COSEWIC
Assessment and Status Report

on the

Hickorynut
Obovaria olivaria

in Canada

ENDANGERED
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Hickorynut

Scientific name
Obovaria olivaria

Status
Endangered

Reason for designation
This freshwater mussel lives in mid-sized to large rivers in southern Ontario and Quebec. There has been an historical decline in the species' distribution with losses of the populations in the Detroit and Niagara rivers. Other locations are threatened by the continuing invasion of dreissenid mussels. In addition, the one known host of this mussel, the Lake Sturgeon, is at risk and may be declining in some locations where the mussel is known to still occur. The species is also affected by degraded water quality in many freshwater systems in southern Ontario and Quebec.

Occurrence
Ontario, Quebec

Status history
Designated Endangered in May 2011.

COSEWIC
Executive Summary

Hickorynut
Obovaria olivaria

Wildlife species description and significance

The Hickorynut (also known as the Olive Hickorynut, *Obovaria olivaria*) is a freshwater mussel in the family Unionidae. The shell of this medium-sized mussel is usually less than 75 mm long. This species is easily distinguished from other mussels in Canada and can be recognized primarily from its relatively small and nearly oval shell, its unique hinge features and the far anteriorly located peak of the shell.

There are five recognized species in the genus; only the Hickorynut and the endangered (SARA) Round Hickorynut (*O. subrotunda*) have ranges extending into Canada. Hickorynut was among the shells considered valuable for the pearl button industry in the early 20^{th} century, and was harvested for these purposes in the Mississippi River drainage, but has never been deemed commercially important in Canada.

Distribution

The Hickorynut occurs in large bodies of water in the Mississippi River drainage system and in the Great Lakes/St. Lawrence basin. In Canada, this species is distributed discontinuously within the Great Lakes and St. Lawrence drainage system from Lake Huron to Quebec City.

Habitat

Hickorynuts are typically found on sandy substrates in relatively deep water (compared with other species of mussels), at depths usually exceeding 2 to 3 m, with a moderate to strong current. All rivers with extant Hickorynut are large, wide, and deep. Many of the large-river habitats of Hickorynut (or its host fish) have been degraded due to Zebra and Quagga Mussel infestation, habitat alteration due to dam construction, and/or industrial and agricultural pollution.

Biology

Current information on the reproduction of the Hickorynut indicates that the sexes are separate, as in the vast majority of unionid North American mussels. Adult Hickorynut are on average between 7 and 14 years old. Like all unionid mussels, the Hickorynut has a specialized larval stage called a glochidium that is parasitic on one or more species of fish. The probable host for the Hickorynut in Canada is the Lake Sturgeon. As Lake Sturgeon are capable of long-distance migration, this is likely the primary method of dispersal for the Hickorynut.

Population sizes and trends

Hickorynuts have recently (since 1998) been collected alive or as freshly dead shells from six locations (rivers) in Canada: the Mississagi River (Lake Huron drainage, Ontario), the Ottawa River (St. Lawrence drainage, Ontario and Quebec), Rivière Coulonges (Ottawa River drainage, Quebec), the lower St. Lawrence River between Trois-Rivières and Quebec, the Rivière Batiscan (St. Lawrence drainage, Quebec), and the Rivière Saint-François (St. Lawrence drainage, Quebec). Over the last few decades, population units may have been lost from the Detroit River (Ontario), Niagara River (Ontario), the St. Lawrence River between Montreal and Trois-Rivières, and the Rivière L'Assomption (St. Lawrence River drainage, Quebec).

Threats and limiting factors

The biggest direct threat to Hickorynuts in Canada is infestation by exotic Zebra and Quagga mussels (collectively known as dreissenids). The locations in the Detroit and upper St. Lawrence Rivers were likely lost following heavy infestations in the late 1980s by the Zebra Mussel and early 1990s by the Quagga Mussel. Other locations are at continued risk of dreissenid mussel infestations. All locations in Canada may have been suffering declines due to direct effects caused by degraded water quality from industrial and agricultural pollution, but there is no evidence that this caused the extirpation of mussels.

A second major threat is the reduced abundance of the Hickorynut's likely host, the Lake Sturgeon. Lake Sturgeon in the Great Lakes-St. Lawrence region was assessed as Threatened by COSEWIC in 2006 due to the loss of several populations and a variety of continued threats: poor habitat due to water manipulation, water quality, and substrate destruction. Lake Sturgeon (Great Lakes-Upper St. Lawrence River population) was also identified as a Threatened species under Ontario's *Endangered Species Act, 2007*. Without the presence of their host, Hickorynuts cannot complete their lifecycle, resulting in extirpation. The decline of Lake Sturgeon from the Niagara River could have led to the extirpation of this population unit by the 1970s.

Protection, status, and ranks

The federal *Fisheries Act* and several provincial acts in Ontario and Quebec represent the only pieces of legislation currently protecting the Hickorynut in Canada. The Hickorynut is apparently secure globally and is ranked as apparently secure in the United States but nationally imperiled in Canada by NatureServe. It is not on the IUCN's Red List. While still broadly distributed in Mississippi drainage of the U.S., it is imperiled or extirpated from most of the U.S. Great Lakes states.

TECHNICAL SUMMARY

Obovaria olivaria (Rafinesque 1820)
Hickorynut Obovarie olivâtre
Range of occurrence in Canada: Ontario, Quebec

Demographic Information

Generation time (usually average age of parents in the population); indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used *(See **BIOLOGY** section)*	7-14 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
Inferred percent reduction in total number of mature individuals over the last 3 generations. *Inferred from 52.1% decline in IAO*	Yes
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
Inferred percent reduction in total number of mature individuals over any 3 generations period, over a time period including both the past and the future. *Inferred from 52.1% decline in IAO*	Yes
Are the causes of the decline clearly reversible and understood and ceased? **causes not easily reversible (Zebra and Quagga mussels, dams, and loss/declines in host fish populations), they are not completely understood, they have not ceased for some locations see **Habitat trends** and **THREATS AND LIMITING FACTORS***	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence *Calculated using minimum convex poylgon of records with live and fresh dead shells since 1998.*	141,268 km²
Index of area of occupancy (IAO) *2x2 km (4 km^2) grid value using records of live and fresh-dead shells since 1998. IAO (92km^2) more appropriate for Hickorynut because distribution rarely continuous. There has been a 52.1% reduction in IAO*.	92 km²
Is the total population severely fragmented? *Dams on the Ottawa River, St. Lawrence River, Great Lakes, and tributaries make gene flow (via Lake Sturgeon host) impossible. A once near-continuous population is now restricted to 6 isolated and anthropogenically fragmented locations. Does not meet IUCN criteria for severely fragmented*.	No
Number of locations∗ (live or fresh-dead shells since 1998) Mississagi River, ON Ottawa River, ON/QC Rivière Coulonges, QC St. Lawrence River, QC (Lac Saint-Pierre to Quebec) Rivière Batiscan, QC Rivière Saint-François, QC	6

∗ See definition of location.

Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an inferred or projected continuing decline in quality of habitat? *The probable host of* O. olivaria *(Lake Sturgeon) is Threatened and may be declining in some locations where* O. olivaria *is known to occur (see* ***Habitat trends****)*. *Zebra and Quagga mussels continue to expand their range and could infest impounded sections of river upstream of* O. olivaria *population units*.	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each location)

Location	**N Mature Individuals**
Mississagi River, ON	Unknown
Ottawa River, ON/QC	Unknown
Rivière Coulonges, QC	Unknown
St. Lawrence River, QC (Lac St. François to Quebec)	Unknown
Rivière Batiscan, QC	Unknown
Rivière Saint-François, QC	Unknown
Total Population	Unknown (likely tens of thousands)

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Zebra and Quagga mussel infestations
Loss of host (Lake Sturgeon)
Barriers to host movement (dams)
Degraded water quality

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Imperiled (S1, S2) or extirpated or historic (SH, SX) from 10 U.S. states, stable in only 3 states.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (May 2011)

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2c+4c
Reasons for designation: This freshwater mussel lives in mid-sized to large rivers in southern Ontario and Quebec. There has been an historical decline in the species' distribution with losses of the populations in the Detroit and Niagara rivers. Other locations are threatened by the continuing invasion of dreissenid mussels. In addition, the one known host of this mussel, the Lake Sturgeon, is at risk and may be declining in some locations where the mussel is known to still occur. The species is also affected by degraded water quality in many freshwater systems in southern Ontario and Quebec.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets EN A2c as there is an inferred reduction of 52.1% in the total number of mature mussels based on a decline in IAO over the past 3 generations (A2c). Does not meet A1 as the causes of reduction are not clearly reversible. Does not meet A3 as the projected or suspected reduction in the number of mature individuals over the next 10 years or 3 generations is unknown. Meets EN A4c as there is an inferred and projected reduction of 52.1% in the total number of mature mussels based on a decline in IAO (A4c).
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets TH under B2ab(ii,iii,iii) because the index of area of occupancy (IAO) of 92 km² is lower than the threshold value of 2000 km², fewer than 10 locations (but more than 5 locations), with continuing decline in (i) EO, (ii) IAO, (iii) quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable because the number of mature individuals is unknown.
Criterion D (Very Small or Restricted Total Population): Not applicable because the number of mature individuals is unknown, there are 6 locations and IAO is greater than 20km².
Criterion E (Quantitative Analysis): None available

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2011)

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

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

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

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

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

Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

The Hickorynut, *Obovaria olivaria*, was first described by Rafinesque (1820), under the name *Amblema olivaria*. It was also named a few years later as *Unio ellipsis* Lea, 1828. Many authors used the specific epithet *ellipsis* in the 1800s and Rafinesque's *olivaria* name regained acceptance at the beginning of the 20th century. As in other Unionidae, genus names for *O. olivaria* have changed several times and its taxonomic status became resolved around 1900. In 1900, it was definitively placed under the genus *Obovaria* by Simpson (Oesch 1995; Parmalee and Bogan 1998). The genus *Obovaria* includes five species, distributed in the Mississippi/Ohio drainage, Gulf Coast and St. Lawrence/Great Lakes basin (Zanatta and Murphy 2006; Graf and Cummings 2007).

Phylum Mollusca
- Class Bivalvia (Pelecypoda)
  - Subclass Palaeoheterodonta
    - Order Unionoida
      - Superfamily Unionacea
        - Family Unionidae
          - Subfamily Ambleminae
            - Tribe Lampsilini
              - Genus *Obovaria*
                - Species *Obovaria olivaria*

Morphological description

<u>Shell</u>

The Hickorynut is a medium-sized mussel, usually less than 75 mm long, but it can reach up to 100 mm length (Cummings and Mayer 1992; Parmalee and Bogan 1998). The shell is subovate and the posterior slope is regularly rounded, without a distinct posterior ridge. Both sexes are of similar shape, but Parmalee and Bogan (1998) mention that the posterior end is broadly pointed in males and broadly rounded in females. The height/length ratio is usually 0.65-0.80 (Strayer and Jirka 1997). The shell is thicker anteriorly (often more than 4 mm in adults) and thinner posteriorly. The beaks are inflated, elevated above the hinge line and oriented toward the anterior part of the shell (Figure 1). The beak sculpture is usually obliterated in adults and only evident in very young individuals. When present, it is faint and composed of four to five weakly double-looped bars. The beak cavity is shallow. The pseudocardinal and lateral teeth are thick and well defined (Figure 2). The pseudocardinal teeth are triangular, massive and divergent. The lateral teeth are straight to slightly curved, wide, long and striated. The left valve bears two lateral teeth and two pseudocardinal teeth, and a small, thin tooth is also often present anteriorly to the pseudocardinals. The right valve has one lateral and one pseudocardinal tooth, and bears also a thin tooth anteriorly. The interdentum is narrow. The muscle scars and the pallial line are pronounced. The periostracum ranges from green to yellowish brown, becoming dark brown in old individuals. Thin greenish rays are often present in juveniles. The valves are also relatively smooth and growth rings are well marked. The nacre is white, rarely with a pink wash, and slightly bluish in the posterior region. This species is easily distinguished from other mussels in Canada (including its congener, *O. subrotunda*) and it can be recognized primarily by its medium-sized and subovate shell, the heavy and complete hinge teeth, and the beak far to the anterior.

Figure 1. Live *Obovaria olivaria* (Hickorynut) from the Mississagi River, Ontario (length 59 mm). Photo: D. Zanatta, CMU.

Figure 2. Internal shell morphology of *Obovaria olivaria* (Hickorynut) from the Ottawa River at Maclaren's Landing. Photo: J. Madill, CMN.

Soft tissue

The branchial and anal openings are both papillose and the supra-anal opening is large and crenulated. The mantle margin is anterio-ventral to the branchial opening with lamellae or crenulations. The foot is pinkish, the mantle edge is dark near the siphon and the rest of the soft parts are white (Oesch 1995).

Population spatial structure and variability

Nothing is known of the population genetic structure of this species; however data are available on its putative host in Canada, the Lake Sturgeon, *Acipenser fulvescens* (see **Designatable units** below).

Designatable units

Historically, *Obovaria olivaria* was widely distributed throughout the Great Lakes-St. Lawrence region. The presence of an apparently disjunct population of *O. olivaria* in the Mississagi River, ON (Lake Huron drainage) is interesting biogeographically. It raises the questions of post-glacial origin for the *O. olivaria* populations in the Great Lakes region (Graf and Underhill 1997; Graf 2002) for which there are three possible recolonization routes: the Wabash-Maumee River spillway, the Chicago-Illinois River spillway, the St. Croix River-Lake Superior spillway—all in the U.S. *Obovaria olivaria* records are known from several American tributaries of Lake Michigan, Lake Huron, and Lake Superior (Ohio State University Museum of Biological Diversity - Division of Mollusks 2009; University of Michigan Museum of Zoology - Division of Mollusks 2009). To verify these records and assess the status of the populations, intervening rivers need to be surveyed to determine if the Mississagi population is in fact disjunct or if it represents a continuum. In additon to habitat protection, removal of dams and barriers and prevention of invasive dreissenid mussels are needed to properly manage this rare mussel in the Great Lakes region. Also, range-wide studies are needed to determine the geographic genetic population structure (conservation genetics) of this species (e.g., Zanatta *et al*. 2007; Zanatta and Murphy 2007, 2008).

The remaining locations for *O. olivaria* in Canada are congruent with the Great Lakes-St. Lawrence designatable unit (DU) of its probable host, the Lake Sturgeon (*Acipenser fulvescens*) (COSEWIC 2006b). Therefore, a single DU is recommended for the Canadian population of Hickorynut until future studies of the species' phylogeography and genetic population structure to determine if it meets the criteria for multiple DUs.

Special significance

There are five recognized species in the genus *Obovaria*; only the Hickorynut (*O. olivaria*) and Round Hickorynut (*O. subrotunda*) have ranges extending into Canada. *Obovaria subrotunda* is listed as endangered in Canada and Ontario. One of the five species, the Ring Pink (*O. retusa*), is listed as federally endangered in the United States. Three other species, the Southern Hickorynut (*O. jacksoniana*), Alabama Hickorynut (*O. unicolor*) and Round Hickorynut are listed as special concern (a species or subspecies that may become endangered or threatened by relatively minor disturbances to its habitat, and deserves careful monitoring of its abundance and distribution) by the American Fisheries Society (Williams *et al.* 1993); only *O. olivaria* is considered to be stable in the United States, but has declined severely in the northern parts of its range. *Obovaria olivaria* was among the shells considered valuable for the pearl button industry in the early 20th century, and was taken for these purposes in the Mississippi River drainage (Anthony and Downing 2001). There are no records of the species being used for buttons in Canada.

DISTRIBUTION

Global range

Obovaria olivaria occurs in large bodies of water in the Mississippi River drainage system and in the Great Lakes-St. Lawrence basin (Figure 3). In the Mississippi basin, it is widespread and common in the Wabash and lower Ohio rivers, but it is disappearing in the Mississippi and upper Ohio rivers (Cummings and Mayer 1992). It reaches Missouri, Arkansas and Louisiana in the south, New York and Pennsylvania in the east and Kansas in the west (Parmalee and Bogan 1998). In Missouri, it has been found only in Meramec River (Oesch 1995). In Tennessee, it has been found in the main channel of the Mississippi River in northwest Tennessee and the main channels of the lower Tennessee and Cumberland rivers. The Hickorynut is presently extremely rare in the Tennessee River and possibly extirpated there (Parmalee and Bogan 1998). It may be extirpated from Ohio and Pennsylvania (Watters *et al.* 2009).

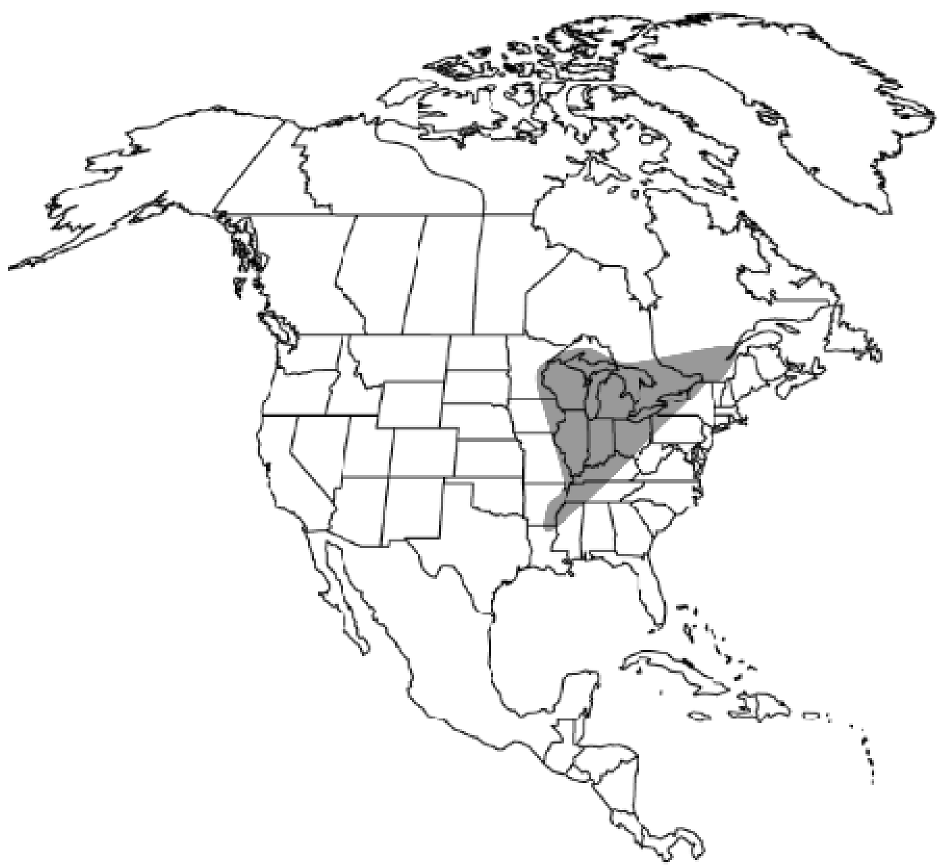

Figure 3. Global distribution of the Hickorynut (*Obovaria olivaria*; modified from Parmalee and Bogan 1998).

Canadian and Great Lakes range

In Canada, this species inhabits the Great Lakes and St. Lawrence drainage system from Lake Huron to Quebec City (Figure 4, Figure 5). The largest populations are in the St. Lawrence and Ottawa Rivers (Martel *et al.* 2006), but small populations are also present in some other tributaries of the St. Lawrence (Batiscan River, Rivière St-François, Rivière L'Assomption) (Figure 8). In the Great Lakes region there were historically populations of *O. olivaria* in the Detroit River (ON, MI; Schloesser *et al.* 2006) (Figure 5). In New York, it seems to have been fairly abundant in the Niagara River, because museum lots contain multiple specimens; however there have been no records of live animals since 1970 (Strayer and Jirka 1997). There are records from high-order (large river) tributaries of Lake Michigan (Fox River WI, Grand River MI, Menominee River MI/WI, Wolf River WI), Lake Superior (Bad River WI), Lake Huron (Mississagi River ON), Lake St. Clair (Thames River ON), and Lake Erie (Grand River ON) (Metcalfe-Smith *et al.* 2000; Ohio State University Museum of Biological Diversity - Division of Mollusks 2009; University of Michigan Museum of Zoology - Division of Mollusks 2009).

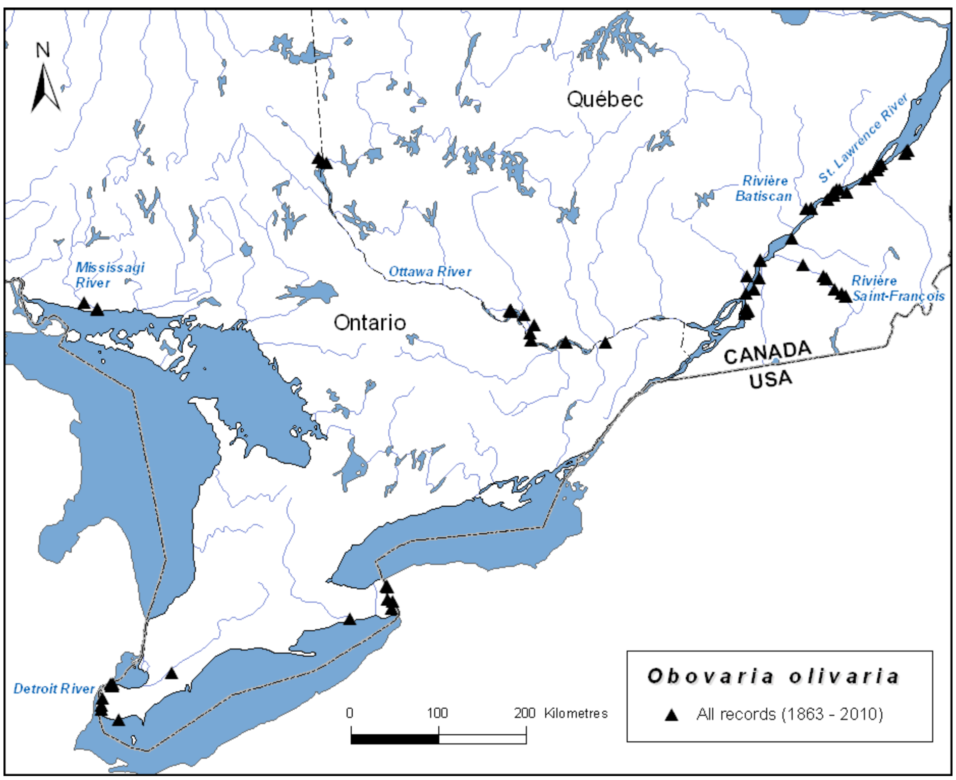

Figure 4. Historical and current distribution of *Obovaria olivaria* in Canada (all known records).

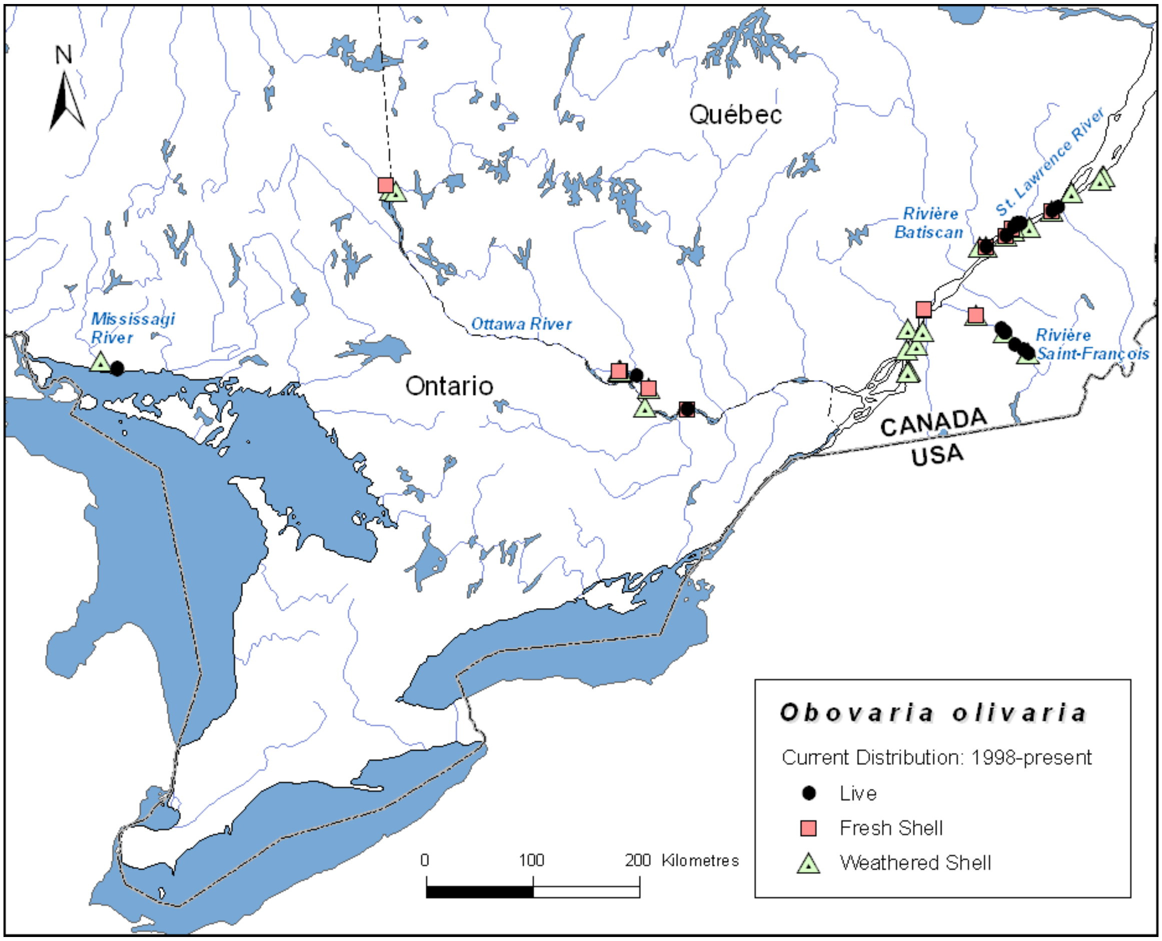

Figure 5. Recent distribution of *Obovaria olivaria* in Canada, showing live, fresh and weathered shell records collected from 1998 to 2009.

Based on the most serious threat, heavy Zebra and Quagga mussel fouling unionids (see **Threats and Limiting Factors** below), there are six known "locations" (as per the COSEWIC / IUCN definition) where *O. olivaria* is currently extant in Canada: Mississagi River, Ottawa River, Rivière Coulonges, St. Lawrence River, Rivière Batiscan, Rivière Saint-François. Two locations were likely lost over the last three generations: Niagara River and Detroit River due to loss of host fish and presence of dreissenid mussels, respectively. While the remaining locations of Hickorynut in Canada are isolated from one another, the total population does not meet the IUCN (2010) definition of "severely fragmented": "A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance."

Historical and recent extent of occurrence (EO) for the Canadian population of *O. olivaria* were calculated using a minimum convex polygon. The EO (within Canada's extent of jurisdiction), using all shell records since 1980 (~3 generations), was 302,982 km^2. Recent EO was calculated using only live animals and fresh shells (e.g., intact hinge, peristracum, clean nacre) since 1998 at 141,268 km^2, a 53.4% reduction in EO. This reduction in EO is mostly a result of the loss of the Detroit River location following the invasion of dreissenid mussels in 1986. Hickorynut from Niagara River were probably lost prior to 1970 (beyond 30 years or 3 generations; Strayer and Jirka 1997), thus their loss was not considered in the change in EO or IAO (described below).

Index area of occupancy (IAO) calculations were made using a 2 x 2 km grid. Collections of live and fresh-dead shells were used as valid records of probable live animals. The IAO was calculated assuming that each site record stands alone (resulting in an IAO of 92 km^2) Table 1 gives the calculations of IAO for *O. olivaria* in the 6 locations in Canada. This is considered the most cautious approach because unionid mussels in large river systems are patchily distributed (not continuously distributed) and are not found in areas of unsuitable habitat (Woolnough 2006). Historial IAO was also calculated using all shell records since 1980 (~3 generations), again calculating IAO for large-river reaches. The historical IAO value is 192 km^2, respectively. This results in an estimated 52.1% (i.e. (192-92)/192) decline in mean IAO over the last 3 generations for *O. olivaria*. The decline in IAO is likely underestimated because the historical surveys were not done nearly as well as the more recent surveys. The decline in IAO is a result of the loss of unionid mussels in the Detroit River (Schloesser *et al.* 2006) and upper St. Lawrence River (Ricciardi *et al.* 1996) following the invasion of the Zebra Mussel in 1986 and the Quagga Mussels in 1991. The Zebra Mussel is continuing its invasion into inland freshwaters of Ontario and Quebec.

Table 1. Calculation of index area of occupancy (IAO) for *Obovaria olivaria* using 2 x 2 km grids for each of the six locations in Canada. IAO was calculated using records of both live and fresh-dead shells from 1998 or later as evidence of live *O. olivaria*.

Location	IAO (2x2 grid)
Mississagi River, ON	4 km^2
Ottawa River, ON/QC	16 km^2
Rivière Coulonge, QC	4 km^2
St. Lawrence River, QC	40 km^2
Rivière Batiscan, QC	4 km^2
Rivière Saint-François, QC	24 km^2
Total IAO	92 km^2

The loss in IAO is assumed to also result in the loss of mature individuals, while declines in EO may not necessarily result in declines of mature individuals.

Search effort

Hickorynut is a large river, deep-water species (see **Habitat requirements** below) that requires specialized surveys (SCUBA) and it is, as such, difficult and often prohibitively costly to do proper surveys. It is difficult to determine the total search effort dedicated to surveying the range of *O. olivaria* in Canada as it is not usually found in the typical wadeable riffle and run habitats of other mussel species determined to be at risk by COSEWIC in Canada. Many collections of *O. olivaria* in Canada have been incidental. See **Sampling effort and methods** below.

HABITAT

Habitat requirements

Obovaria olivaria has been called a "lover of water of moderate depth and sandy river beds" (Scammon 1906, cited in Parmelee and Bogan 1998). This mussel is typically found on sandy substrates in deep water (compared with other species of mussels), at depths usually exceeding 2 to 3 m, with a moderate to strong current (Parmelee and Bogan 1998). All rivers with extant *O. olivaria* are large, wide, and deep. Live Hickorynuts are usually observed at depths of 3 to 5 m, in sandy or silty sand bottom areas and with strong to moderate water current (D. Zanatta and A. Martel, pers. obs.). It should be noted however, that live individuals have been found at a depth of less than 60 cm in the Batiscan River (a tidal river in the St. Lawrence drainage) at low tide (A. Paquet, pers. obs.). Similar to other unionids, the Hickorynut lives partly to nearly completely buried in the sandy river bottom, with only the siphonal apertures exposed. Because of its deep-water habit, empty shells of this species are, in contrast with *Elliptio* spp. and *Lampsilis* spp., usually a rare find along river banks.

Habitat trends

The large river habitats of the Great Lakes-St. Lawrence region have been degraded due to pollution (industry and agriculture, especially in southern Quebec; Metcalfe and Charlton 1990; Metcalfe-Smith *et al.* 1996), construction of impoundments, and dreissenid mussel introductions. These impacting factors have effects on both *O. olivaria* and its probable host, the Lake Sturgeon (see **Life cycle and reproduction**). The habitat for the Hickorynut has been subject to a variety of threats over the last several decades.

The most significant change in habitat for the Hickorynut is associated with the invasion of the dreissenid mussels: Zebra Mussels, *Dreissena polymorpha*, in 1986 and Quagga Mussels, *Dreissena rostriformis bugensis*, in 1991. Dreissenid mussels compete with native unionids for space and food and, by attaching directly to native mussel shells, impair the ability of the native mussels to feed, respire and move normally (see **LIMITING FACTORS AND THREATS**). Within about a decade of the first invasion, native unionids had been almost completely eradicated from Lake St. Clair, Lake Erie, the Detroit River and Niagara River, and parts of the St. Lawrence River (Schloesser and Nalepa 1994; Nalepa *et al.* 1996; Ricciardi *et al.* 1996; Schloesser *et al.* 2006). Locations in the Detroit, Niagara, and upper St. Lawrence rivers where *O. olivaria* was known to have occurred historically have been severely impacted by dreissenid mussels and represent areas where *O. olivaria* and other unionids are now considered essentially extirpated. Despite these catastrophic effects, there are still areas where dreissenid mussels occur at sufficiently low densities to allow coexistence with unionids, such as the St. Clair delta (McGoldrick *et al.* 2009). Recent work by Strayer and Malcom (2007) suggests the potential for continued coexistence in areas where the impacts of dreissenids are more related to competition for food (e.g., the Hudson River in New York) than to biofouling. Hickorynuts are known to coexist with low densities of dreissenids in the lower St. Lawrence (see **POPULATION SIZES AND TRENDS**).

Both short-term toxic water pollution from heavy industry and long-term chronic impacts of agriculture are known to have negative effects on habitats for unionid mussels (Strayer *et al.* 2004). However, there has been no study of these impacts on the habitat or live populations of *O. olivaria* in Canada (Metcalfe-Smith *et al.* 1996; Metcalfe and Charlton 1990).

Dams are known to have major impacts on both unionids and their hosts (e.g., Vaughn and Taylor 1999). The effects of dams in the Great Lakes-St. Lawrence region on the probable host for *O. olivaria* are well documented in the COSEWIC (2006b) status report on Lake Sturgeon. The habitats of Lake Sturgeon and, as a result, Hickorynut, have been split into a series of isolated units. The fragmentation associated with dam construction is especially severe in the St. Lawrence and Ottawa river drainages, where Lake Sturgeon were once capable for migrating of the “limits of brackish water [downstream of Quebec City] up to at least Brockville (Ontario)” (COSEWIC 2006b) and presumably into tributary rivers like the Ottawa, Saint-François, and Batiscan.

BIOLOGY

The general biology of the Hickorynut is, in many aspects, similar to that of most freshwater mussels living in North America, and is described in the following paragraphs (Kat 1984). The information found in the paragraphs below is derived from a review of the literature on North American unionid mussels, and also includes specifics on the Hickorynut based on the status report writers' knowledge of this species. No detailed study has focused on this species in Canada because of its rarity and its deep-water habitat (see below).

Similar to other freshwater mussel species with heavy and globose shell morphology, the Hickorynut is limited in its ability to crawl through substrates. Its shell is not tapered for efficient movement. As such, the Hickorynut is a mostly sedentary animal.

Like other unionid mussels, the Hickorynut has been described primarily as a filter-feeder, obtaining its food by siphoning microscopic algae (phytoplankton), organic detritus and bacteria from the water column into its mantle cavity, where the gills entrap and sort food particles before ingestion (McMahon and Bogan 2001). Recent stable isotope enrichment and feeding behaviour studies have shown that deposit feeding is also very important in the feeding biology of various freshwater bivalve taxa, including unionid mussels (Raikow and Hamilton 2001; McMahon and Bogan 2001; Nichols *et al.* 2005; Vaughn *et al.* 2008) and may even suggest that the bulk of the food ingested by some freshwater mussels at certain times of the year may originate from the bottom sediments of the river or stream (Raikow and Hamilton 2001). Feeding on bottom deposits can be accomplished through the production of a water current by the ciliary activity of the foot's epithelium, bringing food particles into the mantle cavity, where they are conveyed to the mouth by the gills (Nichols *et al.* 2005). The early juvenile stages of many species of freshwater mussels are commonly found completely buried in the substrate, obtaining food particles directly from the substrate or from interstitial water (Yeager *et al.* 1994; Gatenby *et al.* 1997).

Life cycle and reproduction

Current information on the reproduction of the Hickorynut, indicates that the sexes are separate (dioecious, or gonochoristic), as in the vast majority of North American unionid mussels (Hoeh *et al.* 1995). There is little obvious evidence of sexual dimorphism in shell morphology of the Hickorynut. Female spawning (or ovulation) in the Hickorynut, as well as in other freshwater mussel species, typically involves the transfer of thousands of mature ovocytes (eggs that have almost completed the meiotic division) from the ovary into two specialized brooding regions of the gills called marsupia (Mackie 1984; McMahon and Bogan 2001), located at the posterior half of the outer gills. During male spawning, sperm are released into the water via the excurrent siphon and females living downstream take in these sperm via the gills. The sperm then enter the marsupium (superbranchial chamber), where the eggs are fertilized (Parmalee and Bogan 1998; Williams *et al.* 2008). Once fertilized, brooded eggs undergo normal molluscan spiral cleavage and develop into a specialized larva called glochidia within the marsupium (Mackie 1984).

It is believed that fertilization success can be very low in cases where freshwater mussels occur in extremely low densities, such as 0.01-0.1 individuals/m^2 (Neves 1997). This is commonly the case with low-density species like the Hickorynut. Yet gravid female Hickorynuts have been observed in the Ottawa and Mississagi rivers where adult densities are commonly very low (0.01 - 0.05 individuals/m^2). Thus, the presence of adult females with marsupia full of glochidia in these areas suggests (i) that fertilization success is not a problem in these river systems, even at such low population density, or (ii) hermaphroditism, with the capability of self-fertilization (simultaneous hermaphroditism) occurs in the Hickorynut mussel, as it exists in some unionid taxa (van der Schalie 1970). The question whether or not hermaphroditism appears in mussels subject to difficult environmental conditions (van der Shalie 1970) remains unanswered. Yet, simultaneous hermaphroditism could explain why females in low population situations could have marsupial pouches filled with glochidia.

Although detailed studies have not been conducted on the reproductive period of the Hickorynut in Canadian waters, adults with marsupial pouches full of glochidia during September (Mississagi River) as well as during October (Ottawa River) have been observed (A. Martel, pers. comm. 2010). American studies in rivers (Surber 1912; Ortman 1919; Baker 1928) demonstrate that the Hickorynut is a long-term brooder or “bradytictic”, and that gravid females with glochidia are found from August to June of the following summer.

The reproductive cycle of gravid female freshwater mussels, including that of the Hickorynut, is linked to the host fish (Kat 1984; McMahon and Bogan 2001). Normally, the female mussel is stimulated to release her glochidia either when a host fish is near, or in response to factors such as shadows cast, touching of the female’s mantle edge, or after the release of natural substances or chemicals by the host (McMahon and Bogan 2001).

Like many other Ambleminae, the Hickorynut has hookless glochidia (Hoggarth 1999) adapted to attach to the soft tissue of the gill filaments of their host fish(es), unlike the subfamily Unioninae whose glochidia are equipped with hooks along the ventral margin of the larval shell (prodissoconch). Hickorynut glochidia (Figure 6) are subelliptical in shape. Glochidia collected from gravid individuals in the Mississippi River (U.S.) were approximately 202 µm in length and 258 µm in height (Hoggart 1999). The dimensions of glochidia of Hickorynuts from the Ottawa River, Ontario, collected by SCUBA divers in October 2005 (Martel unpublished data) are slightly smaller, with a mean larval (prodissoconch) shell length of 197.9 µm (sd=4.7, n=41) and a mean larval shell height of 238.8 µm (sd=5.8, n=41).

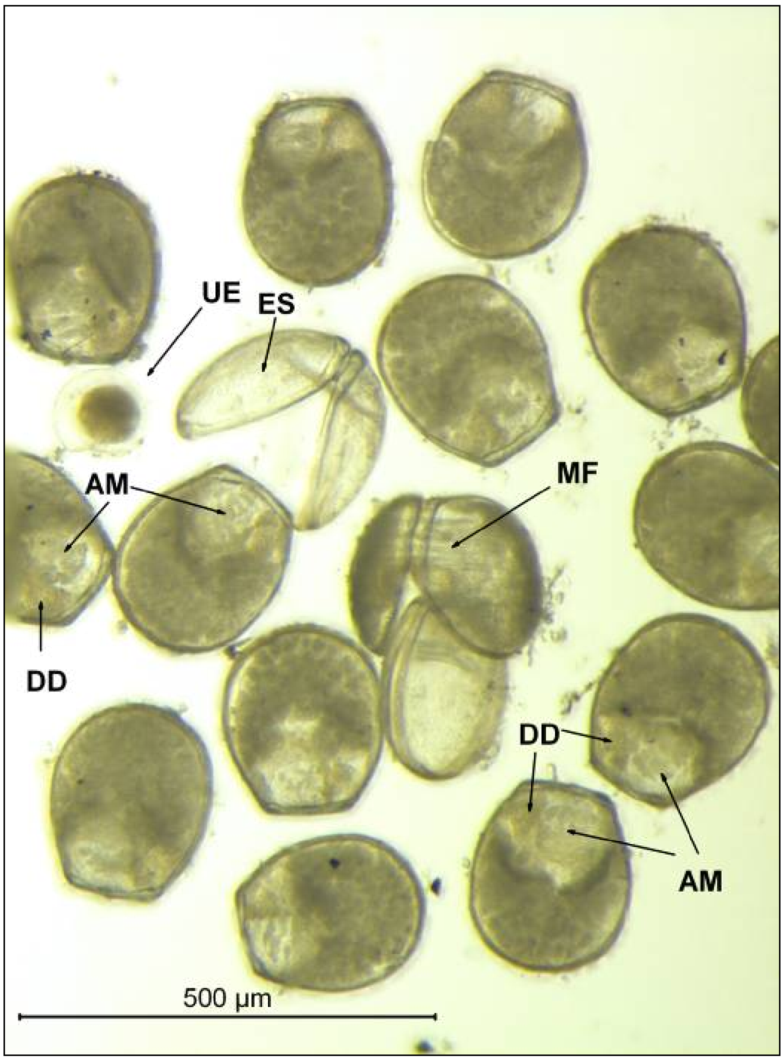

Figure 6. Glochidia of the Hickorynut, *Obovaria olivaria*. The glochidia were excised from the gravid marsupia of an adult mussel collected during a SCUBA dive at an extensive sandy shoal approximately ½ km southwest of Mohr Island, Ottawa River, during 20 October 2005. AM = adductor muscle; DD = embryonic digestive diverticulum; ES = empty shell; MF = muscle fibre of the adductor muscle; UE = unfertilized egg. Scale bar represents 500 µm or 0.5 mm. Photo: A. Martel, CMN.

Once Hickorynut glochidia are clamped onto the gills of the host, they encapsulate in the host's tissues (Mackie 1984) and are nourished by the host's body fluids until they metamorphose into small juveniles, each with a tiny foot, two adductor muscles and gill buds (Coker *et al.* 1921; Kat 1984; Zardus and Martel 2002). After metamorphosis, the juveniles dislodge themselves from the host fish and fall to the bottom of the river as free-living benthic mussels. This life cycle enables the dispersal of larvae on host fish over substantial distances, even upstream. The likelihood of an individual glochidium attaching to a host fish and settling on a suitable type of river bottom is estimated to be extremely low (Jansen and Hanson 1991; Oesch 1995; McMahon and Bogan 2001). In contrast, the survival rate of adult freshwater mussels is usually high (McMahon and Bogan 2001) because of huge numbers of glochidia. The two marsupial pouches of a typical gravid female freshwater mussel may contain hundreds of thousands of developing glochidia, evidence of the high fecundity (Bauer 1987; Jansen and Hanson 1991; Bauer 1994; McMahon and Bogan 2001). Several factors are linked to the difficulty in locating newly released juvenile mussels in nature, including (i) the high mortality that takes place at the glochidia stage (ii) their small size, and (iii) their tendency to quickly burrow into the sediment upon release from the fish, sometimes remaining buried until they are much larger and more visible (Watters *et al.* 2001).

In the Hickorynut, metamorphosis from the glochidium to the juvenile stage has been confirmed (laboratory study) on the Lake Sturgeon (*Acipenser fulvescens*) the host fish of this mussel in Canada (Brady *et al.* 2004). The Lake Sturgeon occurs in all river systems where the Hickorynut currently occurs in Canada: Mississagi River, Ottawa River, St. Lawrence River, and St. François River (confirmed with the Ontario Ministry of Natural Resources and the Ministère des Ressources Naturelles et de la Faune du Québec). Concordance between Lake Sturgeon and Hickorynut distribution provides the setting for a relationship between the species. Other possible hosts have been discussed in the literature. Clarke (1981) mentioned the Freshwater Drum (*Aplodinotus grunniens*), although this has not been validated or confirmed. Watters *et al.* (2009) recently stated that sturgeons are the only reported hosts for the Hickorynut. In the wild and in the laboratory the glochidium of the Hickorynut has been found on the Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) (Coker *et al.* 1921) in central United States but this host fish does not occur in Canada (Scott and Crossman 1973). The Atlantic Sturgeon (*Acipenser oxyrinchus*) has been reported to visit freshwater breeding sites in the St. Lawrence River (Richelieu Rapids, Portneuf, St. Antoine de Tilly, Grondines) (Hatin and Fortin 2002), and is found to co-occur with the Hickorynut in the Grondines region. There may be a fish host relationship between the Atlantic Sturgeon and the Hickorynut but this has yet to be proven in the field or in the lab.

Longevity

When compared with other freshwater invertebrates, unionid mussels are long-lived (Carrell *et al.* 1987; McMahon and Bogan 2001). Previous studies have directly or indirectly linked the presence of dark growth rings or bands on or within the shell of unionid mussels with an annual growth cycle, where each dark band is formed during the winter months (Rypel *et al.* 2008). Examination of the number of distinct dark bands of shells from the Ottawa River indicates that most Hickorynut adults are between 7 and 14 years of age (Martel unpublished data). Thus, the generation time for *O. olivaria* is within this age range, which is comparable to that observed for other species of unionid mussels in Canadian waters (Metcalfe-Smith and Green 1992).

Predation

The effects of predation on freshwater mussels can be significant and several vertebrates have been shown to prey on unionids, including the Common Muskrat, (*Ondatra zibethicus*), the North American River Otter (*Lontra canadensis*), the Raccoon (*Procyon lotor*), the American Mink (*Neovison vison*) and turtles (Fuller 1974; Convey *et al.* 1989; Hanson *et al.* 1989; Neves and Odum 1989; Watters 1993-1994; Oesch 1995; McMahon and Bogan 2001; Zahner-Meike and Hanson 2001). It is unlikely that muskrats and other aquatic mammals seriously impact populations of Hickorynut because Eastern Elliptio (*Elliptio companata*) are much more common and more easily captured by this mammal. On the other hand, other predators, including molluscivorous fishes, such as the Freshwater Drum (*Aplodinotus grunniens*), Lake Sturgeon (*Acipenser fulvescens*) and the Atlantic Sturgeon (*Acipenser oxyrinchus*) could potentially feed on these mussels (Adamstone 1923).

Dispersal/migration

Unionid mussels are sedentary at the juvenile and adult stage, remaining in one general area during their entire benthic life. Certain unionid species can, using their muscular foot, crawl across or through the sediment of the lake or river bottom over moderate distances, such as several metres, over a period of a few hours or days (Amyot and Downing 1998), The crawling behaviour of the Hickorynut is limited compared with more compressed species (Martel personal observation). Alternatively, significant dispersal can take place during the parasitic phase of the Hickorynut, at the time its glochidia larvae are attached to the host fish. Infected host fishes can transport larval unionids into new habitats and replenish depleted populations with new individuals, both upstream and downstream. The scale or level of dispersal (gene flow) of the Hickorynut within a river system, or between river systems, is unknown and will depend on the movements or migratory habits of their host fish within and between river systems (McKinley *et al.* 1998).

Interspecific interactions

The glochidia of the Hickorynut are obligate ecto-parasites on fish, including the Lake Sturgeon (Canada) and possibly the Atlantic Sturgeon (St. Lawrence populations). Although the specific host fish for this species has yet to be confirmed for Canadian populations (see **Life cycle and reproduction** section), studies point to sturgeons as key for the reproductive success of this mussel.

POPULATION SIZES AND TRENDS

As described in the **BIOLOGY** section, the Hickorynut is a deep-water unionid found almost exclusively in large rivers. The ecology of this mussel makes targeted surveys difficult (requiring specialized SCUBA gear and training), labor-intensive (to cover large areas of river bottom often in poor visibility), and expensive (gear purchase or rental, and training of crews). Extensive surveys targeting *O. olivaria* have been conducted throughout its Canadian range. Negative results at the hundreds of sites where *O. olivaria* were not found are not exhaustively reported in this status report. It should be understood that the data used in compiling this report are the best available at the time of writing. Additional intensive surveys are certainly needed to further confirm and delineate the presence/absence and densities of Hickorynut across its range in Ontario and Quebec. Discussion of the number of locations (six rivers) can be found in the **DISTRIBUTION** section.

Sampling effort and methods

<u>Great Lakes, tributaries, and connecting channels</u>

Mississagi River (Lake Huron drainage)

SCUBA and snorkel surveys were conducted in September 2009. Five sites were visually surveyed for at least one person-hour (p-h; Table 2) with a total survey effort of 9.1 p-h (Zanatta and Woolnough in press). All sites suveyed were up to 5 m deep. Because of its deep-water habit, empty shells of this species are, in contrast with *Elliptio* spp. and *Lampsilis* spp., usually a rare find along river banks. There were many areas surveyed but because the species was not found there those surveys are not included in this report.

Table 2. Location, site description and search effort in surveys of *Obovaria olivaria* in the Mississagi River, Ontario in September 2009. Sites are listed downstream to upstream (from Zanatta and Woolnough in press).

Site Name*	Effort	*O. olivaria* collected	Unionids
MR-BC	Snorkel: 1.5 p-h	None	Unionids abundant in shallows.
MR-FA	SCUBA: 0.67 p-h Snorkel: 2.5 p-h	5 live	Unionids abundant, but patchily distributed.
MR-17	SCUBA: 0.67 p-h Snorkel: 1.5 p-h	5 live	Unionids abundant among rocks at bottom of highway embankment. *O. olivaria* found in sand.
MR-PP	SCUBA: 0.25 p-h Snorkel: 1.0 p-h	None	Unionids absent from shifting sand in right (North bank) ¾ of river. Fairly abundant in flow refuge on left (South bank) ¼ of river.
MR-IB	SCUBA: 1.0 p-h	Shell (weathered)	Unionids were abundant on left (South) bank of river.

* MR-BC: End of Boom Camp Rd, 4 km West of Blind River near river mouth. Snorkel searches in shallows only (many boom logs making SCUBA hazardous). MR-FA: Immediately downstream of MacIvor Falls in eddy. Maximum depth 2.5 m. MR-17: Area searched between Trans-Canada Highway embankment and islands. Maximum depth 3 m. MR-PP: at Trans-Canada Highway picnic park. Maximum depth 4 m. MR-IB: Village of Iron Bridge, downstream of boat launch. Maximum depth 4 m.

Other large-river tributaries of Lake Huron and Lake Superior are known to have Lake Sturgeon populations (COSEWIC 2006b). It is plausible that these tributaries serve as locations for *O. olivaria*; however these tributaries remain unsurveyed for unionids.

Detroit River, Lake St. Clair, and Lake Erie

Using SCUBA, random timed searches of a 500 m^2 area were conducted at four sites that historically had the highest unionid mussel abundances. Total time searched was 3 p-h in 1992, 3 p-h in 1994, and 4 p-h in 1998 (Schloesser *et al.* 2006). Additional search effort was attempted with quadrat and line-transect searches (time searched for these surveys not available). Large search efforts targeting unionids have also been made on Lake St. Clair (Nalepa *et al.* 1996), the St. Clair Delta (Zanatta *et al.* 2002; Metcalfe-Smith *et al.* 2004; McGoldrick *et al.* 2009), the Sydenham River (Metcalfe-Smith *et al.* 2007; Mackie 2008) and Western Lake Erie (Schloesser and Nalepa 1994; Schloesser *et al.* 1997).

Niagara River

Twenty-two sites were selected for mussel surveys on the American side of the Niagara River. These targeted mussel surveys were conducted for the New York Power Authority (Riveredge Associates LLC 2005). In the summer of 2001 and again in the summer of 2002, two to four observers performed surveys. Each site was visually examined for 15 minutes, often using view buckets or a mask and snorkel, with some limited SCUBA being used around Grand Island, NY. If no evidence of mussels was found after 15 minutes, the site was abandoned. If evidence was found that mussels were present, such as spent shells, shell fragments, or living mussels, the survey was continued for a minimum total time of one hour (2-4 p-h). These surveys were mainly in shallow waters and may not have extensively targeted the specific deep-water habitat preferred by *O. olivaria*.

St. Lawrence River and tributaries

The Ministère des Ressources Naturelles et de la Faune du Québec (MNRF) has records of unionids from 331 sites on the St. Lawrence River. The effort for these records ranges from an incidental shell being collected along the shore to a full SCUBA survey targeting unionids. Total estimated effort is over 240 person-hours of search time. For survey crews from the Quebec MRNF, the effort was mostly made using Aquaviews and waders. In the Batiscan River and St. Lawrence sampling was conducted 2-3 hours before low tide (amplitude of the tide is often between 1 to 3 metres). In the Rivière Saint-François, sampling was carried out when the water level was low and clear, during summer or early fall. This method permited surveyers to cover many sites and maximize the volume of data on species in Quebec. While not necessarily targeting *O. olivaria*, it did find live animals and fresh shells. The MRNF database also benefited from the RSI (réseau de suivi ichtyologique) to get data on mussels (fishing with nets and seines) in the St. Lawrence during surveys of fish species. Since 2000, the RSI kept records of all freshwater mussels caught in fishing nets. Because dressenid mussels and rocks jam in the mesh, many unionid shells and occasionally live unionids were pulled up from the bottom.

Twenty sites on Rivière Saint-François are known from the Quebec MRNF molluscs database, with four sites having recent records of live or fresh-dead *O. olivaria*. Little data are available on search effort, but where data are available effort ranges from 1 to 4 p-h of visual searches.

One site on the Batiscan River has been repeatedly visited since 2002. Numerous person-hours of effort have thoroughly searched the lower reach of the river to its confluence with the St. Lawrence. This river is tidal and effort was concentrated at low tide.

Ottawa River drainage

Recent Canadian Museum of Nature surveys focused on shallow areas and extensively searched for all species in the Rideau River, Ottawa River, Gatineau Park, and Gatineau River. Survey sites were selected based on dead shells found near shore. Museum collections were also examined for historical records. The reported distribution of Lake Sturgeon was also considered but sightings vary and fishers are secretive about reporting on sturgeon (A. Martel, pers. obs.). In addition, Dr. Fred Schueler has extensive experience in the area and has reported areas where he had observed *O. olivaria* shells. Dr. Schueler provided this valuable information to the report writers. Canadian Museum of Nature search crews included: A. Martel, N. Binnie, J. Madill, B. Sawchuck, F. Schueler, and D. McAlpine.

During September and October 2005, an intensive search for the Hickorynut was conducted in a middle section of the Ottawa River called Lac Deschênes. This reach, which begins at the Chat Falls Dam and ends 53 km downstream at the city of Ottawa, is heavily used for sport fishing, power boating and sailing. Historically, only two empty shells of the Hickorynut had been found in this portion of the Ottawa River; near MacLaren's Landing, Ontario, during July and September 1962, about 9 km below the Chat Falls dam (Canadian Museum of Nature Molluscs Collection catalogue numbers 14162, 14163; Martel *et al.* 2006). Numerous SCUBA dives (1-4 person-hours) were conducted nearshore at the historical MacLaren's Landing (4 person-hours) and the Mohr Island area (located just offshore of MacLaren's Landing, 6 person-hours). Between 30 and 120 minutes of diving time at each site was conducted for a total effort of 12 person hours. Depths at all sites were between 1.5 and 6 m.

During 22 October 2004 and 14 September 2007, in Quebec's Pontiac region near Waltham, along the north shore of the Chenal-de-la-Culbute, two SCUBA divers searched that section of the Ottawa River and found evidence of dead shells of *Obovaria olivaria* (2 person-hours), but no live specimens were found. Water depths where *O. olivaria* shells were located were between 3 and 4 m, and the substrate mostly silty sand. Water current was moderate to strong. The Black Sandshell, *Ligumia recta*, was especially common at that site. Fish represented by many species were also abundant.

Four sites on Rivière Coulonge are known from the Quebec MRNF molluscs database with one site having records of live or fresh-dead *O. olivaria*. Data are not available on search effort.

Survey methods not only differed among locations but within locations due to differences in depth (e.g. shallow water were surveyed using waders, deep waters with SCUBA). Hence, there was no attempt made to compare search efforts.

Abundance

<u>Great Lakes, tributaries, and connecting channels</u>

Mississagi River (Lake Huron drainage)

Living *O. olivaria* were found at two of five sites surveyed on the Mississagi River (Figure 7). A total of ten live animals was collected. The animals were found in sand substrates in 1.5 to 4 m of water. Five live animals were found in an eddy immediately downstream of MacIvor Falls (Table 2) and an additional five live animals were collected approximately 1 km upstream of the falls (Table 2). An old half-valve of *O. olivaria* was collected near the village of Iron Bridge, 20 km upstream from the river mouth and delta into Lake Huron (Table 2). Unionids were found at all sites surveyed, with *Elliptio complanata* representing >95% of the total mussel community; this common species was extremely abundant (estimated density >10 m^{-2}) over large areas of the river bottom. *Obovaria olivaria* was less than 1% of the total unionid community. Although only ten animals were collected, this population likely numbers in the thousands of animals as only a small portion of the available habitat was surveyed (~23,000 m^2, <1% of the habitat in the 20 km reach surveyed) (Zanatta and Woolnough in press). The total IAO for Mississagi River is 4 km^2.

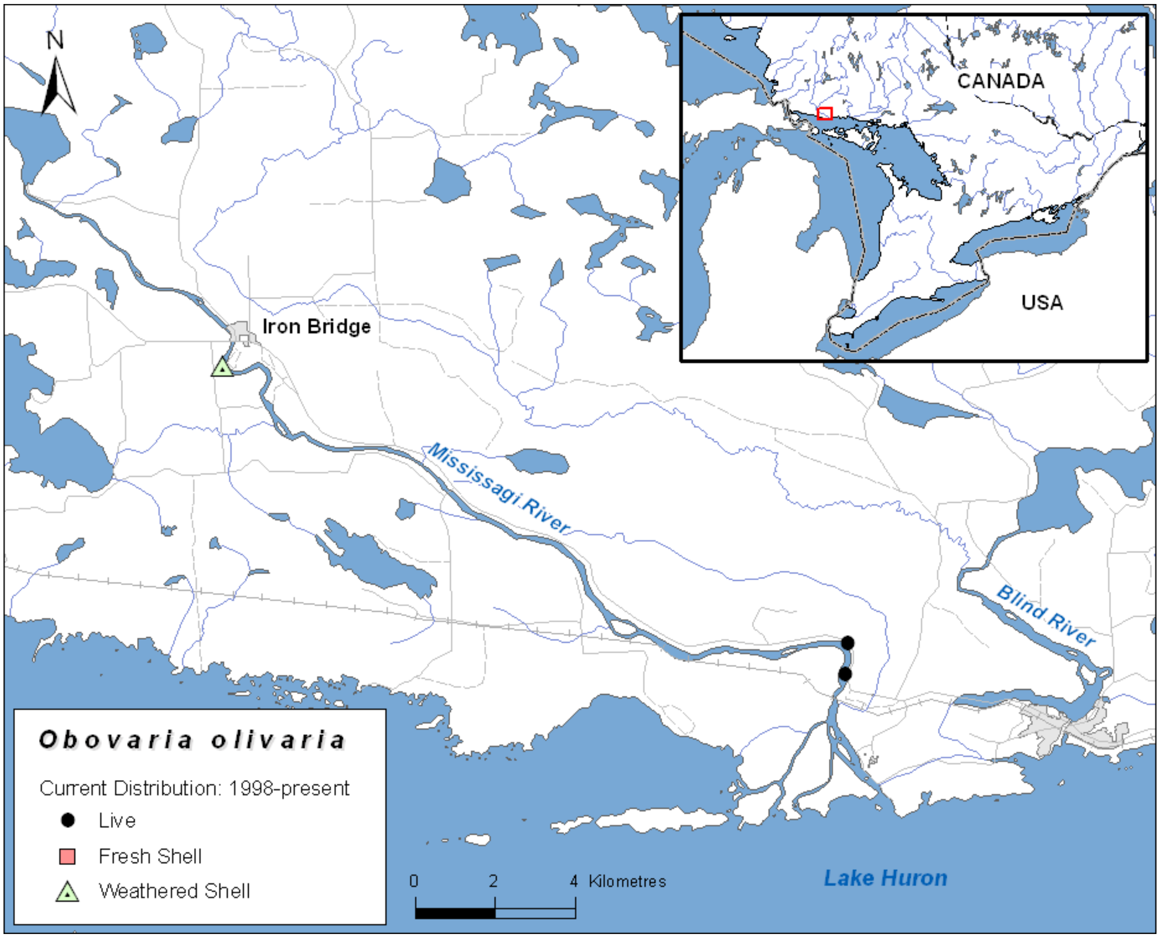

Figure 7. Recent records (1998-2010) of *Obovaria olivaria* in the Mississagi River, Ontario.

Detroit River, Lake St. Clair, and Lake Erie

Prior to the invasion of dreissenid mussels, *O. olivaria* existed at extremely low density (<<0.1/m^2) in the Detroit River with one live animal collected in 1992 (several more were collected in the 1980s – see Figure 4). In subsequent surveys in 1994 and 1998 (at the same level of effort – see above), *O. olivaria* was not detected (Schloesser *et al.* 2006). Additional recent surveys on the Detroit River confirm that *O. olivaria* is extirpated (Badra 2006a, b). No evidence of *O. olivaria* exists from recent surveys (post-dreissenid mussel invasion) of Lake St. Clair or Lake Erie (Schloesser *et al.* 1997; Nichols and Amberg 1999; Zanatta *et al.* 2002; Bowers and de Szalay 2004, 2005, 2007; Bowers *et al.* 2005; McGoldrick *et al.* 2009).

Niagara River

Live unionids were collected at 15 of 22 sites on the upper Niagara River (Riveredge Associates LLC 2005) (Figure 4). Hickorynut was not found alive, only weathered and sub-fossil shells were collected at three sites. Spent shells and live mussels found at the 15 sites revealed 16 species of which six are common and widely distributed and not inventoried by the New York Natural Heritage Program. These six common species were *Anodontoides ferussacianus*, *Elliptio complanata*, *Elliptio dilatata*, *Lampsilis radiata*, *Lampsilis siliquoidea*, and *Pyganodon grandis* (Riveredge Associates LLC 2005).

St. Lawrence River and tributaries

Since 2001, 121 live *O. olivaria* have been collected in the St. Lawrence River from upstream of Lac Saint-Pierre (Berthierville, upstream of Trois-Rivières) to Quebec (~60 km reach, Figure 8). In contrast, prior to 2001, only weathered shells were collected between Montréal and Lac Saint-Pierre. Live *O. olivaria* have only been collected at 2.4% of sites where unionids have been recorded on the St. Lawrence River in Quebec (8 of 331 total sites in the MRNF Quebec Mussel Database). The total IAO for St. Lawrence mainstem is 40 km^2 calculated using discrete sites. One site near Grondines likely has the highest density of Hickorynut in Canada, with 104 live animals being collected from this tidal area in 2007 (estimate 0.75/m^2) (A. Paquet and C. Laurendeau, MRNF surveys). Numerous fresh-dead shell were collected along the shoreline in 2009 near Berthierville QC, upstream of Lac Saint-Pierre; additional SCUBA surveys of this area are needed.

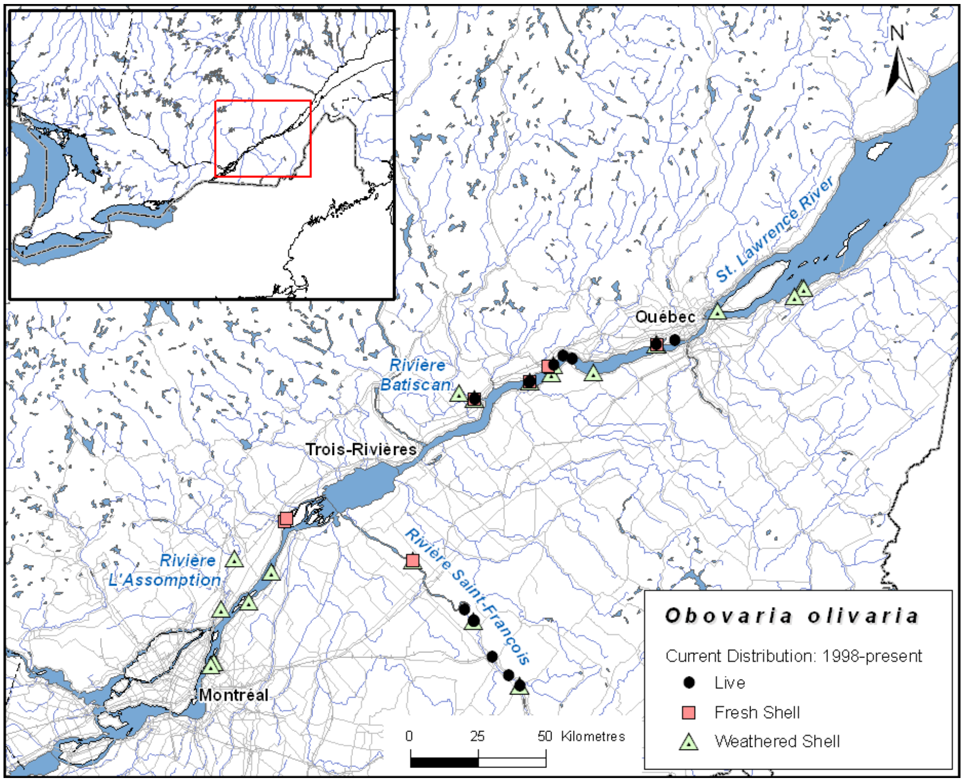

Figure 8. Recent records (1998-2010) of *Obovaria olivaria* in the St. Lawrence River (mainstem) and tributaries, Quebec.

A population of living *O. olivaria* was discovered in the Rivière Saint-François in 2002 by A. Paquet and I. Picard (MRNF surveys). Since then, 11 live animals (2 collected alive in 2009) have been found along a 73 km reach downstream of Drummondville to Windsor, QC (Figure 8). Live animals have been found at 3 of the 20 total sites (15%) from the Rivière Saint-François in the MNRF Quebec Mussel Database. Most animals collected have been old and there is no evidence of recent recruitment (A. Paquet and I. Picard, personal observations). The total IAO for this location is 24 km^2 calculated using discrete sites. *Obovaria olivaria* was first recorded in the Batiscan River in 2002 by A. Paquet and I. Picard (MRNF surveys). This tidal river is a north shore tributary to the St. Lawrence between the cities of Trois-Rivières and Quebec. Since 2002, 25 live animals have been found at a single site (of five sites from the river with unionid records in the MRNF Quebec Mussel Database) within 5 km of the confluence with the St. Lawrence (Figure 8). The total IAO for this location is 4 km^2. In 1998 and 2001 a few weathered shells were collected in Rivière L'Assomption, north of Montréal (Figure 4). These sites bookend a 29 km reach.

Ottawa River drainage

Historical records for *O. olivaria* exist in the vicinity of Ottawa (1937 and earlier). Since 2000, live and fresh-dead *O. olivaria* have been collected sporadically over a 110 km reach of the river between Ile-aux-Allumettes (upstream of Fort Coulonges) and

McLaren's Landing (downstream of Arnprior; IAO = 12 km^2 calculated using discrete sites). A total of five live animals and numerous fresh shells have been collected (Figure 9). A single fresh shell was also collected in 2000 during drought conditions in the upper Ottawa River in the Timiskaming region along the Ontario-Quebec border (IAO = 4 km^2, total IAO using discrete sites = 16 km^2).

Since 2000, the Hickorynut has been found in three free-flowing reaches of the Ottawa River (Figure 9). The northernmost and farthest upstream sites are represented by weathered shells from the tributary Blanche River at Judges and Belle Vallée (Timiskaming District of Ontario), a fresh complete shell from the mainstem of the river at Notre-Dame-du-Nord (Quebec), as well as in mid-river sites at Chenal-de-la-Culbute, near Waltham (Quebec). Empty shells were found at Petite-le-Limerick and Rapides-de-Sable (Quebec). It is possible that live individuals could be found using SCUBA. Shells were collected during drought conditions in 2000 and 2001. The paucity of shells in comparison with dozens of other unionids shells found indicated very low abundance of *O. olivaria* in this area (F. Schueler pers. comm. 2011).

During September 2005 numerous SCUBA dives conducted nearshore at the historical MacLaren's Landing site, south shore of the Ottawa River downstream of Arnprior, yielded not a single empty shell or live specimen. Following the initial failure to locate specimens along the shore, underwater searches focused on the habitat preferred by the Hickorynut mussel in other river systems, such as the Mississippi River, U.S.: mid-river relatively deep habitats, moderate to fast current, and sandy substrates (Parmelee and Bogan 1998). Using these criteria, the Mohr Island area, located just off MacLaren's Landing, Ottawa River, was surveyed in the same manner

The Mohr Island area consists of an extensive underwater plateau of pure sand covering nearly 3 km^2 of river bottom at a water depth of 1.5 to 6 m, in the middle of the river, where water current is moderate (Martel *et al*. 2006). Specimens of Hickorynut were found during the first and subsequent SCUBA dives within the sandy shoal. Living or empty shells of Hickorynut were found partly buried in the sand. Single shells of Hickorynut were found amongst hundreds of other live freshwater mussels belonging to diverse unionid species, including the *Lampsilis cardium* (Plain Pocketbook), *Elliptio complanata*, *Lampsilis radiata, Ligumia recta* and *Alasmidonta undulata* (Triangle Floater). Density of all unionid mussel species combined in the area of Mohr Island is high, commonly ranging between 30 and 130+ mussels per m^2 (Martel, unpublished data). However, the density of the Hickorynut is very low, estimated to range between 0.01 and 0.05 individuals per m^2 of sandy bottom. An estimate of the population of Hickorynuts for sandy shoals around Mohr Island would be in the range of 10,000-30,000 individuals (Martel *et al.* 2006). No evidence of juvenile stages has been found at these sites, although the methodology used to collect the Hickorynut at these sites was not adequate for determining the presence of small juveniles or to evaluate recruitment.

One live animal (1 of 4 total sites in the MRNF Quebec Mussel Database) was collected by I. Picard in the Rivière Coulonge, within 6 km of its confluence with the Ottawa River (Figure 9). This location is contiguous with the population in the Ottawa River described above, but could be considered a separate location when dealing with threats such as impacts from dreissenid mussels. The total IAO for this location is 4 km^2.

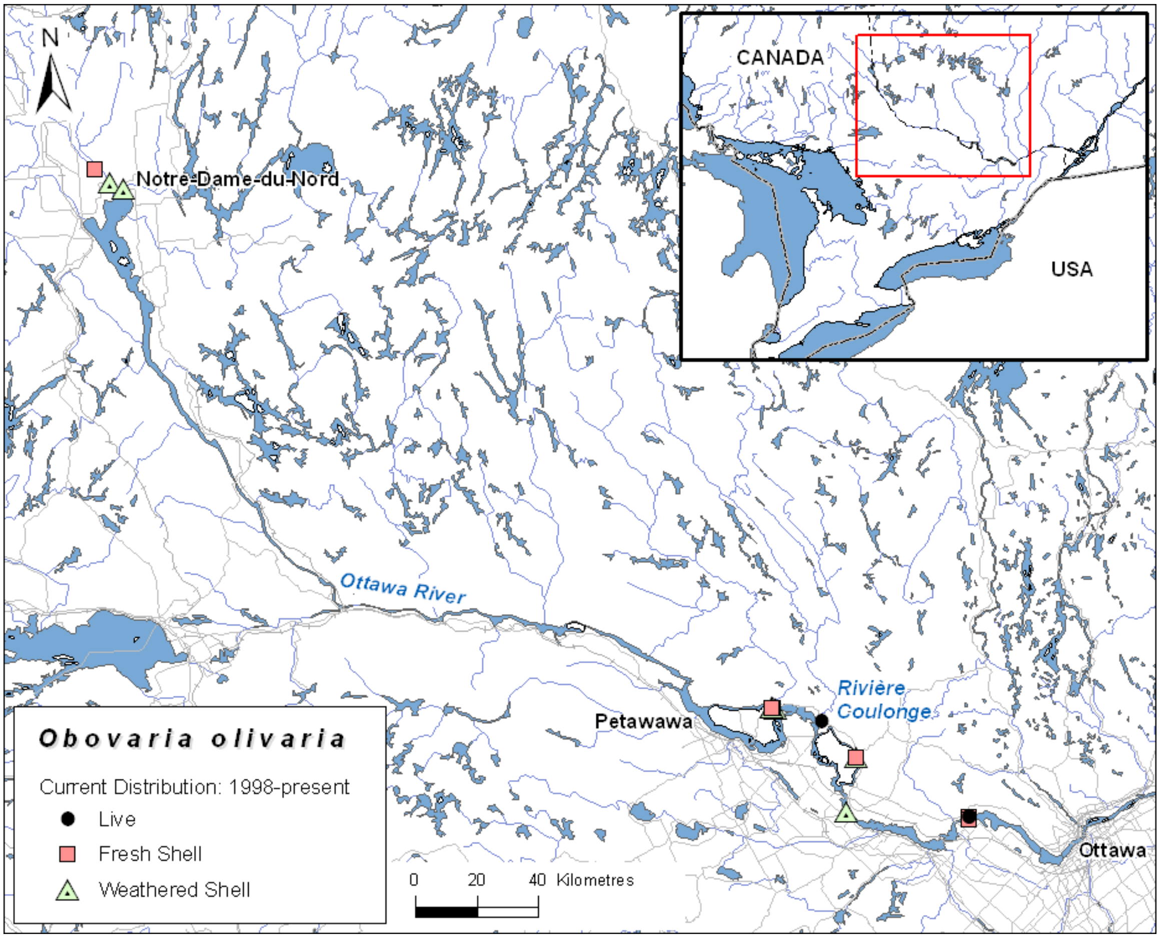

Figure 9. Recent records (1998-2010) of *Obovaria olivaria* in the Ottawa River (Ontario and Quebec) and Rivière Coulonge (Quebec).

Fluctuations and trends

Great Lakes, tributaries, and connecting channels

Mississagi River (Lake Huron drainage)

Obovaria olivaria was first documented from the Mississagi River in 1955 from shell collections in the University of Michigan Museum of Zoology (UMMZ catalogue number 26921). A second finding from the same location was reported in June 2000 (Ontario Natural Heritage Information Centre, collection number 23493). It can only be assumed that *O. olivaria* have remained extant at this location since the 1950s (date of the UMMZ record). During surveys in 2009, several fresh empty valves and live sub-adults and several gravid females were encountered (size range 36-79 mm, Table 3). This indicates minor fluctuations but recent recruitment to the population.

Table 3. Mean shell length and size ranges (where available) for live *Obovaria olivaria* by location in Canada.

Location	Mean size	Size range
Mississagi River, ON	56 mm	36-79 mm
Ottawa River, ON/QC	52 mm	51-53 mm
St. Lawrence River, QC	42 mm	22-59 mm
Rivière Batiscan, QC	28 mm	17-54 mm
Rivière Saint-François, QC	73 mm	64-87 mm

Detroit River, Lake St. Clair, and Lake Erie

Obovaria olivaria was likely extirpated from the Detroit River by the mid-1990s as a result of declines of the Lake Sturgeon host combined with the invasion of dreissenid mussels (Schloesser *et al.* 2006). As a result of dreissenid mussel infestation, overall unionid densities declined from 19.8/m^2 in 1987 to 0.1/m^2 in 1998 (Schloesser *et al.* 2006). Hickorynut was a rare species in the Detroit River, Lake St. Clair, and Lake Erie even prior to the dreissenid mussel invasion. Lake Sturgeon have been recovering in the Detroit River and Lake St. Clair over the past few years (COSEWIC 2006b) and could potentially act as hosts should dreissenid population densities drop below lethal thresholds (Ricciardi *et al.* 1995). These recent minor fluctuations and lack of apparent trend are likely to continue.

Niagara River

Obovaria olivaria may have been extirpated from the Niagara River by the 1970s (Strayer and Jirka 1997). Numerous weathered and sub-fossil shells have been recovered in 2001-02 surveys on the American side of the river, indicating a once robust population (Riveredge Associates LLC 2005). No surveys have been conducted on the Canadian side of the Niagara River, thus it can only be assumed that the remaining unionid community on the Ontario side of the river is similar to what was found on the American side; additional survey work is needed.

St. Lawrence River and tributaries

Few historical records exist in the St. Lawrence River, with only four records available prior to 1999. As such, fluctuations and trends are difficult to determine. Historical records show that *O. olivaria* existed in the river between Montréal and Quebec (Figure 4). Since 2004, a total of 121 live animals have been collected in the St. Lawrence from downstream of Trois-Rivières to Quebec (Cap-Rouge). However, only weathered shells were collected between Montréal and Lac Saint-Pierre. This is evidence of a decline in abundance and area of occupancy in the St. Lawrence River. Prior to the dreissenid invasion in the early 1990s it is plausible that *O. olivaria* were found along a reach of ~220 km, since 1998 there are only records along a 60 km reach (>70% decline). There is evidence of recruitment in the St. Lawrence population downstream of Trois-Rivières to Quebec, with numerous juveniles being collected at Grondines (Table 3, Figure 10).

Figure 10. Numerous (n = 104) live *Obovaria olivaria* collected from the St. Lawrence River near Grondines, QC. Note dreissenid mussels and byssal thread clumps on some individuals. Photo: A. Paquet, MRNF.

The unionid mussels in the upper St. Lawrence River suffered catastrophic declines in the early 1990s. It is possible that *O. olivaria* had been extirpated from the reach by the early 1990s, as Ricciardi *et al.* (1996) did not report them. Janice Metcalfe-Smith (pers. comm. 2010) found a single live *O. olivaria* in 1989 while sampling unionids from the St. Lawrence (using unionids as bioindicators of heavy metal contamination) in the vicinity of Sorel (Metcalfe-Smith *et al.* 1996). The biomonitoring research in the St. Lawrence ceased after dreissenid mussels were found coating unionids in the study area in the early 1990s (J. Metcalfe-Smith, pers. comm. 2010). It is not currently known if any refugia exist from dreissenid mussels (e.g., McGoldrick *et al.* 2009) or if any recovery of unionid communities has occurred in the St. Lawrence River since the declines were reported (Ricciardi *et al.* 1996; Strayer and Malcom 2007). Unionids in the lower St. Lawrence (downstream of Trois-Rivières) do not appear to have been as negatively affected by dreissenid mussels as in the upper St. Lawrence (only slight dreissenid infestations were observed on *O. olivaria* shells, Figure 10).

The population of *O. olivaria* in the Rivière Saint-François was only discovered in 2002. There are no historical records of live or fresh-dead shells along the entire 73 km reach, where *O. olivaria* is now known to exist. There are numerous dams along this river, fragmenting the population of mussels and their Lake Sturgeon hosts. The Lake Sturgeon in the Rivière Saint-François are known to have a skewed age structure with over-representation of very old individuals and little evidence of recruitment (COSEWIC 2006b). The same can be said for the Hickorynut in the river; the shells and living specimens are all large, with no evidence of recent recruitment (Table 3, A. Paquet and I. Picard pers. obs. 2009).

There are no records of *O. olivaria* from the Batiscan River prior to 2002. Fourteen Hickorynuts were collected alive in 2002, five in 2005, six in 2006 with similar levels of effort in each year. Lake Sturgeons are known to be abundant in the river (A. Paquet pers. obs. 2009). Numerous small animals were collected indicating recent recruitment (Table 3).

As only weathered shells were collected from the Rivière L'Assomption, one can assume that there was a decline from a previously extant location. Additional survey work is needed on this river, to determine if any living *O. olivaria* remain.

Ottawa River drainage

Most of the reach that was historically known to be habitat for *O. olivaria* in the Ottawa River and Rivière Coulonges remains unsurveyed (including the upstream sites in the Timiskaming region, downstream of McLaren's Landing, and downstream of the city of Ottawa to the confluence with the St. Lawrence). As such, the lack of SCUBA surveys at the depths where *O. olivaria* lives makes it extremely difficult to determine population trends or any fluctuations. Although the density of the Hickorynut is very low, it may be widely distributed within the entire reach of the Ottawa River, inhabiting large mid-river sandy shoals with fair or moderate water current. Such habitats occur in many areas of the Ottawa River and large tributaries that have yet to be explored for

O. olivaria. Additional SCUBA searches of these habitats are required to better outline the distribution and abundance of the species in both the upper and lower Ottawa River (Martel *et al.* 2006). Gravid female *O. olivaria* have been encountered in surveys, thus new recruitment to the population is possible if hosts are present. Little can be elucidated about trends and fluctuations for *O. olivaria* in the Ottawa River location.

Rescue effect

At the large-river scale (Mississagi River, Ottawa River and tributaries, and St. Lawrence River and tributaries), most Canadian locations of the Hickorynut are isolated from one another and from American populations by large areas of unsuitable habitat and dams making the likelihood of natural re-establishment of extirpated populations by host fish dispersal small. The probable host of the Hickorynut, the Lake Sturgeon, may be capable of the movements large enough to connect these populations; however dams and unsuitable habitat make this extremely unlikely. Furthermore, Hickorynut populations in adjacent U.S. states that could act as sources are not considered stable (Table 4). The Hickorynut historically occurred in all of the U.S. Great Lakes states. However the species is likely extirpated from Pennsylvania, Ohio and New York, is considered Imperiled in Michigan (S2) and Vulnerable in Minnesota and Wisconsin. Only the states of Illinois and Indiana consider it as apparently secure (S4). The Hickorynut is a rare species in all of the Great Lakes drainages of the U.S. (see **Canadian and Great Lakes range**); it is more common in large rivers in the Mississippi River drainage (Oesch 1995; Parmalee and Bogan 1998). Thus, immigration from U.S. populations in Great Lakes tributaries is equally unlikely.

Table 4. Subnational conservation rankings for *Obovaria olivaria* in U.S. jurisdictions. All information taken from NatureServe (2009). Great Lakes states are bolded.

Conservation rank	Description	Jurisdiction
SX	Presumed extirpated	**Pennsylvania**, **Ohio**, West Virginia, Kansas, Alabama
SH	Possibly extirpated	**New York**
S1	Critically imperiled	South Dakota, Louisiana
S2	Imperiled	**Michigan**, Tennessee
S3	Vulnerable	**Minnesota**, **Wisconsin**, Missouri, Arkansas
S4	Apparently secure	**Illinois**, **Indiana**, Kentucky
S5	Secure	N/A
SNR	Not ranked	Iowa, Nebraska

THREATS AND LIMITING FACTORS

Dreissenid mussel infestation

As described above, the invasion of dreissenid mussels in 1986 may have dealt the final blow to populations of *O. olivaria* in the Great Lakes and connecting channels (e.g., Detroit River and Niagara River) and the upper St. Lawrence (Ricciardi *et al.* 1996; Schloesser *et al.* 2006) (see **Habitat trends**). Live *O. olivaria* have not been collected in nearly two decades (~2 generations for *O. olivaria*) from these parts of the Canadian range. Impounded sections upstream of *O. olivaria* in all locations not currently infested with dreissenids are still at imminent risk of dreissenid infestation, thus putting unionid downstream habitat (with population of *O. olivaria*) at risk of fouling. Fortunately, some parts of the range of *O. olivaria* in Canada are in relatively calcium-poor waters and may be less susceptible to invasion by dreissenid mussels (Jokela and Ricciardi 2008). These areas include parts of the Ottawa River, lower St. Lawrence River, and Mississagi River populations.

Threats to host fish

Without the presence of a proper host fish, the parasitic glochidia of unionid mussels will not survive to metamorphose into juvenile mussels and therefore recruit into the population. Given enough years of recruitment failure the population will ultimately die out (see **Lifecycle and reproduction**). This is a realistic threat for *O. olivaria* in Canada as its probable host, the Lake Sturgeon in the Great Lakes-St.-Lawrence region was assessed as Threatened in 2006 (COSEWIC 2006b). Even with Lake Sturgeon numbers slowly increasing in many parts of the Great Lakes and St. Lawrence region, populations are still much smaller when compared with historical levels.

The age of the host fish is also a factor. Host fish gradually acquire resistance to the parasitic larvae (glochidia) of freshwater mussels. Several studies have shown that compatible hosts acquire resistance to glochidia after one or more infections (Rogers and Dimock, 2003; Dodd *et al*. 2005). Rogers and Dodd (2003) showed that Bluegill Sunfish *Lepomis macrochirus* aquire resistance to glochidia larvae of the freshwater mussel *Utterbackia imbecillis* (Bivalvia: Unionidae) following multiple infections. Studies by Dodd *et al*. (2005) indicate that host-acquired resistance can extend across mussel genera and subfamilies and might involve both specific and nonspecific mechanisms. The Lake Sturgeon was historically extremely abundant in the Great Lakes-St. Lawrence, but was overfished in the 1890s and early 1900s; since the 1920s, they were also subjected to habitat degradation to the point of population collapse and extirpation from many spawning rivers (COSEWIC 2006b). Much of the reduction in Hickorynut populations may have happen simulateously with historical declines in the Lake Sturgeon or lagged behind as the mussels aged and dwindled over several decades due to the loss or rarity of the host. Many of the remaining populations where the Lake Sturgeon is found (including those with extant *O. olivaria*) are mostly small, isolated, and have age-structures skewed toward older individuals. Of the remaining sturgeon populations, those of the St. Lawrence appear the most secure with all 14 of the known spawning locations remaining extant. Spawning has been recorded in recent years in all historical reaches of the Ottawa River, but recruitment is limited in several locations. In Lake Huron, the Mississagi River is among the best studied and has an estimated spawning run of only 150 Lake Sturgeon, but this population is reproductively successful and not isolated from other Lake Sturgeon populations in the Great Lakes (COSEWIC 2006b).

Where Lake Sturgeon populations are largely sympatric with *O. olivaria* in the Great Lakes, parallel patterns in trends and/or abundance can be observed. Throughout the Great Lakes, Lake Sturgeon abundances are certainly much lower than they were historically, but self-sustaining population units are present in all the Great Lakes and many tributaries where *O. olivaria* were known historically. The major declines of Lake Sturgeon were usually in late 1800s or early 1900s, following opening of commercial fisheries. All commercial fisheries in the Great Lakes have been closed or greatly reduced for many decades and recreational catches are tightly restricted (in Quebec) or closed (in Ontario); only Aboriginal subsistence fishing is allowed in Ontario waters. Many spawning components remain in the Great Lakes and their tributaries, and some monitoring programs suggest that abundances are increasing (COSEWIC 2006b). The area in the Ottawa River where Hickorynut has been found (Lower Allumette Lake and Coulonge River) coincides with the greatest abundance of Lake Sturgeon in the river. Lake Sturgeon populations are now somewhat depressed in Lac Deschenes, the area where the mussel (or evidence of the mussel) could not be found. In contrast, Freshwater Drum populations are greatest in the Ottawa River in the area downstream of Ottawa/Hull where Hickorynut could not be found (T. Haxton pers. comm. 2010).

In contrast to the Great Lakes, in the St. Lawrence River and its tributaries, commercial fisheries for Lake Sturgeon collapsed in only a few areas, such as the Ottawa River drainage basin. Enforcement and regulation of the commercial and recreational fishery have been improved, and there are indications that these catches may be sustainable (COSEWIC 2006b). Initiatives have begun to improve habitat quality for Lake Sturgeon, particularly in spawning and nursery areas, and to improve water flow regimes. These improvements may be having an impact on the observed increase in recruitment for Lake Sturgeon in parts of the St. Lawrence drainage in Quebec (COSEWIC 2006b).

Threats to water quality

Agriculture runoff (including pesticides and herbicides) together with eutrophication, represent a significant burden upon the remaining small populations of Hickorynut living in some of the smaller tributary rivers, especially the Saint-François and the Batiscan. Along these watersheds, agriculture plays an important role in the local economies. The extremely small number of live Hickorynuts found in the Rivière Saint-Francois, despite numerous freshwater mussel surveys that have been conducted by local experts, clearly shows how rare this mussel is in that system. Moreover, the environmental conditions in which these mussels live are not improving. Such conditions are not favourable to the Hickorynut, and have been noted as detrimental to

Lake Sturgeon as well (COSEWIC 2006b). Industrial pollutants also likely lead to declines in hosts and mussels in the Niagara, Detroit and St. Lawrence rivers. The Niagara and Detroit rivers remain AOCs (Areas of Concern) due to contamination from a variety of industrial pollutants (COSEWIC 2006b).

PROTECTION, STATUS, AND RANKS

Legal protection and status

The federal *Fisheries Act* represents the only piece of legislation currently protecting the Hickorynut in Canada. As shellfish, freshwater mussels are considered "fish" under the *Fisheries Act* and receive the same protections granted to finfish. The *Fisheries Act* contains provisions that can be applied to regulate flow needs for fish, fish passage, killing of fish by means other than fishing, the pollution of fish-bearing waters, and harm to fish habitat. As well, the *Fisheries Act* requires a permit to be issued for the collection of freshwater mussels. In Ontario, this permit is issued by the Ontario Ministry of Natural Resources. Similarly, the collection of live *O. olivaria* and other freshwater molluscs species are regulated in Quebec under the Quebec Fishery Regulations and thus requires a SEG licence for scientific, educational or wildlife management use issued by the Ministère des Ressources naturelles et de la Faune du Québec. The host for *O. olivaria*, Lake Sturgeon, was assessed as Threatened by COSEWIC (2006), but Lake Sturgeon is not currently protected under the Canadian *Species at Risk Act* (SARA).

Non-legal status and ranks

The Hickorynut is apparently secure (G4) globally and is ranked as apparently secure (N4) in the United States but nationally imperiled (N2) in Canada (NatureServe 2009; see Table 4). It is not on the IUCN's Red List. In an assessment of the status of freshwater mussels in Canada (Metcalfe-Smith and Cudmore-Vokey 2004; CESCC 2006) the Hickorynut was assigned a status of "May be At Risk" in view of subnational ranks in both Ontario and Quebec of "S1" and that species had not yet been formally assessed and a status designated by either COSEWIC or the Ontario provincial range jurisdiction. In Quebec, the Hickorynut and the Lake Sturgeon are likely to be listed as a threatened or vulnerable species under the *Act Respecting the Conservation and Development of Wildlife* (Annie Levesque, pers. comm.). The Hickorynut is considered vulnerable to possibly extirpated in 14 U.S. jurisdictions and apparently secure in only three (Table 4).

Habitat protection and ownership

The Ontario *Lakes and Rivers Improvement Act* prohibits the impoundment or diversion of a watercourse if siltation will result. Streamside development in Ontario is managed through floodplain regulations enforced by local conservation authorities, where they exist. The majority of the land adjacent to the rivers where the Hickorynut is found is privately owned; however, the river bottom is generally owned by the federal Crown.

The species and its habitat are also afforded some degree of protection under the Quebec *Environment Quality Act* (R.S.Q., c. Q-2) and the Regulation Respecting Wildlife Habitats of the *Act Respecting the Conservation and Development of Wildlife* (R.S.Q., c. C-61.1). Authority for the application and enforcement of the Policy for Protection of Rivers, Littoral Zones and Flood Plains (Ministère du Développement durable, de l'Environnement et des Parcs du Québec) is delegated to the municipalities.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Dr. David Zanatta is an Assistant Professor in the Biology Department at Central Michigan University. Dr. Zanatta has over ten years of experience working on unionid mussels. He has a B.Sc. (Hons.) in Biology from Laurentian University (1998); a M.Sc. in Zoology from the University of Guelph (2000); a Ph.D. from the University of Toronto (2007) where he researched the evolution and population genetics of lampsiline mussels; and held an NSERC post-doctoral fellowship at Trent University in 2008 prior to starting a tenure-track professorship at Central Michigan University. Dr. Zanatta has authored numerous peer-reviewed papers on freshwater mussel biology, ecology, and evolution. He has also co-authored six COSEWIC status reports on Ontario freshwater mussel species and is a member of the Molluscs Specialist Subcommittee of COSEWIC. Dr. Zanatta is a member of the recovery teams for Thames, Sydenham and Ausable rivers as well as the Ontario Freshwater Mussel Recovery Team.

Dr. André Martel is a Research Scientist in the Life Sciences Section (Malacology) at the Natural Heritage Building of the Canadian Museum of Nature (CMN), in Gatineau, Quebec. Martel's career in malacological research began in 1982 with a M.Sc. (Université du Québec à Chicoutimi) on the life history of subtidal marine molluscs in the Gulf of St Lawrence. He obtained his Ph.D. in 1990 at the University of Alberta (reproduction, larval biology and dispersal mechanisms in marine bivalves and gastropods), with his field research conducted at the Bamfield Marine Station, in British Columbia. After his Ph.D. he accepted a position as Curator of Malacology (1991) at the CMN, followed by a position of Research Scientist in Malacology (1992) at the same institution. His current research program focuses on the life history, comparative morphology and taxonomy of marine and freshwater bivalves. He has so far published 52 publications, reports and bulletin articles dealing with Canadian molluscs, including 30 publications in peer-referred journals. He is co-author on a previous COSEWIC status report, along with senior author Kate Bredin, on the Brook Floater, *Alasmidonta varicosa*. He previously shared the position as Assistant Director at the Bamfield Marine Sciences Centre (BC) and taught field courses at the Huntsman Marine Sciences Centre in NB (marine invertebrate biology), as well as at the Queen's University Biological Station in ON (aquatic molluscs of Ontario). He regularly participates in mollusc-related activities including identification workshops and talks to school and nature groups as well as to the general public about Canadian molluscs, primarily on the diversity, life history and conservation of marine and freshwater bivalves.

Jaqueline Madill is Senior Research Assistant to Dr. A. Martel in the Research Services Division, Life Sciences Section at the Canadian Museum of Nature. She has 15 years of experience working on freshwater mussels, 15 years working as a hirudinologist and 8 years studying other freshwater invertebrates. She has a B.Sc. in Zoology from McGill University (1969) and worked at Beak Consultants before joining the Canadian Museum of Nature. She has co-authored 2 peer-reviewed articles on freshwater mussels and authored 3 peer-reviewed articles on leeches.

Annie Paquet is a senior Wildlife Technician for the Ministère des Ressources naturelles et de la Faune du Québec (MRNF) for the Direction de l'expertise sur la faune et ses habitats. She has 11 years of experience in the field of freshwater mussels and is currently responsible for issues related to freshwater mussels at the MRNF. She works on the eight mussels species that are likely to be designated as threatened or vulnerable in the province of Quebec and is writing the status reports for these species (reports in preparation). She is also co-author of other publications on this group. She gives identification workshops on freshwater mussels and does regular sampling across the province. She also works on the Asian Clam (*Corbicula fluminea*).

Isabelle Picard is a private biological consultant with numerous years of expertise on unionoid mussels in Quebec. Ms. Picard has conducted extensive unionid surveys (including targeted searches for *O. olivaria*) in the St. Lawrence River, Ottawa River and their tributaries.

COLLECTIONS EXAMINED

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

In 1996, all available historical and recent data on the occurrences of freshwater mussel species throughout the lower Great Lakes drainage basin were compiled into a computerized, GIS-linked database referred to as the Lower Great Lakes Unionid Database. The database is housed at Fisheries and Oceans Canada’s Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario. Original data sources included the primary literature, natural history museums, federal, provincial, and municipal government agencies (and some American agencies), conservation authorities, Remedial Action Plans for the Great Lakes Areas of Concern, university theses and environmental consulting firms. Mussel collections held by six natural history museums in the Great Lakes region (Canadian Museum of Nature, Redpath Museum, Ohio State University Museum of Biodiversity, Royal Ontario Museum, University of Michigan Museum of Zoology, Rochester Museum and Science Center, and Buffalo Museum of Science) were the primary sources of information, accounting for over two-thirds of the initial data acquired. Janice Metcalfe-Smith personally examined the collections held by the Royal Ontario Museum, University of Michigan Museum of Zoology and Buffalo Museum of Science, as well as smaller collections held by the Ontario Ministry of Natural Resources. The database continues to be updated with new field data and now contains approximately 8200 records of unionids from Lake Ontario, Lake Erie, Lake St. Clair and their drainage basins as well as several of the major tributaries to lower Lake Huron. The majority of records in the database are now from recent (post-1990) field collections made by Fisheries and Oceans Canada, Environment Canada, provincial agencies, universities and conservation authorities.

In 1999, the Quebec MRNF started a first database on freshwater mussels. This database contains observations and sampling data of MRNF and their collaborators and data from collections and personnal observations of Fay Cotton and Jean Dubé, the collection of the Direction de l’Aménagement de la Faune de la Montérégie MRNF; Redpath Museum of McGill University database; CMN database, Delaware Museum of Natural History, Museum of Biological Diversity Ohio database, Milwaukee Public Museum, Illinois Natural History Survey database, Centre Saint-Laurent d’Environnement Canada Richelieu river data and a part of Isabelle Picard and Jean-François Desroches personnal collection and observations. This database contains 7800 observations on Quebec’s species through 2003. A second database contains the data from 2004 and later and contains 2400 observations of MRNF surveys and observations of collaborators. These databases are in the process of being combined.

The report writers have personally verified live specimens from all populations described in this report.