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Information in support of a Recovery Potential Assessment of Wavy-rayed Lampmussel (*Lampsilis fasciola*) in Canada

Information à l'appui de l'évaluation du potentiel de rétablissement de la lampsile fasciolée (*Lampsilis fasciola*) au Canada

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ABSTRACT

In October 1999, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Wavy-rayed Lampmussel (*Lampsilis fasciola*) as Endangered. Wavy-rayed Lampmussel was subsequently listed on Schedule 1 of the *Species at Risk Act* (SARA) when the Act was proclaimed in June 2003. In April 2010, the status was reassessed as Special Concern. The reason for this designation was that surveys since the first assessment identified a large, previously unknown reproducing population in the Maitland River and that there is evidence that some of the populations are reproducing. The Recovery Potential Assessment (RPA) provides information and scientific advice needed to fulfill various requirements of SARA including permitting activities that would otherwise violate SARA. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements, and threats of Wavy-rayed Lampmussel. Mitigation measures and alternative activities related to the identified threats, that can be used to protect the species, are also presented. The information contained in the RPA and this document may be used in assessing SARA Section 73 permits.

RÉSUMÉ

En octobre 1999, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a désigné la lampsile fasciolée (*Lampsilis fasciola*) comme étant une espèce en voie de disparition. La lampsile fasciolée a par la suite été inscrite à la liste 1 de la *Loi sur les espèces en péril* (LEP) lors de l'adoption de la loi, en juin 2003. En avril 2010, son statut a été réévalué comme étant préoccupant. La raison de cette désignation en est que les relevés effectués depuis la première évaluation indiquaient une importante population en reproduction, auparavant inconnue, dans la rivière Maitland et qu'il y avait des preuves selon lesquelles certaines des populations se reproduisaient. L'évaluation du potentiel de rétablissement (EPR) donne l'information et l'avis scientifique nécessaires pour satisfaire aux diverses exigences de la LEP, dont la permission d'avoir des activités qui enfreindraient autrement la LEP. Ce document de recherche décrit l'état actuel des connaissances sur la biologie, l'écologie, l'aire de répartition, les tendances de la population, les exigences d'habitat et les menaces pour la lampsile fasciolée. On y présente aussi les mesures d'atténuation et les activités de remplacement pour les menaces indiquées, lesquelles peuvent contribuer à protéger l'espèce. L'information contenue dans l'EPR et dans ce document peut servir pour l'évaluation des permis en vertu de l'article 73 de la LEP.

SPECIES INFORMATION

Scientific Name – *Lampsilis fasciola* (Rafinesque 1820)
Common Name – Wavy-rayed Lampmussel
Current COSEWIC Status & Year of Designation – Special Concern, 2010
COSEWIC Reason for Designation – "This medium-sized freshwater mussel is confined to four river systems and the Lake St. Clair delta in southern Ontario. Since the original COSEWIC assessment of Endangered in 1999, surveys have identified a large, previously unknown reproducing population in the Maitland River. The mussels in the Thames River are also now reproducing. The largest population is in the Grand River; smaller but apparently reproducing populations are in the Ausable River and Lake St. Clair delta. Although water and habitat quality have declined throughout most of the species' former range in Canada, there are signs of improvement in some populations but habitats in Great Lakes waters are now heavily infested with invasive mussels and are uninhabitable for native mussels. The main limiting factor is the availability of shallow, silt-free riffle/run habitat. All riverine populations are in areas of intense agriculture and urban and industrial development, subject to degradation, siltation, and pollution. Invasive mussels continue to threaten the Lake St. Clair delta population and could be a threat to populations in the Grand and Thames rivers if they invade upstream reservoirs."
SARA Schedule – 1
Range in Canada – Ontario

BACKGROUND

The Wavy-rayed Lampmussel (*Lampsilis fasciola*, Rafinesque 1820) is a small, sexually dimorphic mussel with a smooth, yellow shell covered with dense wavy green rays of varying widths (Metcalfe-Smith *et al.* 2005). Females are easily distinguished from the males with a distended shell shape. Wavy-rayed Lampmussel is medium-sized, generally 75-100 mm long (COSEWIC 2010). Wavy-rayed Lampmussel can be confused with the Plain Pocketbook (*Lampsilis cardium*), although the Wavy-rayed Lampmussel is generally smaller, relatively thicker and more regularly ovate (COSEWIC 2010).

This mussel species is generally found in small to medium, clear, hydrologically stable rivers, around shallow riffle areas, although it is also known to inhabit lacustrine areas. It can be found on sand or gravel substrates, at times stabilized with cobble or boulders usually at depths of up to 1 m (Metcalfe-Smith *et al.* 2005; COSEWIC 2010).

Key threats limiting the occurrence of this species in riverine systems include habitat degradation from agricultural and sediment runoff, loss of riparian vegetation, pollution, the physical destruction of streambeds by livestock, and increased levels of ammonia and copper. The introduction of the invading Zebra Mussel (*Dreissena polymorpha*) has been attributed to the rapid devastation of the Wavy-rayed Lampmussel populations of the Great Lakes and its connecting channels, although Zebra Mussel invasion has yet to affect the riverine populations. There is also evidence that muskrat (*Ondatra zibethicus*) predation could be a threat to small, local populations.

A meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in October 1999 recommended that the Wavy-rayed Lampmussel, which is found solely in the Great Lakes drainage, be designated as Endangered. Subsequent to the COSEWIC designation, Wavy-rayed Lampmussel was listed on Schedule 1 of the *Species at Risk Act* (SARA) when the Act was proclaimed in June 2003. In April 2010, the status was reassessed as Special Concern. The reason for this designation was that surveys since the first assessment identified a large, previously unknown reproducing population in the Maitland River, and that there is evidence that most of the populations are reproducing. A Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill SARA requirements, including the development of recovery strategies and authorizations to carry out activities that would otherwise violate SARA (DFO 2007). This document provides background information on the Wavy-rayed Lampmussel to inform the RPA.

CURRENT STATUS

Historic Wavy-rayed Lampmussel records exist for the Grand River (first record 1894; CMN-ML002518), Thames River (1902; CMN-ML002542), Detroit River (1930s; UMMZ 84186), Maitland River (1935; UMMZ 186322), Sydenham River (1965; OSUM-19210), western Lake Erie (1967 (OSUM-18666), Lake St. Clair (1986; Nalepa *et al.* 1996), and Ausable River (1993; Morris and Di Maio 1998) (Figure 1). Wavy-rayed Lampmussel is now thought to be extirpated from Lake Erie, Lake St. Clair proper (excluding St. Clair River delta), and the Detroit River resulting from the introduction of Zebra Mussel to these systems. The Wavy-rayed Lampmussel is primarily a riverine species with only 15% of its historic records occurring in waters now infested with Zebra Mussel (Metcalfe-Smith *et al.* 2000b). Despite the greater historic abundance in riverine systems, it is believed that the Sydenham River population has been extirpated as no Wavy-rayed Lampmussel has been found alive in this river since 1971, despite over 600 person-hours of search effort from 1997 to 2004 (Morris *et al.* 2008). The historic distribution of the Wavy-rayed Lampmussel in the Sydenham River was believed to be a 42 km reach between Rokeby and Florence (Morris *et al.* 2008). Extant populations remain in the Ausable, Grand, Maitland and Thames rivers and the St. Clair River delta. The largest population occurs in the Grand River, while the Maitland River and Thames River populations are similar to one another but an order of magnitude smaller than the Grand River population (Morris *et al.* 2008).

AUSABLE RIVER

The Ausable River population was discovered in 1993 (Morris and Di Maio 1998). Increased sampling efforts over the following 12 years yielded only three additional individuals; two individuals found in a timed-search in 2002 and one juvenile found during an observational study in 2005. In 2006 DFO and Ausable-Bayfield Conservation Authority (ABCA) completed quadrat surveys and found 18 animals at five sites (Baitz *et al.* 2008). An additional timed-search survey was completed in 2008 where one live individual was found (ABCA, unpubl. data).

The distribution of the Wavy-rayed Lampmussel includes reaches in both the Little Ausable River (3 km) and the main stem (84 km). The Area of Occupancy (AO) for the Ausable River population was calculated to be approximately 0.7 km^2 (Morris *et al.* 2008).

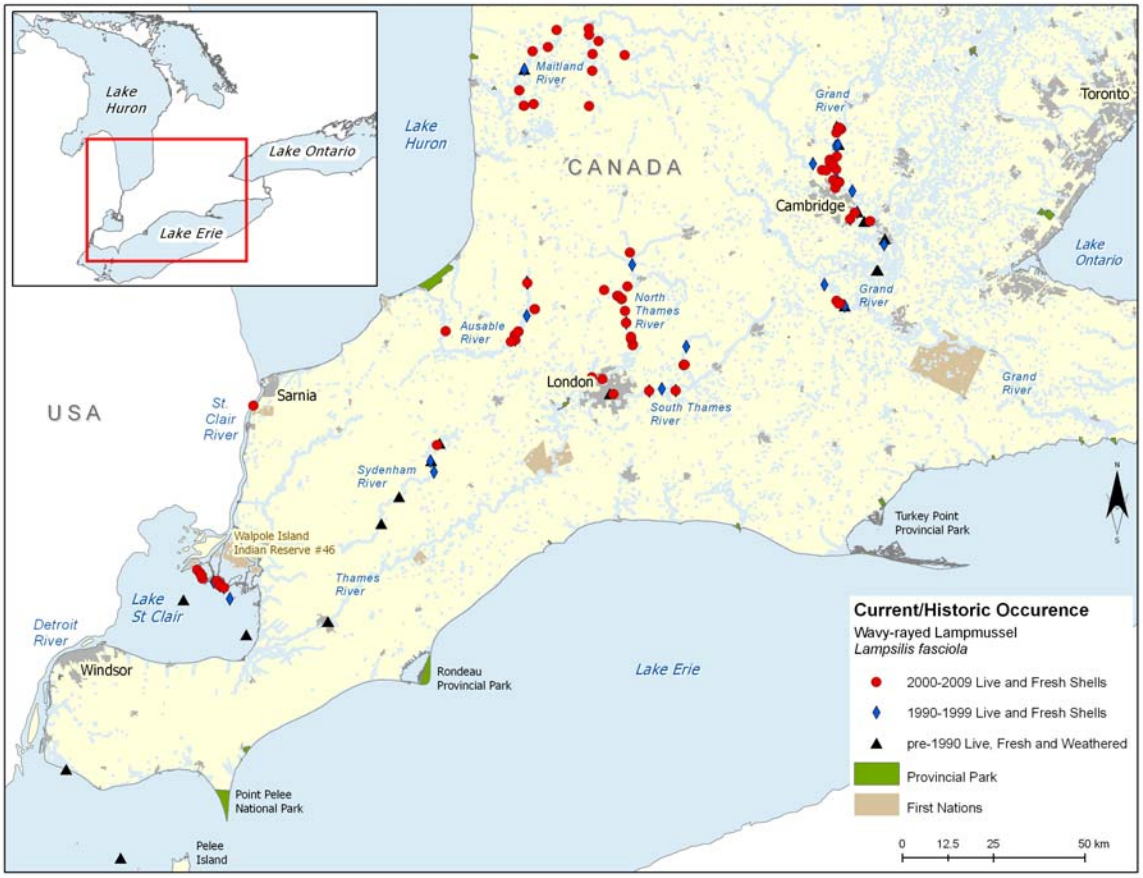

Figure 1. Current distribution of the Wavy-rayed Lampmussel in Canada.

GRAND RIVER

The Grand River Wavy-rayed Lampmussel population is one of the healthiest Canadian populations (Table 1; Morris 2006). It appears that this population has recovered from poor water quality conditions present in the 1970s and early 1980s (Morris 2006). Sampling on the Grand River from 1995 to 1998 resulted in 22 live animals, 38 fresh whole shells, and seven fresh half-shells from 11 sites, including two sites on the Nith River and one on the Conestoga River (both tributaries of the Grand River) (Mackie 1996; Metcalfe-Smith *et al.* 1998; Metcalfe-Smith *et al.* 1999). Various mussel collections from 2001-2006 resulted in the capture of 73 live individuals, 20 fresh whole shells, and seven fresh half-shells. In addition, two relocation studies completed in 2006 noted 248 live individuals (Mackie 2008; Mackie, unpubl. data), while a mark and recapture study (one plot sampled 13 times between May and October) noted 88 unique individuals (DFO, unpubl. data).

In the Grand River watershed, Wavy-rayed Lampmussel occurs from Inverhaugh (north of Waterloo) downstream to Glen Morris (south of Cambridge) (Morris *et al.* 2008; COSEWIC 2010). Wavy-rayed Lampmussel has also been found in three Grand River tributaries: 13.5 km of the Conestogo River, 30 km of the Nith River, and the lower portion of the Speed River (10 km; COSEWIC 2010). Based on these known distributions Morris *et al.* (2008) calculated the AO of the Wavy-rayed Lampmussel in the Grand River to be 7.5 km^2.

MAITLAND RIVER

Wavy-rayed Lampmussel occurs in all four branches of the Maitland River watershed. Sampling completed in 1997-1998 yielded three live animals, as well as three whole shells (Metcalfe-Smith *et al.* 2000b). Additional timed-search sampling between 2003-2004 recorded 21 live individuals at nine sites (McGoldrick and Metcalfe-Smith 2004). In 2008, DFO (unpubl. data) found Wavy-rayed Lampmussel at three of these previously sampled sites, as well as one additional site. The trajectory of the Maitland River population is unknown due to a lack of historic distributional data.

Wavy-rayed Lampmussel has been noted to occur over a 23 km stretch in the Middle Maitland River, 15 km in the Little Maitland River, 54 km in the main stem, and 10 km in the South Maitland River (Morris *et al.* 2008; COSEWIC 2010). The AO for the Maitland River is approximately 3.2 km^2 (COSEWIC 2010).

THAMES RIVER

Wavy-rayed Lampmussel has been identified from the North, South and Middle Thames rivers and in two tributaries of the North Thames branch: Fish and Medway Creeks (Morris *et al.* 2008). Surveys conducted in 2004 indicated that the North Thames River contains one of the healthiest populations remaining in Canada. The species currently occupies all of its known historic range in the Thames River and size/age distributions indicate that recruitment is occurring throughout most of the sites (Morris 2006). In addition, sampling completed from 2006-2008 noted 75 live individuals (Zanatta, unpubl. data), while a mark and recapture study (one plot sampled 14 times between May and October) noted 138 unique live individuals (DFO, unpubl. data).

Wavy-rayed Lampmussel occurs over 65 km of the North, South and Middle branches of the Thames River upstream of the city of London (Morris 2006; COSEWIC 2010). The AO for the Thames watershed is estimated at 2.5 km^2 (Morris *et al.* 2008).

SYDENHAM RIVER

The most recent record of a live individual in the Sydenham River dates back to 1971 (COSEWIC 2010) when a single individual was recorded. The Sydenham River was intensively sampled from 1997-2003 (over 600 p-h) and not a single live individual was recorded, which provides support for the belief that the Wavy-rayed Lampmussel is extirpated from this system (COSEWIC 2010). The historic distribution of the Wavy-rayed Lampmussel included 42 km of the middle reach of the East Sydenham River.

ST. CLAIR RIVER DELTA

Although the Lake St. Clair population of Wavy-rayed Lampmussel has been decimated since the introduction of the Zebra Mussel to the Great Lakes, a population was found to persist in the St. Clair River delta. The population can be found over 12 km^2 of the shallow nearshore areas of the delta within the territory of Walpole Island First Nations (Morris *et al.* 2008). Sampling from 1999-2005 resulted in the capture of 34 live individuals (Zanatta *et al.* 2002; Metcalfe-Smith *et al.* 2004). Based on these surveys, it appears that the St. Clair River delta population is the last historic lake population to persist. Methods provided by Metcalfe-Smith *et al.* (2004) were used to calculate the AO, which resulted in a AO of 5.5 km^2 (Morris *et al.* 2008).

LAKE ERIE AND CONNECTING CHANNELS

Wavy-rayed Lampmussel was reported from Lake Erie in 1967 and 1980, but was not found in a subsequent surveys completed by Schloesser and Nalepa (1994) including the survey of 17 sites. A small remnant population may still exist in Lake Erie but it is unlikely that a significant population exists due to the establishment of Zebra Mussel in this system. A single Wavy-rayed Lampmussel was recorded from the St. Clair River in 2001 when it was found in a ponar sample (Environment Canada, unpubl. data). This is the only known Wavy-rayed Lampmussel sample from this area. Extensive mussel community surveys by SCUBA divers were completed in the Detroit River in 1982-83, 1992 and 1994 and no Wavy-rayed Lampmussel was recorded (Schloesser *et al.* 1998).

POPULATION STATUS

To assess the Population Status of Wavy-rayed Lampmussel, each population was ranked in terms of its abundance (Abundance Index) and trajectory (Population Trajectory). The Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown, and was based on quantitative density estimates and estimates of population size that are currently available for the Ausable, Grand, Maitland, Thames rivers, and the St. Clair River delta (Table 1; COSEWIC 2010). A quadrat method, as described in COSEWIC (2010), was used to determine density estimates for all populations. The sampling method and effort were consistent between sites, allowing for a comparison of population strengths across the various populations. Based on quantitative sampling the Wavy-rayed Lampmussel is found in greatest density in the Grand River, followed by the Thames, Maitland and Ausable rivers (Table 1; Morris *et al.* 2008; COSEWIC 2010). Density estimates were subsequently multiplied by the AO to obtain the Estimated Population Size, as described in COSEWIC (2010). The Estimated population sizes were then used to determine the current Abundance Index for each population (Table 2).

Table 1. Population estimates for all current Wavy-rayed Lampmussel (WRLM) populations in Canada.

Population	Total Unionid Density ($\#/m^2$) (SE)	WRLM Density ($\#/m^2$) (SE)	WRLM Area of Occupancy[d] (km^2)	WRLM Estimated Population Size[d] (± SE)
Ausable River	5.98 (2.526)[a]	0.048 (0.016)[a]	0.7	33 600(± 11 200)
Grand River	0.89 (0.289)[b]	0.28 (0.16)[b]	7.5	2 100 000 (± 1 200 000)
Maitland River	1.21 (0.402)[b]	0.096 (0.027)[b]	3.2	310 000 (± 86 400)
Thames River	1.57 (0.618)[b]	0.13 (0.067)[b]	2.5	325 000 (± 167 500)
St. Clair River delta	0.096 (0.008)[c]	0.0006 (0.00021)[c]	5.5	3300 (± 1100)

[a] ABCA (unpubl. data); [b] DFO (unpubl. data); [c] Metcalfe-Smith *et al.* (2007); [d] COSEWIC (2010)

The Population Trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available knowledge about the current trajectory of the population (Table 2). The number of individuals caught over time for each population was considered. Trends over time were classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time) and Stable (no change in abundance over time). If insufficient information was available to inform the Population Trajectory, the population was listed as Unknown. Certainty has been associated with the Abundance Index and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=standardized sampling; 3=expert opinion.

Table 2. Abundance Index and Population Trajectory of each Wavy-rayed Lampmussel population in Canada. Certainty has been associated with the Abundance Index and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=standardized sampling; 3=expert opinion.

Population	Abundance Index	Certainty	Population Trajectory	Certainty
Ausable River	Low	1	Unknown	3
Grand River	High	1	Increasing	2
Maitland River	Medium	1	Unknown	3
Thames River	Medium	1	Increasing	2
St. Clair River delta	Low	1	Decreasing	3
Lake Erie and connecting channels	Extirpated	2	-	-
Sydenham River	Extirpated	1	-	-

The Abundance Index and Population Trajectory values were then combined in the Population Status matrix (Table 3) to determine the Population Status for each population. Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Not applicable (Table 4).

Table 3. The Population Status matrix combines the Abundance Index and Population Trajectory rankings to establish the Population Status for each Wavy-rayed Lampmussel population in Canada. The resulting Population Status has been categorized as Extirpated, Poor, Fair, Good, or Unknown.

		Population Trajectory			
		Increasing	**Stable**	**Decreasing**	**Unknown**
Abundance Index	**Low**	Poor	Poor	Poor	Poor
	Medium	Fair	Fair	Poor	Poor
	High	Good	Good	Fair	Fair
	Unknown	Unknown	Unknown	Unknown	Unknown
	Extirpated	Extirpated	Extirpated	Extirpated	Extirpated

Table 4. Population Status of all Wavy-rayed Lampmussel populations in Canada, resulting from an analysis of both the Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index or Population Trajectory).

Population	Population Status	Certainty
Ausable River	Poor	3
Grand River	Good	2
Maitland River	Poor	3
Thames River	Fair	2
St. Clair River delta	Poor	3
Lake Erie and connecting channels	Extirpated	2
Sydenham River	Extirpated	1

HABITAT REQUIREMENTS

To fully understand the habitat requirements of the Wavy-rayed Lampmussel, we must first understand the unique life cycle of freshwater mussels. During the spawning period, males located upstream release sperm into the water column. Females subsequently utilize their gills to filter the sperm from the water column, and the sperm is deposited in the posterior portion of the female gill, in a specialized region, where the ova are fertilized. The fertilized ova are held until they reach a larval stage. Mature females are characterized by a swelling of the posterior-ventral margin (Metcalfe-Smith *et al.* 2000b). Wavy-rayed Lampmussel is considered a long-term brooder because it generally spawns in August and glochidial release does not occur until the subsequent year (Clarke 1981).

GLOCHIDIUM

Females release mature larvae (glochidia) which must encyst on the gills of an appropriate host fish. Smallmouth (*Micropterus dolomieu)* and Largemouth Bass (*M. salmoides*) have been identified as suitable hosts for the Wavy-rayed Lampmussel (McNichols *et al.* 2005). Females have developed specialized mantles, which mimic lures to attract host fish (Morris *et al.* 2008). Four lure types have been identified in the Ausable, Grand, Thames and Maitland rivers. When the fish comes in contact with the mantle, it retracts into the shell, resulting in a sudden release of glochidia and subsequent glochidial attachment on the gills. Glochidia will remain encysted until they metamorphose into juveniles. This process may last from a few weeks to several months (Morris *et al.* 2008). Encystment is an obligate step in the life cycle of the Wavy-rayed Lampmussel, and development will not occur in the absence of this phase. The gills of the appropriate host fish can be considered a habitat requirement for the glochidial life stage of the Wavy-rayed Lampmussel.

JUVENILE

Subsequent to metamorphoses, juvenile Wavy-rayed Lampmussel are released from the gills of the fish host and bury themselves in the substrate until they reach several years of age (Morris *et al.* 2008). The proportion of glochidia that survive to the juvenile stage is estimated to be as low as 0.000001% (Morris *et al.* 2008). A survival tactic to overcome this increased level of mortality is to produce very high numbers of glochidia. It is difficult to classify required habitat for juvenile mussels because they are difficult to detect and because they have a tendency to burrow; although, they are generally found when implementing adult mussel survey methods (Morris *et al.* 2008). Once sexually mature they emerge from the substrate surface to participate in gamete exchange (Watters *et al.* 2001).

ADULT

Adult Wavy-rayed Lampmussel are typically found in clear rivers and streams, in and around riffle/run areas, where the water flow is steady (Clarke 1981; Cummings and Mayer 1992). In riverine systems, they are generally found on substrate composed of sand or gravel, up to approximately 1 m deep (Clarke 1981; Cummings and Mayer 1992; Morris *et al.* 2008). The last lacustrine population located in the St. Clair River delta can be found in shallow sand flats. and along shallow wave-washed shoals (Metcalfe-Smith and McGoldrick 2003). Many historically-abundant Wavy-rayed Lampmussel areas are no longer suitable since the infestation of Zebra Mussel.

RESIDENCE

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

THREATS

In the past 30 years, species diversity and abundance of native freshwater mussels has declined throughout Canada and the United States (Williams *et al.* 1993). It appears that the two greatest limiting factors to the stabilization and growth of the Wavy-rayed Lampmussel populations in the Great Lakes are Zebra Mussel introduction and decreases in water quality (i.e., increased turbidity and suspended solids). The historic vast distribution of the Wavy-rayed Lampmussel in Lake St. Clair, Lake Erie and its connecting channels has been devastated by the introduction of the Zebra Mussel, and these areas no longer provide suitable habitat for the recovery of this species. There is also strong evidence that decreases in water quality, specifically increased turbidity and suspended solids, also limits the distribution of the Wavy-rayed Lampmussel (Metcalfe-Smith and McGoldrick 2003). These declines in water quality are the result of activities such as dam construction, impoundments, channel modifications (e.g., channelization, dredging, snagging), and land use practices (Fuller 1974; Bogan 1993; Williams *et al.* 1993; Watters 2000). Land use practices, such as agricultural and urban activities, lead to high silt, contaminant and nutrient loadings. In addition to these inputs, agricultural practices of installing drainage tile in crop fields has altered the hydrological regime in these watersheds (Morris *et al.* 2008). Due to the obligate nature of the mussel reproductive cycle, any threat leading to the separation of mussel and fish host during reproduction can be detrimental to the mussel population. Direct threats to the host, such as barriers to movement, and recreational activities, such as angling and harvesting pressures, will have cumulative effects on the mussel population. There is also evidence that predation by muskrats and raccoons (*Procyon lotor*) may be negatively affecting Wavy-rayed Lampmussel populations (Neves and Odom 1989).

It is important to note that these threats may not always act independently on Wavy-rayed Lampmussel populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect on the Wavy-rayed Lampmussel populations. It is quite difficult to quantify these interactions and, therefore, each threat is discussed independently.

EXOTIC SPECIES

The Zebra Mussel has severely affected native, lacustrine Wavy-rayed Lampmussel populations. The invasion and spread of this invasive species throughout the Great Lakes and their tributaries has decimated many native freshwater mussel populations (e.g., Nalepa *et al.* 1996; Ricciardi *et al.* 1996; Schloesser *et al.* 1996; Schloesser *et al.* 1998; Zanatta *et al.* 2002). They have destroyed the lacustrine habitat historically inhabited by the Wavy-rayed Lampmussel, in both Lake St. Clair (Nalepa *et al.* 1996), and western Lake Erie (Schloesser and Nalepa 1994). Zebra Mussel compete with native mussel species for space and food and can attach to the Wavy-rayed

Lampmussel shells, impairing movement, burrowing, feeding, respiration and other physiological activities (Haag *et al.* 1993; Baker and Hornbach 1997; COSEWIC 2010). This typically results in the death of the unionid mussel. Zebra Mussel exhibit rapid population growth and are able to eliminate entire unionid populations in a very short time (COSEWIC 2006).

This threat is particularly relevant to the remnant St. Clair delta population, which is the last known lake population of Wavy-rayed Lampmussel in Canada (Morris 2006). Zebra Mussel are not only a threat for lacustrine populations but do pose a threat to riverine populations should they become established in reservoirs. Impoundments behind reservoirs act to increase water retention times, allowing time for Zebra Mussel veligers to settle and act as a seed population. Infestation may occur if water retention time is greater than the life span of the larval stage of the Zebra Mussel (G. Mackie, University of Guelph Emeritus, pers. comm.). This increases susceptibility to invasion by these exotics (Metcalfe-Smith *et al.* 2000b). Zebra Mussel have already been reported in two reservoirs on the Thames River (UTRCA 2003). Fortunately, these reports have been downstream of the Wavy-rayed Lampmussel population. If similar infestations were to occur upstream, this could potentially be detrimental to the mussel community. Another highly susceptible population is that of the Grand River, which is heavily impounded with a total of 34 dams/weirs (GRCA 1998). Zebra Mussel infestation in the Luther, Belwood, Guelph, Conestogo reservoirs could seriously impact the Grand River Wavy-rayed Lampmussel population (Metcalfe-Smith *et al.* 2000a; Morris 2006).

TURBIDITY AND SEDIMENT LOADING

The increase in turbidity, and the subsequent decrease in silt-free riffle/run habitats has reduced the quantity and quality of Wavy-rayed Lampmussel habitat across its Ontario range (Morris *et al.* 2008). Increased siltation affects the Wavy-rayed Lampmussel by hindering the intake of oxygen and impeding reproductive functions. Increased suspended solids in the water column can clog the gill structures and ultimately suffocate the mussel. Furthermore, the reproductive cycle of the Wavy-rayed Lampmussel necessitates a visual predator that can locate the lure, and subsequently become infested with glochidia. Increased siltation would decrease the likelihood that the fish host will be able to locate and encounter the mussel (Morris 2006). Dennis (1984) indicated that a Tennessee Wavy-rayed Lampmussel population was mildly tolerant to high silt conditions during periods of low flow. However, a recent study completed by Metcalfe-Smith and McGoldrick (2003) indicated that Wavy-rayed Lampmussel is associated with areas of higher water clarity, and catch-per-unit effort was positively correlated with water clarity. Increased sediment loading is often associated with increased agricultural land use. Areas of increased agricultural use can also lead to riparian vegetation clearing or unrestricted livestock access to the river leading to poor water quality with increased sediment loads (WQB 1989a; Morris 2006).

CONTAMINANTS AND TOXIC SUBSTANCES

Freshwater mussel life history characteristics also make them particularly sensitive to increased levels of sediment contamination and water pollution. Adult mussels feed primarily by filter feeding, while juveniles remain buried deep in the sediment feeding on particles associated with the sediment (Morris *et al.* 2008 and reference therein). Toxic chemicals from both point and non-point sources, especially agriculture, are believed to be one of the major threats to mussel populations today (Strayer and Fetterman 1999). The effects of heavy metals on mussels have been reviewed by Fuller (1974). Substances such as arsenic, cadmium, chlorine, copper, mercury and zinc can be toxic to freshwater mussels which accumulate these substances from their environment. Specifically, Wavy-rayed Lampmussel is very sensitive to two particular contaminants: copper and un-ionized ammonia (Gillis *et al.* 2008; Morris *et al.* 2008 and reference therein). In the Thames River, mean ammonia concentrations exceed federal guidelines in all sub-basins (Morris *et al.* 2008). While mean concentrations of copper exceed guidelines in several sub-basins, including those where small Wavy-rayed Lampmussel populations were found (Metcalfe-Smith *et al.* 2000b). A few study sites in the upper reaches of the Grand River were found to be within federal guidelines for copper levels, and these reaches correspond to areas where the Wavy-rayed Lampmussel has been found (Metcalfe-Smith *et al.* 2000b).

Categorization of contaminants and toxic substances as a threat to Wavy-rayed Lampmussel has been greatly based on the presence of copper and un-ionized ammonia; however, it is recognized that a multitude of contaminants and toxic substances are present in areas where Wavy-rayed Lampmussel occurs. The effects of these additional contaminants are currently unknown and therefore have not attributed to the Threat Status categorization.

NUTRIENT LOADING

Agriculture, the primary land use in the Ausable and Sydenham rivers, appears to be contributing to poor water quality in these two watersheds through agricultural runoff and manure seepage (ARRT 2005; Morris 2006). In addition, phosphorus and nitrogen loadings in the Thames River watershed are some of the highest loadings for the entire Great Lakes basin (WQB 1989b; Morris 2006). The Maitland River population also faces threats from agricultural runoff with nitrate values exceeding federal guidelines (Morris 2006). As for the Thames River, tile drainage, wastewater drains, manure storage and spreading has contributed to poor water quality (Metcalfe-Smith *et al.* 2000b). Particularly relevant to Wavy-rayed Lampmussel are the indirect effects of increased nutrient loading, such that, increases in nutrient levels can lead to increased algal growth, which subsequently decreases the amount of dissolved oxygen available in the water column. Freshwater mussels are particularly sensitive to decreases in dissolved oxygen.

ALTERED FLOW REGIMES

The presence of impoundments and dams on freshwater streams and rivers has been shown to negatively affect mussel communities. Impoundments typically result in siltation, stagnation, loss of shallow water habitat, pollutant accumulation and water of poor quality due to high nutrient concentrations, while dams alter flow and can affect the natural thermal profile (Bogan 1993; Watters 2000). Dams can also cause sediment retention upstream and scouring downstream (COSEWIC 2010). Increased pressures from urbanization can include increased water taking from rivers as well as storm water management that greatly alter flow regimes surrounding urbanized centers. Man-made alterations to the environment have also been detrimental to mussel communities. For example, channelization, dredging and snagging activities result in the disruption of the riffle-run-pool sequence, as well as alterations to circulation patterns and substrate composition (Watters 2000). Increased tile drainage, resulting from the conversion of the forest-covered land to agricultural, allows for large inputs of sediments into the watercourse. Wavy-rayed Lampmussel was extirpated from the Tennessee River after the construction of the Wilson Dam in 1925 (Metcalfe-Smith *et al.* 2000b) and from the South Fork Holston River in Tennessee after the construction of dams and impoundments in the 1950’s (Parmalee and Polhemus 2004).

HABITAT REMOVAL AND ALTERATION

Physical loss of Wavy-rayed Lampmussel habitat can occur as a result of many activities. Activities particularly relevant to Wavy-rayed Lampmussel habitat include dredging, infilling, construction of impoundments, marinas and docks, and channelization. Although there is no quantitative information available regarding the number of Wavy-rayed Lampmussel affected by human activities in Canada, removal or alteration of preferred habitat could have a direct effect on the recovery or survival of Wavy-rayed Lampmussel.

FISH HOSTS

The obligate glochidial encystment stage necessitates access to a suitable fish host. Therefore, the distribution of many freshwater mussel species is limited by the distribution of its fish host(s). If host fish populations decline, recruitment will not occur, and the mussel species may become functionally extinct (Bogan 1993). Although it is not known whether fish hosts for the Wavy-rayed Lampmussel are a limiting factor for this species, laboratory infestation experiments have determined four larval hosts for the Wavy-rayed Lampmussel in Canada: Brook Stickleback (*Culaea inconstans*), Largemouth Bass, Mottled Sculpin (*Cottus bairdii*) and Smallmouth Bass (McNichols *et al.* 2005). The functional hosts in natural settings are likely visual predators such as Smallmouth and Largemouth Bass due to the nature of the specialized “lure” produced by the female mussel to attract hosts (Morris *et al.* 2005). All of these fish species are present throughout the range of the Wavy-rayed Lampmussel and their populations are considered secure in Ontario (NatureServe 2010).

Due to the obligate nature of the mussel reproductive cycle, any threat leading to the separation of mussel and fish host during reproduction can be detrimental to the mussel population. Threats include barriers to movement such as impoundments and dams which limit the dispersal of the fish host. For example, improvements in the Grand River mussel community have been linked to the addition of fish ladders in this system, allowing for mussel dispersal through the host fish (Metcalfe-Smith *et al.* 2000a). Other fish host threats include decreased water quality, which can create an uninhabitable environment for the fish host. Increased turbidity can also decrease the probability that the fish host, a visual predator, will be attracted to the mussel’s lure enabling infestation to occur.

Currently, populations of Smallmouth Bass, which is thought to be the most likely natural host species, in the Ausable, Maitland, and Thames rivers appear to have remained stable or increased over the past 20 years (Morris *et al.* 2008). In the Sydenham River, Smallmouth Bass populations have remained relatively stable but are rare, which may explain the decline of the Wavy-rayed Lampmussel in that system (Morris *et al.* 2008).

PREDATION AND HARVESTING

Two known Wavy-rayed Lampmussel predators are muskrats and raccoons (Neves and Odom 1989). Neves and Odom (1989) also reported that predation by these two species is size- and species-specific, choosing Wavy-rayed Lampmussel when they are available. In addition to predation, harvesting freshwater mussels for human consumption has been highlighted as a potential concern. To date, there has been a single recorded occurrence where Wavy-rayed Lampmussel shells were found with other discarded freshwater mussel shells at a site where human consumption was apparent (J. Barkley, DFO, pers. comm.).

RECREATIONAL ACTIVITIES
Recreational activities, such as driving all-terrain vehicles (ATVs) through streams, boating, fishing, canoeing, and kayaking may negatively impact mussel beds. ATVs are noted as a potential threat to mussel beds in the Thames, Ausable and Sydenham rivers where ATVs travel up and down the rivers, crushing mussel beds. Propeller channels from recreational boats, speed boats, and jet skies have been noted through the mussel beds in the St. Clair River delta (D. McGoldrick, Environment Canada, pers. comm.). Fly fisherman may be crushing mussel beds as they fish throughout the rivers. The paddling action from canoeist or kayakers in shallow waters may disturb the riverbed, dislodging mussels that are subsequently carried downstream to potentially unsuitable habitat (Metcalfe-Smith *et al.* 2000b). Certain Wavy-rayed Lampmussel populations on the Grand River coincide with popular areas for canoeists. In these areas, this recreational activity may act as a threat on the native mussel population.

CLIMATE CHANGE
Through discussion on the effects of climate change on aquatic species, impacts such as decreases in water levels, increases in water and air temperatures, increases in the frequency of extreme weather events, and emergence of diseases have been highlighted, all of which may negatively impact native freshwater mussels (Lemmen and Warren 2004). Since the effects of climate change on Wavy-Rayed Lampmussel are highly speculative, it is difficult to determine the likelihood and impact of this threat on each Wavy-rayed Lampmussel population; therefore, the threat of climate change is not included in the following population-specific Threat Status analysis.

THREAT STATUS

To assess the Threat Status of Wavy-rayed Lampmussel populations, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population basis (Tables 5, 6). The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Status matrix (Table 7) resulting in the final Threat Status for each population (Table 8). Certainty has been classified for Threat Impact and is based on: 1=causative studies; 2=correlative studies; and, 3=expert opinion.

Table 5. Definition of terms used to describe Threat Likelihood and Threat Impact.

Term	Definition
Threat Likelihood	
Known (K)	This threat has been recorded to occur at site X.
Likely (L)	There is a > 50% chance of this threat occurring at site X.
Unlikely (U)	There is a < 50% chance of this threat occurring at site X.
Unknown (UK)	There are no data or prior knowledge of this threat occurring at site X.
Threat Impact	
High (H)	If threat was to occur, it <u>would jeopardize</u> the survival or recovery of this population.
Medium (M)	If threat was to occur, it <u>would likely jeopardize</u> the survival or recovery of this population.
Low (L)	If threat was to occur, it <u>would be unlikely to jeopardize</u> the survival or recovery of this population.
Unknown (UK)	There is no prior knowledge, literature or data to guide the assessment of the impact if it were to occur.

Table 6. Threat Likelihood and Threat Impact of each Wavy-rayed Lampmussel population in Canada. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty is associated with Threat Impact (TI) and is based on the best available data (1=causative studies; 2=correlative studies; and 3=expert opinion). References (Ref) are provided. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located.

	Ausable River				**Grand River**				**Maitland River**				**Thames River**			
Threats	**TLH**	**TI**	**C**	**Ref**	**TLH**	**TI**	**C**	**Ref**	**TLH**	**TI**	**C**	**Ref**	**TLH**	**TI**	**C**	**Ref**
Exotic species	U	H	2	7,9	L	H	2	7	U	H	2	8	L	H	2	7
Turbidity and sediment loading	K	H	2	5,6,7,9	U	H	2	8	U	H	2	7	U	H	2	8
Contaminants and toxic substances	L	H	1	5,6,7	L	H	1	6,8	L	H	1	6,7	L	H	1	5,6,7
Nutrient loading	K	H	2	5,6,7	K	H	2	1,5,6	K	H	2	6,7	K	H	2	5,6,7
Altered flow regimes	K	M	2	7	K	H	2	7	L	M	2	8	K	H	2	4,7
Habitat removal and alteration	L	M	3	8,9	K	M	3	8	L	M	3	8	K	M	3	8
Fish hosts	U	H	2	8	K	H	2	5,7	U	H	2	8	K	H	2	8
Predation and harvesting	K	L	3	8	K	L	3	8	K	L	3	8	L	L	3	8
Recreational activities	K	L	3	8,9	K	L	3	8	K	L	3	8	K	L	3	8

1 – Mackie (1996)
2 – Strayer and Fetterman (1999)
3 – Metcalfe-Smith *et al.* (2003)
4 – Taylor *et al.* (2004)
5 – Morris (2006) and references therein
6 – Morris *et al.* (2008) and references therein
7 – COSEWIC (2010) and references therein
8 – Wavy-rayed Lampmussel Recovery Potential Assessment Meeting Participants (26 May 2010, Burlington, Ontario)
9 – K. Jean, Ausable-Bayfield Conservation Authority, pers. comm.
10 – M. Andreae, St. Clair Region Conservation Authority, pers. comm.

Table 6 (continued). Threat Likelihood and Threat Impact of each Wavy-rayed Lampmussel population in Canada. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty is associated with Threat Impact (TI) and is based on the best available data (1=causative studies; 2=correlative studies; and 3=expert opinion). References (Ref) are provided. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located.

	St. Clair River delta				Lake Erie and connecting channels				Sydenham River			
Threats	**TLH**	**TI**	**C**	**Ref**	**TLH**	**TI**	**C**	**Ref**	**TLH**	**TI**	**C**	**Ref**
Exotic species	K	H	2	5	K	H	2	5	U	H	2	8,10
Turbidity and sediment loading	U	H	2	8	U	H	2	8	K	H	2	2,3, 5,10
Contaminants and toxic substances	L	H	1	6,8	K	H	1	6,8	K	H	1	2,6,10
Nutrient loading	L	H	2	8	L	H	2	8	K	H	2	2,10
Altered flow regimes					U	M	2	8	K	M	2	8,10
Habitat removal and alteration	U	L	3	8	K	L	3	8	K	L	3	10
Fish hosts	L	H	2	8	L	H	2	8	K	H	2	3,10
Predation and harvesting	K	L	3	8	U	L	3	8	L	L	3	8,10
Recreational activities	K	L	3	8	U	L	3	8	K	L	3	10

1 – Mackie (1996)
2 – Strayer and Fetterman (1999)
3 – Metcalfe-Smith *et al.* (2003)
4 – Taylor *et al.* (2004)
5 – Morris (2006) and references therein
6 – Morris *et al.* (2008) and references therein
7 – COSEWIC (2010) and references therein
8 – Wavy-rayed Lampmussel Recovery Potential Assessment Meeting Participants (26 May 2010, Burlington, Ontario)
9 – K. Jean, Ausable-Bayfield Conservation Authority, pers. comm.
10 – M. Andreae, St. Clair Region Conservation Authority, pers. comm.

Table 7. The Threat Status matrix combines the Threat Likelihood and Threat Impact rankings to establish the Threat Status for each Wavy-rayed Lampmussel population in Canada. The resulting Threat Status has been categorized as Poor, Fair, Good, or Unknown.

		Threat Impact			
		Low (L)	**Medium (M)**	**High (H)**	**Unknown (UK)**
Threat Likelihood	**Known (K)**	Low	Medium	High	Unknown
	Likely (L)	Low	Medium	High	Unknown
	Unlikely (U)	Low	Low	Medium	Unknown
	Unknown (UK)	Unknown	Unknown	Unknown	Unknown

The Threat Status results were used to assess the overall effect each threat may have on Wavy-rayed Lampmussel populations as a whole. Each threat was categorized in terms of both Spatial and Temporal Extent (Table 9). Spatial Extent was categorized as Widespread [threat is likely to affect a majority of Wavy-rayed Lampmussel populations (i.e. threat status classified as medium or high for four or more populations)] or Local [threat is likely to not affect a majority of Wavy-rayed Lampmussel populations (i.e. threat status classified as medium or high for less than four populations)]. Temporal Extent was categorized as Chronic (threat that is likely to have a long-lasting, or re-occurring affect on a population) or Ephemeral (threat that is likely to have a short-lived, or non-recurring affect on a population).

Table 8. Threat Status for all Wavy-rayed Lampmussel 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 Status, 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. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located.

Threats	Ausable River	Grand River	Maitland River	Thames River	St. Clair River delta	Lake Erie and connecting channels	Sydenham River
Exotic species	Medium (2)	High (2)	Medium (2)	High (2)	High (2)	High (2)	Medium (2)
Turbidity and sediment loading	High (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (2)
Contaminants and toxic substances	High (1)	High (1)	High (1)	High (1)	High (1)	High (1)	High (1)
Nutrient loading	High (2)	High (2)	High (2)	High (2)	High (2)	High (2)	High (2)
Altered flow regimes	Medium (2)	High (2)	Medium (2)	High (2)		Low (3)	Medium (2)
Habitat removal and alteration	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Low (3)	Low (3)	Low (3)
Fish hosts	Medium (2)	High (2)	Medium (2)	High (2)	High (2)	High (2)	High (2)
Predation and harvesting	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)

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

Table 9. Overall effect of threats on Wavy-rayed Lampmussel populations.

Threat	Spatial Extent	Temporal Extent
Exotic species	Widespread	Chronic
Turbidity and sediment loading	Widespread	Chronic
Contaminants and toxic substances	Widespread	Chronic
Nutrient loading	Widespread	Chronic
Altered flow regimes	Widespread	Chronic
Habitat removal and alteration	Widespread	Chronic
Fish hosts	Widespread	Chronic
Predation and harvesting	Local	Ephemeral
Recreational activities	Local	Ephemeral

MITIGATIONS AND ALTERNATIVES

Numerous threats affecting Wavy-rayed Lampmussel populations are related to habitat loss or degradation. DFO – Fish Habitat Management has developed generic mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Ontario Great Lakes Area (Table 10; Coker *et al.* 2010). Additional mitigation and alternative measures, specific to the Wavy-rayed Lampmussel, related to the introduction of exotic species, disruptions to the host fish relationship and predation are discussed.

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

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

EXOTIC SPECIES

As discussed in the **THREATS** section, Zebra Mussel introduction and establishment could have negative effects on Wavy-rayed Lampmussel populations.

Mitigation

- Watershed monitoring for exotic species that may negatively affect Wavy-rayed Lampmussel populations, or negatively affect preferred habitat of the Wavy-rayed Lampmussel.
- Develop and implement plans to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.

- Introduction of a public awareness campaign on proper boat cleaning methods when transferring boats from an infested waterway.
- Restrict the use of boats in areas particularly susceptible to Zebra Mussel introduction and infestation (i.e., reservoirs in the Thames and Grand rivers).

Alternatives

- Unauthorized introductions
  - None.
- Authorized introductions
  - Do not carry out introduction where Wavy-rayed Lampmussel is known to exist.

FISH HOSTS

As discussed in the **THREATS** section, increased siltation may be limiting the host's ability to visually locate the displaying mussel, impeding the transfer of glochidia from the mussel to the fish host. If decreases in visibility resulting from increased siltation is found to be a limiting factor in the reproductive success of the Wavy-rayed Lampmussel, mitigations pathways related to increased siltation should be implemented (Coker *et al.* 2010).

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

Mitigation

- Implement a management plan for the appropriate fish host species. This would increase the host's survival, increasing number of host individuals, creating a healthy host population and subsequently increasing the likelihood that the fish host would encounter a gravid Wavy-rayed Lampmussel.
- Immediate release of host fish if caught angling in areas where Wavy-rayed Lampmussel are known to occur.

Alternatives

- Seasonal or zonal restrictions applied to fish species known to be used as a host to the Wavy-rayed Lampmussel glochidia.

PREDATION AND HARVESTING

As discussed in the **THREATS** section, muskrat and raccoon predation may have negative effects on Wavy-rayed Lampmussel populations. It should be considered that if this threat were to occur, it would be much localized, and have a relatively small impact on the Wavy-rayed Lampmussel population. In addition, human harvesting for consumption was also noted as a threat to Wavy-rayed Lampmussel.

Mitigation

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

Alternatives
- None.

RECREATIONAL ACTIVITIES

As discussed in the **THREATS** section, recreational activities such as driving all-terrain vehicles (ATVs) through streams, boating, fly-fishing, canoeing, and kayaking may negatively impact mussel beds

Mitigation
- Introduction of a public awareness campaign on the negative effects of the above-listed recreational activities on Wavy-rayed Lampmussel.

Alternatives
- None.

SOURCES OF UNCERTAINTY

Despite concerted efforts to increase our knowledge of the Wavy-rayed Lampmussel in Canada, there are still areas of uncertainty related to their life history, and to the factors that are limiting their existence. Areas of particular uncertainty are related to the juvenile life stage. Very little information is available regarding the preferred habitat of juvenile Wavy-rayed Lampmussel and the survival of individuals from the glochidial stage up to, and including, the juvenile life stage. Additional studies on habitat requirements are imperative to determine critical habitat for all life stages of the Wavy-rayed Lampmussel. Additional studies on the preferred habitat of this species may also help to determine possible candidate areas for relocation.

Numerous threats have been identified for Wavy-rayed Lampmussel populations in Canada, although the severity of these threats is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on each Wavy-rayed Lampmussel population with greater certainty. In the literature, the threat impacts are generally discussed at a broad level (i.e. mussel community level). It is important to further our knowledge on threat likelihood and impact at the species level. Specifically, little is known about the sensitivity of Wavy-rayed Lampmussel to contaminants, toxic substances, nutrient and sediment loading. Laboratory experiments should be conducted to increase our knowledge of threshold values of Wavy-rayed Lampmussel survival. It is necessary to determine host distribution and abundance, and to quantify the amount of overlap between the mussel and host fish populations.

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