RECOVERY POTENTIAL ASSESSMENT OF LILLIPUT (*Toxolasma parvum*) IN CANADA

*Lilliput (*Toxolasma parvum*). Photograph by Environment Canada, reproduced with permission.*

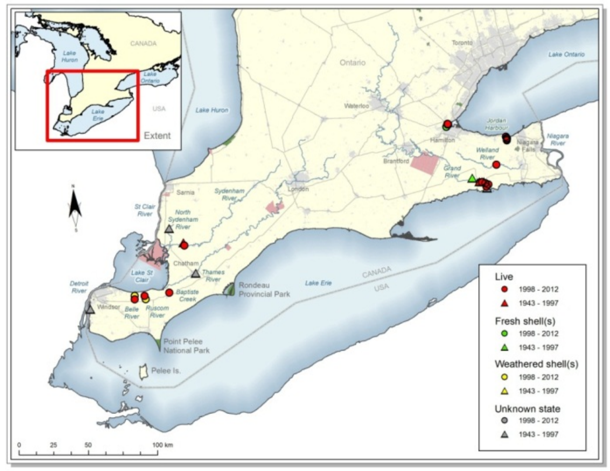

Figure 1. Distribution of Lilliput in Canada

Context:

*In May 2013, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Lilliput (*Toxolasma parvum*) and determined the designation to be Endangered. The reason provided for this designation is that, "This species has a fairly restricted range in Canada, confined to tributaries of Lake St. Clair, Lake Erie, and Lake Ontario. Populations once found in the open Canadian waters of Lake St. Clair, Lake Erie and the Detroit River have disappeared. Overall, the species has lost 44% of its former range in Canada. The invasion of freshwater habitat by the exotic Zebra and Quagga mussels, combined with pollution from urban development and sedimentation are the main cause of populations disappearing and the range shrinking." Lilliput is currently not listed under the* Species at Risk Act *(SARA).*

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the SARA, including advice to the Minister of DFO regarding the listing of the species under the SARA. It is also used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. If listed, this scientific advice will also be used in the development of a recovery strategy, and to support decision-making with regards to SARA agreements and permits. This assessment considers the scientific data available to assess the recovery potential of Lilliput in Canada.

SUMMARY

- In Canada, the current and historic known distribution of Lilliput is limited to nine confirmed populations, one of which is currently considered to be extirpated. Extant populations include four tributaries of Lake St. Clair (East Sydenham, Thames, Belle and Ruscom rivers), Grand River (Lake Erie drainage), Welland River (tributary of the Niagara River),

Jordan Harbour (a wetland at the mouth of Twenty Mile Creek) and Hamilton Harbour and surroundings (Cootes Paradise, Carroll's Bay, Grindstone Creek, Sunfish Pond; Figure 1).

- Lilliput glochidia must encyst on the gills of an appropriate host fish to survive and metamorphose. The putative host fishes for Lilliput in Canada are Johnny Darter (*Etheostoma nigrum*), Green Sunfish (*Lepomis cyanellus*), White Crappie (*Pomoxis annularis*) and Bluegill (*Lepomis macrochirus*). This is supported by laboratory infestation experiments and direct distributional overlap between each of these four fish species and Lilliput known distribution in Canada.
- Although Lilliput is found in a variety of habitats (e.g., small rivers, larger rivers, wetlands, shallow areas of ponds and backwaters), it is mostly commonly found in the lower reaches of large rivers, wetlands, and backwater areas with little current.
- Based on what is known of Lilliput life history (probable low fecundity, short lifespan, early maturity) previous modeling of Unionid mussels suggests that, compared to other Unionid species, Lilliput is expected to be most sensitive to perturbation or uncertainty in juvenile survival, adult survival, and lifespan, and relatively insensitive to changes in glochidial survival, fecundity, or age at maturity.
- It appears that the greatest limiting factors to the stabilization and growth of Lilliput populations in Canada are largely attributed to the presence of contaminants and toxic substances in their environment, and the introduction and establishment of various invasive species.
- A number of key sources of uncertainty exist for this species related to population distribution, population structure, habitat preferences and to the factors limiting their existence.
- Specifically, there is a need for a continuation of quantitative sampling to inform the population status assessment. There is a need for exploratory sampling in systems with habitat characteristics similar to those areas where Lilliput is known to occur. To confirm host fishes in Canada, there is a need to complete laboratory, and if feasible field experiments. Many life history characteristics required to inform population modelling efforts are currently unknown for this species and should be investigate to inform modelling efforts.

BACKGROUND

In May 2013, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Lilliput (*Toxolasma parvum*) and determined the designation to be Endangered. The reason provided for this designation is that, "This species has a fairly restricted range in Canada, confined to tributaries of Lake St. Clair, Lake Erie, and Lake Ontario. Populations once found in the open Canadian waters of Lake St. Clair, Lake Erie and the Detroit River have disappeared. Overall, the species has lost 44% of its former range in Canada. The invasion of freshwater habitat by the exotic Zebra and Quagga mussels, combined with pollution from urban development and sedimentation are the main cause of populations disappearing and the range shrinking." Lilliput is currently not listed under the *Species at Risk Act* (SARA).

When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by the SARA to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including permitting on harm and recovery planning. This RPA focuses on the Lilliput populations in Canada and is a summary of the conclusions and advice from a Canadian Science Advisory Secretariat peer-review meeting that occurred on September 24, 2013 in Burlington, Ontario. A research document, providing background information on the species biology, habitat preferences, current status, sensitivity to perturbations, threats, and mitigations (Bouvier et al. 2014) provides an in-depth account of the information summarized below. Proceedings that document the activities and key discussions of the meeting are also available (DFO 2013). Please note that reference citations have been removed from the following document to minimize the length of the document. Complete reference citations are available at Bouvier et al. (2014).

Species Description

Lilliput is a small-sized freshwater mussel with an average shell length of approximately 25 mm. A maximum shell length of 50 mm was reported, but this length has recently been surpassed by a Lilliput recorded from the Royal Botanical Gardens (RBG) with a shell length of 58 mm. Lengths of Lilliput shells collected from RBG between 2004 and 2009, and live individuals collected from all other sites between 2008 and 2011 ranged in length from 13 to 49.5 mm (Figure 2).

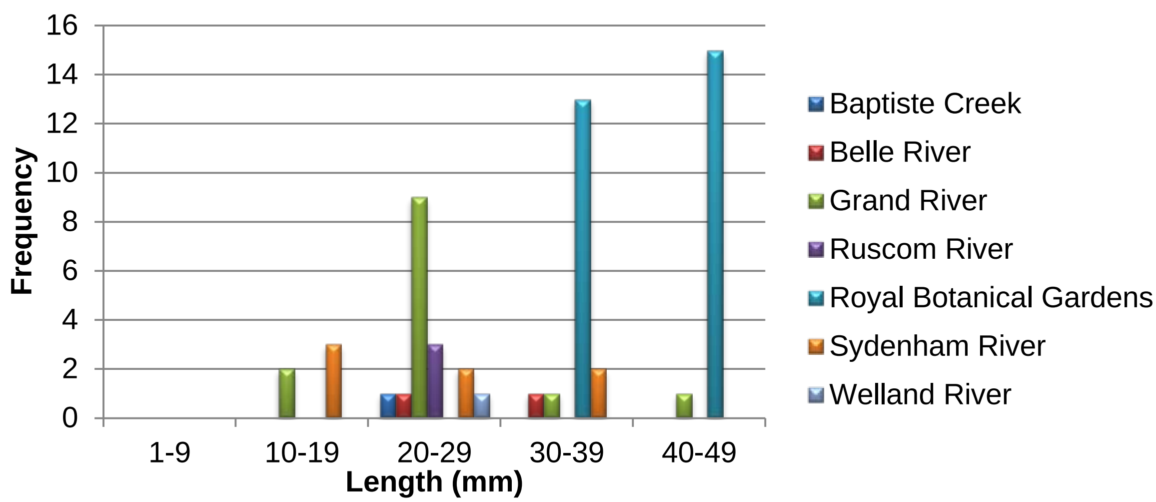

Figure 2. Size distribution of Lilliput from various sites recorded from 2008-2011.

The shell is described as thick, elliptical, moderately flattened in males and oval and more inflated in females. The anterior end is roudned, and the posterior end is roudned in males, and squared in females. The ventral margin is described as straight or slightly curved. The beak is inflated, and slightly elevated about the hinge line, and generally consists of four to six coarse concentric ridges, aligned slightly obliquely so that the ridges open anterior to center. The exterior of the shell (periostracum) varies from pale yellow, green, or gray, with a satin-like shine in younger individuals to darker, uniformly blackish-brown in large specimens. COSEWIC (2013) indicated that green rays may be present; although, Watters et al. (2009) describes Lilliput as being rayless. The nacre is white and iridescent posteriorly.

Similar Species

Lilliput is the only member of the genus *Toxolasma* currently known to occur in Canada. Morphologically similar species include Rayed Bean (*Villosa fabalis*) and Salamander Mussel (*Simpsonaias ambigua*). Rayed Bean can be distinguished from Lilliput by its prominent rays and thick hinge line, while Salamander Mussel can be distinguished by its thinner shell and more elongate shape.

Age and Growth

Lilliput are considered to be a short-lived species, with maximum range estimates reported between four and five years. Although Watters et al. (2009) found similar results, in that most individuals were approximately five years old, they also reported a few individuals as old as 12 years. Successful sampling efforts from 2004 to 2009 at the RBG has allowed for a study to determine Lilliput size at age (Figure 3). Two of the 26 mussels sampled (46 and 49.5 mm) were estimated to be over seven years of age (age 9 and age 12, respectively), while the remaining mussels were estimated to be between age 2 and age 7 (Figure 3). These findings support previous age estimates reported by Watters et al. (2009). No additional information on age and growth patterns is available, locally or globally for this species.

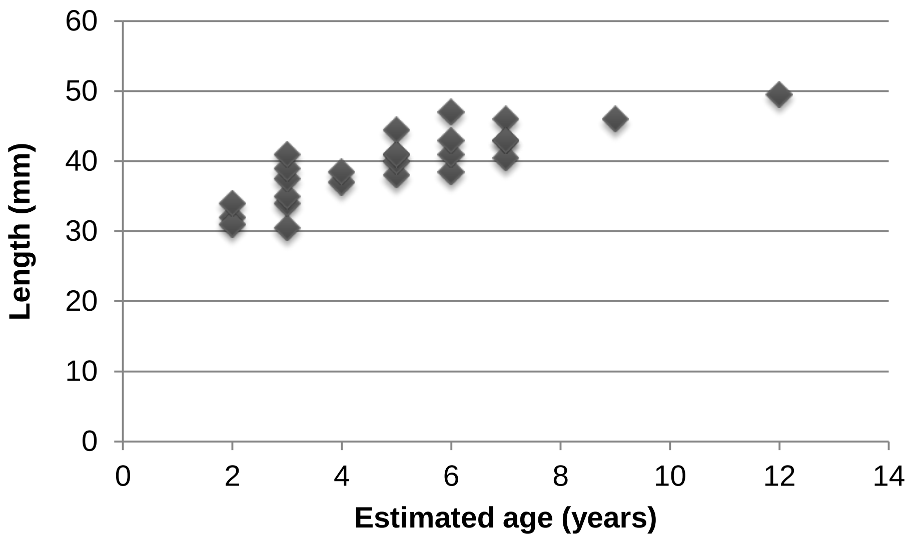

Figure 3. Length at age estimates for Lilliput collected from the Royal Botanical Gardens between 2004 and 2009 (Smith and Morris unpubl. data).

Diet

Like most other unionid mussels, Lilliput is considered to be a filter feeder. Cilia present on their foot may also be evidence that Lilliput may be deposit feeders as these cilia direct particles towards the mouth. Filter feeding (also called suspension feeding) is accomplished by using cilia to pump water through their incurrent siphon and over the gills. Particles are subsequently sorted by cilia on the gills and directed towards the mouth for consumption. In the early juvenile stage, when the mussel is most commonly buried in the substrate, food is obtained directly from the substrate in the form of algae and bacteria. Species-specific dietary information is not available for Lilliput.

ASSESSMENT

Current Species Status

In Canada, the current and historic known distribution of Lilliput is limited to nine confirmed populations, one of which is currently considered to be extirpated. Extant populations include four tributaries of Lake St. Clair (East Sydenham, Thames, Belle and Ruscom rivers), Grand

River (Lake Erie drainage), Welland River (tributary of the Niagara River), Jordan Harbour (a wetland at the mouth of Twenty Mile Creek) and Hamilton Harbour and surroundings (Cootes Paradise, Carroll's Bay, Grindstone Creek, Sunfish Pond) (Figure 1). Live individuals have been recorded from all extant sites, with the greatest number of Lilliput being recorded from the Grand River in 2011 (n=13). It should be noted that the following maps represent all current and historic records of Lilliput, and may not accurately represent the current distribution. Substantial mussel sampling has occurred throughout Ontario; however, the habitat most often associated with Lilliput has not been extensively sampled and therefore the following maps may be an underrepresentation of the current distribution. Historically, Lilliput were recorded from the Detroit River (1943), Sydenham River (1967, 1991), Thames River (1963), and Grand River (1963, 1966, 1977). Historical records are comprised of museum records of valves or shells. Rarity of this species, in addition to difficulties in detecting this species due to inefficiencies in sampling its preferred habitat has yielded a mere 48 live individuals in Canada.

Sydenham River

The first historical record of Lilliput from the North Sydenham River was dated 1967 and collected by H.D. Athearn and M.A. Athearn. A second record, this one of a live individual was recorded in 1991 from the East Sydenham River (collector: A.H. Clarke). Recent sampling efforts to verify the presence of this species in the Sydenham River yielded seven live individuals at a site east of Tupperville Bridge (Tupperville, Ontario, Figure 4).

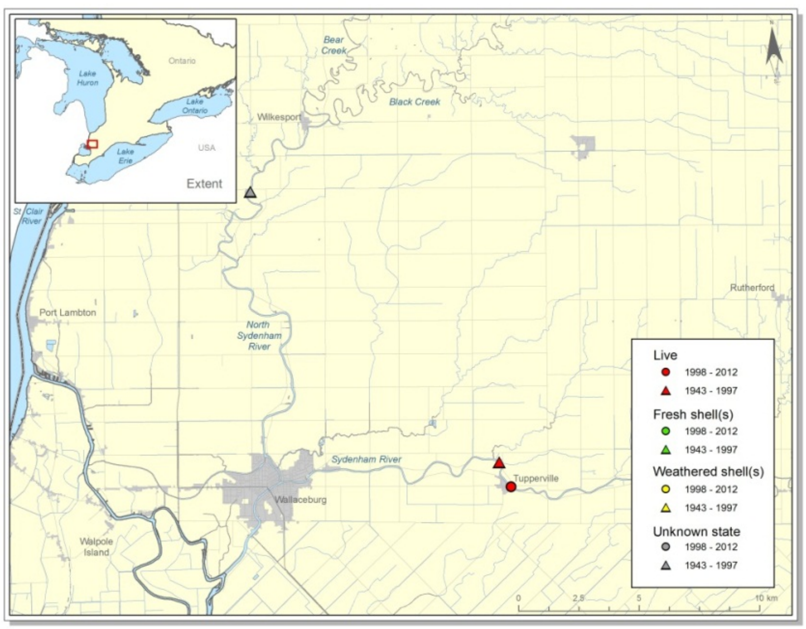

Figure 4. Distribution of all known current and historic Lilliput records from the Sydenham River, Ontario.

Thames River

There are currently two records of Lilliput in the Thames River. The first record originates from H.D. Athearn's 1963 collection in Chatham, Ontario. The second record is represented by a single live individual recorded from Baptiste Creek (a tributary of the Thames River) in 2010 (Figure 5).

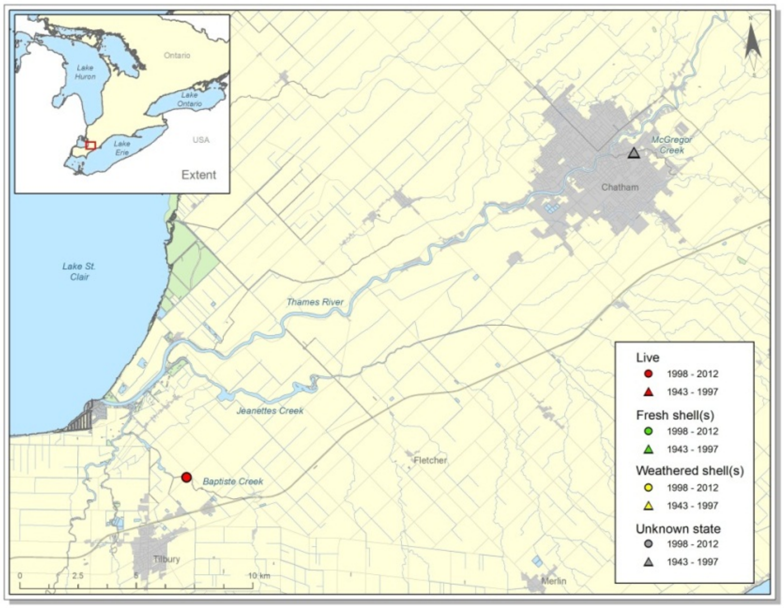

Figure 5. Distribution of all known current and historic Lilliput records from the Thames River and tributaries.

Ruscom and Belle rivers

Ruscom River

Ruscom River represents one of two Lake St. Clair southern shore tributaries known to be occupied by Lilliput (Figure 6). Three live Lilliput and two weathered shells were recorded from two sites in 2010. The first site was located at Saint Joachim, and the second was approximately 4 km upstream. No additional mussel sampling has occurred in this system.

Belle River

Bell River is the second of two Lake St. Clair southern shore tributaries occupied by Lilliput (Figure 6). The first record of Lilliput in this system originates from a single weathered shell collected in 1999, while the second record consists of two live individuals recorded from the road crossing upstream of Lions Club road.

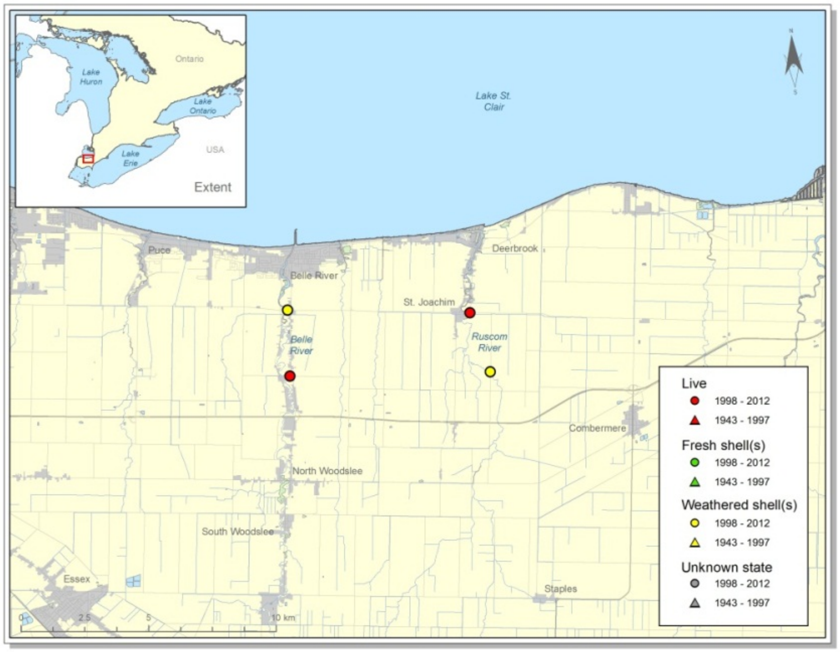

Figure 6. Distribution of all known current and historic Lilliput records from the Ruscom and Belle rivers.

Detroit River

The only record of Lilliput from Canadian waters of the Detroit River is dated 1943 (collector: F.R. Latchford; UM186265). This historical record is lacking information on the state of the individual; therefore, the quality of the specimen is unknown. Additional mussel surveys have occurred in the Detroit River since this time but have not detected Lilliput (Figure 7). The Detroit River will not be considered in the Population Status Assessment.

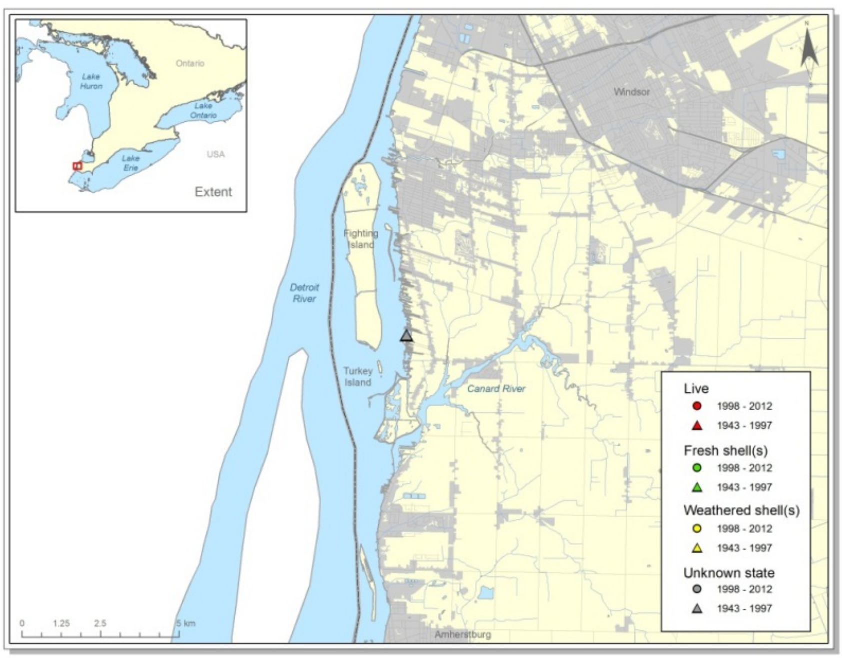

Figure 7. Distribution of all known current and historic Lilliput records from the Detroit River.

Grand River

All Lilliput records from the Grand River originate from the mouth of the river to approximately 15 km upstream, with the majority occurring within the first 8 km of river (Figure 8). Historically, Lilliput shells were recorded from the Grand River in 1952 by A. Clarke and L. Clarke (CMNML 014332), in 1963 by D.H. Stansbery and C.B. Stein (OSUM 1963:0060), in 1966 by J.G. Oughton (CMNML 070974 CMNML 0709746) and in 1971 by Kidd (1973). The first detection of live individuals occurred in 1997 when two live individuals were recorded from Byng. Additional surveys of the river in 2011 resulted in 13 live individuals and nine weathered shells.

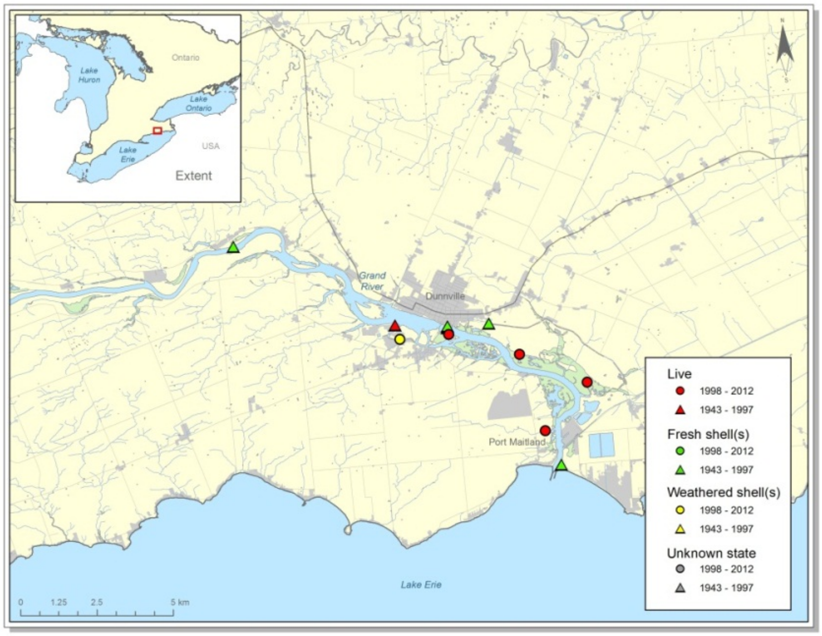

Figure 8. Distribution of all known current and historic Lilliput records from the Grand River.

Welland River

A single live individual was recorded from the Welland River in 2008 (Figure 9). A total of eight sites were visited during this sampling event and only a single individual was detected. Additional sampling in the Welland River to confirm the presence of a Lilliput population has yet to be completed.

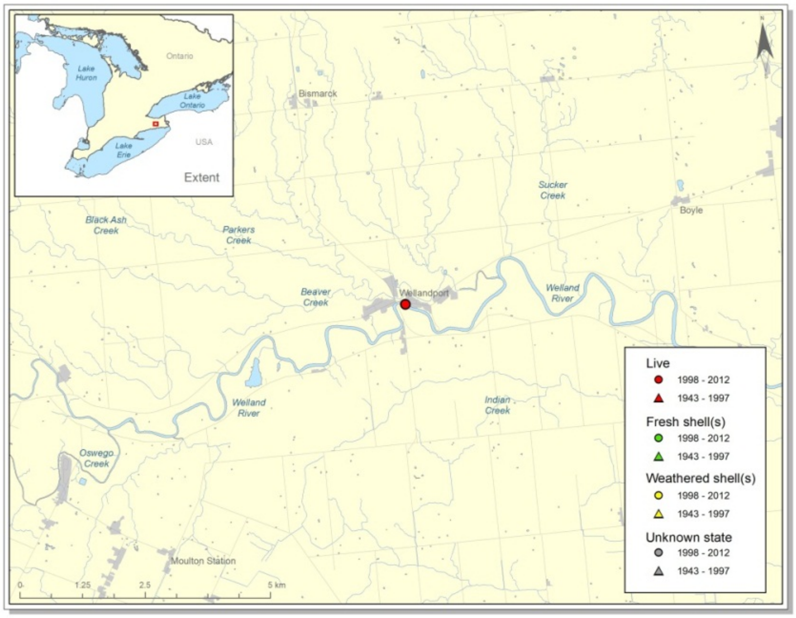

Figure 9. Distribution of all known current and historic Lilliput records from the Welland River.

Jordan Harbour

In 2012, Lilliput targeted sampling, by means of visual timed search and clam rakes, occurred in Jordan Harbour, a wetland located along the south shore of Lake Ontario at Twenty Mile Creek (Figure 10). This sampling event detected the presence of nine live Lilliput at five sites. There are no historical records for Lilliput at Jordan Harbour.

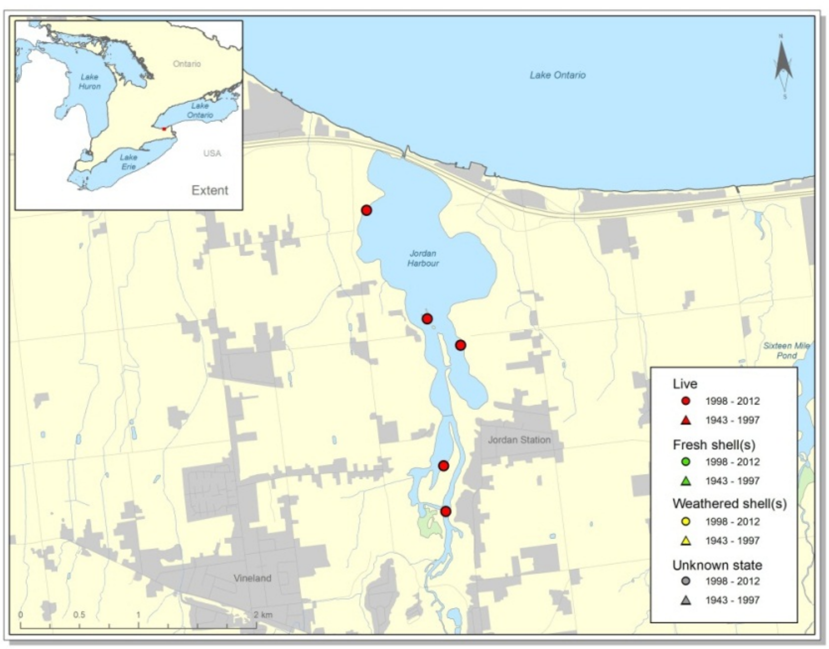

Figure 10. Distribution of all known current and historic Lilliput records from Jordan Harbour.

Hamilton Harbour and surroundings

Lilliput has been detected throughout western Hamilton Harbour (Carroll's Bay), the lower Grindstone estuary (Sunfish Pond, Blackbird Marsh) and Cootes Paradise (Figure 11). A total of 155 fresh shells (whole and valves) and 11 weathered shells (whole and valves) have been recorded from these areas since 2000. Lilliput targeted sampling occurred in 2011 to determine the presence of an extant population. Two live individuals were detected from a single site in Sunfish Pond (Smith and Morris unpubl. data). Mussel sampling by visual search in 2012 resulted in the observation of live individuals in Sunfish Pond (n=2), Grindstone Creek (n=1) and Cootes Paradise (n=4). These observations represent the first time live individuals were recorded from both Grindstone Creek and Cootes Paradise.

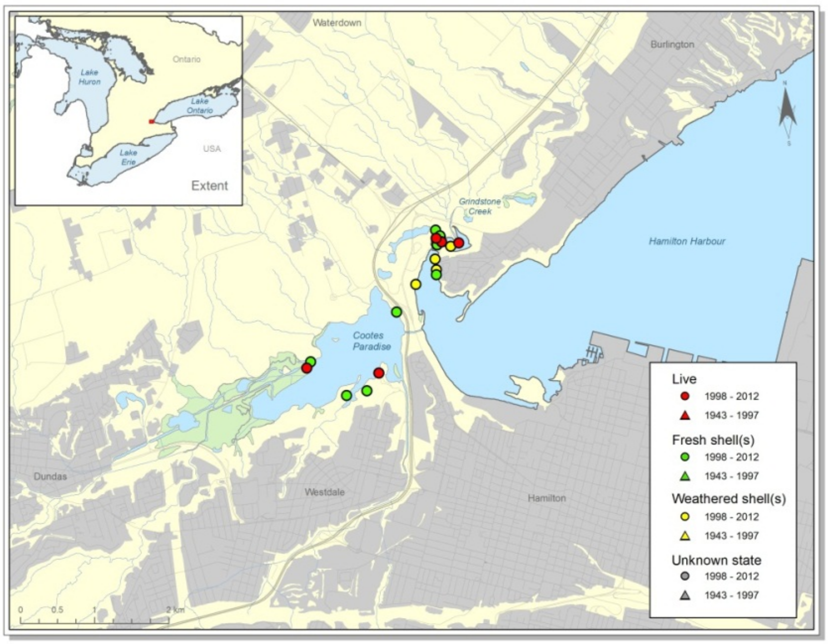

Figure 11. Distribution of all known current and historic Lilliput records from Hamilton Harbour and its surroundings.

Population Status Assessment

For the purposes of this RPA, populations have been delineated based on the ability of the host fish to move from one location where Lilliput is known to exist to another. The putative host fishes for Lilliput are Johnny Darter, Green Sunfish, White Crappie and Bluegill. Distribution of these putative host fishes directly overlaps that of Lilliput. Characteristics that were considered when delineating populations include movement of the individual mussel (including movement of the host fishes), availability of suitable habitat between two locations, state of the Lilliput recorded, and date of the record. These characteristics were used when determining the population structure used for the Population Status Assessment. Refer to Bouvier et al. (2014) for a thorough review of population categorization.

To assess the population status of Lilliput in Canada, each population was ranked in terms of its abundance and trajectory. The level of certainty was associated with each assignment (1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion). The Abundance Index and Population Trajectory values were combined in the Population Status matrix to determine the Population Status for each population. Each Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Extirpated (Table 1). The Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter. Refer to Bouvier et al. (2014) for details on the methods used in the assessment of Population Status.

Table 1. Population Status of all Lilliput populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status	Certainty
Sydenham River	Poor	3
Thames River (Baptiste Creek)	Poor	3
Ruscom River/Belle River	Poor	3
Grand River	Poor	3
Welland River	Poor	3
Jordan Harbour	Poor	3
Hamilton Harbour and surroundings	Poor	3

Habitat Requirements

Glochidium

To fully understand the habitat requirements of freshwater mussels, we must first understand their unique life cycle. Some believe Lilliput to be wholly hermaphroditic, while others believe that the relative proportion of hermaphrodites may increase under low population densities to help increase population numbers. Regardless of reproductive strategy, Lilliput are believed to express very little sexual dimorphism. During the spawning period, males located upstream release sperm into the water column via the excurrent siphon. Females subsequently utilize their gills to filter the sperm from the water column, and the sperm is deposited in the posterior portion of the female gill in a specialized region where the ova are fertilized. The fertilized ova are held until they reach a larval stage.

Freshwater mussels are often categorized in terms of their brooding and glochidial release patterns. Two brooding categories are long-term brooders (bradytictic) and short-term brooders (tachytictic). Lilliput is classified as a long-term brooder, with eggs being reported in June to August, and glochidia present in July. Although gravid individuals have not been observed in Ontario, they have been observed in April (Texas), June (Pennsylvania and Arkansas), and August (Indiana and Wisconsin) in the United States. Regardless of brooding strategy, once females release their glochidia they must encyst on the gills of an appropriate host fish. Glochidial mortality is currently unknown but it is estimated that as little as 0.001% of glochidia successfully attach to an appropriate host fish. Metamorphosis from glochidia to juvenile cannot occur without a period of encystement, which has been recorded to occur at 12 days post infestation on Johnny Darter, and 30-35 days post infestation on Green Sunfish.

Host fishes

Infestation experiments to determine host fish for Lilliput in Canada have not occurred, but Johnny Darter, Green Sunfish, White Crappie, Bluegill, Warmouth (*Lepomis gulosus*) and Orangespotted Sunfish (*Lepomis humilis*) have been identified to be appropriate host fish in the United States. Complete distributional overlap with the extant range of Lilliput in Canada does exist for Johnny Darter, Green Sunfish, White Crappie, and Bluegill, providing circumstantial evidence of host fish interaction. A detailed account of host fish interactions with Lilliput can be found at Bouvier et al. (2014).

Juvenile

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

Adult

Although Lilliput is found in a variety of habitats (e.g., small rivers, larger rivers, wetlands, shallow areas of ponds and backwaters), it is mostly commonly found in the lower reaches of large rivers, wetlands, and backwater areas with little current (Metcalfe-Smith et al. 2005; Watters et al. 2009). Additional details on adult habitat preferences are discussed in Table 2.

Residence

Residence is defined in SARA as “dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating”. Residence is interpreted by DFO as being constructed by the organism (DFO 2010). In the context of the above narrative description of habitat requirements during glochidial, juvenile and adult life stages, Lilliput does not construct a residence during its life cycle.

Functions, Features and Attributes

A description of the functions, features, and attributes associated with Lilliput habitat can be found in Table 2. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Lilliput. In addition to the habitat function, a feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. Optimal habitat attributes from the literature for each life stage have been combined with habitat attributes from current records (recorded from 1997 to present) to show the maximum range in habitat attributes within which Lilliput may be found (see Table 2 and references therein). This information is provided to guide any future identification of critical habitat for this species. It should be noted that habitat attributes associated with current records may differ from those presented in the scientific literature as Lilliput be currently occupying areas where optimal habitat is no longer available.

Population sensitivity to perturbation

There was insufficient information on the life history of Lilliput to complete a population model of the species. For use in such data-poor scenarios, Young and Koops (2011) used a population matrix model framework to explore the sensitivity of Unionid mussel populations to perturbations.

Sensitivity was quantified using elasticities, which can be used to describe the expected percent change in the long-term population growth rate as a result of a percent change in a vital rate (Caswell 2001). A range of possible Unionid life histories were classified into groups with similar elasticities. It was found that sensitivity groups could be predicted if certain vital rates were known to be on either the high or the low end of the parameter range.

Table 2. Summary of the essential functions, features and attributes for each life stage of Lilliput. Habitat attributes from published literature, and habitat attributes recorded during recent Lilliput surveys (recorded since 1997) have been combined to derive the habitat attributes required for the delineation of critical habitat (see text for a detailed description of categories).

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Spawning and fertilization (long-term brooder: gravid females with eggs found in June to August, and glochidia present July)	Reproduction	Lower reaches of large rivers, small rivers, wetlands, and shallow backwater areas		• There are no records of Lilliput spawning in Canada.	• Same habitat as adult
Encysted glochidial stage on host fish until drop off	Development	Appropriate host fish	• Infestation experiments reported that Johnny Darter, Green Sunfish, White Crappie, Bluegill, Warmouth and Orangespotted Sunfish are appropriate host fish for Lilliput in the United States (Watters et al. 2009) • In Canada, distributional overlap does exist between Lilliput and Johnny Darter, Green Sunfish, White Crappie and Bluegill, providing circumstantial evidence of host fish interaction • There are no records from the literature of infestation of putative host fishes by Lilliput in Canada	• There are no records of natural infestations of Lilliput glochidia on gills of putative host fishes	• Presence of sufficient host fish (putative host fishes in Canadian waters are Johnny Darter, Green Sunfish, White Crappie and Bluegill)
Adult/juvenile	Feeding Cover Nursery	Lower reaches of large rivers, small rivers, wetlands, and shallow backwater areas	**General** • Categorized as occupying small rivers, large rivers, wetlands, shallow areas of ponds and backwaters (Metcalfe-Smith et al. 2005; Watters et al. 2009)	• General characteristics taken from the literature supported by recent reports of live individuals	
			Depth • Lilliput is generally categorized as occupying relatively shallow areas (Watters et al. 2009)	• Live Lilliput recorded at depths ranging from 0.5 to 1.5 m (McNichols-O'Rourke et al. 2012; Morris et al. 2012)	• Known to occupy water ranging from 0.5 to 1.5 m in depth

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
			Substrate • Lilliput is most often found in soft substrates composed of mud, sand, silt and clay (Parmalee and Bogan 1998; Watters et al. 2009; COSEWIC 2013).	• Maximum depth may be imposed by biases related to sampling technique • The majority of sites where live Lilliput were recorded were composed of a combination of sand, silt, clay, muck and detritus (McNichols-O'Rourke et al. 2012; DFO, unpubl. data; S. Reid, OMNR, unpubl. data; Morris et al. 2012)	• Most often found in areas where the substrate is composed of sand, silt, clay, muck and detritus, or a combination thereof
			Presence of dreissenid mussels • Introduction and establishment of dreissenid mussels has negatively affected freshwater mussels in the Great Lakes	• During a sampling event at Baptiste Creek in 2011 at a site where a live Lilliput was recorded, it was noted that there were many Zebra Mussel shells present (McNichols-O'Rourke et al. 2012) • Zebra Mussel present in the Grand River up to the Dunnville Dam (G. Mackie, pers. comm.)	

Life histories were classified into the following groups:

- Reproduction dominant: population growth was most sensitive to perturbation or uncertainty in age at maturity; glochidial survival and fecundity were more influential in this group than in others.
- Adult survival dominant: adult survival influenced population growth much more than juvenile survival. Remaining vital rates were relatively less important.
- Juvenile survival dominant: population growth was most influenced by juvenile survival.

The relative fecundity of Lilliput is unknown. However, Lilliput is thought to be a relatively short-lived species (maximum observed age of 12 years) (Watters et al. 2009), with early maturity (COSEWIC 2013). Using the classification system from Young and Koops (2011), Lilliput falls into either the reproduction dominant group (if fecundity is high) or the adult survival dominant group (if fecundity is low). An updated version of this classification system (DFO unpublished data) also suggests that if fecundity is low, Lilliput may fall into a fourth “low sensitivity” group. This group is similar to the adult survival dominant group but with lower sensitivity to adult survival (i.e., population growth is less sensitive to all vital rates compared to other groups). In this group, population growth is equally sensitive to changes in adult survival, juvenile survival, and lifespan. It is thought that Lilliput produce a small number of conglutinates with relatively low numbers of glochidia (G. Watters, pers. comm.). We therefore conclude that Lilliput belongs to the fourth “low sensitivity” group.

Note that sensitivity analyses are meant to compare expected responses in population growth to changes in vital rate. Pertinent threats to the species may affect life stages not identified as being most sensitive to perturbation.

Threats to Survival and Recovery

A wide variety of threats negatively affect Lilliput across its range. Our knowledge of threat impacts on Lilliput populations is limited to general documentation, as there is a paucity of threat-specific cause and effect information in the literature. The threats thought to have the largest effect on the survival and recovery of Lilliput in Canada are largely attributed to the presence of contaminants and toxic substances in their environment, and the introduction and establishment of various invasive species, including dreissenid mussels (Zebra Mussel, *Dreissena polymorpha*; Quagga Mussel, *Dreissena rostriformis*), Round Goby (*Neogobius melanostomous*) and Common Carp (*Cyprinus carpio*). Decreases in the quality of freshwater mussel habitat resulting from increases in nutrient loading, turbidity, and sediment loading, and quantity of suitable habitat through habitat loss and alteration is currently affecting Lilliput populations. In addition, due to the obligate glochidial encystement stage, Lilliput is directly affected by host fish abundance and indirectly affected by the threats affecting the host fish. It is important to note the threats discussed may not always act independently on Lilliput populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect on Lilliput populations. It is difficult to quantify these interactions and cumulative effects; therefore, each threat is discussed independently.

Threat Level Assessment

Each threat was ranked in terms of the Threat Likelihood and Threat Impact for all river systems where it is believed that a population of Lilliput may exist (see Bouvier et al. 2014 for complete details on threat assessment approach). Threat Impact categorization was assigned on a location-by-location basis. If no information was available on the Threat Impact at a specific location, a precautionary approach was used - the highest level of impact from all sites was applied. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Status Matrix resulting in the final Threat Status for each location

(Table 3). Certainty has been classified for Threat Impact and is based on: 1= causative studies; 2=correlative studies; and, 3=expert opinion [level of certainty listed from highest (1) to lowest (3)].

Table 3. Threat Level for Lilliput populations, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Level, which relates to the level of certainty associated with Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and 3=expert opinion.

Threat	Sydenham River	Thames River (Baptiste Creek)	Belle/Ruscom rivers	Grand River
Contaminants and toxic substances	High (3)	High (3)	High (3)	High (3)
Nutrient loading	High (3)	Medium (3)	Medium (3)	Medium (3)
Turbidity	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)
Sediment loading	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Invasive species	Low (3)	High (3)	High (3)	High (3)
Altered flow regimes	Low (3)	Low (3)	Low (3)	Medium (3)
Habitat removal and alteration	High (3)	High (3)	High (3)	High (3)
Host fish (barriers to movement)	Medium (3)	Medium (3)	Medium (3)	High (3)
Host fish (invasive species)	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)
Predation				

Threat	Welland River	Jordan Harbour	Hamilton Harbour and surroundings
Contaminants and toxic substances	High (3)	High (3)	High (3)
Nutrient loading	Medium (3)	Medium (3)	Medium (3)
Turbidity	Unknown (3)	Unknown (3)	Unknown (3)
Sediment loading	Medium (3)	Medium (3)	Medium (3)
Invasive species	High (3)	High (3)	High (3)
Altered flow regimes	Low (3)		
Habitat removal and alteration	Medium (3)	Medium (3)	Medium (3)
Host fish (barriers to movement)	Medium (3)		Medium (3)
Host fish (invasive species)	Unknown (3)	Unknown (3)	Unknown (3)
Predation		Unknown (3)	Medium (3)

Mitigations and Alternatives

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects, or activities in Lilliput habitat. Lilliput has been assessed as Endangered by COSEWIC and is not currently listed nor protected under the *Endangered Species Act 2007.*

Within Lilliput habitat, a variety of works, undertakings, and activities have occurred in the past few years with project types including: water crossings (e.g., bridge maintenance), shoreline and streambank works (e.g., stabilization), instream works (e.g., channel maintenance) and the placement or removal of structures in water. Research has been completed summarizing the types of work, activity, or project that have been undertaken in habitat known to be occupied by Lilliput (Table 4). The DFO Program Activity Tracking for Habitat (PATH) database, as well as summary reports of fish habitat projects reviewed by partner agencies (e.g., conservation authorities), have been reviewed to estimate the number of projects that have occurred during a three-year period from 2010-2012. Only 25 projects were identified in Lilliput habitat. It is likely that this number does not represent a comprehensive list of activities have impacted Lilliput as projects occurring in the proximity of current Lilliput records but not in the area of occurrence were not included in the summary. Some projects may not have been reported to partner agencies or DFO if they occurred under conditions of an Operational Statement. It was noted that five projects were completed under conditions of Operational Statements primarily for bridge maintenance.

The remaining projects were deemed low risk to fish and fish habitat and were addressed through letters of advice with standard mitigation. Without appropriate mitigation, projects or activities occurring adjacent or close to these areas could have impacted Lilliput (e.g., increased turbidity or sedimentation from upstream channel works). The most frequent project type (7) was for shoreline stabilization works with most of these occurring in the Ruscom and Belle rivers. As well, maintenance dredging (6) at the river mouths in these systems also occurred annually. Based on the assumption that historic and anticipated development pressures are likely to be similar, it is expected that similar types of projects will likely occur in or near Lilliput habitat in the future. The primary project proponents were local municipalities.

As indicated in the Threat Analysis, numerous threats affecting Lilliput populations are habitat-related threats that have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 4). DFO FHM has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. At the present time, we are unaware of mitigation that would apply beyond what is included in the Pathways of Effects.

Invasive Species

As discussed in the **THREATS** section, aquatic invasive species (e.g., dreissenid mussels) introduction and establishment may have a negative effect on Lilliput populations. Mitigation and alternatives should not only be considered for current established invasive species but species that may invade in the future.

Mitigation

- Evaluate the likelihood that a waterbody will be invaded by an invasive species.
- Monitor watersheds for invasive species that may negatively affect Lilliput populations directly, or negatively affect Lilliput habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an invasive species.
- Introduce a public awareness campaign on proper boat cleaning methods when transferring boats from an infested waterway, and on the proper identification of native and invasive freshwater mussels. The public awareness campaign could include an educational fact sheet to better educate the public on native and invasive species.
- Encourage the use of existing invasive species reporting systems.

Table 4. Summary of works, projects and activities that have occurred during the period of January 2010 to December 2012 in areas known to be occupied by Lilliput. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Lilliput population, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects have been indicated for each threat associated with a work, project or activity (1 - Vegetation clearing; 2 – Grading; 3 –Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity	**Threats** (associated with work/project/activity)						**Watercourse / Waterbody** (number of works/projects/activities between 2010-2012)						
	Contaminants and toxic substances	**Nutrient loading**	**Turbidity and sediment loading**	**Altered flow regimes**	**Habitat removal and alteration**	**Host fish (barriers to movement)**	**Sydenham River**	**Thames River (Baptiste Creek)**	**Ruscom/ Belle River**	**Grand River**	**Welland River**	**Jordan Harbour**	**Hamilton Harbour and surroundings**
Applicable pathways of effects for threat mitigation and project alternatives	1,4,5,6, 7,11,12, 13,14, 15,16,18	1,4,7,8, 11,12, 13,14, 15,16	1,2,3,4,5, 6,7,8,10, 11,12,13, 15,16,18	10,16, 17	1,2,3,4,5,7,8, 10,11,13,14, 15,16,18	10,16, 17							
Water crossings (bridges, culverts, open cut crossings)	✓		✓	✓	✓	✓	4			1			
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)	✓		✓	✓	✓				5	1			2
Dams, barriers, structures in water (maintenance, modification, hydro retrofits)			✓	✓	✓								
Instream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	✓	✓	✓	✓	2		7				1
Water management (stormwater management, water withdrawal)	✓	✓	✓	✓									
Structures in water (boat launches, docks, effluent outfalls, water intakes)	✓	✓	✓	✓	✓					1			1

- Restrict the use of boats in areas particularly susceptible to Zebra Mussel introduction and infestation.

Alternatives

- Unauthorized
  - None.
- Authorized
  - Use only native species.
  - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

Host Fishes

As discussed in the **THREATS** section, decreases in the number of individual host fish or decreases in the area of overlap between host fish and freshwater mussel may decrease the likelihood that a fish-mussel encounter will occur.

Mitigation

- If putative host fish populations appear to be decreasing, a management plan for the appropriate host fish should be implemented. This would increase the host's survival, increasing the number of hosts available, creating a healthy host population and subsequently increasing the likelihood that the host fish would encounter a gravid freshwater mussel.

Alternatives

- None.

Predation

As discussed in the **THREATS** section, raccoon predation may have negative effects on Lilliput populations in urbanized wetlands. It should be noted that if this threat were to occur, it would be localized.

Mitigation

- If predators were identified at a local scale to have an impact on Lilliput populations, predator control should be considered.

Alternatives

- None.

Sources of Uncertainty

Despite concerted efforts to increase our knowledge of Lilliput in Canada, there are still a number of key sources of uncertainty for this species related to population distribution, structure, habitat preferences and to the factors limiting their existence.

There is a need for a continuation of quantitative sampling of Lilliput in areas where it is known to occur to determine population size, current trajectory, and trends over time. There is also a need for additional targeted sampling in the Sydenham River, Baptiste Creek, Ruscom River, Belle River and Welland River, as very few live individuals have been recorded from these systems. Exploratory sampling should be completed in systems with habitat characteristics similar to those areas where Lilliput is known to occur to determine the extent of their distribution. Candidate areas would include tributaries on the southern shore of Lake St. Clair with similar habitat to the Belle and Ruscom rivers. In addition, supplementary sampling is necessary for all populations that were assigned a low certainty in completing the population status assessment. As is now common practice, shell length of all live individuals should be recorded to gain information on population structure and to understand recruitment within each population. These baseline data are required to monitor Lilliput distribution and population trends as well as the success of any recovery measures implemented.

Additional studies on habitat requirements are imperative to determine critical habitat for all Lilliput life stages. Additional sampling should include a quantitative habitat assessment including substrate categorization, water depth, and water velocity. There is a need to better understand the effects of water level variation on Lilliput as this species may be particularly negatively affected by low water levels, resulting from climate change. Laboratory experiments, and if feasible field experiments, should be completed to determine the host fish of Lilliput in Canada. Currently, putative host fish species are inferred from experiments on this species in the United States. Infestation experiments, using samples from Canadian populations, should be completed to verify the usage of Bluegill, Johnny Darter, White Crappie, Green Sunfish, Orange-spotted Sunfish and Warmouth as host fishes for Lilliput. Sampling of putative host fish should be completed in areas known to be inhabited by Lilliput, during which the gills should be inspected and sampled for Lilliput glochidia. Once host fish species have been confirmed, additional investigations to determine the glochidial carrying capacity, as well as the relationship between mussel attachment probability and host-mussel density should be completed.

Many of the life history characteristics required to inform population modelling efforts are currently unknown, and should be considered a priority when collecting additional information on this species. At minimum, order of magnitude fecundity estimates are required to properly classify Lilliput as being most sensitive to changes in age at maturity, fecundity and glochidial survival (reproduction dominant) or in adult survival (adult survival dominant). In addition, survival rates of all life stages are unknown.

Numerous threats have been identified for Lilliput populations in Canada, although the direct impact that these threats may have is currently unknown. There is a need for more quantitative studies to evaluate the direct impact of each threat on Lilliput populations with greater certainty. In the literature, the threat impacts are generally discussed at a broad level (i.e., mussel assemblage level). It is important to further our knowledge on threat likelihood and impact at the species level. Research is needed to determine the effect of contaminants and toxic substances on Lilliput, as these pollutants are known to occur in areas where Lilliput is currently found. This type of research would provide insight on the factors currently limiting Lilliput populations. Thresholds for other water quality parameters (e.g., nutrients, turbidity) should also be investigated.

SOURCES OF INFORMATION

This Science Advisory Report is from the September 24, 2013 Recovery Potential Assessment of Lilliput (*Toxolasma parvum*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Bouvier, L.D., Young, J.A.M., and Morris, T.J. 2014. Information in support of a Recovery Potential Assessment of Lilliput (*Toxolasma parvum*) in Canada. DFO Can. Sci. Advis.Sec. Res. Doc. 2013/103. v + 42 p.

Caswell, H. 2001. Matrix population models: construction, analysis, and interpretation. 2nd Ed edition. Sinaur Associates, Sunderland, Massachusetts. 722 p.

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

COSEWIC. 2013. COSEWIC Status Report on Lilliput, *Toxolasma parvum*, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario. vi + 59 p.

DFO. 2003. National code on introductions and transfers of aquatic organisms. Task Group on Introductions and Transfer. September 2003. 53 p.

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McNichols-O'Rourke, K.A., Robinson, A., and Morris, T.J. 2012. Summary of freshwater mussel timed search surveys in southwestern Ontario in 2010 and 2011. Can. Manuscr. Rep. Fish. Aquat. Sci. 3009: vi + 42 p.

Metcalfe-Smith, J.L., MacKenzie, A., Carmichael, I., and McGoldrick, D.J. 2005. Photo Field Guide to the Freshwater Mussels of Ontario. St. Thomas, Ontario, Canada. 60 p.

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Watters, G.T., Hoggarth, M.A., and Stansbery, D.H. 2009. The Freshwater Mussels of Ohio. The Ohio State University Press, Columbus, OH. 400 p.

Young, J.A.M., and Koops, M.A. 2011. Recovery potential modelling of Eastern Pondmussel (*Ligumia nasuta*), Fawnsfoot (*Truncilla donaciformis*), Mapleleaf (*Quadrula quadrula*), and Rainbow (*Villosa iris*) in Canada. Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/119. iv + 10 p.

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