3mm in width at the broad end. The conglutinate is typically white and may have sparse randomly distributed dark "dots". Presumably the fish host is infested when it bites the conglutinate releasing the glochidia which can then attach to the gills. There are no data on the fecundity of *Q. quadrula*. Haag and Staton (2003) investigated reproductive traits of several mussel species including the congeners *Quadrula asperata* and *Quadrula pustulosa* collected from sites in Mississippi and Alabama. For those 2 species they report that fecundity increases with shell length for both species. There were differences in maximum fecundity, and fecundity as a function of age, for these 2 species. *Quadrula asperata* had a maximum fecundity approaching 30,000 developing ova in the gills whereas *Q. pustulosa* had a maximum fecundity of approximately 50,000 ova. Haag and Staton (2003) also report differences in age at which reproductive capacity is maximized for these 2 species. Maximum fecundity for *Q. asperata* is reached around 15 years of age while *Q. pustulosa* reaches maximum fecundity around 30 years of age (Haag and Staton 2003). Fecundity for both species declines following those maxima. These data would suggest that *Q. quadrula* likely reaches sexual maturity around the same age as *Q. asperata* and *Q. pustulosa*; somewhere between 3 and 10 years. The differences reported for these 2 congeners make it difficult to predict maximum fecundity and age after which fecundity declines for *Q. quadrula*. It seems likely that climatic conditions in Canada could extend time to maturity and would result in fecundity values that are much less than those reported for *Q. asperata* and *Q. pustulosa* from individuals collected from the southern U.S.

Howard and Anson (1922) identified the flathead catfish (*Pylodictus olivaris*) as a suitable host. This species is considered to be not native in Canada (Scott and Crossman, 1973) although a single specimen was caught in Canadian waters of Lake Erie (Crossman and Leach 1979). There are no documented specimens of this species recorded from Manitoba. The flathead catfish was the only known host for *Quadrula quadrula* until Schwebach *et al.* (2002) reported successful transformation of *Q. quadrula* glochidia on channel catfish (*Ictalurus punctatus*), a species common in both Manitoba and Ontario (Scott and Crossman 1973; Stewart and Watkinson 2004).

Transformation took 51-68 days with water temperature starting at 13° C and ending at 20° C (Schwebach *et al.* 2002). It seems reasonable to assume that channel catfish would serve as a suitable host for Canadian *Q. quadrula* populations. Other *Quadrula* species also have been recorded as having catfish species as suitable hosts (Fuller 1974). It is worth noting that the brown bullhead (*Ictalurus nebulosus*) has a range that is closest, and almost identical, to that of *Q. quadrula* (Lee *et al.* 1980) and it seems likely that this catfish species would be a suitable host, although this has yet to be demonstrated.

Quadrula quadrula is a long-lived species. Carney (2003a, b; personal observation) using shell thin sections (Clark 1980; Neves and Moyer 1988) reported individuals from the Assiniboine River in Manitoba up to 64 years with an average age of 22.1 (n = 47). Age data specific to Ontario populations are not available but are likely to be consistent with those reported from Manitoba.

Predation and Parasitism

Predators of mussels include fishes, mammals and birds. Baker (1918) identified freshwater drum (*Aplodinotus grunniens*), lake sturgeon (*Ascipenser fulvescens*), pumpkinseed (*Lepomis gibbosus*) and suckers (*Catostomus* spp.) as fish predators of mussels. Muskrat (*Ondatra zibethicus*) predation can be an important factor that may limit some mussel populations (Tyrrell and Hornbach 1998) and have been reported to prey upon *Quadrula quadrula* (Nakato *et al.* 2005). Muskrat have been reported to eat as many as 37,000 mussels annually in a northern Alberta lake (Convey *et al.* 1989; Hanson *et al.* 1989) and may represent a serious natural threat to endangered species and populations (Neves and Odum 1989). Larval chironomids feeding on mussel tissue can result in the loss of up to 50% of the gill (Gordon *et al.* 1978), affecting both respiration and reproduction, and may represent either parasitism or predation depending on definitions used.

Mussels are parasitized by helminths (Digenea) and mites which may have a detrimental effect on the infected mussel. Mussels can be infected by both adult digeneans and by larval digeneans that include the sporocyst or metacercaria stages. Parasitism by sporocysts can result in sterilization of the infected mussel (Esch and Fernandez 1993). An extensive survey of mussels in Manitoba that included examination for parasites did not show parasitism of *Quadrula quadrula* by sporocysts (Carney 2003a). A single individual *Q. quadrula* was infected with metacercariae but this stage has not been demonstrated to cause sterility and there was no indication of sterility in that infected individual. A variety of adult helminths also can parasitize mussels. *Aspidogaster conchicola* in the pericardial sac and kidney, and *Cotylogaster occidentalis* in the gut, both have been reported from *Q. quadrula* (Hendrix *et al.* 1985). Carney (2003a) examined *Q. quadrula* from the Assiniboine River in Manitoba and reported approximately 60% infected with *A. conchicola* and 6% infected with *C. occidentalis*. Mean intensity of infection ranged from 1-71 (mean = 17) for infections by *A. conchicola* and mean intensity of 1-2 for infections by *C. occidentalis*. Infection by *A. conchicola* may cause damage to the renal epithelium (Williams 1942; Michelson 1970).

Adult mites belonging to the family Unionicolidae are common symbionts in the mantle cavity of mussels and also in the mantle tissue as parasitic larvae and there may be close evolutionary ties between the two groups that possibly represents examples of coevolution, in some cases (Vidrine, 1996). Carney (2003a) reported no *Quadrula quadrula* collected from the Assiniboine River in Manitoba to be infested with mites. To date there are no data pertaining to parasitism of Q. *quadrula* from Ontario. It does seem likely that what has been reported from Manitoba would also be valid for populations in Ontario, given that the hosts and parasites are present in both regions (Carney 2003a; Hendrix *et al.* 1985).

Physiology

No studies specific to the physiology of *Quadrula quadrula* are known. As they would require a supply of calcium sufficient to meet their needs to make shell as they grow. Juveniles of other unionid species are known to be sensitive to ammonia at levels below current U.S. Environmental Protection Agency water quality criteria (Augspurger *et al.* 2003). It seems likely this sensitivity would extend to Q. *quadrula*. *Quadrula quadrula* must be able to survive a wide range of temperatures. In winter the rivers in Manitoba would be ice covered with water temperature at or near 0° C while in summer water temperatures can reach 27° C.

Dispersal/migration

Adult freshwater mussels are largely sessile, typically moving no further than 100 m, and usually much less than that. Therefore the ability of the adult stage to disperse or migrate is highly constrained. Larval mussels can be transported great distances while attached to the fish host. This is the dispersal stage and the limit to dispersal is how far the fish host moves. Mussels that use highly vagile hosts, or that use many host species, should be capable of greater dispersal than mussels that use hosts that do not travel very far or mussels that use a single host species. Therefore it is the host that determines the dispersal of the mussel and may introduce the mussel into new habitats, enhance gene flow between and among populations and bring new individuals into populations that may be in peril. The known hosts of *Quadrula quadrula* are catfish species that are known to travel great distances over short time periods (Stewart and Watkinson 2004). This would suggest Q. *quadrula* is capable of being dispersed over large distances. Berg *et al.* (1998) used allozyme variation to show there were high levels of gene flow among distant populations within the Ohio and Mississippi drainages. Populations in Ontario and Manitoba each lie within drainages that are isolated from each other, and have been separated from the Ohio-Mississippi drainages for thousands of years and rescue from these sources is not possible. American populations within the Red River drainage in North Dakota and Minnesota have been subject to the same population declines as in Manitoba (Hart 1995; Ceas 2001; Carney 2003b) and as such do not provide a source population from which Manitoba populations could be replenished. A similar situation occurs in the American waters of the Lake Erie drainage. As a consequence it is not reasonable to assume that depauperate Canadian Q. *quadrula* populations could be naturally replenished from more robust American populations, since those American populations are in the same state as the Canadian populations.

Interspecific interactions

There has been extensive debate regarding the food and source of nutrition of unionid mussels. Much of this debate has centered on the fact that there are problems in separating what is ingested and what is actually assimilated. As unionids filter water they feed by sorting food particles in the mantle cavity before ingestion and in the stomach after ingestion (Nicholls and Garling 2000). Although the feeding and nutrition of *Quadrula quadrula* has not been specifically addressed, Raikow and Hamilton (2001) and Christian and Smith (2004) demonstrated that a variety of mussel species were using similar food resources. The following discussion assumes that what has been reported for other mussel species can be extended to *Q. quadrula*.

Available information indicates adult mussels feed upon fine particulate organic matter suspended in the water column (Tanklersley 1996; Ward 1996). However, it is unclear regarding which components of this suspended material is actually used for nutrition (Gatenby *et al.* 1993; Nicholls and Garling 2000). Allen (1914) reported diatoms and algae in the gut and proposed that algae, protozoa, bacteria and organic material were the primary sources of nutrition (Allen 1921). Ingested materials are not necessarily digested but may survive passage through the digestive tract intact and alive (Churchill and Lewis 1924; Miura and Yamashiro 1990). Imlay and Paige (1972) suggested that unionids derive their nutrition from feeding on bacteria and protozoa. Nicholls and Garling (2000) studied the diet of 7 mussel species using stable isotope analysis, gut contents and biochemical analyses and determined there was positive selection of food items in the diet based on the concentration of algae and diatoms in the gut. Although algae and diatoms were selectively ingested and concentrated in the gut, the main source of nutrition was bacteria. However, algae were still a necessary part of the diet by providing essential nutrients (Nicholls and Garling 2000).

There is also uncertainty regarding the degree to which mussels feed upon detritus and organic matter within the substrate. Juvenile mussels may use cilia on their foot to feed from the substrate, a method called pedal feeding. Gatenby *et al.* (1993) suggested juveniles fed on algae and silt. Yeager *et al.* (1993) and Yeager and Cherry (1994) have shown that juvenile mussels may feed primarily on bacteria from within the substrate but the importance of this as a source of nutrition for adults is less clear. Adult mussels are capable of filtering suspended particles ranging in size from 0.9 – 250 µm (Silverman *et al.* 1997; Nicholls and Gatenby 2000) suggesting suspended organic materials are important in the diet and nutrition of mussels. However, Raikow and Hamilton (2001) used stable isotope ratios to determine diets of 12 mussel species and suggested their diet was comprised of 80% deposited material and 20% suspended material.

If the preceding data apply to *Quadrula quadrula* the following conclusions regarding feeding may be drawn. Feeding on interstitial material may be the primary source of nutrition for juveniles. Adults may also be feeding from the substrate as well as upon organic materials suspended in the water column. Bacteria appear to be the primary source of nutrition with algae supplying many essential elements in the diet. Clearly there is much more research required to clarify the food habits and nutrition of unionid mussels.

Adaptability

The range of suitable habitats suggest this species is quite adaptable. Glochidia have been successfully transformed in an experimental situation using channel catfish as host. Informal accounts of these mussels being successfully transplanted by commercial interests suggest this species can be transported and transplanted.

POPULATION SIZES AND TRENDS

Ontario

Search effort

<u>Historical surveys</u>

Approximately 80% of the information on the historical distribution of *Quadrula quadrula* in Ontario is based on either museum specimens or presence-absence data. There is little if any information on sampling method, search effort, numbers of sites visited where the species did *not* occur, or even whether the animals were dead or alive when collected. Data on relative abundance (Catch-Per-Unit-Effort or CPUE) are available from timed-search surveys of 10 sites on the Sydenham River in 1985 (Mackie and Topping 1988) and 16 sites on the same river in 1991 (Clarke 1992). Two of the sites surveyed by Mackie in 1985 were re-surveyed 12-13 years later by Metcalfe-Smith *et al.* (1998b, 1999), so these data can be compared. Three of the sites surveyed by Clarke in 1991 were also re-surveyed in 1997-98, but the Mapleleaf was never found at any of these sites. Kidd (1973) surveyed 68 sites on the Grand River in 1970-72 and 14 of these sites were re-surveyed 25 years later using a similar sampling effort (Metcalfe-Smith *et al.* 2000a). Nine sites were in the upper and middle reaches of the river, which is outside the species' distribution in the system, but 5 sites were in the lower reaches and can be compared.

<u>Recent surveys</u>

Surveys conducted between 1995 and 2004 within the range of the Mapleleaf in Ontario have been either semi-quantitative (timed-searches) or quantitative (quadrat surveys). The same sampling methods and efforts were used throughout and are described below. The only exception was the 1995 survey on the Grand River, which used a lower sampling effort than other surveys (see Metcalfe-Smith *et al.* 2000a).

Timed-search surveys: In rivers, surveys were conducted using an intensive timed-search technique developed by Janice Metcalfe-Smith and her team for detecting rare species of mussels. The technique is described in its entirety in Metcalfe-Smith *et al.* (2000b). Briefly, the riverbed is visually searched by a team of 3 or more persons using waders, polarized sunglasses, and underwater viewers for a total of 4.5 person-hours (p-h) of sampling effort. Where visibility is poor, searching is done by feel. The length of reach searched varies depending on river width, but is generally 100-300 m. Live mussels are held in the water in mesh diver's bags until the end of the search period when they are identified to species, counted, measured (shell length), sexed (if sexually dimorphic) and returned to the riverbed. Over the past 10 years, such surveys have been conducted in the Grand, Thames, Sydenham, Ausable, Maitland, Saugeen and Moira Rivers and several smaller tributaries to Lake Ontario and Lake Erie by several different researchers.

In Lake St. Clair, searches at waters depths greater than 2 m were conducted by two SCUBA divers for a total effort of 0.5 p-h whereas searches at depths less than 2 m were conducted by three people using mask and snorkel for a total of 0.75 p-h (Zanatta *et al.* 2002). At sites where live mussels were found (all were shallow), snorkel searches were extended to a total of 1.5 p-h.

Quantitative surveys: Surveys in rivers employed an intensive quantitative sampling technique that would allow the generation of precise estimates of demographic variables such as density, size class frequencies and recruitment levels. The monitoring protocol was developed in consultation with Dr. David R. Smith, a biostatistician with the U.S. Geological Survey who advises the U.S. Army Corps of Engineers on methods for assessing the impacts of development projects on federally endangered mussels in the United States. Dr. Smith and Dr. David L. Strayer, another American mussel expert, were recently commissioned by the Guidelines and Techniques Committee of the Freshwater Mollusk Conservation Society to prepare a guide to sampling freshwater mussel populations. This guide (Strayer and Smith 2003) includes a description of the protocol, which is summarized below:

Sampling employed a 2-person search team and a data recorder and required approximately 2 days of work per site. At each site, roughly 400 m^2 of the most productive portion of the reach (usually a riffle) was selected for sampling. Quantitative sampling was conducted using 1 m^2 quadrats and a systematic sampling design with three random starts. The area to be sampled was divided into blocks of equal size (5 m long × 3 m wide) and each block was further divided into 15 – 1 m^2 quadrats. The same three randomly chosen quadrats were sampled in each block; thus, 20% of the 400 m^2 area was sampled at each site. Each quadrat was searched by 2 people until all live mussels had been recovered (~ 8 person-minutes). All embedded stones (except large boulders) were removed and the substrate was excavated to a depth of 10-15 cm in order to obtain juveniles (young mussels are known to burrow deeply in the substrate for the first three years of life). All live mussels found in each quadrat were identified, counted, measured, sexed where possible and returned to the riverbed. Several habitat variables (e.g., depth, current velocity, substrate composition) were also measured and recorded. To date, quantitative surveys have only been conducted on the Sydenham and Thames Rivers.

Quantitative surveys were also conducted in the delta area of Lake St. Clair. At each site, sampling was performed by several (usually three) 2-person teams, with each team consisting of a snorkeler and a helper to carry the gear and mussels. Each snorkeler swam until a mussel was seen, then surveyed a 65 m^2 circular area around the mussel and collected any other live mussels found. Each team surveyed 10 such circle plots. All live mussels were identified, counted, measured, sexed and returned to the lake bottom. Methods are described in detail in Metcalfe-Smith *et al.* (2004). Such surveys were conducted in 2001 and 2003 and to a limited extent in 2004.

Abundance

Quadrula quadrula no longer occurs in the Great Lakes and connecting channels, so there are no abundance data to discuss for these waters (see section on Fluctuations and trends). The species presently occurs in the Grand River (Lake Erie drainage), Thames and Sydenham rivers (Lake St. Clair drainage) and Ausable River (lower Lake Huron drainage) of southwestern Ontario. Timed-search surveys were conducted at 113 sites on these rivers between 1997 and 2004 using 4.5 p-h sampling effort/site. Results of such semi-quantitative surveys can be used to compare the relative strengths of *Q. quadrula* populations among rivers (Table 4). The Mapleleaf is a minor component of the mussel fauna in all four rivers. It was found at the greatest proportion of sites in the Sydenham River but made up the largest proportion of the mussel community by abundance in the Grand River. The population in the Ausable River is extremely small, with only 18 live specimens found. Based on CPUE, population densities in the Grand and Sydenham Rivers are greater than those in the Thames and Ausable Rivers. However, these numbers may be somewhat misleading. The Mapleleaf mainly occurs in the lower reaches of medium-sized to large rivers and a large proportion of the sites surveyed in both the Grand and Thames Rivers were in the headwaters or tributaries. If CPUE is compared using only those data from sites in the occupied reaches of each river, population density is greatest in the Grand River (CPUE = 6.9 specimens/p-h), followed by the Thames (2.9), Sydenham (2.0) and Ausable (1.0).

Catch-per-unit effort data obtained from timed-search surveys provide information on *relative* population density. True density estimates are only available at present for the Sydenham River (Note: quantitative surveys were also conducted at 5 sites on the Thames River in 2004, but all sites were in the headwaters and no *Quadrula quadrula* were found). Twelve sites on the East Sydenham River and 3 sites on the north branch of the river (known as Bear Creek) were quantitatively sampled between 1999 and 2003. The Mapleleaf was found at 9 sites on the East Sydenham at an average density of 0.218 individuals/m^2. As the species was found at every site surveyed by timed-searches, quadrat sampling or both techniques within the occupied reach of the East Sydenham, it is reasonable to assume that the population is continuous. Based on an average density of 0.218 individuals/m^2 and an AO of 1.2 km^2, population size is estimated to be 261,600 animals. The Mapleleaf was found at one of the 3 sites sampled on Bear Creek at a density of 0.16 individuals/m^2. It was also found at the next-closest site downstream that was surveyed during timed-searches in 1998. Based on an average density of 0.16 individuals/m^2 and an AO of 0.16 km^2 and assuming the population is continuous, population size is estimated to be 25,600 animals. It is likely that the Grand and Thames River populations of *Q. quadrula* are an order of magnitude larger and the Ausable River population an order of magnitude smaller than the population in the Sydenham River. This would result in an overall estimate of approximately 5.5 million individuals.

Table 4. Comparisons of population strength for *Quadrula quadrula* from four southwestern Ontario rivers.

River	# sites surveyed	# live mussels collected (all species)	Frequency of occurrence of *Q. quadrula* (% of sites)	Relative abundance of *Q. quadrula* (% of community)	Catch-per-unit-effort for *Q. quadrula* (#/person-hour)	Year(s) of surveys
Ausable	25	5013	16%	0.4%	0.2/p-h	1998[2], 2002[3], 2004[3]
Sydenham	18	2357	50%	3%	1.0/p-h	1997-98[1,2], 2003[3]
Thames	41	4906	17%	2%	0.5/p-h	1997-98 [1,2], 2004[4]
Grand	29	1903	17%	8%	1.1/p-h	1997-98 [1,2], 2004[3]

[1]Metcalfe-Smith *et al.* (1998b); [2]Metcalfe-Smith *et al.* (1999); [3]Metcalfe-Smith *et al.* (unpublished data); [4]Morris (unpublished data)

Shell length was measured for every live mussel collected during the above-described surveys. Size frequency distributions for live *Quadrula quadrula* collected during recent timed-search surveys on the Grand, Thames and Ausable Rivers are presented in Figure 9. Specimens captured in the Grand River measured 16 to 125 mm in shell length with good representation in many different size classes. Such a distribution is indicative of a healthy, reproducing population. The population in the Thames River is dominated by larger animals with < 10% of individuals measuring less than 80 mm – a pattern that suggests recruitment may be declining or no longer occurring. Nothing can be said about the population in the Ausable River from only 18 specimens. The population is so sparse that additional sampling effort would be needed to determine if there has been recent recruitment. Size frequency distributions for live *Q. quadrula* collected during both timed-search and quadrat surveys on the Sydenham River are shown in Figure 10. As expected, more small specimens were collected during quadrat surveys with excavation of the substrate than during timed-search surveys; however, the data from both types of survey show that the population is healthy and reproducing.

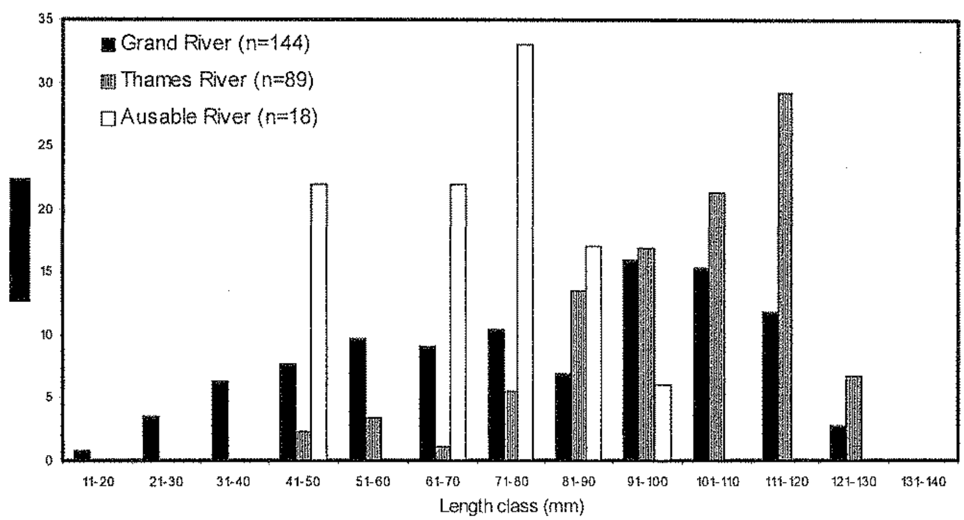

Figure 9. Size frequency distributions for live *Quadrula quadrula* collected from the Grand, Thames and Ausable Rivers, Ontario, from 1997 to 2004.

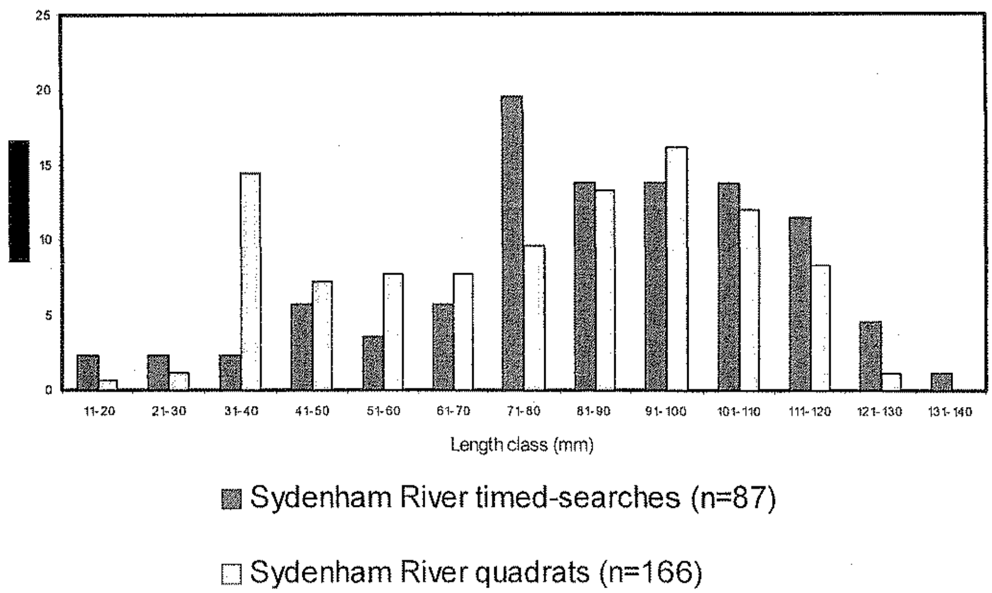

Figure 10. Size frequency distributions for live *Quadrula quadrula* collected during timed-search and quadrat surveys in the Sydenham River, Ontario, from 1997 to 2003.

Fluctuations and trends

Quadrula quadrula appears to be extirpated from Lake Erie, Lake St. Clair and the Detroit and Niagara Rivers due to impacts of the zebra mussel; however, it was always extremely rare in these waters. For example, there are some scattered records from Canadian waters of Lake Erie, but only for shells. These records include 3 from Rondeau Bay (1894, 1961 and one with no date) 4 from Pelee Island (1962, 1978 and 1992, 2004) and one from Port Maitland at the mouth of the Grand River in 1936. *Quadrula quadrula* was found at only one of 29 sites surveyed in the offshore waters of Lake St. Clair in 1986 prior to the zebra mussel invasion and represented 0.7 % of the 281 mussels collected from all sites (Nalepa *et al.* 1996). Similarly, only 1 of 1279 live mussels (0.08%) collected from 13 sites throughout the Detroit River in 1982-83 were this species (Schloesser *et al.* 1998). Finally, Zanatta *et al.* (2002) collected 2356 live mussels from 95 sites in the nearshore waters of Lake St. Clair between 1999 and 2001, and only one mussel (0.04%) was a Mapleleaf. Nevertheless, even at low population densities, because of their enormous size these waterbodies must have once supported a substantial proportion of the Ontario population of this species.

Catch-per-unit-effort reported for the Mapleleaf in the Sydenham River was 1.4/p-h over 10 sites in 1985 (Mackie and Topping 1988), 0.12/p-h over 6 sites in 1991 (Clarke 1992) and 1.1/p-h over 18 sites in 1997-98 and 2003 (Metcalfe-Smith *et al.* 1998b, 1999, unpublished data). Two sites were surveyed in both 1985 and 1998; CPUE for a site on the East Sydenham was 8.0/p-h in 1985 and 1.1/p-h in 1998 and CPUE for a site on Bear Creek was 5.0/p-h in 1985 and 1.3/p-h in 1998. These data suggest that *Quadrula quadrula* may be declining in abundance in the system but this is inconsistent with evidence showing that the species is encountered more frequently now than in the past (see section on Distribution). Kidd (1973) collected 0, 0, 0, 1 and 9 *Q. quadrula* from 5 sites on the lower Grand River in 1971-72 whereas Metcalfe-Smith *et al.* (2000a) collected 0, 0, 1, 57 and 27 specimens from the same sites 25 years later. Kidd (1973) found that the number of mussel species living in the river had declined dramatically from historical counts – only 6 of 25 species previously reported from the lower reaches were still present in the 1970s. This decline was attributed to siltation, the creation of dams and reservoirs and especially sewage pollution. The Mapleleaf was one of the species that had survived. Populations of most mussel species, including *Q. quadrula*, have since rebounded due to significant improvements in water quality. There are no data available for determining if there have been changes in population size over time for *Q. quadrula* in the Ausable or Thames Rivers.

Rescue effect

All Ontario populations of *Quadrula quadrula* are isolated from one another and from other populations in Manitoba and the United States; thus, there is no chance of a healthy population of the species returning to Ontario if the Ontario population should become extirpated. Populations in tributaries to the lower Great Lakes on both sides of the Canada/U.S. border may once have been connected by populations in Lake Erie and Lake St. Clair, but native mussels have been virtually extirpated from the lakes due to impacts of the zebra mussel and this connection has been broken. Although the catfish hosts are vagile, there is no robust population in the U.S. part of the Lake Erie drainage from which a rescue effect can occur. The continued decline of these populations is testament to the absence of a rescue effect.

Manitoba

Search effort

Historical surveys

All of the historical information for the distribution of *Quadrula quadrula* in Manitoba are either museum specimens or in the form of presence-absence data. Data on sampling methods and search efforts are unavailable. Sites where *Q. quadrula* did not occur can be determined by comparison with sites from which other species were recovered. However there are no data on sites that were examined from which no mussel species were recovered.

Recent surveys

There are 7 recent surveys that report on the distribution of freshwater mussels in Manitoba. The goals of these surveys differed, as did the collecting methods and efforts. This makes comparisons difficult. In 1992, under the direction of Dr. Terry Dick from the University of Manitoba, Carney and colleagues (unpublished data) surveyed 4 sites on the Assiniboine River and 1 site on the Roseau River to provide a preliminary determination of what mussel species were present. *Quadrula quadrula* was recovered from 3 sites on the Assiniboine and from the single site on the Roseau River. This undertaking is best considered as qualitative because of different times spent searching involving different numbers of people (range from 1-5). Search in all cases was by feel. The effort expended varied from a low of 2 person hours to a high of 10 person hours (Table 5).

Scaife and Janusz (1992) investigated the viability of a commercial shell harvest from the lower Assiniboine River. They reported the results of a survey over 21 km using randomly placed 1m^2 quadrats and SCUBA. Scaife and Janusz (1992) reported 62 *Quadrula quadrula* from 24 of 120 quadrats and an average density of 0.52/m^2.

Watson *et al.* (1998) undertook a study to determine the distribution and abundance of freshwater mussels in the lower Assiniboine River and 15 of its tributaries. Sampling sites on the Assiniboine between Portage la Prairie and Winnipeg were selected following a stratified sampling design (Watson *et al.* 1998). Eighteen transects across the river were sampled using a mini bull rake. Collecting involved raking the bullrake across the substrate 5 times at each of 5 equidistant points across the river. Tributaries were sampled by sight, by feel, or by using the bullrake, depending on water clarity and depth. Thirty person-minutes were spent searching at each site. They (Watson *et al.* 1998) recovered a total of 6 live *Quadrula quadrula* from 5 of the 17 sites surveyed on the Assiniboine River, with empty valves recorded at one additional site. There was no evidence of *Q. quadrula* from any of the 167 sites surveyed on tributaries of the Assiniboine.

Pip (2000) in 1998 undertook a very large survey of freshwater mollusks in Manitoba for comparison to the results from previous surveys. Although the focus of this survey was directed to gastropods there were results relevant to mussels. Of particular interest is the fact that there was a decline from 4 to 2 in the number of sites from which *Quadrula quadrula* was recorded. This decline occurred in the 20 year interval from the previous survey. Unfortunately no collecting methodology, site information or abundance data were reported (Pip 2000).

Carney (2003a, 2004a) collected mussels from sites along the length of 10 different rivers in Manitoba. The purpose was to collect tissue for DNA analyses, determine the reproductive status and demographics and investigate the parasites of the mussels. Permits restricted the number to no more than 20 individuals of any one species from any single site, excepting one reference site on the lower Assiniboine. Once 20 individuals of a species had been collected that species was no longer collected. As a result, collecting effort on common species would stop and the focus would be on the less common species. Nonetheless, time spent searching was noted so effort in terms of person hours could be determined. At no site was the limit for *Quadrula quadrula* reached and in fact effort was focused on this species due to its rarity, and absence of evidence for successful production of glochidia.

Carney (2004b) reported the results of a quantitative survey of mussels in the Assiniboine River through Spruce Woods Provincial Park. A total of 620 1 m^2 quadrats at 49 transects were searched with no *Quadrula quadrula* being recovered. The average density for all species in this study was estimated to be 0.08/m^2.

Table 5. Comparisons of population strength for *Quadrula quadrula* from the Assiniboine River in Manitoba from surveys based on timed searches.

Source	# sites surveyed	# live mussels collected (all species)	Frequency of occurrence of *Q. quadrula* (% of sites)	Relative abundance of *Q. quadrula* (% of community)	Catch-per-unit-effort for *Q. quadrula* (#/person-hour)
Carney 1992 unpub.	3	540	100%	11%	1.26
Watson *et al.* 1998	18	75	27%	8%	0.66
Pip 2000	302	n/a	0.006%	n/a	n/a
Carney 2003a (below Portage Diversion)	6	239	33%	18%[1]	1.5
Carney 2003a (above Portage Diversion)	16	316	6%	0.3%	0.025
Watkins 2003 unpub.	6	485	33%	6.19%	1.54
Watkins and Carney 2004 unpub.[2]	1	n/a	100%	n/a	2

1. This overestimates the abundance of *Q. quadrula* because many other individuals of abundant species were not kept or recorded. See text for details.
2. This survey was targeted to *Quadrula quadrula* and no other species were recorded. Numerous individuals of several species were recovered.

Abundance

Estimating the density of *Quadrula quadrula* in Manitoba is possible only for the lower Assiniboine River using the results reported by Scaife and Janusz (1992). As described previously Scaife and Janusz (1992) recovered 62 *Q. quadrula* from 24 of the 120 quadrats. This would result in an average density of 0.52 *Q. quadrula*/m^2. This should be considered an upper bound inasmuch as Carney (2004b) reported an average density of 0.08/m^2 for all mussel species from a larger survey on a different stretch of the Assiniboine River.

If we accept 0.52/m^2 as an approximate upper estimate of the density of *Quadrula quadrula* then we can estimate the population size within this river. The data indicate that *Q. quadrula* is limited in the Assiniboine River to locations from the Portage Diversion to the confluence with the Red River in Winnipeg. The area of occupancy (AO) for this stretch of the Assiniboine River is 7.5 km^2 (Table 3). At a density of 0.52 per m^2, this provides an estimate of a total population in this river of 3,900,000 individuals. It needs to be noted that this should be considered an extreme upper bound because long stretches of the Assiniboine have a substrate of drifting soft sand unsuited as mussel habitat. This is reflected in the much lower density values for all species reported by Carney (2004b). Furthermore, Watson *et al.* (1998) recovered *Q. quadrula* from 27% of sites along the Assiniboine River. This many samples along the Assiniboine without *Q. quadrula* clearly indicate that this species does not occur along the entire length of this river. If we use this value (27%) to calculate the proportion of the river suitable for *Q. quadrula* we arrive at a population estimate of 1,050,000 individuals. Thus we calculate the *Q. quadrula* population in the Assiniboine River to lie between 1 and 4 million individuals. These widely divergent numbers only serve to highlight the pressing need for more data on mussels from this, and the other Manitoba watersheds.

There are no data amenable to estimating *Quadrula quadrula* populations in the Red or Roseau rivers. Live specimens have not been recovered from the Red River since the investigations reported by Clarke (1973). The last live specimens from the Roseau was 1 individual collected in 1992 (Carney, unpublished data). Based on this information it is not even known if there are viable populations in either of these rivers. It seems probable they exist in the Red River simply based on the size of the river, there is no basis for this likelihood in the Roseau River.

Neither Watson *et al.* (1998) nor Scaife and Janusz (1992) reported size values for the mussels they collected. All individuals collected by Carney (2003a) were measured and aged using thin sections. Only lengths will be presented here in order to maintain consistency with the data presented for Ontario. Size frequency distributions are shown for mussels collected from the Assiniboine River reported in Carney (2004a) (Figure 11). Specimens ranged in size from 53mm to 123mm (mean = 101mm) There was an absence of small individuals which seems to be the common situation for the Manitoba populations (Carney, personal observation). The absence of smaller individuals, even in the range of 50-100mm is indicative of little or no recruitment. It is worth noting that Carney (2003a, unpublished data) has only ever recovered 2 female *Quadrula quadrula* gravid with glochidia. This apparent lack of reproduction is consistent with little or no recruitment.

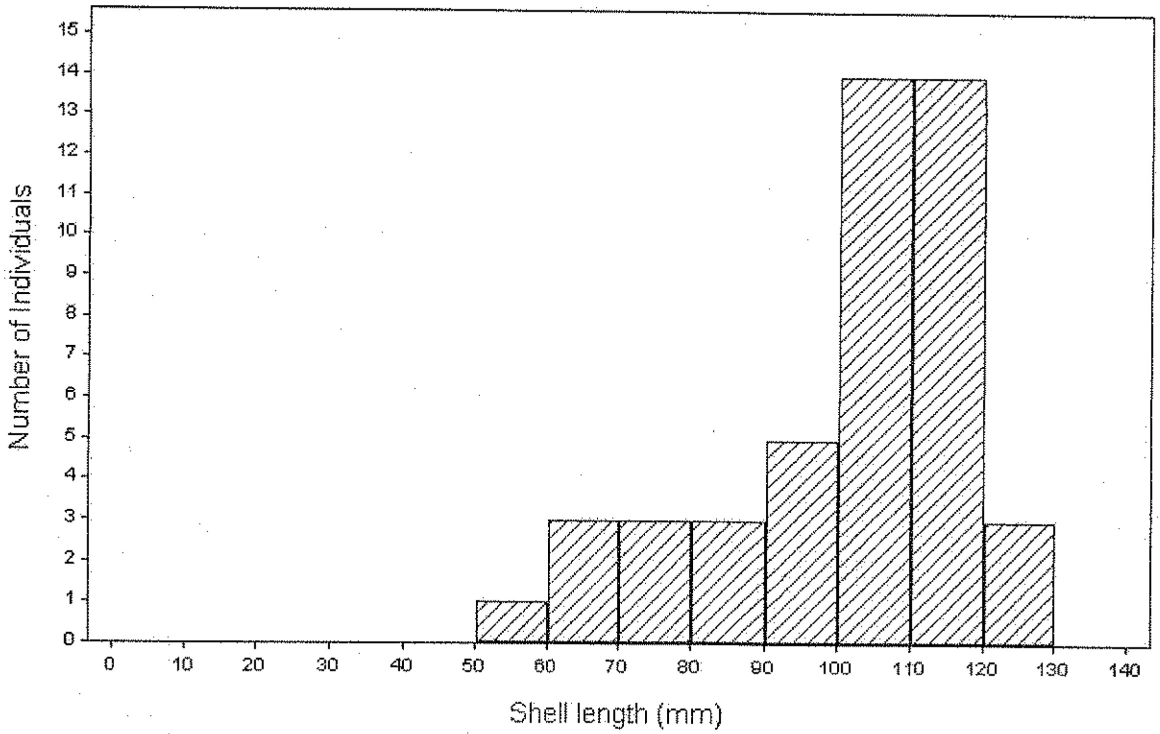

Figure 11. Size frequency distributions for *Quadrula quadrula* collected from the Assiniboine River (Carney, 2003).

Fluctuations and Trends

Clarke (1973) indicated that *Quadrula quadrula* was relatively common to abundant (Table 2, page 12) on the one hand, but in the text indicated it was "...ordinarily uncommon..." (page 33). Where Clarke (1973) does provide collecting data the numbers collected within Manitoba are never very high. Current information is consistent with *Q. quadrula* being uncommon. Watson *et al.* (1998) surveyed the greatest number of sites in the lower Assiniboine River (below the Portage Diversion) and recorded the presence of *Q. quadrula* at 27% of the sites examined, recovering just 6 individuals over 157 km of river with an estimated CPUE of 0.66 (Table 5). Comparisons of CPUE indicates population densities are quite variable, even within rivers, from a low of 0 in the Red and Roseau Rivers to a high of 1.5 in the Assiniboine (Table 5). In 2003 Watkins (unpublished data) surveyed 6 sites in the Assiniboine within Winnipeg for 19.5 person-hours with a CPUE of 1.54 (range 0-9). In 2004 Carney and Watkins (unpublished data) resurveyed one of these sites (which had a CPUE = 9) in for 3 person-hours and recorded a CPUE of 0.37, more than an order of magnitude below the value of the previous year. The available data indicate *Q. quadrula* abundance is the highest in the Assiniboine River within and near the western perimeter of Winnipeg and then decreases proceeding upstream to the Portage Diversion and downstream toward the confluence with the Red River. Just a single individual has been documented from the almost 900km of the Assiniboine upstream of the Portage Diversion (Carney, 2003).

The distribution of *Quadrula quadrula* has undoubtedly become smaller. Historical records indicate a distribution that includes the Red River and many tributaries, the length of the Assiniboine River to Lake of the Prairies and many sites in Lake Winnipeg (Figure 7). In the time period from 1992-2004 *Q. quadrula* has only been recorded from about ½ the length of the Assiniboine River, with the Portage Diversion representing a line of demarcation. No live specimens have recently been recovered from the Red River or from Lake Winnipeg (Figure 8). With the exception of a single individual from the Roseau River, no evidence of *Q. quadrula* has been observed in the other tributaries of the Red River from which it had been previously recorded.

Quadrula quadrula is likely declining in abundance within Manitoba. Clarke (1973) reported *Q. quadrula* from the Roseau River. Since then just one individual has been recorded in 1992 (Carney unpublished data) with no specimens being encountered in recent, more extensive, surveys of this river (Carney 2004a). No live *Q. quadrula* has been recently observed in the Red River (Carney 2004a, Carney and Watkins unpublished data) Clarke (1973) reported collecting 25 *Q. quadrula* from the Red River at St. Jean Baptiste. In 2003, Carney (2004a) surveyed the same site and found no living specimens, but observed many empty valves along the shore. In 2004, Carney and Watkins (unpublished data) returned to this, and other sites along the Red from which Clarke (1973) had collected *Q. quadrula* and found no living specimens of this species and just a few, highly weathered empty valves. This strongly suggests there has been a decline in abundance of *Q. quadrula* within the Red River in Manitoba.

Rescue effect

The Red River drainage is part of the Hudson Bay drainage with no connection to the adjacent Mississippi River drainage. Thus there could be no natural rescue of the populations in the Red River drainage from populations in the Mississippi/Missouri drainages to the east and south, respectively. Although Manitoba populations appear to occur as widely separated assemblages of individuals, there are few barriers limiting the movement of potential fish hosts, and as such, *Quadrula quadrula* can reasonably be considered to be a single, diffuse population. The Portage Diversion on the Assiniboine River, locks on the Red River at Lockport and lowhead dams on the Roseau represent the only barriers to fish movement within the extent of occurrence in Manitoba. The Portage Diversion is an impassable barrier for upstream movement of fish and represent a complete barrier for the upstream dispersal of glochidia-infested hosts. This precludes any natural establishment of *Q. quadrula* upstream of this barrier in the Assiniboine River.

The status of this species in the North Dakota and Minnesota portions of the Red River drainage are not well known. There is no recent information from North Dakota (S. Dyke pers. comm.). Investigations by Carney (2003b) did not encounter this species from sites in North Dakota reported by Cvancara (1970) to hold *Quadrula quadrula*. Limited recent investigations in the upper Red River undertaken by Minnesota Department of Natural Resources staff recovered just 3 *Q. quadrula* (M. Davis pers. comm.). A survey by Hart (1995) of the Otter Tail River, a tributary of the Red River in Minnesota, recovered just 10 *Q. quadrula* from a total of 4,851 individual mussels. A project to translocate mussels from 2 bridge construction sites on the Otter Tail River (Ceas 2001) reported no *Q. quadrula*. This would essentially be a census of the mussels from these 2 sites. These reports suggest that *Q. quadrula* is an uncommon component of the mussel fauna of the Red River drainage in Manitoba, North Dakota and Minnesota. The known mobility of channel catfish potential hosts (Stewart and Watkinson 2004) within the Red River suggests a limited capacity for a rescue effect from populations within the Red River system outside of Manitoba. However, the current evidence indicates that there are few populations in North Dakota and Minnesota to act as a source for rescue. There is no possibility of rescue from the Mississippi/Missouri drainage system.

LIMITING FACTORS AND THREATS

Many mussel species within the Great Lakes have had local populations destroyed by the establishment of the invasive zebra mussel (*Dreissena polymorpha*) (Schlosser *et al.* 1996, submitted). Zebra mussels attach to the unionid mussel shell and impair burrowing, movement, feeding, respiration and other physiological activities (Haag *et al.* 1993, Baker and Hornbach 1997). This impairment results in the death of the unionid mussel. Because the zebra mussel has such explosive population growth they can effectively wipe out entire unionid mussel populations in a very short time. The evidence indicates that *Quadrula quadrula* has been extirpated from Lake Erie, Lake St. Clair and the Niagara and Detroit rivers as a result of infestations by the zebra mussel. Recent reports of zebra mussel from the Fanshawe Reservoir of the Thames River indicates the populations of *Q, quadrula* in this river may be threatened by this invasive species (Maskant 2004). The zebra mussel must be considered a serious threat to *Q. quadrula* and all unionid mussel species. Strayer and Fetterman (1999) identify non-point source inputs, of nutrients, sediment and toxins as the major threats to unionid mussels, with agricultural activities as the major contributor. Agricultural activity comprises 75% of land use in the Grand River basin and inputs of silt and nutrients from agricultural activities can be expected to increase. Agriculture comprises about 80% of land use within the Sydenham River basin and the Thames River basin. Nutrients have been recorded to be consistently above accepted standards in the Sydenham basin. Dams and siltation are of concern in the Thames watershed. The pattern is the same in the Ausable river with approximately 80 of the land being used for agriculture and suspended solids and nutrient levels exceed federal guidelines. There is also an expectation of increasing human populations within these watersheds resulting in increased urbanization with concomitant effects on water quality.

Agricultural activity comprises the majority of land usage in the Assiniboine, Red and Roseau river basins. Nutrient inputs have been increasing dramatically in recent years. The developing hog industry also represents a substantial potential threat to water quality resulting from the increasing use of liquid manure as fertilizer. As the number of hogs continues to increase there will be increasing strain to dispose of the manure that is produced. Damage to river banks and the riparian zone is also of concern, but generally in a much more localized focus. General decline in water quality from these agricultural sources as well as urban and industrial inputs can also result in the accumulation of metals in the tissues of mussels which is a source of additional stress and toxicity (Pip 1995).

The major natural limitation to distribution and abundance of freshwater mussels is the availability, distribution and abundance of the fish hosts required for successful completion of the life cycle. If the fish host is absent then there can be no recruitment. If a mussel species is long-lived, persistence of adult populations can lead to the illusion of healthy mussel population despite the lack of recruitment due to a missing fish host. Because *Q. quadrula* is relatively long-lived, it is evidence for recruitment that would indicate a healthy viable population, not just the presence of adult mussels. The known host fishes for *Q. quadrula* include the channel catfish and flathead catfish. Channel catfish is a common species in Ontario and in Manitoba and this should not limit the possibility for successful reproduction by *Q. quadrula*. However, fish populations should be monitored to ensure mussel reproduction is possible.

In summary, the major threats in Ontario are derived from the zebra mussel and habitat (water degradation) associated with agriculture and urbanization. In Manitoba the major threats are related to decreasing water quality resulting from agricultural activities. The zebra mussel has not yet been recorded in Manitoba waters.

ABORIGINAL TRADITIONAL KNOWLEDGE

Dr. Nicholson (pers. comm.) believes Manitoba First Nations used mussel shell for simple tools (i.e. spoons) based on encountering isolated shells rather than aggregations from archeological sites. Information provided by Centre for Indigenous Environmental Resources, Inc. (CIER) indicated that freshwater mussels were not an important food source for Manitoba First Nations, but are important as a food item for other animals that are important to First Nations People (e.g. muskrat). So, indirectly, mussels may be important. There has been no information from Ontario First Nations, to date.

SPECIAL SIGNIFICANCE OF THE SPECIES

There are 20 recognized species in the genus *Quadrula* of which 1 species is considered extinct and 4 species are considered endangered in the United States. Almost all the remaining species are considered vulnerable to critically imperiled in most of their ranges (www.natureserve.org. accessed 26 November 2004). Two species of the genus, *Q. pustulosa* and *Q. quadrula*, are recorded from Canada. *Quadrula quadrula* is the most widespread species of the genus and, in Canada, is present in Manitoba and southwestern Ontario. *Quadrula quadrula* also appears, for now, to be the most stable in much of its distribution of all the species in the genus. Considering the state of the members of the genus, *Quadrula quadrula*. may represent the best opportunity to maintain representation of the genus *Quadrula* for the long term. Canadian populations occur in separate continental watersheds that are separate from the main distribution of this species and appear to represent unique genetic and ecological information important in conserving the diversity of the species.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Quadrula quadrula is listed as secure (G5) in North America; its national status is N5 in the United States and N3 in Canada (NatureServe 2004). The IUCN Red List of Threatened Species categorizes the species as LR/lc, which means Lower Risk/least concern (The IUCN Species Survival Commission 2004). The national general status of freshwater mussels in Canada was completed in 2004 (CESCC 2004) and the Mapleleaf was ranked as 2 (May be at Risk) nationally and in both jurisdictions (Manitoba and Ontario) where it occurs. The species is provincially ranked as S2 (Rare) by the Manitoba Conservation Data Centre (Duncan 1999) and S3 (Uncommon) by Ontario's Natural Heritage Information Centre (D. Sutherland, pers. comm. 2004). According to NatureServe (2004), current state ranks for *Q. quadrula* are: Alabama (S5), Arkansas (S5), Illinois (S5), Indiana (S4), Iowa (SNR), Kansas (S4), Kentucky (S4S5), Louisiana (S5), Michigan (SNR), Minnesota (SNR), Mississippi (S5), Missouri (SNR), Nebraska (SNR), New York (SH), North Dakota (S2), Ohio (SNR), Oklahoma (S5), Pennsylvania (S1S2), South Dakota (S2), Tennessee (S5), Texas (SNR), West Virginia (S2) and Wisconsin (S2S3). Contact with the relevant state agencies confirms most of these designations with the following exceptions. Ranked S2 in South Dakota, this species is considered to be stable and a more accurate rank is considered S2/S3 (Steve Backlund pers. comm.). Ranked S2/S3 in Wisconsin this species is considered healthy and to be have commercially harvestable populations (Karl Scheidegger pers. comm.)

Manitoba is a province with its own Endangered Species Act. The purpose of this Act is to designate indigenous species as endangered, threatened, extinct or extirpated, to protect and enhance survival of species considered endangered or threatened and to permit the reintroduction of extirpated species. Under this Act no person can cause harm, possess disturb or interfere with species that are recognized as endangered, threatened or reintroduced. Furthermore, habitat or required resources of such species cannot be destroyed, disturbed or interfered with. It is not permitted to kill, capture, collect or hold alive such species. Exceptions to this require a permit and include reasons such as scientific investigations and purposes related to protection or reintroduction of such species. Another exception is ministerial discretion based on assurance of protection and preservation of the species, or appropriate measures being established to minimize impact of whatever the activity under consideration might be. Mussels are considered shellfish in Manitoba and fall under the jurisdiction of the Fisheries Branch. Currently, the collection of freshwater mussels in Manitoba requires a permit from the Fisheries Branch. At present, there is no specific protection afforded

Quadrula quadrula under either the provincial Endangered Species Act, or the Fisheries Act other than requiring a permit to collect.

Ontario is one of six provinces that have stand-alone Endangered Species Acts. Species designated as endangered are protected from willful destruction under these Acts. Since freshwater mussels are not regulated in Ontario at the present time, the Mapleleaf would not benefit from endangered species legislation in this province. The federal Fisheries Act may represent the most important legislation protecting mussel habitat in Canada. Freshwater mussels are considered to be shellfish and, as such, are included in the definition of "fish" under the Act. Collection of live mussels is considered "fishing" and falls under the Ontario Fishery Regulations made under the federal Fisheries Act. This means that mussels cannot be collected in Ontario without a permit from the Ontario Ministry of Natural Resources. Threatened and endangered species in Ontario receive policy level protection from development and site alteration through the Provincial Policy Statement under the provincial Planning Act. The Ontario Lakes and Rivers Improvement Act (prohibiting the impoundment or diversion of watercourses that would lead to siltation) and the voluntary Land Stewardship II program of OMAFRA (designed to reduce the erosion of agricultural lands) also protect mussel habitat. Stream-side development in Ontario is managed through flood plain regulations enforced by local Conservation Authorities.

TECHNICAL SUMMARY

Quadrula quadrula

Mapleleaf

Mulette feuille d'érable

Range of Occurrence in Canada: Ontario, Manitoba

Extent and Area Information: ONTARIO	
• *Extent of occurrence (EO)(km²)* **Janice Metcalfe-Smith, calculated using ARCview on GIS maps**	13,000 km²
• *Specify trend in EO*	decline
• *Are there extreme fluctuations in EO?*	no
• *Area of occupancy (AO) (km²)* **Janice Metcalfe-Smith, see text for details**	0.29 km² in Ausable River 0.16 km² in North Sydenham River 1.2 km² in East Sydenham River 8.8 km² in Thames River 24.75 km² in Grand River Total = ~ 35.2 km²
• *Specify trend in AO*	decline
• *Are there extreme fluctuations in AO?*	no
• *Number of known or inferred current locations*	5
• *Specify trend in #*	decline
• *Are there extreme fluctuations in number of locations?*	no
• *Specify trend in area, extent or quality of habitat*	decline

Population Information	
• *Generation time (average age of parents in the population)*	unknown estimate 10 years
• *Number of mature individuals*	unknown
• *Total population trend:*	decline
• *% decline over the last/next 10 years or 3 generations.*	unknown
• *Are there extreme fluctuations in number of mature individuals?*	no
• *Is the total population severely fragmented?*	Yes, populations from different rivers don't mix
• *Specify trend in number of populations*	decline
• *Are there extreme fluctuations in number of populations?*	no
• *List populations with number of mature individuals in each:*	unknown, total population estimated to be 5.5 million individuals

Threats (actual or imminent threats to populations or habitats)

Zebra mussels (invasive species) Habitat loss and degradation resulting from municipal and industrial pollution, urbanization and agricultural activity (resulting nutrient loading, loss of riparian vegetation and siltation).

Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* **USA: Status apparently secure within most of US distribution. In same watersheds as Canadian populations (Lake Erie) it is either not ranked or is S2 or is in the same state of decline as Canadian populations.**	
• *Is immigration known or possible?*	not possible
• *Would immigrants be adapted to survive in Canada?*	likely but needs to be confirmed by testing
• *Is there sufficient habitat for immigrants in Canada?*	no, currently occupied by existing populations
• ***Is rescue from outside populations likely?***	**no**

Quantitative Analysis [provide details on calculation, source(s) of data, models, etc]	[x% probability of extirpation in y years]

Current Status COSEWIC: not ranked

Extent and Area Information: MANITOBA	
• *Extent of occurrence (EO)(km²)* **Joe Carney, calculated using polygons on 1:50,000 maps**	11,500 km²
• *Specify trend in EO*	decline
• *Are there extreme fluctuations in EO?*	no
• *Area of occupancy (AO) (km²)* **Joe Carney, see text for details**	2.5 km² in Assiniboine River above Portage Diversion 7.5 km² in Assiniboine River below Portage Diversion 18.15 km² in Red River 0.99 km² in Roseau River Total = ~29.14
• *Specify trend in AO*	likely declining
• *Are there extreme fluctuations in AO?*	no
• *Number of known or inferred current locations*	4
• *Specify trend in #*	stable, may be declining
• *Are there extreme fluctuations in number of locations?*	no
• *Specify trend in area, extent or quality of habitat*	declining

Population Information	
• *Generation time (average age of parents in the population)*	unknown estimate 10 years

• *Number of mature individuals*	unknown
• *Total population trend:*	decline
• *% decline over the last/next 10 years or 3 generations.*	unknown
• *Are there extreme fluctuations in number of mature individuals?*	no
• *Is the total population severely fragmented?*	no, rivers are connected so genetic mixing (via fish hosts) is possible
• *Specify trend in number of populations*	decline
• *Are there extreme fluctuations in number of populations?*	no
• List populations with number of mature individuals in each:	unknown, total population estimated to be at minimum 1-4 million individuals

Threats (actual or imminent threats to populations or habitats)
Habitat loss and degradation resulting from agricultural activity (siltation, loss of riparian vegetation and streambank erosion and especially nutrient loading), municipal and industrial pollution, and urbanization

Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* **USA: Status apparently secure within most of US distribution. In same watersheds as Canadian populations (Red River) it is either not ranked or is S2 or is in the same state of decline as Canadian populations.**	
• *Is immigration known or possible?*	not possible
• *Would immigrants be adapted to survive in Canada?*	likely, needs to be confirmed by testing
• *Is there sufficient habitat for immigrants in Canada?*	unknown
• ***Is rescue from outside populations likely?***	**no**

Quantitative Analysis [provide details on calculation, source(s) of data, models, etc]	Not Available

Current Status COSEWIC: not ranked

Author of Technical Summary: Joe Carney, June 2005.

Recommended Status and Reasons for Designation
[This table is to be completed in the Interim Report by the SSC;
COSEWIC will approve or modify the text in this section for the Final Report]

Recommended Status: EN	**Alpha-numeric code:** EN B2a i,ii,iii,iv
Reasons for Designation: [Note especially if it is a Canadian endemic with 100% of its distribution in Canada]	

<u>**Applicability of Criteria**</u> **Criterion A** (Declining Total Population): **Criterion B** (Small Distribution, and Decline or Fluctuation): **Criterion C** (Small Total Population Size and Decline): **Criterion D** (Very Small Population or Restricted Distribution): **Criterion E** (Quantitative Analysis):

ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Joseph Carney, at the start of this document, was an assistant professor at Brandon University, Brandon Manitoba. He is currently an assistant professor at Lakehead University, Thunder Bay Ontario. He received his Ph.D. from the University of Manitoba in 2000 investigating the evolution and community ecology of parasites of yellow perch (*Perca flavescens*). Since 2002 he has initiated a research program investigating the ecology and conservation of freshwater mussels (Mollusca: Unionidae) within the Red River drainage in Manitoba, Saskatchewan and North Dakota. He has published 11 scientific papers and reports. Four of these have focused on freshwater mussels, with an additional three pending. He is a member of the Society for the Study of Evolution, Ecological Society of America, Society for Conservation Biology and the Freshwater Mollusk Conservation Society.

Janice Smith is a Research Biologist with the National Water Research Institute of Environment Canada in Burlington, Ontario. She has a B.Sc. (Hons.) in Zoology from the University of Manitoba (1973) and M.Sc. equivalency from the University of Waterloo (1990). Over her 31-year career with the Federal Government (EC and DFO), she has conducted research in many areas including the effects of forestry practices and acid rain on Atlantic salmon, the use of benthic macroinvertebrates in water quality assessment, the development of biomonitoring techniques for contaminants in freshwater ecosystems and aquatic toxicology. She has published over 75 scientific papers and reports and has been conducting research on the conservation status of freshwater mussels in Ontario since 1995. She is a member of the Specialist Subcommittee of COSEWIC.

William Watkins is the senior zoologist with the Conservation Data Centre (CDC) of the Manitoba Department of Conservation. He has a B.Sc. Hons. (1978) and an M.Sc. (1982) from the University of Manitoba. During his 19 year career with the Manitoba government he has been involved in protected lands planning and wildlife management planning in all areas of the province. He has participated extensively in consultations with First Nations respecting the establishment of new provincial parks and is a member of the joint Manitoba Conservation/Skownan First Nation Wood Bison Management Committee. Since 2002 he has been compiling historical and recent data on the distribution of freshwater mussels in Manitoba for the CDC database and has initiated mussel surveys in southern Manitoba for the purpose of reassessing provincial conservation status ranks and contributing to national general status ranking. He has written 8 scientific papers and reports and has extensive experience in producing government extension and consultation materials.

COLLECTIONS EXAMINED

Collections of freshwater mussels from Manitoba are limited. The Manitoba Museum of Man and Nature has a small collection deposited by Ernie Watson. This has been examined by William Watkins, one of the authors of this report. A larger, research collection, is maintained by J. Carney, another author and this collection is regularly examined. Vouchered specimens from the personal collection maintained by Dr. Eva Pip have been examined. Data from various recent reports (Scaife and Janusz 1992; Watson et al. 1998; Carney 2003a, 2004a, b) are in the process of being compiled in a GIS linked database by one of the authors (William Watkins).

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 the National Water Research Institute in Burlington, Ontario. 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 data acquired. One of us (J.L. 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 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.

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